BEHAVIOUR, WELFARE AND NUTRITION OF GROUP-HOUSED SOWS FED IN AN ELECTRONIC SOW FEEDING SYSTEM

by

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ABSTRACT

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A programme of study was undertaken to assess the welfare status of multiparous gestating sows housed in dynamic groups in a straw yard and fed by electronic sow feeders (ESF). Comparison of production figures from the Seale-Hayne herd with those nationally confirmed its status as a typical commercial unit.

In an initial series of investigations, detailed ethograms were compiled to describe the animals' repertoire of activities and interactions. Lying and straw manipulation were found to be the predominant behaviours and attacks directed towards the head were the most commonly performed type of interaction. Although there was little evidence of aggressive behaviour, most interactions were found to occur in areas where there was an obvious source of competition, namely the feeding and lying areas.

A recording scale was devised to assess the level of skin damage arising from aggressive interactions. Whilst data revealed a relationship between parity and the extent of injury, both the frequency and intensity of injury were found to be low for all animals and there was very little evidence of vulva biting, commonly cited as a major criticism of group-housing systems.

Animals were observed to rest predominantly in the lying area. There was an association between parity and resting location, with older animals occupying those areas perceived to be more favourable. Recently introduced gilts and sows were observed to integrate gradually with the main group. An argument is put forward for the existence of sub-groups based upon parity within the main group, although it was concluded that it was difficult to prove such a theory.

A series of voluntary feed intake (VFI) trials revealed that the animals' feeding motivation was not satisfied by the allowance fed in gestation. Results from a trial when animals were offered a high fibre, low energy diet in comparison with their conventional feed suggested that the animals had a requirement for a certain level of energy and were not motivated simply by a desire for gut-fill. However, a subsequent investigation into the animals feeding behaviour did not reveal any evidence of a frustrated feeding motivation; there was little evidence of non-feeding visits and few animals were recorded in the feed queue throughout the day.

It is concluded that sows can be group-housed in a dynamic system on a restricted feed intake without detriment to their welfare or productivity status. A number of factors were found to be critical to the success of such a system including the freedom for animals to behave as individuals, the regular provision of fresh straw and adequate space for newly introduced animals to integrate gradually with the herd.

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AUTHOR'S DECLARATION

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award.

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Chapter One: Introduction

1.1 Brief outline of welfare legislation and consequences on husbandry systems

Present welfare codes for the protection of farm animals arose as a result of the public outcry against intensive farming practices in the 1960s. This was largely a response to Ruth Harrison's book *Animal Machines* (Harrison 1964), rather than a result of any physiological or behavioural assessments (Baxter and Baxter 1984). The Brambell Committee was set up by the UK government in 1964. Its remit, stated in paragraph one of the published report, was

> "to examine the conditions in which livestock are kept under systems of intensive husbandry and to advise whether standards ought to be set in the interests of their welfare, and if so what they should be" (HMSO 1965).

The committee reviewed the history of welfare legislation (paragraphs 19-24, HMSO 1965) and concluded that the current provision, essentially afforded by the Protection of Animals Act (1911), was inadequate and had little real effect due to problems of enforcement.

One of the outcomes of the committee was the establishment in 1967 of the Farm Animal Welfare Advisory Committee later replaced in 1979 by the Farm Animal Welfare Council which, taking principles from the Brambell report, established a basis for the discussion and legislation of animal welfare, widely known as the *Five Freedoms* (FAWC/1 1979). With developments in the understanding of positive welfare, the Council reviewed the concept and content of the *Five Freedoms* and, in 1992, published a revised version now referred to as the *FAWC Five Freedoms* (FAWC 1992; Appendix 1). Guidelines are constantly revised and updated and now include a demand for less restrictive dry sow housing.

Individual and group housing systems for dry sows have traditionally alternated in their perceived status with respect to animal welfare. As herd size started to increase in the 1960s, problems arose in group housing systems from bullying and competition for food. The response to this was initially to provide individual feeding stations and subsequently total confinement systems (tethers and stalls). This was considered a logical and perfectly acceptable idea at the time. These practices were developed initially in continental Europe (particularly Denmark) where it was, and still is, common practice to house sows in this way. Problems were later identified, evidenced by the development of stereotypies although, even now, it can be argued that such behaviours are a consequence of a frustrated feeding motivation and not a direct reaction to the environment.

In short, the major argument against intensive, confined systems has been the associated high levels of stereotypic behaviour (Stolba, Baker and Wood-Gush 1983; Jensen 1988) whereas group housed sows have been found to sustain a high level of injury as a consequence of frequent and intense aggressive interactions (Lambert, Ellis and Rowlinson 1986; Van Putten and Van de Burgwal 1990; Bure 1991). The Brambell Committee stated that although individual housing prevented aggressive bullying in sows, "pregnant sows should not be kept without daily exercise in quarters which do not allow them to turn around freely" (paragraph 125, HMSO 1965).

The construction of stalls and tethers has been banned in Great Britain since 1 October 1991 and it will be an offence to use existing systems after 1 January 1999 (HMSO 1991). In the EU, the installation of new tether systems was prohibited from 31 December 1995 with existing systems to be phased out by the end of 2005 (EC 1991). Therefore, the future of sow welfare depends upon the development of housing systems which accommodate the animals in groups whilst maintaining aggression at a minimum. Much research has been carried out into the social organisation and behaviour of pigs (e.g. Beilharz and Cox 1967; Ewbank 1969a; Jensen 1982). Technology, equipment and expertise are more advanced today than in the past. However, further research is needed to ensure that, in designing new housing systems, one set of problems are not replaced by another. Furthermore, as stated by Silver (1989), the concept and importance of welfare is a philosophy that needs to be embraced by those involved in the farming industry. The welfare status of the sow will not be improved by the introduction of legislation alone.

1.2 The concept of animals' "needs"

All animals perform a number of activities in the wild that are essential for survival. In short, they need to compete for living space, acquire food, procreate the species, adapt to climatic change and avoid enemies. However, evidence suggests that mammals and birds, at least, have evolved psychological needs and their well-being depends on providing themselves with facilities for an appropriate and satisfying programme of activity, including provision for security, appropriate environmental complexity, novelty and opportunities for achievement (Poole 1992). In conflict with evolutionary theory, they have been observed to work for goals when there is no physiological gain and seem to experience a need to carry out leisure and play activities that are unnecessary for their survival (Dawkins 1990). This can be exemplified by a study by Duncan and Hughes (1972) in which domestic fowl offered feed *ad lib.* chose to work for at least part of their diet.

Opinions differ as to the criteria which should be used for assessing whether a behaviour is a necessity. Thorpe (1967) stated that the importance of an activity was related to the frequency with which it was performed whereas Broom (1988) argued that "necessities" are not necessarily those activities the animals spend most time performing but those for which they are most motivated to work. Operant conditioning techniques (for review, see Kilgour, Foster, Temple, Matthews and Bremner 1991) have been used to assess the extent to which animals are prepared to work for various rewards and to measure the relative perceived importance of these rewards. Beilharz and Zeeb (1981) stated that if an animal could not be trained to work for a reward then its motivation for that reward was weak and the reward was not perceived as very important. However, animals that originally were unwilling to work for a reward may do so when the amount and intensity of effort required is reduced. Hens that could not be trained to peck a key in order to gain access to litter were eventually trained to break a photobeam for the same reward (Dawkins and Beardsley 1986). Dawkins (1983) adapted Laidler's theory of elasticity of demand (Laidler 1981) to categorise an animal's requirements as either necessities or luxuries. However, external environmental factors may compound this theory with the perceived importance of certain behaviours depending on the prevailing situation (Jensen and Toates 1993).

Whilst Poole (1992) argued that only a natural environment can fully meet the animals behavioural needs, Markowitz (1982) suggested that an interesting and complex artificial situation can be satisfactory, especially if it provides the animals with the opportunity to carry out activities similar to those performed in their natural environment. For example, the provision of straw allows pigs to perform rooting behaviours. However, the animal's behavioural repertoire has necessarily been changed by domestication (Ratner and Boice 1975) and subsequent attempts to increase their environmental complexity are often short lived. Accepting that such controlled situations inhibit the animals' natural behaviours, with possible implications on welfare and economics, those in favour of such systems maintain that if the animals were distressed they would not thrive (Barnett and Hemsworth 1990). However, Ewbank (1969b) discussed situations where this was not the case and the Brambell Committee (HMSO 1965) stated that factors such as high productivity and weight gain simply equate to an adequate diet and are not good measures of freedom from discomfort and stress.

1.3 The behaviour of pigs in the wild/semi-wild

A number of authors have highlighted the importance of studying the behavioural repertoire of the undomesticated pig in order to gain an insight into its behaviour in captivity (Maple 1975; Graves 1984; Dellmeier and Friend 1991). This theory has been taken one step further by Thorpe (1965) and Martin (1979) who argued that domesticated animals need to be able to perform all those activities demonstrated by those living in the wild. However, Duncan (1981) suggested that domestication may have had a fundamental influence on the pig and that the behavioural needs of domestic animals may be different from those in the wild. An animal living in the wild may experience no behavioural deprivation if the necessity to search for food and shelter is removed.

The pig is traditionally a free-ranging, foraging, forest-dwelling animal. The basis of the social structure in wild swine is the matriarchal herd, consisting of one or more females and their most recent offspring (Signoret, Baldwin, Fraser and Hafez 1975; Mauget 1981; Graves 1984). These females separate at farrowing and give birth alone. The young within a group are often of a similar age, suggesting that oestrus in the females is synchronised (Delcroix, Mauget and Signoret 1990). Males are only associated with such herds during the mating period and for the rest of the year range alone or in small bachelor groups. Daily activity patterns depend on a number of factors including location, season, food availability and predator threat.

Dellmeier and Friend (1991) observed that extensively managed pigs possess a rich behavioural repertoire including exploratory activities, elaborate nest-building, individual and group thermoregulatory behaviour and altruism. They found the animals to be highly gregarious and tolerant towards one another. This tolerance was observed by Schnebel and Griswold (1983) and Stolba and Wood-Gush (1989) to depend upon the availability of resources. Frequent and intense interactions were observed in captive wild pigs when competing for resources that were limited and defendable. Similar interactions were reported by Jensen and Wood-Gush (1984).

Van Putten (1989) referred to the following Jewish quotation cited by Rosten (1972) "You can deck a pig in palms ... but it will still act as a pig" and interpreted it to imply that the accommodation should be designed to facilitate the pig's behaviour and not *vice versa.* Wild pigs have been observed to occupy a communal sleeping area which affords protection whilst allowing an open view of the surrounding area (Graves 1984; Stolba and Wood-Gush 1989). Animals commonly dung away from the sleeping area (Stolba and Wood-Gush 1989).

In short, pigs are social animals with a complex behavioural repertoire. Their welfare may be threatened if they are unable to control events in their environment, if they are frustrated or if they are subjected to unpredictable situations.

1.4 The welfare of pigs

1.4.1 Definitions of welfare

The welfare status of an animal has been defined by a number of authors (For review see Rushen and de Passille 1986). The Brambell Committee (HMSO 1965) stated that the term welfare embraced both "the physical and mental well-being of the animal" and attributed animals with "feelings" which may be assessed by observing "cries, expressions, reactions, behaviour, health and productivity." Hughes (1976) developed this concept and described welfare as "a state of complete mental and physical health where the animal is in harmony with its environment". Broom (1986) defined an animal's welfare in relation to its attempts to cope with its environment and De Koning (1984) stated that animals experience good welfare when their behavioural and physical needs are fulfilled. Alternatively, Barnett and Hemsworth (1990) equated welfare with biological fitness and an animal's ability to survive and reproduce. Dawkins (1980) approached the subject from a more emotive angle and made the following statement: "suffering is not a mildly unpleasant experience, like an itch, it has attributes of being prolonged and very unpleasant". The term "suffering" has been defined in terms of discomfort, stress and pain (paragraph 181, Report of the Departmental Committee on Experiments on Animals 1965). Van Putten (1989) stressed that welfare should be assessed in relation to the individual animal and not the group as a whole.

In summary, Rushen and de Passille (1992) stated that the term welfare should encompass both the ethical treatment and the long-term biological functioning of the individual animals.

1.4.2 Methods for assessing welfare status

Sandoe and Simonsen (1992) outlined two requirements implicit to the assessment of animal welfare. Firstly, the *experience* requirement whereby something can only affect the welfare of an animal if it affects the conscious experiences of the individual and secondly the requirement of *non-speciesism*: The mere fact that an animal is non-human is not a sufficient condition for restricting the types of experiences which are taken to contribute to its welfare. The Report of the Committee on Cruelty to Wild Animals (1951) stated that animals "suffer physical pain in the same way as humans." They also suggested that, whilst animals do not possess the ability to anticipate a situation, they suffer mentally "when pursued or caught." However, Broom (1988) and Sandoe and Simonsen (1992) stated the importance of avoiding anthropomorphism and of keeping measurements scientific and objective.

A number of behavioural, physical, physiological and productivity methods are available for assessing the welfare status of the pig (Fraser, Ritchie and Fraser 1975; Sybesma 1981; Broom 1983; Barnett and Hemsworth 1990) although, as stated by Rushen and de Passille (1992) and Mason and Mendl (1993), these measurements may be contradictory and are often difficult to interpret. Whilst Rushen (1986) questioned the use of physiological methods and Barnett (1987) queried the reliability of behavioural studies, Dantzer and Mormede (1983) found these two techniques to be interrelated. All assessment criteria rely on some evidence of change other than that necessary to maintain homeostasis, but it is difficult to determine precisely at what level of behavioural change welfare becomes at risk (Barnett and Hemsworth 1990; Mendl 1991). The practical advantages of observable external indicators of internal suffering were discussed by Dawkins (1980).

1.4.2.1 Behavioural indicators of welfare status

The importance of studying the behavioural repertoire of an animal before assessing its welfare status has been widely stated (Ewbank 1969a; Wood-Gush 1973; Dawkins 1983). Without this knowledge it would not be possible to detect whether an animal's behaviour pattern was abnormal.

Stereotypies have been defined as "unvarying, repetitive behaviour patterns that have no obvious goal or function" (Fox 1965; Hutt and Hutt 1965; Odberg 1978); for review, see Lawrence and Rushen (1993). Jensen (1988) described stereotypies as abnormal behaviours and supported Rushen (1984) in suggesting that they bore some resemblance to the particular behaviour that was being thwarted. Examples in pigs include bar-biting, sham-chewing and chain manipulation (Cronin and Wiepkema 1984). Rushen (1984) observed that behaviours such as head waving, bar biting and rubbing the snout against the bars occurred before feeding whilst manipulating the drinker, rubbing and rooting behaviours were performed after feeding. Vacuum chewing, chain manipulation and aggression were not found to be related to the feeding period.

Stereotypic behaviour has been widely reported as an indicator of poor welfare status (Stolba *et al.* 1983; Broom 1988). Such behaviours indicate past or current conflict or frustration and, once developed, often persist after the problem has been solved (Stolba *et al.* 1983; Von Borrell and Hurnik 1990a). Terlouw and Lawrence (1993) observed that the performance of stereotypic behaviour was perpetuated across parities. Increasing the food allowance of previously feed-restricted fourth parity sows had no effect on the incidence of stereotypic behaviour.

Through the process of social facilitation, stereotypic behaviour may also be perpetuated throughout a group. An association was observed between the amount of stereotypic behaviour performed by a tethered gilt and that of her adjacent neighbours (Appleby, Lawrence and Illius 1989). The indirect effect on the stereotypic behaviour of an animal observing a neighbouring sow feed when still hungry itself was also recorded.

Opinions differ about the point at which the incidence of stereotypic behaviour indicates that welfare is suffering. Broom (1983) stated that a problem exists if an animal spends more than 10% of its waking time in stereotypic behaviour whereas Wiepkema (1987) argued that an animal only needs to display stereotypies for 5% of its active life for it be suffering poor welfare. In a comparison of stall and group-housed sows, Arellano, Pijoan, Jacobson and Algers (1992) recorded the mean incidence of stereotypic behaviours around feeding time as 14.9 and 0.3 per sow per hour respectively.

Pigs respond to short term stressors such as attack, cold and novelty with an elevation in their plasma corticosteroid levels. Barnett, Cronin, Hemsworth and Winfield (1984) showed that individual housing of gilts resulted in an increase in free corticosteroid levels. Both Barnett *et al.* (1984) and Von Borrell and Hurnik (1990b) suggested that by performing stereotypies such as chain biting, drinker manipulation and sham chewing, animals adapt their behaviour to cope with their environment without recourse to physiological changes.

Von Borell and Hurnik (1990b) studied the behaviour of 37 multiparous sows at around 85 days of pregnancy, this stage having been identified as the start of the period of peak frequency and duration of stereotypic behaviours (Cronin 1985). Over half of the sows surveyed did not demonstrate stereotypic behaviour suggesting either that they were not affected negatively by the housing conditions or that they lacked the prerequisite behavioural mechanisms for stereotypic behaviour. The authors suggested that it was not possible to determine whether those animals that demonstrated stereotypies were experiencing better or worse welfare than those that did not. Similarly, Broom (1986) and Fraser and Broom (1990) stated that the performance of stereotypies alone was not sufficient to indicate poor welfare.

Abnormally low levels of activity and lack of response to novel stimuli have been described as indicators of poor welfare (Van Putten 1980; Wiepkema, Broom, Duncan and van Putten 1983; Broom 1986). Stall-housed sows, perceived to be suffering poor welfare, were found by Jensen (1979) and Gravas (1982) to be less active than those housed in a group. Nygaard, Aulstod, Lys, Kraggerud and Standal (1970) and Bengtsson, Svendsen and Persson (1983) observed the opposite situation.

1.4.2.2 Physical indicators of welfare status

Health status may be used as an indicator of welfare standard, since animals which frequently have to utilise their adrenal cortex may have an impaired immune system function and a greater susceptibility to disease (Broom 1986). In general, animals have evolved coping mechanisms that minimise the consequences of stress on reproductive success and even a slight difference in performance may indicate poor welfare. MacLean (1969) observed group-housed sows subjected to high levels of bullying to have an increased weaning to oestrus interval whereas Sommer (1979) found stall housed sows came into oestrus later than group housed sows, suggesting the problem was not simply one of housing system. Vestergaard and Hansen (1984) studied four groups of sows and found farrowing time to be significantly shorter in sows that were loose-housed during pregnancy than in those that were tethered. This was thought to be due to the physiological stress experienced by the confined animals.

As already discussed, opinions differ as to the value of using productivity as an indicator of welfare status (HMSO 1965; Barnett and Hemsworth 1990). The problem of using this method may be illustrated by considering the example of group-housed sows that are fed simultaneously in a dump-feed system. A subordinate animal may be prevented from obtaining access to the feed and as such both its productivity and welfare will suffer. A similar animal prevented from resting with the rest of the group in a dry, bedded area and restricted to lying alone on damp concrete will suffer a reduced welfare status although its productivity may be unaffected.

Injury has been described as the "destruction of the physical structure of tissue to the detriment of its functioning .... manifested in cuts, bruises and abrasions" (Baxter and Baxter 1984). All injury may be assumed to cause pain to the sow, although Dolf (1986) found the lesions arising from aggressive interactions to be largely superficial and quick-healing. Ekesbo (quoted by de Koning 1984) stated that the condition of the animals integument could be used as an indicator of its welfare status and devised a numerical scale for assessing the extent and severity of lesions on a number of different sites on the body.

Tail biting has been cited as an indicator of impaired welfare (van Putten 1969; Smith and Penny 1986). Ewbank (1973) attempted to determine its cause and investigated a number of factors in relation to the diet and the physical and social environment, including group size, the provision of straw bedding and the energy and fibre content of the diet. None of these factors was demonstrated to have a significant effect and it was concluded that tail-biting was a consequence of a combination of different circumstances.

Fraser, Bernon and Ball (1991) offered a group of 60 growing pigs two pieces of cotton cord to chew, one of which was impregnated with dried blood. The animals clearly showed a preference for the latter, this preference being exaggerated when the protein content of the diet was restricted. These results suggest that once an animal has been attacked and consequently injured the problem is perpetuated as the injury site will attract further attention.

1.4.2.3 Physiological indicators of welfare status

Physiological responses to stress include increased heart and ventilation rate, biochemical changes in skeletal muscles, production of catecholamines from the adrenal medulla, production of glucocorticoids from the adrenal cortex and associated changes in brain chemistry (for discussion, see Broom 1988; Barnett and Hemsworth 1990; Mason and Mendl 1993). According to Fraser *et al.* (1975), an animal is deemed to be in a state of stress if

> "it is required to make abnormal or extreme adjustments in its physiology or behaviour in order to cope with adverse effects of its environment or management."

1.5 Social organisation in the pig

The concept of social dominance has been observed in most livestock species (Ewbank 1969a). Once formed, dominance hierarchies have been observed to maintain group stability in animals and decrease the frequency of aggressive encounters (McBride 1963; Beilharz and Cox 1967; Jensen 1982). Alternatively, Wynne-Edwards (1962) described the dominance hierarchy as a survival mechanism whereby, in times of shortage of resources, at least some of the animals would receive sufficient to thrive and perpetuate the species. In poultry and cattle these hierarchies are typically unidirectional with submissive animals not retaliating. Rasmussen, Banks, Berry and Becker (1962) observed a similar situation in groups of gilts. In contrast, Beilharz and Cox (1967) and Ewbank (1969a) found relationships among groups of pigs to be typically bi-directional with subordinate animals often fighting back. As such, a number of animals often occupy the same social position and circles may occur in the basic linear structure.

Mauget (1981) observed a linear hierarchy in feral pigs with agonistic interactions being most intense at areas of competition e.g. food. The social structure was observed to be extremely variable allowing adaptation to a wide range of environments and also highly tolerant, newcomers being accepted into the female social groups with ease.

Two types of social order have been recognised in domesticated pigs: the teat order (McBride 1963) and the dominance order after weaning (McBride, James and Hodgens 1964). McBride (1963) did not find any direct relationship between these two organisations although both were observed to be related to body size and aggressiveness. Ewbank (1976) discussed whether the teat order in piglets was comparable to the dominance hierarchy in older pigs and suggested that, if the relationships between animals remained stable over time, there may be benefits in housing pigs in their weaner groups until slaughter. Sherritt, Graves, Gobble and Hazlett (1974) found groups of pigs kept in weaner groups grew at a faster rate than those that were mixed.

Pigs start to display aggressive behaviour at 24 hours of age (McBride 1963). When previously unacquainted pigs are mixed there is an increase in activity and aggression as the hierarchy is established and productivity may suffer in the process. Meese and Ewbank (1973) observed fighting to take place between pairs, with fights lasting up to 20-30 minutes. Strong stable relationships were found to develop between animals immediately adjacent to each other in the social hierarchy, with most aggression being directed towards the animal of immediate subordinate rank. Levels of aggression were observed to decrease after 24 hours. The social rank order was established after 48 hours, the dominant animal often being recognisable within the first hour. Wide variations have been observed in the duration of this initial period of intense aggression associated with the establishment of the social hierarchy. Friend, Knabe and Tanksley (1983) and Leuscher, Friendship and McKeown (1990) found levels of aggression to decrease after the first two or three hours in groups of gilts and weaners respectively; whereas Dolf (1986) observed high levels of aggression in sows to be sustained for as long as two to three days. Fraser (1974) observed biting to be the most common aggressive behaviour when young pigs were first brought together, although this was often replaced by butting with time. Pigs that were subjected to continuous attack became less active and refrained from social activities.

Unacquainted animals have been observed to spend as much time investigating their surroundings as in fighting (Meese and Ewbank 1973) and it has been suggested that much initial aggression is associated with territorial behaviour rather than establishment of the social order (Symoens and Van den Brande 1969). Meese and Ewbank (1973) did not find any correlation between social rank and exploratory behaviour, although ultimately higher ranking animals appeared more agitated when first introduced to a new site. Leadership was apparent when directed towards objectives such as food but not when the animals were engaged in exploratory behaviours such as rooting and they suggested the possibility of a leader/follower relationship instead of a dominance hierarchy.

1.5.1 Stability of the social order

The maintenance of the dominance hierarchy and the maximum number of pigs belonging to it have been found to be dependent upon the number of individuals that can be recognised by each member of the group (Rasmussen *et al.* 1962; Ewbank, Meese and Cox 1974). Most of the observational work on pigs has been restricted to groups of up to 12 animals (Ewbank 1969a) although Ewbank and Bryant (unpublished data) recorded a linear hierarchy in a group of 18 pigs. In this context it is interesting to note that, whilst groups of feral sows typically contain less than ten animals (Signoret *et al.* 1975), commercial group housing systems are often comprised of much larger numbers. Stable linear hierarchies containing 50 and 70 cattle have been observed by Brantas (1968) and Schein and Fohrman (1955), respectively.

Pigs have been shown to possess consistent individual behaviour characteristics which manifest themselves in various social and non-social situations (Hessing, Hagelso, Van Beek, Wiepkema, Schouten and Krukow 1993). The potential benefit of composing a group of pigs based on their individual behavioural characteristics was investigated by Hessing, Schouten, Wiepkema and Tielen (1994) with the conclusion that the most stable group would contain a mixture of active and passive "copers".

Once social hierarchies have been formed, Rasmussen *et al.* (1962) and McBride *et al.* (1964) found them to remain stable. However, Meese and Ewbank (1972) recorded spontaneous changes in rank order and found no relationship to exist between some pairs. Instability was most common among middle and lower ranking individuals, dominant animals only rarely being displaced. However, despite these recorded spontaneous changes, Meese and Ewbank (1972) found it almost impossible to alter the dominance hierarchy artificially. They removed top and bottom ranking pigs from the group and gave them the experience of being subordinate and dominant respectively. When these animals were returned to the group they resumed their original positions. Ewbank and Meese (1971) investigated the durability of the dominance hierarchy in dynamic groups of eight fattening pigs and found the initial rank of the individual and the length of time away from the group were important factors in determining an isolated individual's rank on return. Top-ranking animals could be returned to their initial group without being attacked after 25 days isolation although lower ranking individuals were attacked after only three days absence from the group. Both lower and middle ranking pigs were observed to adopt lower ranks when returned. Fraser (1974) discovered that growing pigs could be separated from a group for up to 25 days without vigorous fighting on their return. These findings contradict those of Baxter (1969) who found the removal or addition of individuals to result in a re-establishment of the dominance order. Techniques such as introducing the pig in the dark, providing straw and masking the animals smell have been suggested as techniques to decrease levels of aggression associated with group disruption (Ewbank and Meese 1971).

Introducing sows to a group necessarily results in social disruption (Bresser, TeBrake, Engel and Noordhuizen 1984). Increased levels of aggression and vulva biting were observed by Lambert *et al.* (1986) at the time of mixing a dynamic group of 25 sows and the newly introduced animals had problems feeding.

Wide variations have been observed in the length of time taken for animals to integrate with an established group. The frequency and intensity of fighting has been observed to decrease within twenty minutes of mixing groups of 26 unacquainted pregnant sows with the amount of aggression displayed bearing no relationship to age, weight or parity (Mount and Seabrook 1993). Beckett, Edwards, Simmins and Walker (1986) observed newly introduced animals to remain away from the main sow group for six hours with little evidence of aggression. In growing pigs severe levels of aggression have been observed to prevail in the first 24 hours after mixing with little evidence of fighting eight days later (Stookey and Gonyou 1994).

Moore, Gonyou and Ghent (1993) found the social isolation experienced by a new group of ten pigs introduced into a larger, established group of 30 pigs - representing a practical situation as may occur when sows return to the main group after farrowing - to be a temporary condition as, although the animals were initially observed to remain in the dunging area, some movement towards integration started 21 days after mixing. Sows were found to spend more time fighting than gilts when introduced to the main group. A similar pattern was observed by Hunter (1989). Van Putten and Van de Burgwal (1990) found new groups of sows remained separate from the resident group throughout gestation although housing design may have encouraged this situation: the new sows were provided with access to an additional lying area and the main pen was partitioned.

Edwards, Mauchline and Stewart (1993) found that in a commercial situation, aggression was lower when pigs were mixed in larger groups. Sub-groups often form within a large group with evidence of newly introduced animals forming a sub-group on the periphery of the main group. Aggressive behaviour is reduced if these sub-groups are able to integrate gradually with the rest of the herd (Hunter, Edwards and Simmins 1989) and pen design should incorporate this facility and also allow sufficient space for animals to escape attack.

A series of experiments were carried out at the Victorian Institute of Animal Science in Australia to investigate the effect of various factors on aggression at mixing (Barnett, Cronin, McCallum and Newman 1993). Administering the anti-aggression drug "amperozide" or introducing a boar at the time of mixing reduced the number of interactions but had no effect on the number or length of skin lesions three days after grouping. Similarly, the presence of a mature boar was found to reduce greatly both the incidence and intensity of aggression in a group of mixed slaughter-weight pigs (Grandin and Bruning 1992). The boars showed no aggression towards the pigs and the authors agreed that there may be an advantage in housing a boar with newly mixed sows.

The effect of pen size, shape and design on levels of aggression when grouping four unfamiliar gilts was investigated by Barnett *et al.* (1993). Potential advantages were obtained from housing the pigs in a rectangular pen as opposed to a square pen. Increasing the total space allowance was found to increase the number of aggressive encounters in the immediate period following mixing, although there was no significant difference in the overall level of damage after three days. In the long term, the intensity of interaction and subsequent severity of injury was greatest when space was limited. These findings were supported by Edwards *et al.* (1993). Whilst the distance an animal will chase another may be as great as 20 metres, in most instances flight distances are less than 2.5 metres (Edwards *et al.* 1986). If space is limited, animals may be unable to escape from an aggressive attack.

McGlone and Curtis (1985) found it possible to decrease the levels of aggression in newly-weaned pigs by providing the animals with pop-holes in which they could hide their head and neck. Partial stalls or barriers provide a similar function and were found by Barnett, Hemsworth, Cronin, Newman, McCallum and Chilton (1992) and Edwards *et al.* (1993) to have a similar effect on aggression in sows. Edwards *et al.* (1986) suggested that the provision for animals to separate themselves visually from aggressors may partially compensate for a decreased space allowance. However, the provision of partial stalls have not been found to have any effect on the incidence of aggressive interactions in gilts (Luescher *et al.* 1990; Barnett *et al.* 1993).

Mixing ovariectomized adult pigs in the dark and subsequently providing *ad lib.* feed, resulted in a significant decrease in the level of aggression (Barnett, Cronin, McCallum and Newman 1994). A further trial is to be carried out to investigate whether these findings can be applied to intact gilts and sows.

An evaluation of a number of practical methods on decreasing aggression when mixing gilts was carried out by Luescher *et al.* (1990). Techniques included masking the smell, introducing a boar, administering a tranquilliser, providing partitions in the pen and group-feeding at mixing. The animals had previously been housed in individual pens and fed once a day. Straw was not provided. No treatment had any significant effect on the amount or intensity of fighting, most of which occurred in the first two hours after mixing in all situations. The authors suggested that perhaps a minimum amount of fighting was required to establish a dominance hierarchy.

The effects of age and individual reaction pattern, determined by recording the animal's response to novel stimuli, were not found to be good predictors of whether or not an animal would engage in fights with strangers (Jensen 1984). Age, however, was found to determine both the length and course of the fighting. McGlone (1985) observed differences in behaviour at mixing that identified prepubertal pigs as either winners or losers.

The effect of mixing pigs from different litters was not found to have a detrimental effect on subsequent growth rate (Sherritt *et al.* 1974). However, when additional stresses such as limited space and feed existed, production was adversely affected. A similar situation in beef cattle was observed by Mench, Swanson and Stricklin (1990) who further stated that the social stress experienced by subordinates accumulated over time. Stookey and Gonyou (1994) observed the social conflicts and stress associated with regrouping growing pigs to have an adverse effect on growth rate, detectable two weeks after mixing. They suggested that the negative effects associated with regrouping were variable and essentially short-lived but advised against mixing in the period prior to marketing the animals. Pigs reared in stable groups throughout the fattening period were found by Karlsson and Lundstrom (1992) to have fewer skin lesions and produce better quality meat than those that were regularly mixed. In response to studies that have revealed smaller litter size and lighter birthweights from sows housed in a dynamic as opposed to a stable group, ADAS (1985) and Simmins (1993) recommended that pregnant sows should not be mixed before implantation ie. in the first four weeks of pregnancy.

The importance of sight in sexual and other social encounters was discussed by Hafez and Signoret (1969). Ewbank *et al.* (1974) investigated the role of sight in identification. They induced temporary blindness by using either opaque contact lenses or hoods which completely covered the face. The hoods prevented hierarchy formation in previously unacquainted pigs, whilst contact lenses had only a minimal effect. Neither had any effect on the social order of established social groups and the authors concluded that sight alone was not responsible for hierarchy establishment and subsequent maintenance.

Smell has been demonstrated to play a role in the establishment of the teat order (McBride 1963). Meese and Baldwin (1975) assessed the role of smell in instigating aggressive interactions by surgically removing the olfactory bulbs of pigs in established groups of two to four animals and measuring the amount of aggression associated with the subsequent introduction of an unfamiliar animal. Such intervention did not prevent the formation of dominance relationships but reduced the level of aggression at feeding. These results suggested that the facial region played an important role in recognition and thus supported the findings of Ewbank *et al.* (1974).

From these experiments and with the knowledge that both hearing and vocalisation are well-established in the pigs (McBride *et al.* 1964) it can be concluded that the stimulus for initiation and continuance of aggressive encounters may be multi-sensory as blinding or bulbectomy alone reduce, but do not eliminate, the levels of aggression within groups of pigs.

1.5.2 Social interactions

Jensen (1980) described, in a simple non-interpretive manner, the various interactions performed by group-housed dry sows before identifying behaviours as aggressive or submissive. An ethogram was produced based on observation of over 1000 interactions demonstrated by loose-housed dry sows. Ten main patterns of social interaction were identified. Fraser (1974) observed similar interactions in groups of previously unacquainted growing pigs. Various biting and butting behaviours were recorded, the latter gradually becoming more frequent than the former as dominant/subordinate relationships were established. The importance of familiarity was demonstrated by the fact that the incidence of biting behaviours was reduced when the animals were in visual and tactile contact with one another before mixing. A similar change in the expression of dominance with time was observed by Kondo and Hurnik (1987). Physical methods such as bunting and pushing were replaced with psychological methods such as threatening and avoiding behaviours.

Aggression was described by Scott (1958) simply as the act of initiating an attack. Threatening behaviours directed towards submissive animals were observed by Ewbank and Bryant (1972). Physical attacks including biting and thrusting directed mainly towards the head, neck and shoulders were recorded by Rasmussen *et al.* (1962) and McBride *et al.* (1964). Beilharz and Cox (1967) reported displacement behaviour with one pig replacing another at the feed trough or other sites of competition. All these behaviours were described by Jensen (1980) and in a discussion of aggression in pigs, Ewbank and Meese (1971) stated that social aggression could be categorised into threat, attack and replacement behaviours.

Bryant (1972) investigated theories on the motivation of aggression and concluded that the most popular concept was the frustration/aggression hypothesis whereby aggression originates ultimately in response to some frustration, where frustration is defined as "the interference with an instigated goal response." In this context, aggression may be described as a means of ensuring the assertion of the individual over its conspecifics in situations of competition for a limited resource such as food, shelter or a mate. In support of this theory, Rasmussen *et al.* (1962) and Meese and Ewbank (1972) observed the incidence of aggression to increase when resources were limited and defendable. Rasmussen *et al.* (1962) observed that most aggressive encounters, mainly involving pushing and biting, occurred at places of competition (e.g. the feed trough) and found that when adequate feeding space was available for all animals to feed at the same time it was not possible to determine a social order. A similar situation in a group of captive wild boars was observed by Schnebel and Griswold (1983). Mount and Seabrook (1993) showed the amount of aggression demonstrated by a sow to be a consequence of personality trait and not related to factors such as age, weight or parity.

Scales ranging from immediate submission by the subordinate to severe fighting have been devised in attempts to score the intensity of interactions (Ewbank and Bryant 1972; Schnebel and Griswold 1983). Schnebel and Griswold (1983) observed the most intense interactions to take place between rank neighbours and found that animals would go out of their way to initiate an attack with their subordinate rank neighbour. Similarly, Rasmussen *et al.* (1962) observed gilts to reinforce continually their dominance over their immediate subordinate.

A study on social dominance in growing pigs housed in their litter groups was carried out by Beilharz and Cox (1967). Dominance values were assigned to animals on the basis of the number of fights they won. In concurrence with McBride *et al.* (1964), weight and sex were found to have a significant effect on dominance, with hogs and heavier animals winning the most encounters. Similarly, a relationship between sex, weight, size, strength and parity with dominance has been observed in feral pigs (Mauget 1981). However, Rasmussen *et al.* (1962), working with gilts, and Meese and Ewbank (1973), studying mixed-sex groups of eight growing pigs, did not find weight to be related to social aggression. Meese and Ewbank (1973) went further and distinguished dominance from aggressiveness and stated that the dominant animals within a group were not necessarily the most aggressive. They found a number of factors to have an effect on the dominance hierarchy including genotype, environmental complexity, diet and weaning age as well as individual physical differences such as weight. Dominant animals may be expected to occupy the most favourable resting places, to feed first, to have a lower parasite burden and to be more resistant to disease.

Authors differ in their opinion as to whether or not sows display submissive behaviour. Both Bryant and Ewbank (1972) and Jensen (1980) observed the majority of interactions to end in withdrawal but Jensen (1980) identified the tilting of the head by one individual to be the only form of submission rarely followed by another attack. Van Putten (1978) observed subordinate animals to show their throat in submission. This behaviour was not described in Jensen's (1980) ethogram. Meese and Ewbank (1973) stated that swine do not demonstrate submissive behaviour.

The incidence of aggressive encounters in a free ranging herd has been shown to be lower (six per hour at feeding time (Jensen and Wood-Gush 1984)) than in indoor systems (20.1 per hour (Jensen 1984)) even though the function of the different interactions has been found to be the same. The associated increase in aggression with decreasing space allowance and increasing population density has been widely reported (Ewbank and Bryant 1969; Bryant 1972; Bryant and Ewbank 1972; Ewbank and Bryant 1972; Meese and Ewbank 1973). This was thought to be due to a reduction in manoeuvrability and hence the reduced opportunity for animals to avoid confrontation. Bryant (1972) and Ewbank and Bryant (1972) further suggested that this phenomenon could be a consequence of difficulties in communication and subsequent weakening of relationships and observed increases in the number of both undecided encounters and interactions contrary to the dominance hierarchy. In a study on growing pigs, however, Randolph, Cromwell, Stahly and Kratzer (1981) found space allowance and group size to be independent of each other in their effect on both aggression and productivity.

1.6 Housing systems for dry sows

In intensive housing systems, sows are confined in stalls and may also be tethered to the ground. As such they are unable to turn around and whilst having visual, olfactory, aural and, possibly, tactile association with their neighbours, have limited social contact with them. Floors are typically partially slatted and bedding is rarely provided. Such systems offer a barren physical and social environment.

There are a diversity of indoor group housing systems for dry sows including free access stalls, cubicles and kennels and straw yards (Edwards 1985). Sows may be housed in pairs or in groups of over 100 and fed in a variety of ways ranging from individual stalls to simultaneous dump-feeding systems.

Benefits of group housing systems include the capacity both to reduce the lower critical temperature (LCT) and decrease the occurrence of stereotypic behaviour. However, feed intake remains a critical factor in the successful management of such systems. In the more extensive systems the dry sow herd is kept as one group in a large straw yard. Such groups contain animals of different parities and at different stages of pregnancy and are continually disrupted as animals are removed from or added to the group. In some systems animals are fed simultaneously from dump or trickle feeders. Whilst the Brambell Committee (HMSO 1965) discussed the benefits of simultaneous feeding, such systems do not allow individual rationing and less dominant and younger animals may be prevented from obtaining even their basic AFRC (1990) recommended ration. Benefits arising from group housing may then be lost. An alternative simultaneous feeding system involves feeding the animals in stalls. Whilst all the animals are assured of receiving their allowance, such systems are costly to install, require a large amount of space and may produce aggressive encounters when the stalls are opened to let the sows in. A further alternative is the electronic sow feeding (ESF) system. Hunter (1989) assessed the welfare status of number of group housing systems on the basis of the *Five freedoms* (FAWC/1 1979). Using these criteria systems with individual feeders were judged to be the best, ESF stations to be intermediate and group feeding to be the worst.

Baxter (1986) stated that electronic sow feeding (ESF) systems represented a step forward in relation to the welfare of sows. They allow the animals to be housed as groups but to be fed as individuals. Furthermore, they provide the sows with protection whilst feeding and allow them to select their own feeding pattern albeit within the constraints imposed by the other members of the group (Eddison and Roberts 1991, 1995). Competition for food is reduced since, although they can queue outside a feeder, the sows can not access the system whilst another is feeding. Consequently, the most intense source of aggression is removed.

In a typical ESF system, sows are housed in a group in a straw yard separated into distinct lying, feeding and dunging areas. Through trial and error the best feed station design has evolved as a forward entry, side exit system with the animals directed from the feeding area to the dunging area (Hunter 1989). Each sow has its individual feed allowance programmed into a computer and is fitted with a transponder either on a collar or, more recently, as an ear tag or subcutaneous implant. The sow's ration becomes available at the beginning a feed cycle. From this time the sow may enter the feeder and consume her ration in one or more visits. The sow is protected whilst feeding but after a predetermined time period, following expiry of her allowance, other sows may enter the feeder. Much research has been carried out on feeding behaviour in such systems and results have been used to update and revise recommendations.

An integrated ESF group-housing system in which the animals remain in the same group throughout their productive life was developed at Wageningen in The Netherlands (Houwers, Bure and Koomans 1992). This highly computerised system included automatic oestrus detection and a calling system at the feeding stations (Lokhorst 1988, 1990). However, aggression around the feed stations and vulva biting were at intolerable levels. This was possibly due to the absence of straw.

In the Hurnik-Morris group-housing system, the animals are housed in sub-groups of six, with each sub-group fed in turn, all six animals feeding simultaneously (Morris and Hurnik 1990). This system has been found to sustain high levels of welfare and has been suggested as a realistic alternative in situations where ESF systems have failed (Morris, Hurnik, Friendship, Buhr and Allen 1992). However, whilst the animals may benefit from feeding as a group they are not able to display individual feeding behaviour. To date, this system has found little favour with producers.

The Edinburgh family pen system was developed to encompass the natural behaviour and to maximise the welfare of the pig (Kerr, Wood-Gush, Moser and Whittemore 1988). Groups of four sows are housed together, their offspring remaining with them until slaughter. The boar joins the group after farrowing. Production figures are comparable with the MLC top third but the high capital, management and labour costs have resulted in it not being possible to develop a commercially viable version of this housing system.

1.7 The welfare status of confined and group housing systems

Intensive husbandry involves keeping animals which have been specially selected for high productivity under environmental conditions that enable their genetic potential for growth and production to be fully exploited. Typically, such environments are highly controlled and the animals are often housed at high stocking densities, sometimes being restrained. Such conditions remove all challenges and the animals have to devote little time and expend little or no effort to acquire their daily living requirements. Food is usually presented as a carefully balanced compound in meal, pellet or cube form with rations precisely calculated. Formulations are of a high standard and nutritional deficiencies rare. Hediger's hypertrophy of values (Hediger 1950) can be applied to such situations, suggesting that certain aspects of the animals surroundings become of exaggerated significance when the animals are under stimulated. To illustrate this concept, voluntary feed intake trials have shown that feed intake increases when the animals have little environmental stimulation (Hediger 1950) and decreases when animals are forced to take exercise (Morrison, Hintz and Givens 1968).

Stereotypies often occur in environments of low complexity with little opportunity for exploration (Stolba *et al.* 1983; Appleby and Lawrence 1987). Ewbank (1969b) predicted that housing sows in stall and tether systems would lead to the development of stereotypic behaviours. In contrast, Hafez (1975) reported no such abnormal behaviour in dairy cows tethered in cubicles, although it can be argued that the animals were ruminating for four to nine hours of the day and thus occupied.

Ekesbo (1981) stated that confined sows are subjected to greater stress than those housed in pens. Free sows have been observed to spend more time in active behaviours and manipulating straw and less time in stereotypic activities than confined sows (Lambert, Ellis, Rowlinson and Saville (1983). Jensen (1988) investigated the incidence of stereotypic behaviour, demonstrated as bar-biting, in three different housing systems; loose-housed, semi-confined and stalls. The incidence of stereotypic behaviour was greatest in the confined system and lowest in the extensive situation. Both the loose-housed and the semi-confined sows increased their levels of activity after feeding: this coincided with the peak period of stereotypic activity in the confined sows. Barnett, Cronin, Winfield and Dewar (1984) compared the welfare status of five different housing systems (tethers, pairs or group indoors, in a yard or in a paddock) by assessing their effect on the behaviour, physiology, health and productivity of non-pregnant sows. Whilst observing those tethered or housed in pairs to show a higher incidence of stereotypic behaviour, the authors concluded that there was no clear welfare advantage in housing adult pigs extensively. In a later study, Barnett, Winfield, Cronin, Hemsworth and Dewar (1985) found tethering to result in a chronic stress response and a significant metabolic cost in pregnant sows.

Lambert *et al.* (1986) highlighted the potential welfare problem of aggression, especially at feeding time (Lambert *et al.* 1983), and subsequent high injury status in group-housed sows. Dolf (1986) compared the extent of aggressive behaviour in sows housed in stalls with those housed in groups of four in straw pens separated into lying, feeding and dunging areas. Fighting continued for longer in sows housed in stalls as it was more difficult for the animals to resolve interactions. Similar evidence of increased levels of aggression in confined sows was observed by Vestergaard and Hansen (1984).

Baxter *et al.* (1984) investigated a number of different intensive and group housing systems and concluded that there was no clear welfare advantage in housing non-pregnant adult pigs in a more extensive environment. In a later study, investigating the behaviour of pregnant gilts in the same housing systems they discovered a higher incidence of stereotypic behaviour in the confined animals (Barnett *et al.* (1985). This suggests that pregnancy has some effect on the physiological and behavioural responses of gilts to their environment. A further investigation was carried out to assess the effect of parity on the animals physiological and behavioural response to the housing system (Barnett, Hemsworth, Winfield and Fahy 1987). Gilts were compared with second parity sows. Consecutive pregnancies in tether housing were shown to induce a chronic stress response and there was no evidence to suggest that this stress response became modified by experience. The authors concluded that the welfare of tethered pregnant sows could be at risk. This response to tether housing was shown to be similar in pigs of two different genotypes (Barnett, Hemsworth, Cronin, Winfield, McCallum and Newman 1988).

de Koning, Backus and Vermeer (1990) found the welfare of pregnant sows housed in an ESF system to be no better than that of confined animals. They observed stereotypic behaviour in both systems although the diurnal distribution of these activities differed. Group-housed sows suffered a higher incidence of foot lesions. However, this increased lameness and the unusually high levels of stereotypic behaviour in such a system may be explained by the fact that the animals were housed on partly slatted floors with no straw.

The vulva swells in the last week of pregnancy and as such may become more susceptible to attack (Humik 1985). Vulva biting has been cited as a potential problem of group-housing with electronic sow feeding systems (van Putten and Van de Burgwal 1990; Bure 1991), especially in the feed queue. Providing chopped corn silage on the floor in the lying area approximately half an hour before the start of the feed cycle was found to decrease the incidence of vulva biting from 30% to 10% (Van Putten and Van de Burgwal 1990). This allowed the animals a period of eating simultaneously and decreased the importance of the feeding station. Training the animals to use the feeders before introducing them into the group and allowing newly introduced animals to lie in sub-groups away from the rest of the herd decreased the problem further. The significance of training animals to use the feeders and the benefits of offering chopped corn silage in the lying area were also cited by Bressers *et al.* (1993). Gravas (1986) found that allowing animals free access to silage decreased the levels of aggression. Bure (1991) found that the incidence of vulva biting in group housed sows could be reduced by providing straw pellets in the feeding station. However, this increased feeder occupation time and it was concluded that, whilst providing additional roughage decreased the problem, it would be better to offer straw in the lying area. Side exit systems whereby the sows do not have to reverse out of the feeder have been shown to result in negligible levels of vulva damage (Edwards, Armsby and Large (1988a).

A breeding sow is, on average, pregnant for 75% of her productive life and therefore housing conditions during this period have important implications with regard to her welfare and productivity. Brooks (1988) stated that if a sow is to be profitable she must produce a high number of viable piglets and have the potential to stay in the herd for a number of parities. Sows do not attain reproductive maturity until their fourth parity and, as stated by Dagorn and Aumaitre (1979) and Kroes and Van Male (1979), it is desirable to keep animals in the herd beyond this stage so as to be able to exploit their full breeding potential. Kroes and Van Male (1979) showed both total litter size and number of piglets born alive remained at a high level in sows up to and over parity ten and found that, on average, gilts have a litter size 16% below that of a sow. There are a number of factors that may affect the productive lifespan of the sow including health, genetic potential, the physical and social environment and welfare status.

Although litter traits were not significantly different, Schmidt, Stevenson and Davis (1985) observed sows housed in individual pens during the interval from weaning to service and in the first 35 days following service to suffer a higher incidence of early pregnancy losses than those housed in groups during these periods. Whether these losses were due to embryonic or maternal failure was not discovered. Similarly, Hansen and Vestergaard (1984) found no differences in the number born alive, dead or weaned in tethered compared with loose-housed sows. Total litter size was found by Hemsworth *et al.* (1982) to be significantly lower in individually housed sows than in those housed in groups.

A higher incidence of anoestrus has been recorded in sows housed in pairs than in those housed in groups (Dyck 1988). Fahmy and Dufour (1976) and Dyck (1988) did not find exposing weaned sows to a boar to have any effect on anoestrus. However, Hemsworth *et al.* (1982) and Hemsworth and Barnett (1990) observed both group housing and exposure to a boar to increase the number of sows mated within ten days of weaning. In contrast, failure to show oestrus, lower conception rates and embryo losses as a consequence of injuries from fighting have been found to result in group-housed sows attaining lower levels of productivity that those housed in stalls (Lynch, O'Grady and Kearney 1984).

As discussed earlier, pigs typically form a social hierarchy with higher, intermediate and lower ranking animals (Rasmussen *et al.* 1962; Beilharz and Cox 1967) with the amount of aggression demonstrated and the ability to displace others being positively related to rank. The consequences of rank and aggressive behaviour on subsequent productivity of gilts were investigated by Mendl, Zanella and Broom (1991). Intermediate ranked animals were observed to be less productive than both higher and lower ranking group members and this was thought to be due to the fact that they were often unsuccessful in aggressive situations. In a later experiment, birthweight of piglets from these intermediate gilts was found to be significantly lower than from other gilts (Mendl *et al.* 1991). A relationship between rank and productivity factors was also observed by Meikle, Drickamer, Vessey, Rosenthal and Fitzgerald (1993) although rank was not found to be related to litter size.

The individual space requirement of growing pigs was observed by McGlone and Newby (1994) to decrease as group size increased. Providing the animal with insufficient space was found to have a deleterious effect on performance. Furthermore, Randolph *et al.* (1981) found growth rate in growing pigs to decrease as individual space allowance decreased although there was no relationship between group size and growth rate. Decreased space allowance was also observed to increase the levels of aggression. No interaction was found between space allowance and group size and thus these factors are independent. Barnett, Hemsworth, Winfield and Hansen (1986) investigated the effect of group size in female pigs. Housing the animals in pairs resulted in a lower welfare status and altered social behaviour compared to housing in groups of four or eight. Decreasing the space allowance from 3 to 2 to 1 m^2 per gilt was found by Hemsworth, Barnett, Hansen and Winfield (1986) to result in an increased physiological stress response which may have accounted for the associated impaired oestrus detection rate.

1.8 The potential of ESF systems

As discussed previously, ESF systems enable the animals to combine the potential benefits of group housing with individual feeding. A number of recommendations for the design and management of ESF systems have been published and these are continuously revised and updated (Peet 1985; Gravas 1986; Edwards *et al.* 1988a; Hunter 1989; Corning 1990; Hunter and Smith 1991). However, much of the work which provided the basis for these recommendations was conducted in experimental conditions, not typical of current commercial practice. For example, groups were often small and fed using a single feeder

(Gravas 1986; Edwards *et al.* 1988), static (Simmins 1993) and comprised of animals of similar parities. Whilst some investigations have been carried out on larger units these have often been of short duration (Beckett *et al.* 1986). As such, the results obtained from these experimental conditions do not necessarily translate to commercial systems.

The rationale for this project was to remedy this situation by carrying out a longitudinal study on an established commercial dynamic multiparous unit. The major problem identified in ESF housing systems is that of injuries arising from aggressive interactions, largely caused when the herd is disrupted (for example when animals are mixed) or when animals compete for a desirable goal (for example access to the feeders or a particular resting location).

In this thesis, results from a number of investigations into the sows' social and feeding behaviour will be assimilated in order to explain the processes involved in the functioning of a commercially viable ESF system.

2.1 Introduction

This chapter describes the management practices of the Seale-Hayne herd in order to provide the context for the discussions of later chapters. Throughout the period of this study the herd was not used for any other experimental purpose. The Seale-Hayne herd is run as a commercial enterprise with breeding results comparing well with the national average as shown in Table 1. The management policy is to maximise sow productivity with due regard to sow and piglet welfare at all stages of the production cycle.

Table 1: Comparison of production figures for the period 1990-1995 from the Seale-Hayne breeding sow herd with those from average and top-third producers (as recorded by MLC Pigplan).

	Seale-Hayne	MLC[a] top third	MLC[a] average
Recorded services:farrowings (%)	85.55	88.36	87.34
Av. no. of litters/sow and gilt/year	2.32	2.37	2.26
Av. no. of pigs reared/sow and gilt/year	21.85	23.70	21.68
Av. no. pigs born alive/litter	11.47	11.15	10.75
Av. no. of pigs reared/litter	9.44	10.01	9.57
Av. weight of pigs weaned	6.82	6.10	6.14
Av. weaning age (days)	23.83	22.60	22.40
Mortality of pigs born alive (%)	17.63	10.28	10.75

[a] Data from MLC Pig Yearbooks 1990-1995

During the period of this study, the breeding herd consisted of a mean of 113.12 (SE_{Mean} = 0.67) Large White x Landrace crossbred sows ("Camborough 12 and 15", Pig Improvement Company (PIC), Oxfordshire) ranging from maiden gilts to sows of parity fourteen. This wide parity structure was the consequence of a management decision to increase the size of the herd - gilts were introduced in batches of six at two to three month intervals - and a flexible culling policy based on the following criteria:

- production of more than one poor litter (i.e. less than eight piglets weaned)
- three returns to service in any parity or failure to conceive at first service in more than one parity
- state of feet and udder
- body condition; sows over 300 kg in weight had difficulty in accessing the electronic sow feeders

This decision to increase the size of the herd resulted in a progressive increase in the number of lower parity sows throughout the experimental period (Figures 1a, b and c).

Figure 1a: Herd parity profile - March 1992

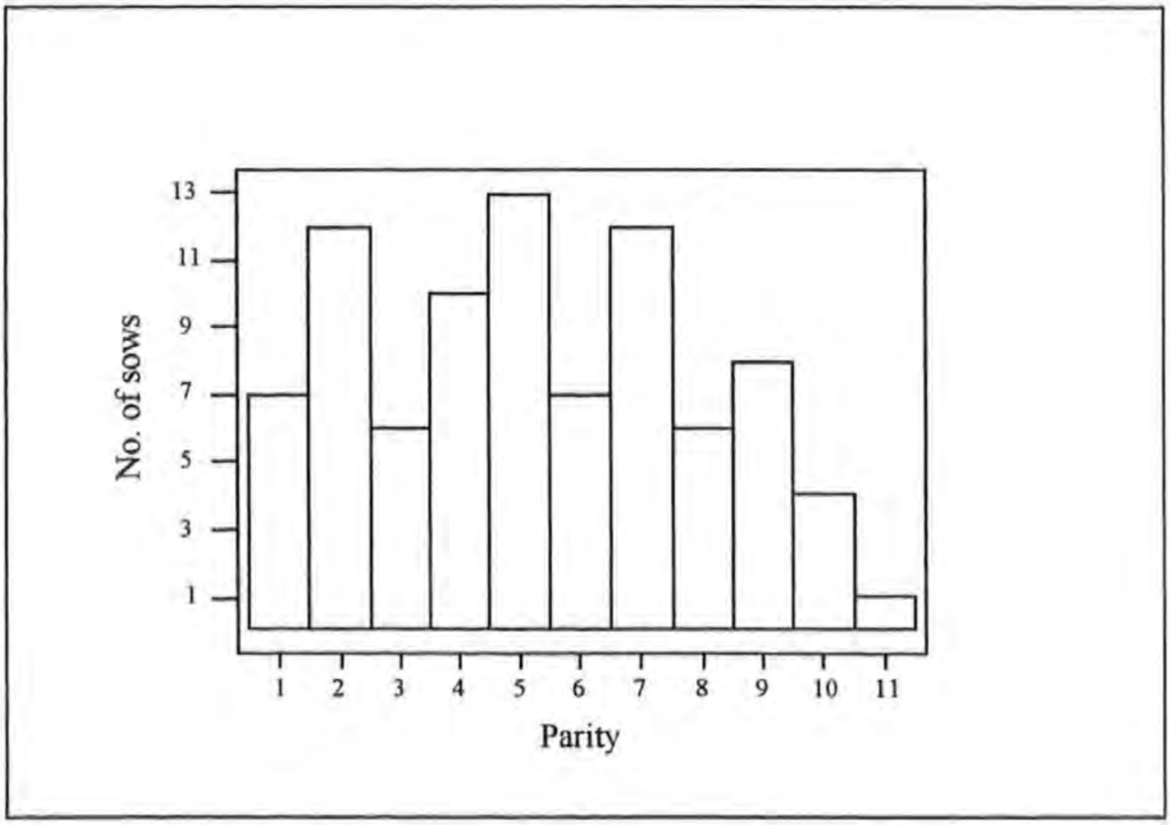


Figure 1b: Herd parity profile - March 1993

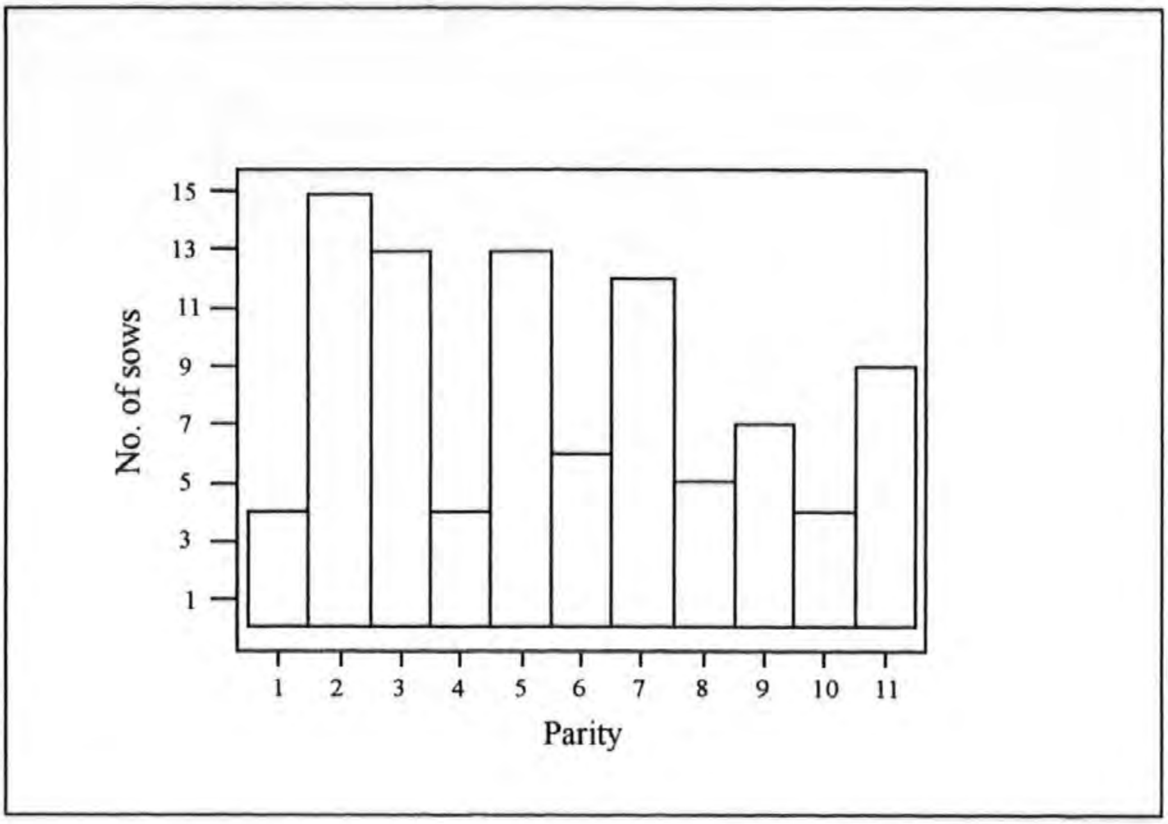
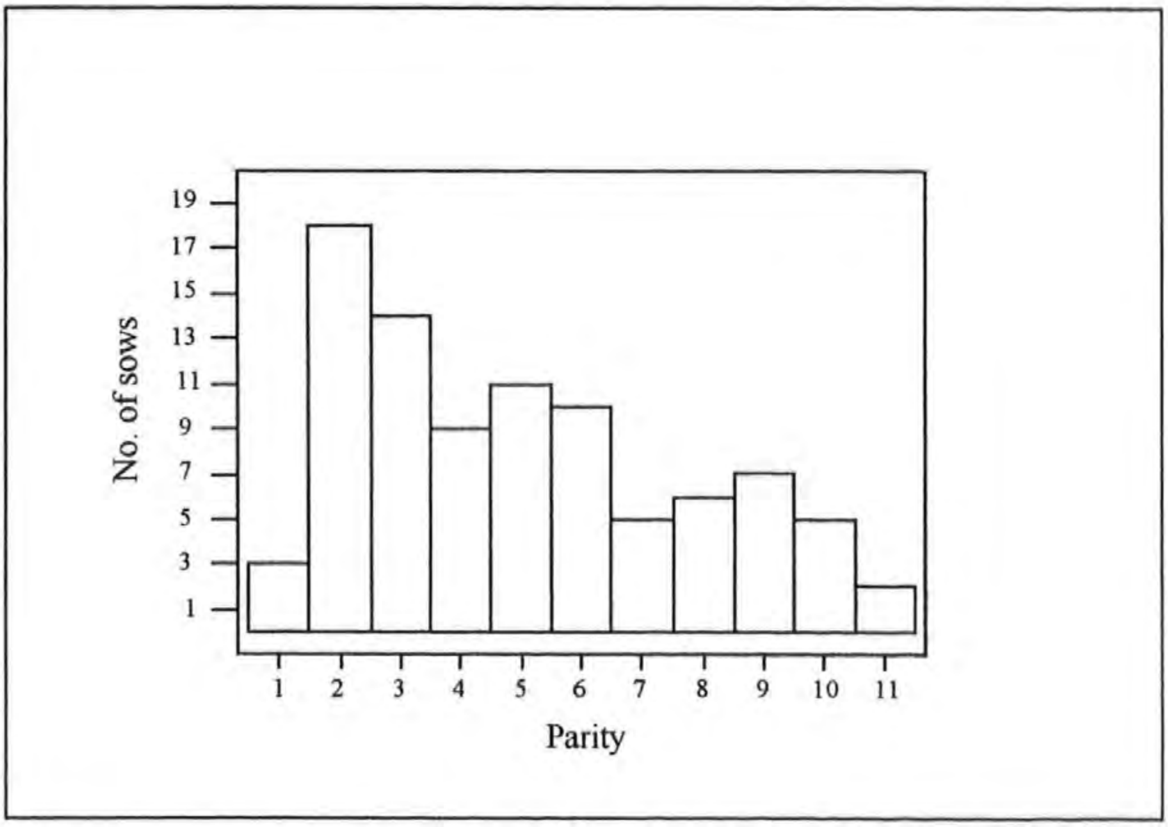


Figure 1c: Herd parity profile - March 1994



2.2 Buildings and Facilities

2.2.1 Gilt accommodation

The gilt accommodation consisted of three pens. Gilts were housed in groups of six as delivered from the breeding company. The area of each pen was 7.5m^2 and each included an enclosed, strawed lying area and an external, covered exercise and dunging area. Two bite drinkers (Arato, Bernard Partridge, Essex) were situated in each dunging area.

2.2.2 The Dry Sow Yard

The Seale-Hayne dry sow herd was originally housed in small sub-groups. In the mid-1980s a group-housing system was introduced. The animals were housed in a straw yard and fed by electronic sow feeders (Porcode, ® Nedap, Hengelo (GLD), The Netherlands). Modifications to herd management and the housing system were carried out as recommendations became available (e.g. Hunter 1989) and, as shown in Figures 2 and 3, the design of the yard during the period of this study differed to that described in earlier published work from Seale-Hayne (Knowles, Eddison, Vranch and Brooks 1989; Eddison 1992; Eddison and Roberts 1991, 1995).

Sows had free access to all parts of the yard but, as shown in Figure 3 and Plate 1, three distinct areas could be identified: a straw-bedded lying area (136.7 m^2); a feeding area including the two feeders and the area immediately adjacent to the entrance gates to the feeders (16.4m^2); a concrete dunging area (88.8m^2). A large round bale of fresh straw was added to the lying area two to three times a week and the dunging area was scraped out daily. Two electronic sow feeders were located in the feeding area and four bite drinkers were sited along the wall in the dunging area. During the months of summer and early autumn (typically June until November) the animals had free 24 hour access to a 0.53 hectare field. Due to the poor drainage characteristics of the soil it was not practicable for the animals to use this area during the wetter months.

Two gilt pens (10.5 m^2), each accommodating up to six animals, were situated at one end of the yard, adjacent to the feeding area. These each consisted of an enclosed lying area bedded with straw and an open covered exercise/dunging area containing a bite drinker.

Figure 2: Plan of the dry sow yard 1984-1988

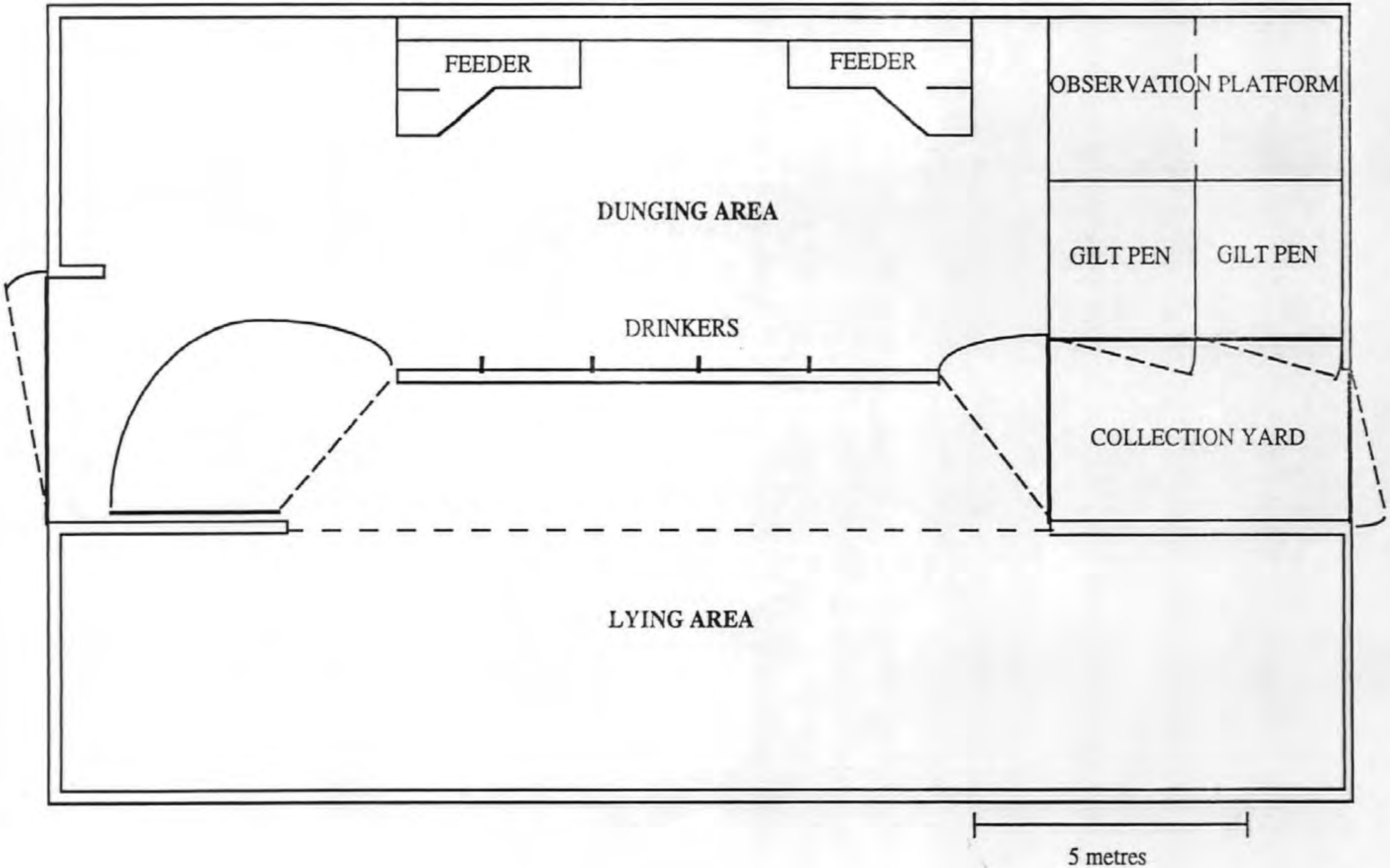
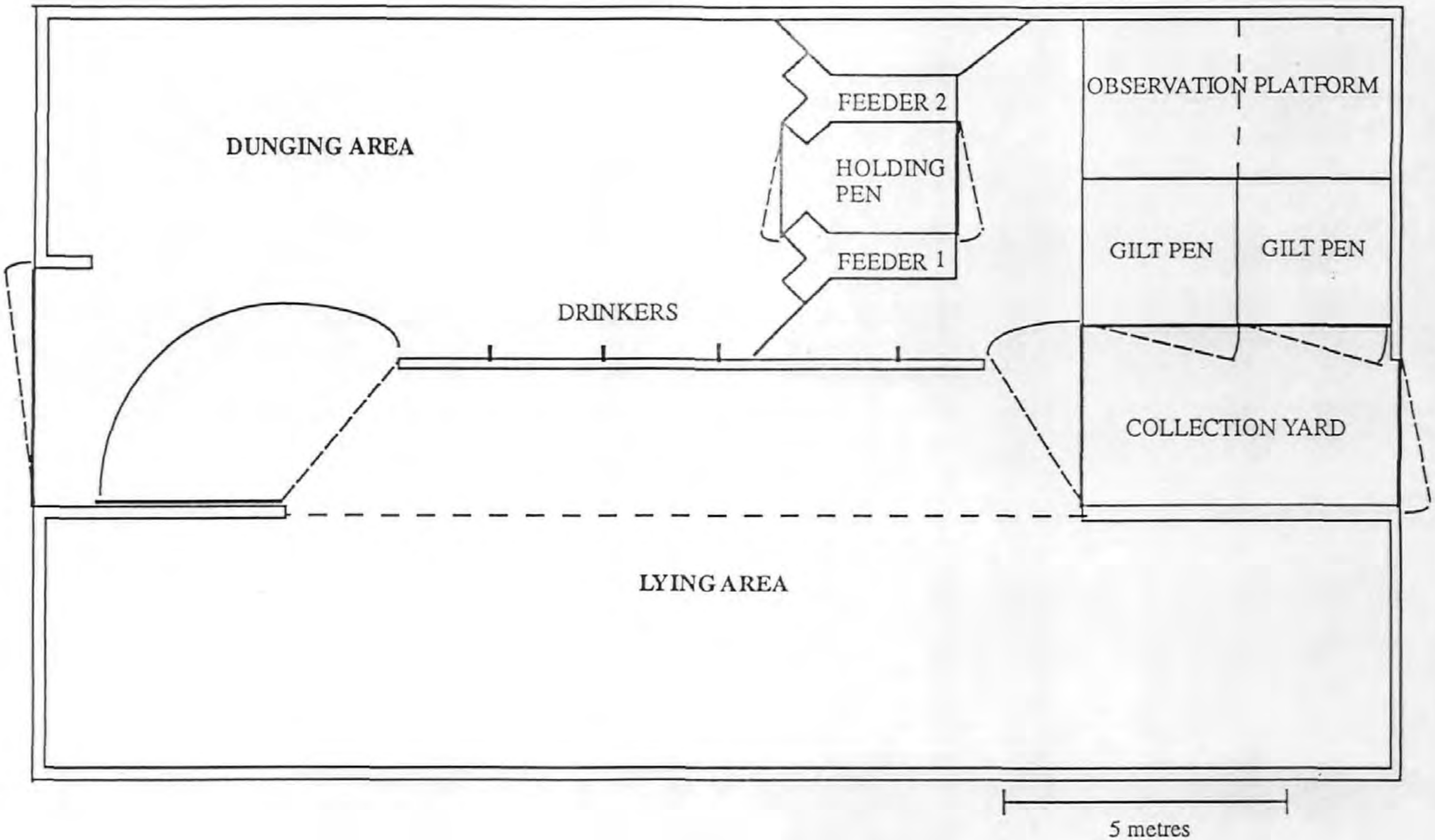


Figure 3: Plan of the dry sow yard 1988-present day



2.2.2.1 The electronic sow feeding (ESF) system

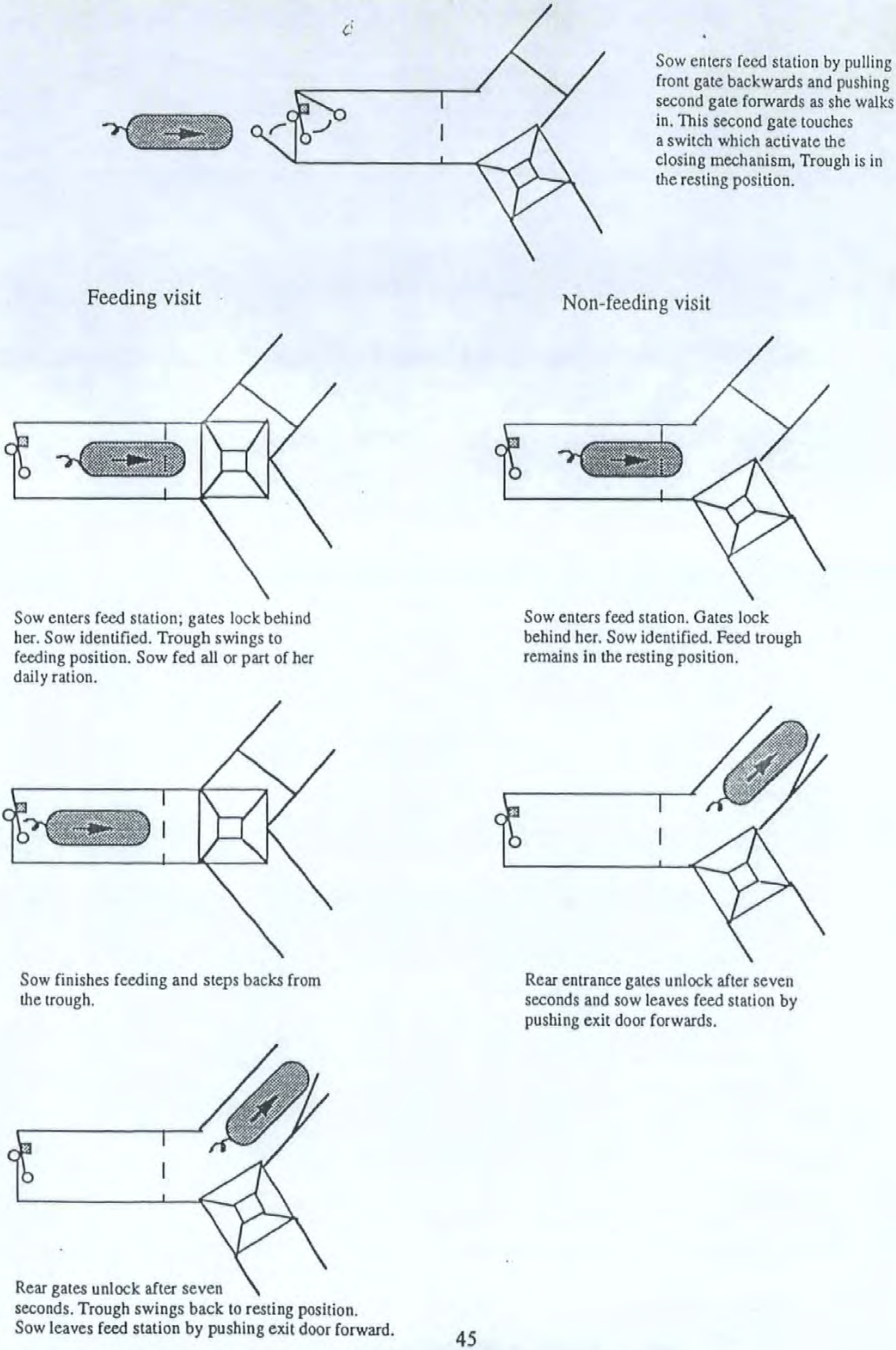
The Porcode Electronic Sow Feeding (ESF) system was based upon individual sow recognition. Each sow wore a collar fitted with a passive responder. Each responder had a unique code which was transmitted to the computer as soon as the responder was activated by the magnetic field of the transceiver. The 24 hour feeding cycle started at 1630 hours. From this time, the sows were able to take their daily allowance in either a single feed or in as many meals as they chose (Eddison and Roberts 1995). Whilst sows could also access the feed station after this daily allowance had been consumed, they did not receive any food until the start of the following feed cycle. The design of the feeding station is shown in Plate 2 and feeding and non-feeding procedures are summarised in Figure 4. The sow entered the feeding station by pulling the first gate open and pushing the second inwards as she walked forward. This second gate made contact with a switch which immediately activated a locking mechanism; delays in this locking procedure have been shown to result in sows accessing the feed station and poaching food (Beckett, Edwards, Simmins and Walker 1986). The sow was then identified by means of her responder. The computer read the responder code several times to check whether the sow had any ration left. If so, the computer transmitted a signal back to the transceiver and the trough swung into the feeding position. The auger then made one complete revolution and dispensed one 110 (±5)g portion of food. The size of this portion was programmed into the computer and was calibrated regularly. Feed was dispensed in pulses every 30-35 seconds; a sow consuming her allowance in a single visit would typically occupy the feeder for a period of 15-20 minutes. Once a sow had received a portion of food, the weight of that portion was deducted from her feed cycle allocation. The entry gates remained locked until the sow either stepped back from the trough, out of reach of the magnetic field of the antennae, or her entire feed balance for that cycle had been dispensed. The trough then swung back to the resting position and the sow left the feed station by pushing through the exit gate which closed immediately behind her via a spring action. If the sow had no ration left when she entered the station, the feed trough remained in the resting position and the entry gates unlocked after seven seconds. This mechanism of a swinging trough was designed to allow sows to be directed into a selection pen, situated between the two feeders. It also discouraged constant repeat visits to the feed station as sows could not gain access to any uneaten food and could not release pellets from the overhead hopper by banging their snouts against the trough. Both these activities were identified as problems in the earlier systems at Seale-Hayne (P.Brooks 1994, personal communication).

One feeder had 180° access, the other 120°. They were situated adjacent to each other with a shared queuing area. The walk through design directed animals away from the feeding area after they had eaten. In previous systems, the sows had to reverse out of the feeders. This design was found to result in unacceptable levels of aggression, predominantly vulva biting (Hunter 1989).

Plate 1: A view of the dry sow yard, showing the feeding stations, the straw bedded lying area and the dunging area.

Plate 2: An electronic sow feeding station.

Figure 4: A summary of feeding and non-feeding procedures.



2.2.3 Farrowing Accommodation

There were two farrowing houses, each equipped with a variety of different farrowing crates. Although the sows were restrained in all crate types, they had visual, auditory and olfactory contact with their neighbours. Straw was provided prior to farrowing to allow the sows to perform limited nesting behaviours. Heated creep areas were situated adjacent to each crate. Pens ($4m^2$) were available to house the sow and piglets in the final week of lactation. These consisted of a lying area bedded with straw, a dunging area and a protected creep area.

2.2.4 Service House

The service house contained a sow pen and a gilt pen, each accommodating up to six animals. Each pen contained six individual feeding stalls, a lying area (13 m^2) and a dunging passage. Bite drinkers were situated along the wall in the dunging area. Up to five boars were housed in separate pens ($10m^2$) from where they had visual, auditory and olfactory contact with each other and the sows. All lying areas were bedded with straw.

2.3 Herd Management

2.3.1 Gilts

Weaner gilts, bought in batches of six from PIC at approximately 25-30 kg, were housed in the gilt accommodation in their delivery groups. When they weighed 100-105 kg, they were transferred to a gilt pen in the dry sow yard where they remained for six weeks in order to build up their immunity to the diseases in the herd. From there they were removed to the service house and served at their third or fourth heat. After two to three weeks they were moved back to a pen in the sow yard. Gilts were pregnancy tested at 28 days after service using an ultrasonic probe (Medata Systems Ltd., West Sussex) and, if positive, were taught to use the feeders within the next two to three weeks.

The gilt pen was located near the feeding area and the gilts had visual, olfactory, auditory and tactile contact with the sows in the yard as well as being able to observe them using the feeders. The potential of observational learning in pigs was discussed by Nicol and Pope (1994) who observed gilts to adopt new behaviour patterns from watching their siblings. This process is most successful if the animal has the opportunity to perform simultaneously the activity it is observing. Spontaneous learning at an automatic feed dispensing station was observed by Vieulle-Thomas and Signoret (1992). A gilt was given the aversive experience of being restrained in the feeder without access to food. This resulted in later avoidance of the system by the animal's conspecifics thought to be a consequence of the presence of pheromones in the restrained sow's urine. These findings suggest that the quality of the training process will have important implications on the success of introducing animals to group-feeding systems.

In this system, having allowed the gilts a period of observation, the training process initially involved tying open the entry gates of the feeders and then gradually encouraging the animals to operate them themselves by enticing them into the feeders with sow nuts. Training took four to five days and, once proficient, gilts were introduced into the dry sow group.

2.3.2 Sows

The dry sow yard housed animals ranging from 1-107 days of pregnancy. The group was dynamic, there being 55-70 animals in the yard at any time. One week prior to their predicted farrowing date, the sows were moved in small sub-groups of two to six individuals to the farrowing accommodation and housed in individual crates. Piglets were weaned at three weeks, after which the sows were moved to the service house where they were served as soon as they showed signs of oestrus. In general, sows received one or two natural services (PIC400, PIC, Hampshire) and a single artificial insemination (pooled terminal sire, JSR

Healthbred Ltd.). Once mated the sows were returned to the main herd in the sow yard in their original sub-groups. A catch boar was housed in the sow yard to serve any sows that returned to service. The sows were therefore separated from the main group for approximately five weeks. This practice of returning sows to the yard immediately after service is common in Electronic Sow Feeding systems although it is widely believed that sows are most susceptible to stress-induced embryo loss during the implantation phase (days 12-28) and some researchers advise that mixing should be avoided until after this period (Simmins 1993).

2.4 The Feeding Programme

All feed levels were based on AFRC recommendations (AFRC 1990).

2.4.1 Gilts

Weaner gilts were fed an allowance of 1.25 kg day^{-1} (D76K, J. Bibby Agriculture Ltd., Peterborough, Appendix 2a) which was gradually increased up to 2.5 kg day^{-1} as they approached sexual maturity at approximately ten months of age. Feed intake was increased to 2.8 kg day^{-1} five days prior to service, a process termed flushing which has been shown to increase the number of ova shed in gilts (Brooks, Cooper, Lamming and Cole 1972). After service, the diet was changed to a conventional dry sow maintenance ration (D73K, J. Bibby Agriculture Ltd., Peterborough, Appendix 2b). Feed intake was reduced to 2 kg day^{-1} and remained at this level until three weeks prior to farrowing when it was increased to 3 kg day^{-1}.

2.4.2 Dry sows

Dry sows were fed 2.5-2.8 kg day^{-1} of the conventional dry sow maintenance diet depending on their weight and condition, assessed visually, at weaning. This basic ration was increased by 1kg three weeks prior to farrowing.

2.4.3 Lactating sows

Once the gilt/sow had farrowed, she was offered 2 kg day^{-1} of a lactation diet (D79K, J. Bibby Agriculture Ltd., Peterborough, Appendix 2c) split over two feeds. The feeding policy was to increase the ration in increments of 0.4 kg day^{-1} to a maximum of 2 kg + 0.4 kg per piglet suckled. However, any sow that appeared to be losing condition was fed to appetite.

2.4.4 Weaned sows

Newly weaned sows were fed 2.5-2.8 kg day^{-1} of the lactation diet depending on their weight and condition as assessed visually by the unit manager.

2.5 Summary

The overall management of the sow herd provided the framework within which this study was carried out. Whilst this investigation has focussed specifically upon the period of sow pregnancy, all stages of the production cycle are inter-related. It is important to emphasise that the sows and gilts were housed in groups yet fed as individuals throughout the majority of their reproductive life, only being restrained in the first two weeks of lactation.

Chapter Three: The Seale-Hayne sow herd: Productivity

3.1 Introduction

It has been stated that the term welfare should encompass both the ethical treatment and long-term biological functioning of the individual animals (Rushen and de Passille 1992). However, whilst Barnett and Hemsworth (1990) equated welfare with biological fitness and the animals ability to survive and reproduce, Ewbank (1969b) discussed situations where productivity was not related to welfare and the Brambell Committee (HMSO 1965) stated that high productivity and weight gain simply equated to an adequate diet and were not good measures of freedom from discomfort and stress. Whatever the relationship between welfare and productivity, group housing systems designed to maximise the welfare status of the sows must not do so at the expense of productivity if such systems are to be commercially viable and thus gain acceptance by producers.

The aims of this chapter were:

- to put Seale-Hayne in the context of other commercial units
- to describe the productivity status of the Seale-Hayne breeding herd, focussing on those measures related to ESF housing in gestation
- to investigate any relationship between parity and productivity

As described in Chapter Two, sows in the Seale-Hayne unit were housed in small groups at weaning before being re-introduced, as a sub-group, into the main group within one or two days after service. Whilst each stage of the production cycle can not be considered in isolation and will have implications on other stages, group housing systems for empty and gestating sows may be expected to have a specific effect on the following production criteria:

- weaning to conception interval
- services: farrowings ratio
- number born alive, dead and total
- culling rate
- individual feed intake

3.1.1 Weaning to conception interval

The weaning to conception interval describes the time period between weaning and a successful service, typically five days. Meredith (1979) defined anoestrus in weaned sows as failure to show oestrus within 10 days of weaning.

There is conflicting evidence on the effect of individual and group housing systems on the weaning to conception interval in sows. Group housing after weaning, with exposure to a boar, has been found to result in a significant increase in the number of sows mated within 10 days of weaning compared with sows housed in confinement or in a group without a boar (Hemsworth *et al.* 1982; Hemsworth and Barnett 1990). However, Dyck (1988) found exposing weaned sows to a boar had no effect on anoestrus in sows either confined in pairs or housed in groups of 8-12.

Comparing confined with group housing systems for gilts, England and Spurr (1969) found 28% of those housed individually and 16% of those housed in groups experienced problems in expressing oestrus and mating behaviour. A greater proportion (17%) of confined gilts failed to breed compared to group housed animals (6%) although there were no significant differences in either the total number of piglets born (alive or dead) or the average piglet birthweight. Dyck (1988) recorded a higher incidence of anoestrus in sows housed in pairs than in those housed in groups of 8-12. In contrast, Fahmy and Dufour (1976) observed a longer weaning to mating interval in sows housed in groups of 8-10 compared with those housed individually. Similarly, Lynch *et al.* (1984) found lower levels of productivity in group housed sows compared with those housed in stalls. This was explained as a consequence of injuries from fighting resulting in failure to show oestrus.

3.1.2 Services : Farrowings ratio

The services to farrowings ratio is a measure of how often a successful farrowing results from one or more services within an oestrus period.

Martinat-Botte, Dagorn, Terqui and Dando (1984) observed a higher fertility rate in confined (81.5%) compared with loose housed (72.0%) sows. This reduced rate in group-housed sows may be explained as a consequence of injuries from fighting (Lynch *et al.* 1984). Bokma (1990), studying sows in partly slatted group housing systems, observed a twofold increase in the number of returns to service when the animals were returned to the group less than eight days after service compared with those returned after implantation had taken place (days 12-28, Hughes and Varley 1980). In a survey of group housing systems, Hunter (1989) recorded that 61% of sows in ESF housing systems were returned to the group before implantation. This suggests that such systems may be expected to sustain a poor conception rate.

3.1.3 Number born alive, dead and total

Hemsworth *et al.* (1982) found individually housed sows produced significantly smaller litters than those housed in groups. However, comparing sows group housed in an outside yard with those housed in confinement, Dyck, Swierstra and Strain (1985) found no significant differences in the number born (either total or alive), piglet birthweight or weaning weights, even though those housed outside weaned a greater number of piglets.

These findings supported earlier work by England and Spurr (1969) comparing group and individually housed gilts. Similarly, Martinat-Botte *et al.* (1984) did not find housing system to have a significant effect on litter size.

Von Borrell and Hurnik (1990a) found stereotypic behaviour to be related to litter size. Such repetitive behaviour has been widely observed in confined housing systems (Fraser and Broom 1990) and may partly explain the poorer productivity sometimes recorded in such systems.

Physiological stress, such as may occur when mixing groups of sows, has been hypothesised to have a deleterious effect on embryo survival (Lynch *et al.* 1984; Simmins 1993). As a consequence, it has been suggested that sows should not be mixed until after implantation (ADAS 1985; Simmins 1993). Simmins (1993) found both the litter size and weight of multiparous animals housed in dynamic groups to be lower than in those housed in a stable group. In contrast, Lambert *et al.* (1986) did not find group housing sows in an ESF system to have an adverse effect on productivity: with data from 55 litters, the mean litter size was 11.65 (S.E.= 3.07) with 10.78 (S.E.= 2.78) born alive at a mean birthweight of 1.44kg (S.E.= 0.22).

3.1.4 Culling rate

A sow's productive lifespan will depend on a number of factors including health, welfare status, genetic potential and quality of her physical and social environment. Sows do not attain reproductive maturity until their fourth parity and, as stated by Dagorn and Aumaitre (1979) and Kroes and Van Male (1979), it is desirable to keep animals in the herd beyond this stage so as to be able to exploit their full breeding potential. Kroes and Van Male (1979) showed both total litter size and number of piglets born alive remained at a high level in sows up to and over parity ten and found that, on average, gilts have a litter size 16% below that of a sow. The two main reasons for culling sows cited by farmers were failure to show oestrus and poor productivity in old age (Dagorn and Aumaitre 1979).

3.1.5 Individual feed intake

Feed is the largest cost to the pig producer. The breeding cycle may be separated into three inter-connected stages; oestrus, gestation, lactation. Management and feeding at each stage will have implications at subsequent stages. A characteristic cycle of weight gain during pregnancy and weight loss in lactation has been observed (Lodge, Elsley and MacPherson 1966). Sows will tend to overeat in relation to their requirements in gestation and undereat in lactation (Friend 1971). Excessive feed intake *(ad lib.)* in pregnancy will result in decreased feed intake in lactation - manifested as a decrease in both meal size and duration (Dourmad 1993) - with implications on subsequent productivity.

Group housing in an ESF system allows individual feed intake to be controlled throughout gestation with the following management objectives:

- To avoid excessive feed intake during the implantation period after service which may result in embryo loss
- To ensure adequate and consistent intake throughout gestation
- To increase feed intake in the latter weeks of gestation

3.1.6 The effect of parity on productivity

As discussed in Chapter One, pigs typically form a social hierarchy with higher, intermediate and lower ranking animals (Rasmussen *et al.* 1962; Beilharz and Cox 1967) with the amount of aggression demonstrated and the ability to displace others being positively related to rank. The consequences of rank and aggressive behaviour on subsequent productivity of gilts were investigated by Mendl *et al.* (1992). Intermediate ranked animals were observed to be less productive than both higher and lower ranking group members and this was thought to be due to the fact that they were often unsuccessful in aggressive situations. In a later investigation, birthweight of piglets from these intermediate gilts was found to be significantly lower than from other gilts (Mendl *et al.* 1992). A relationship between rank and productivity factors was also observed by Meikle *et al.* (1993).

Parity was found to have an effect on the weaning to mating interval by both Fahmy and Dufour (1976) and Hemsworth *et al.* (1982), the former showing the interval to decrease in successive parities. Kirkwood, Mitaru, Gooneratine, Blair and Thacker (1988) found a higher weaning to mating interval and a lower conception rate in gilts compared with sows.

Simmins (1993) stated that litter size decreased in consecutive parities. This was explained by the fact that older sows were high ranking and therefore more likely to be involved in fighting, leading to stress and subsequent embryo loss.

3.2 Methodology

Detailed records of all production criteria were maintained for each sow. This information was entered into the Pigplan recording system (MLC/Signet). Productivity figures affected by ESF housing in gestation were compared with those from other herds and housing systems.

To investigate any effect of parity on productivity, a number of production criteria were compared between sows (1988-1995). A stratified random sample was taken to ensure data independence: each animal was only represented in one parity. Data were analysed using analysis of variance (Minitab Release 10.5 Xtra).

3.3 Results

3.3.1 Reproductive performance

Data collected over an eight year period (1990-1997) were entered into the Pigplan recording system. This enabled production figures from the Seale-Hayne herd to be compared with those from average and top-third (selected on the number of pigs reared per sow per year) herds (Table 2).

Table 2: A comparison of mean production figures from the Seale-Hayne herd with Meat and Livestock Commission recorded top-third and average herds (1990-1997)

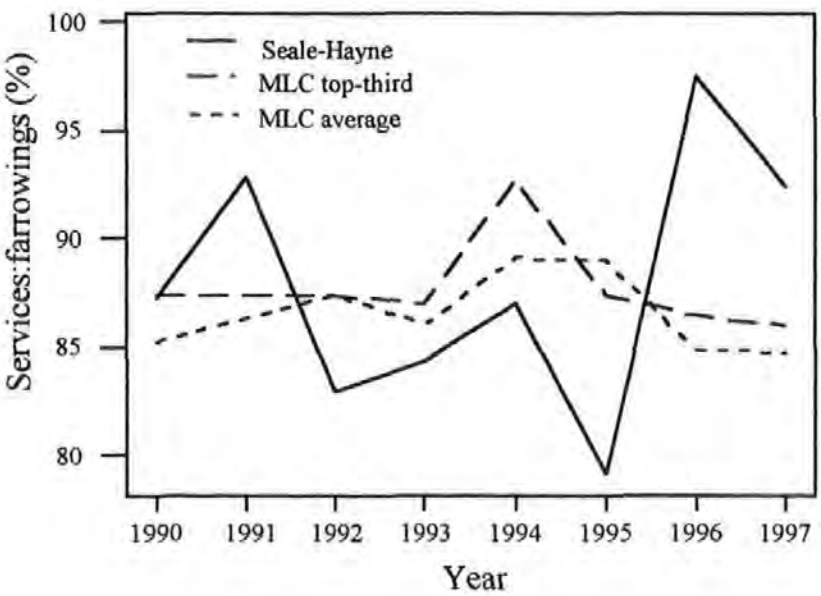
	Seale-Hayne	Top-third	Average
Services:farrowings (%)	87.93	87.74	86.60
No. born alive/litter	11.41	11.23	10.85
No. born dead/litter	1.25	0.82	0.80
Total no. born	12.94	12.17	11.76
Breeding sow sales and deaths (%)	36.71	41.06	41.11

As shown in Figures 5-10, production figures from the Seale-Hayne herd were similar to those recorded for MLC top-third and average herds. Whilst the graphs show more annual variation in the Seale-Hayne figures than in the MLC top-third and average figures this was to be expected as MLC figures represented the means of data accumulated from a number of herds. The anomaly in the data recorded in the Seale-Hayne herd in 1995 may be explained by a change in management personnel.

3.3.1.1 Services : farrowings ratio

The mean services:farrowings ratio for the Seale-Hayne herd (Figure 5) compared favourably with that from MLC top-third and average herds, ranging from 79.1% (1995) to 97.6% (1996).

Figure 5: Services:farrowings ratio



3.3.1.2 The number of piglets born alive, dead and total

Seale-Hayne recorded a higher number of piglets born alive, dead and in total than both MLC top-third and average herds (Figures 6-8). From Table 2 it can be seen that sows in the Seale-Hayne herd produced 0.5 more live piglets per litter than average herds. However, there was a similar increase in the number of dead piglets per litter born to the Seale-Hayne herd.

Figure 6: The number of live piglets born / litter

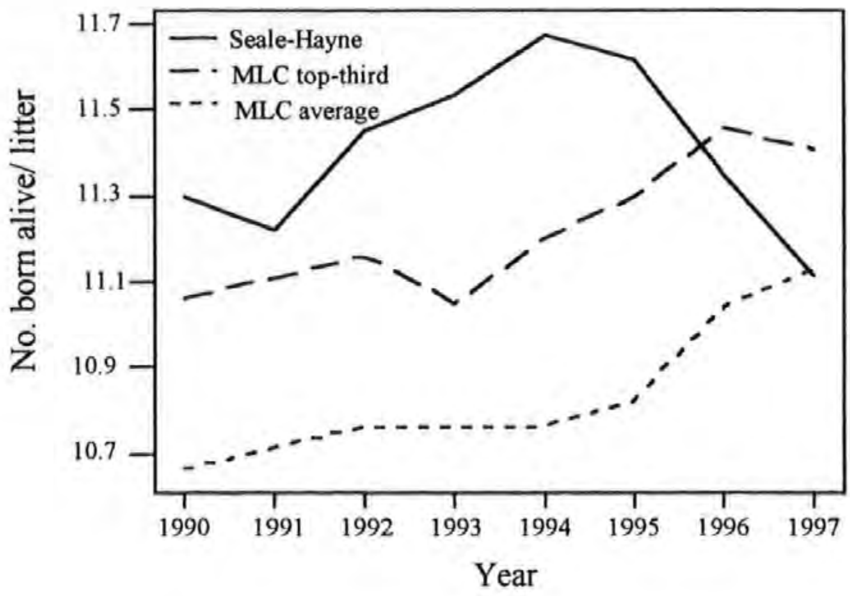


Figure 7: The number of dead piglets born / litter

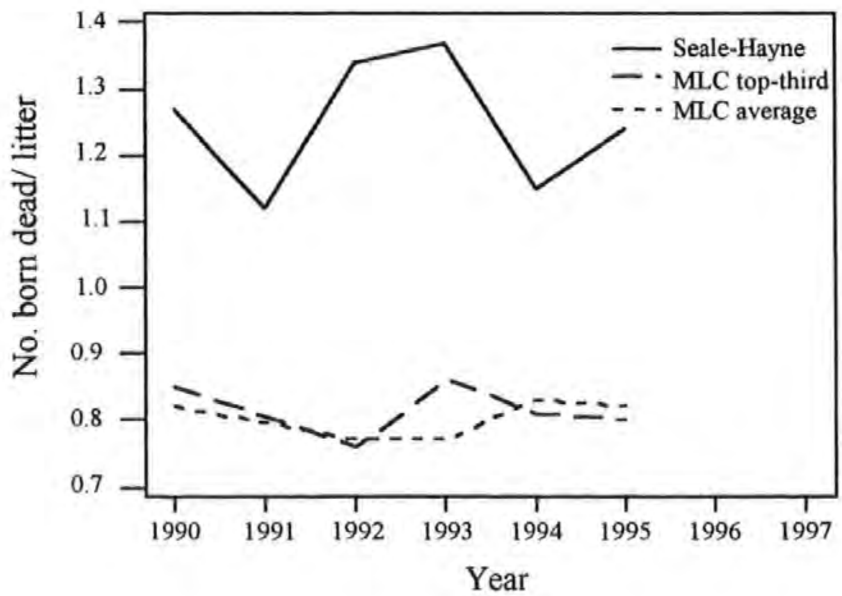
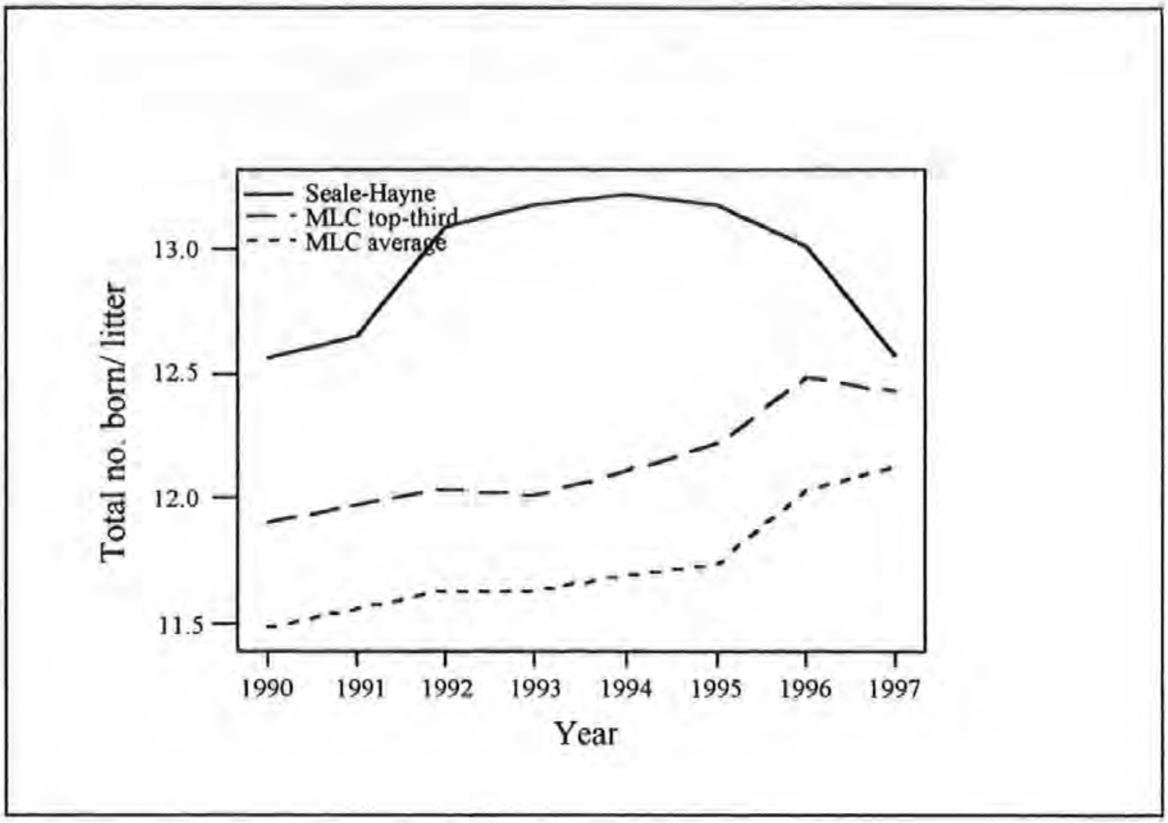


Figure 8: The total number of piglets born / litter



3.3.1.3 Culling rate

The culling rate - expressed as the proportion of breeding sow sales and deaths - in the Seale-Hayne herd followed a similar pattern to that of MLC top-third and average herds (Figure 9). However, the culling rate is a function of two factors; sow driven culling (e.g. lameness; anoestrus; poor health) and management driven culling (e.g. sows not fulfilling the desired performance criteria; a decision to increase or decrease the size of the herd) and as such there will inevitably be variation between herds. The peak in the Seale-Hayne culling rate in 1993 coincided with a management decision to increase the number of gilts and lower parity animals.

3.3.1.4 Feed intake

As illustrated in Figure 10, annual total feed consumption in the Seale-Hayne herd was similar to that in the MLC top-third and average herds.

Figure 9: Breeding sow sales and deaths (culling rate)

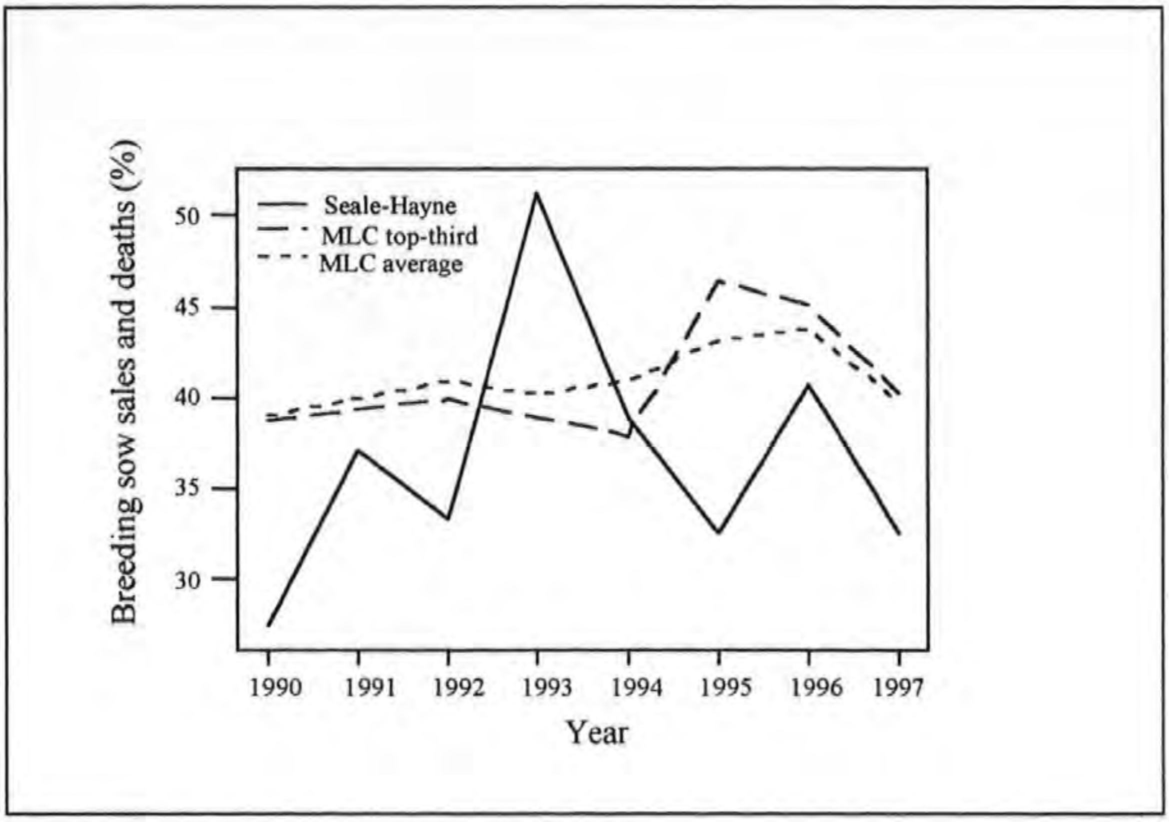
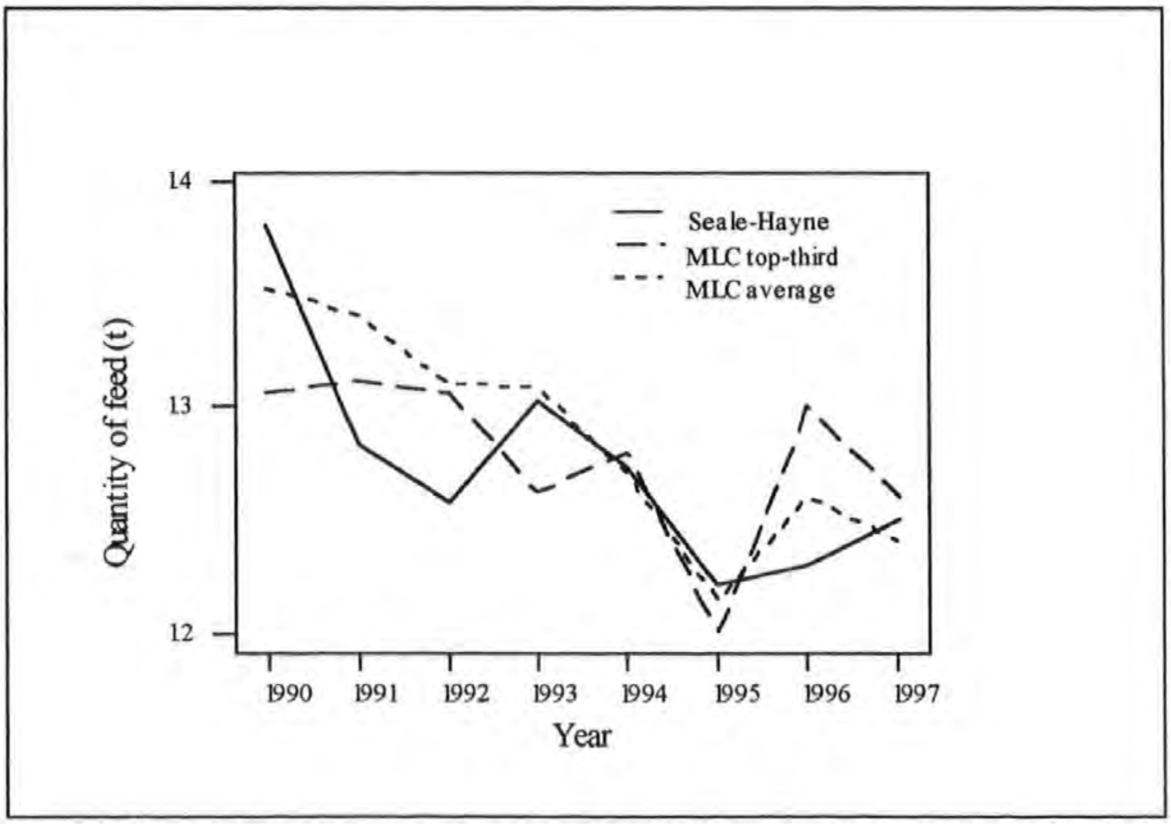


Figure 10: The quantity of sow and boar feed / sow and gilt / year (t)



3.3.2 The effect of parity on production parameters

Analysis of variance of the data revealed that parity had no significant effect on any of the following production criteria (P>0.05):

- service : farrowing ratio
- number of piglets born alive, dead, total/litter
- number of piglets weaned/litter
- total live birthweight

A high service to farrowing ratio was recorded in the Seale-Hayne unit and therefore the number of returns to service was expected to be low throughout the herd. Further investigation of the production data from the stratified random sample showed that only one animal (gilt) returned to service more than once within a parity.

3.4 Discussion

3.4.1 Services: farrowings ratio

There was little difference between the services:farrowing ratio in the Seale-Hayne system than in either the top-third or the average herds. Despite recommendations to avoid mixing sows until after implantation has taken place (ADAS 1985; Varley 1991; Simmins 1993), sows in the Seale-Hayne system were returned to the dry sow yard in small groups of four to six animals one to two days after service. It has been suggested that physiological stress at such a time may depress performance (Varley, Peaker and Atkinson 1984). Bokma (1990) cited a twofold increase in the number of returns to service when sows were returned to the main group less than eight days after service compared with those returned after implantation had taken place. However, as shown in Table 3, production figures from the Seale-Hayne herd compared favourably with those recorded by Simmins (1993) in smaller stable and dynamic groups.

This high services:farrowings ratio in the Seale-Hayne herd may be explained by a number of factors. Weaned sows were housed in small groups of four to six, with provision for individual feeding, in close contact with a boar. These factors have been shown to decrease the weaning to mating interval (Hemsworth *et al.* 1982; Hemsworth and Barnett 1990). After receiving their daily feed allowance in the service house, served sows were returned to the dry sow yard in a small sub-group at 1000-1200 hours. At this time, the sows in the yard had also received their daily feed allocation and were engaged in manipulating the recently introduced straw (Figure 13). The size and design of the yard allowed the newly introduced animals to remain in a sub-group and integrate gradually with the rest of the herd.

Table 3: A comparison of production figures from the Seale-Hayne herd (1988-1995) with those of Simmins (1993).

Source	Simmins (1993)			Seale-Hayne	
	Stable group (12)	Dynamic group (18)		Dynamic group (55-70)	
	Mean	Mean	s.e.d.	Mean	s.e.m.
no. pigs born alive/litter	10.9	10.1	0.47	12.4	2.75
no. pigs born dead/litter	0.78	0.32	0.139	1.38	1.401
total no. pigs born/litter	11.7	10.4	0.49	13.9	3.2
live litter weight (kg)	16.1	14.3	0.57	18.9	3.501
total litter weight (kg)	16.9	14.6	0.57	-	-
mean birthweight (kg)	1.43	1.48	0.036	1.56	0.228

3.4.2 Number of piglets born alive, dead and in total

The number born alive was greater in the Seale-Hayne herd than in the MLC top-third and average groups. Thus animals did not appear to be suffering from physiological stress and subsequent embryo loss at the time of implantation. A similar increase in the number born dead may indicate some physiological stress later in gestation. However, neither of these theories can be supported by the data available.

3.4.3 Culling rate

As illustrated in Table 4, the Seale-Hayne herd contained over 60% of animals in parity four and above from 1992-1994. In 1992 and 1993, over a third of the herd consisted of animals in parity seven and above. Attempts to increase the number of gilts and lower parity animals was reflected in the herd profile for 1994. The lack of any significant relationship between parity and productivity suggested that performance from these higher parity animals was comparable with the rest of the herd and that this ESF system enabled the full breeding potential of the animals to be exploited.

Table 4: The proportion of the herd in parities 4, 7 and 10 and above

	parity 4 +	parity 7+	parity 10+
March 1992	0.70	0.35	0.05
March 1993	0.64	0.39	0.13
March 1994	0.60	0.27	0.07

3.4.4 Feed consumption

Feed intake in the Seale-Hayne herd was similar to that recorded in other MLC herds. Feed represents the largest production cost to the farmer and thus it is important that it is utilised efficiently. In an ESF system, there is little wastage and each animal is able to consume its allocated ration. Thus the problems that may arise from over or under feeding in gestation may be avoided.

3.4.5 The effect of parity on production parameters

Parity had no effect on any of the production criteria investigated. However, other work has revealed a relationship between rank and productivity (Mendl *et al.* 1991, Meikle *et al.* 1993, Simmins 1993). Simmins (1993) stated that gilts and older sows were most likely to be involved in aggressive interactions, with decreased productivity as a consequence. In the Seale-Hayne system, gilts and animals returning from the service house were allowed to integrate gradually with herd and thus avoid aggressive encounters. The presence of fresh straw enriched the physical environment and there was little evidence of competition for feed or other resources.

In summary, production figures from the Seale-Hayne herd illustrate its status as a typical commercial unit.

Chapter Four: Preliminary observation studies on the gestating sow herd

4.1 Introduction

A number of preliminary observation studies were carried out to gather information on the social behaviour of the gestating sow herd. The objectives were as follows:

- to identify and describe all activities and interactions demonstrated by the herd
- to record activity patterns and investigate how the animals utilised various components of their environment
- to record the frequency and location of interactions
- to identify temporal activity patterns in order to plan subsequent investigations.

4.2 Methodology

Direct observation studies were made by a single observer from a viewing platform in the dry sow yard. The location of the platform is shown in Figure 3. All areas of the yard could be observed with the exception of the area marked LLA (Figure 23). Although the viewing platform was visible to the sows, they did not appear to show any response to the presence of the observer.

Direct observations of the dry sows were made daily over a two week period (03/1992); from 0800-1000 hours and from 1530-1730 hours. All behaviours performed by the sows were recorded using *ad libitum* sampling (Altmann 1974; Martin and Bateson 1986; Bernstein 1991) and the information was used to compile ethograms of activities and interactions (Tables 6 and 7).

Following these initial observations, the spatial and temporal incidence of activities and interactions was recorded over a three week period (04/1992). Observation periods lasted four hours (0000-0400; 0400-0800; 0800-1200; 1200-1600; 1600-2000; 2000-0000) and throughout the three weeks, observations were carried out five times over each period giving a total of 120 hours observation time (Table 5).

Table 5: Observation periods

Week 1	0000-0400 and 1200-1600 for 5 days
Week 2	0400-0800 and 1600-2000 for 5 days
Week 3	0800-1200 and 2000-0000 for 5 days

Instantaneous scans (Altmann 1974; Bernstein 1991) were carried out at regular 15 minute intervals during each observation period and the activity and location of every individual at that time was recorded. Behavioural states rather than events were scored (Altmann 1974).

During each observation period every interaction was recorded, along with the time and location of its occurrence. This practice is referred to as all occurrence scanning (Bernstein 1991) or behaviour sampling (Martin and Bateson 1986) and was chosen because the interactions recorded satisfied the two major criteria of this technique in that they were both conspicuous events and did not occur too frequently as to be missed.

In a final investigation (05/1992), all occurrence scanning was used to assess the frequency of the different interactions described. The sows were observed from 1530 hours on four days and the first 250 social interactions demonstrated on each occasion were recorded.

4.2.1 Data analysis

Data were entered into the ORACLE database and analysed using MINITAB (Release 10.5 Xtra). Data were analysed using analysis of variance (Zar 1984).

4.3 Results

4.3.1 Activities and interactions demonstrated

Observations were used to compile an ethogram of all activities and interactions demonstrated by the herd (Tables 6 and 7, respectively).

Table 6: Activities performed by the dry sow herd.

Activity		Description
Locomotory	Walking	Forward locomotion with three feet in contact with the substrate at any moment
	Running	Trotting/ cantering movement; animal may lash out with one/both hind legs. Activity often accompanied by sudden snorting/grunting sounds
	Backing	Backwards locomotion (as for walking)
Feeding	Feeding visits	Visiting ESF station and eating nuts from trough
	Queuing	Standing facing feeder; within 2m of entry gates
	Drinking	Imbibing water
Grooming	Head shaking	Shaking head vigorously; often performed whilst manipulating straw bedding
	Rubbing	Rubbing body against yard surfaces
	Scratching	Scratching body with hind limb
	Wallowing	Immersing body/part of body in wet substrate. Animal may lie still or move around, sometimes vigorously
Exploratory	Licking	Rubbing tongue against yard surfaces or other sows
	Nosing	Using snout to manipulate or inhale substrate or other sows
	Pawing	Extending one foreleg, then sweeping it over the substrate, flexing at the knee joint
Displacement	Champing	Exaggerated chewing motion with mouth empty
	Chewing bars	Chewing bars of gates
	Non-feeding visits	Visiting ESF station when ration expired. Activity often accompanied by frustrated attempts to access trough
Inactive	Sitting	Resting inactive, with hindquarters, back legs and fore feet in contact with the ground
	Standing	Inactive with all four feet on the ground
	Lying	Inactive with head and body in contact with the ground, legs extended or bent under body

Table 7: Interactions demonstrated by the dry sow group.

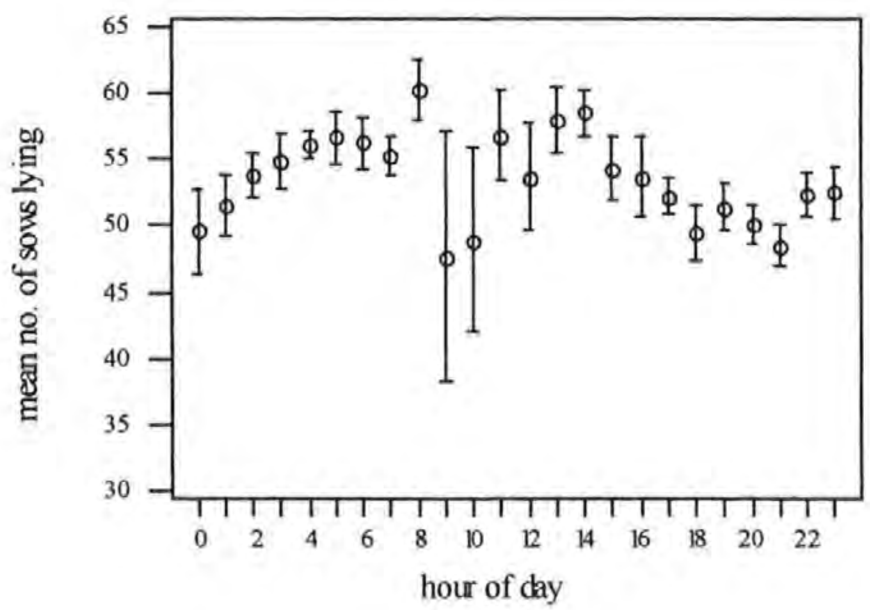
Interactions	Description
head -> head with/without bite	thrusts with the snout or head directed towards the head of another sow, with or without simultaneous attempts to bite same area
head -> body with/without bite	thrusts with the snout or head directed towards the body of another sow, with or without simultaneous attempts to bite same area
head -> anus/vulva with/without bite	thrusts with the snout or head directed towards the anus/vulva of another sow, with or without simultaneous attempts to bite same area
parallel pressing	sows stand side by side and push against each other with their shoulders
levering	sow puts its snout under the body of another individual (from the side or behind) and attempts to lift
approaching	sow moves towards another sow
chasing	sow runs after another sow
snout -> snout	snout of one sow approaches/contacts the snout of another
snout -> body	snout of one sow approaches/contacts the body of another
snout -> anus/vulva	snout of one sow approaches/contacts the anus/vulva of another
mounting	sow places front hooves on the back of another (from any direction)
Responses	
no response	sow shows no reaction and continues in present activity
retaliation	sow reacts by performing interaction (as described above)
retreat	sow moves away from attacking sow
squeal	sow vocalises - with/without other response
head tilt	sow lowers head and tilts it to one side

These ethograms were based upon those of Fraser (1974) and Jensen (1980).

4.3.2 Activity patterns

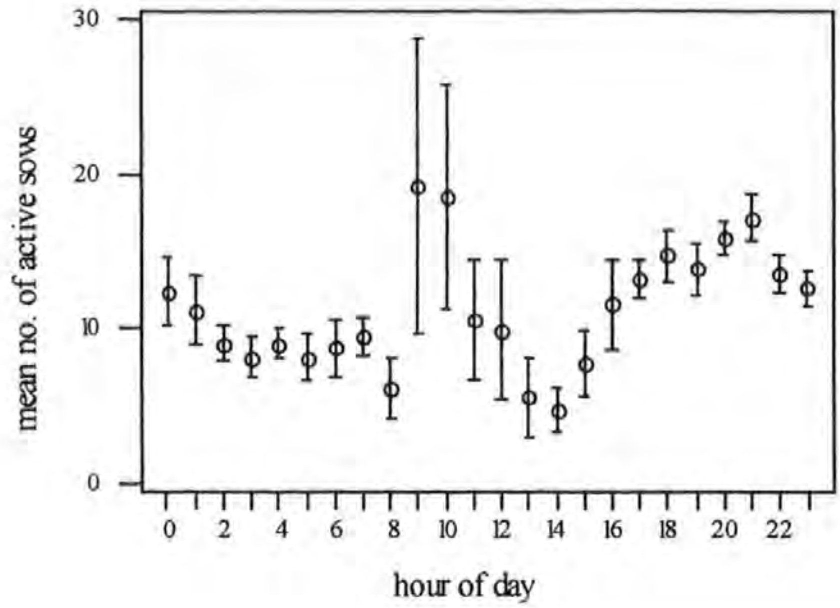
Throughout the day the majority of the herd were found to be lying inactive (mean =76.4%; S.D.= 10.73%). The mean number, with 95% confidence intervals, of sows lying down, in all areas of the yard, over the 24 hour period is shown in Figure 11. There was a significant decrease in the number resting at 1000 hours (11.43%) when fresh straw was added to the yard ($P<0.001$). Significantly fewer animals were resting at the start of the feeding cycle (52.9%) than in the early morning (0200 - 0800 hours) when the majority of the herd had fed ($P<0.001$).

Figure 11: The mean number of sows observed lying inactive.



The incidence of all active behaviours was summed to illustrate the level of general activity throughout the day (Figure 12). A trough was apparent in the latter part of the feeding cycle with activity levels beginning to rise as the start of the next cycle approached. A significant increase in the level of activity coincided with the introduction of fresh straw ($P<0.001$).

Figure 12: The mean number of sows engaged in active behaviours.



Fresh straw was added to the yard on all the days when observations were made. The importance of this resource was investigated over a 24 hour period (Figure 13). As expected, there was a significant increase ($P<0.001$) in the number of sows manipulating straw immediately after it was introduced at 1000 hours (64.3%; S.D.=22.79%). The number of sows engaged in this activity gradually decreased and then began to rise again as the feeding cycle started.

The number of sows in the feed queue throughout the daily cycle is shown in Figure 14. There was a significant increase at the start of the feeding cycle and a significant decrease when fresh straw was added to the yard ($P<0.001$).

Figure 13: The mean number of sows observed manipulating straw.

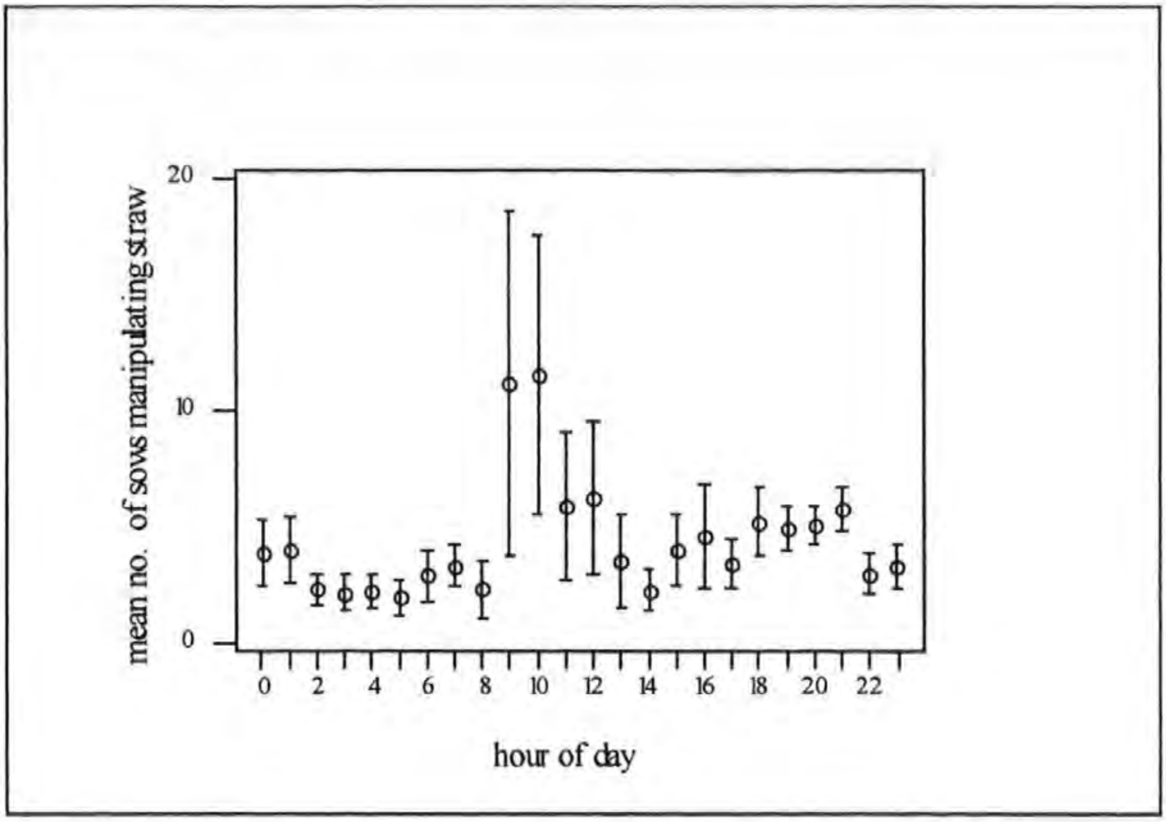
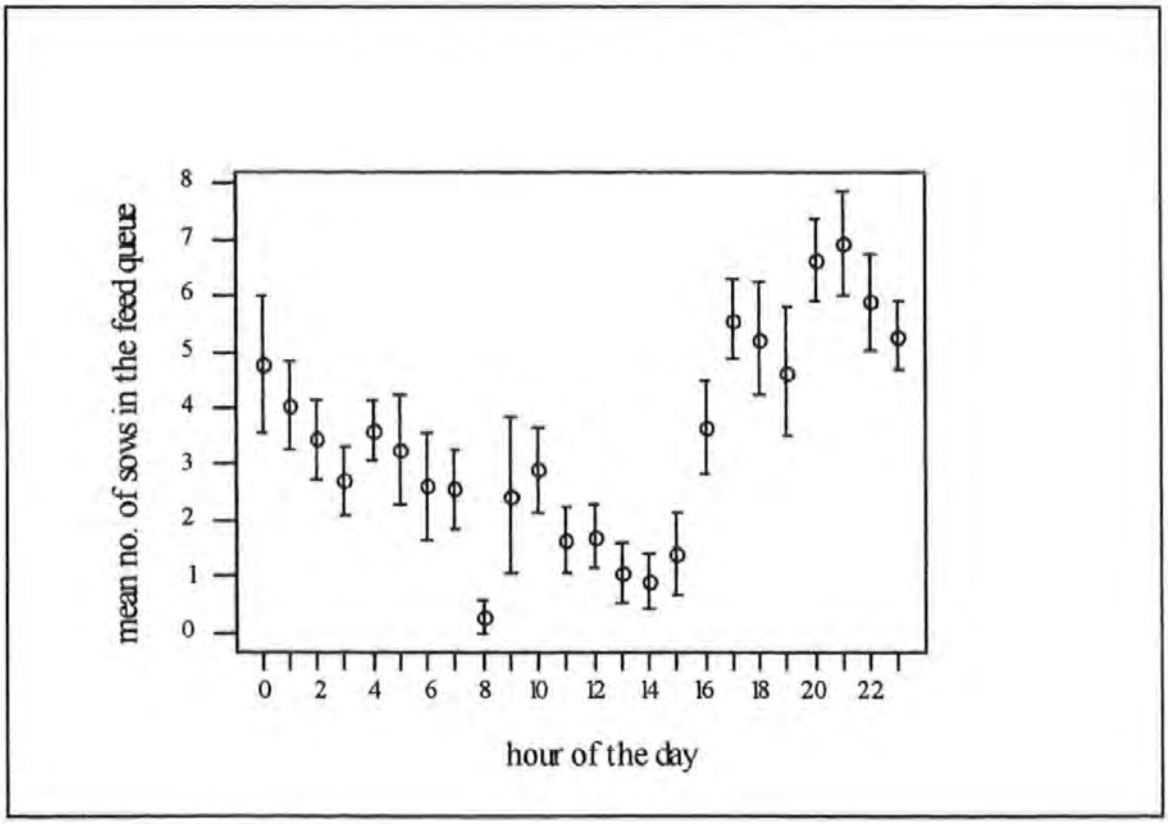


Figure 14: The mean number of sows in the feed queue.



As described in Chapter Two, distinct lying, feeding and dunging areas could be identified within the yard. In order to examine how the animals utilised the space available throughout the day, the number of sows in each area was recorded at fifteen minute intervals (Figures 15 a,b,c). Sows spent the majority of their time in the lying area (mean =82.2% of the herd; S.D. =5.72%) although, as expected, there was a significant decrease in the number found in this area at the start of the feeding cycle (P<0.001). This coincided with a significant increase in the number of animals in both the feeding area (P<0.001) and the dunging area (P<0.001). There was a lot of variation in the number of sows found in the dunging area throughout the day.

Figure 15a: The mean number of sows recorded in the lying area

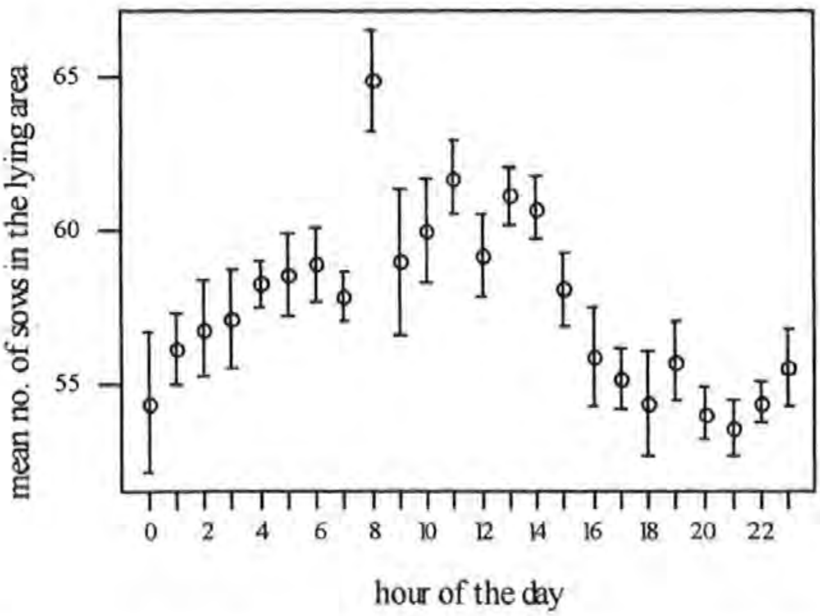


Figure 15b: The mean number of sows recorded in the feeding area

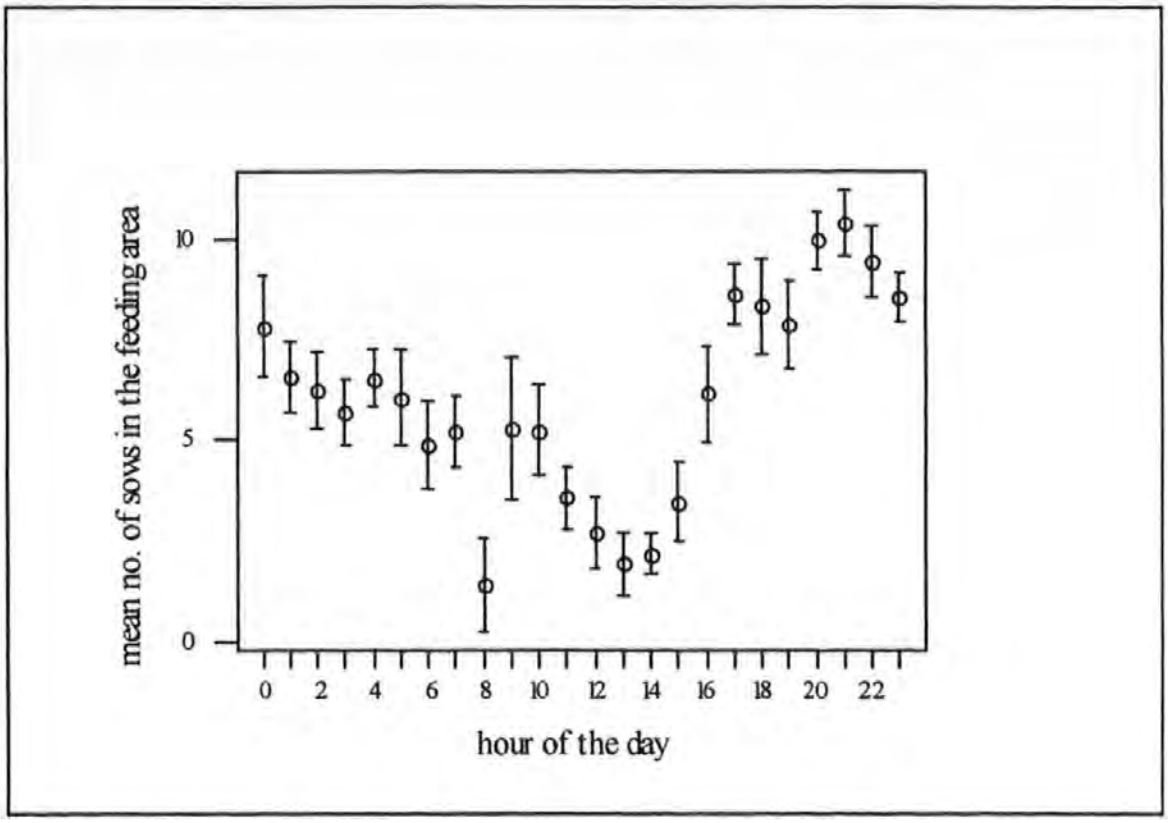
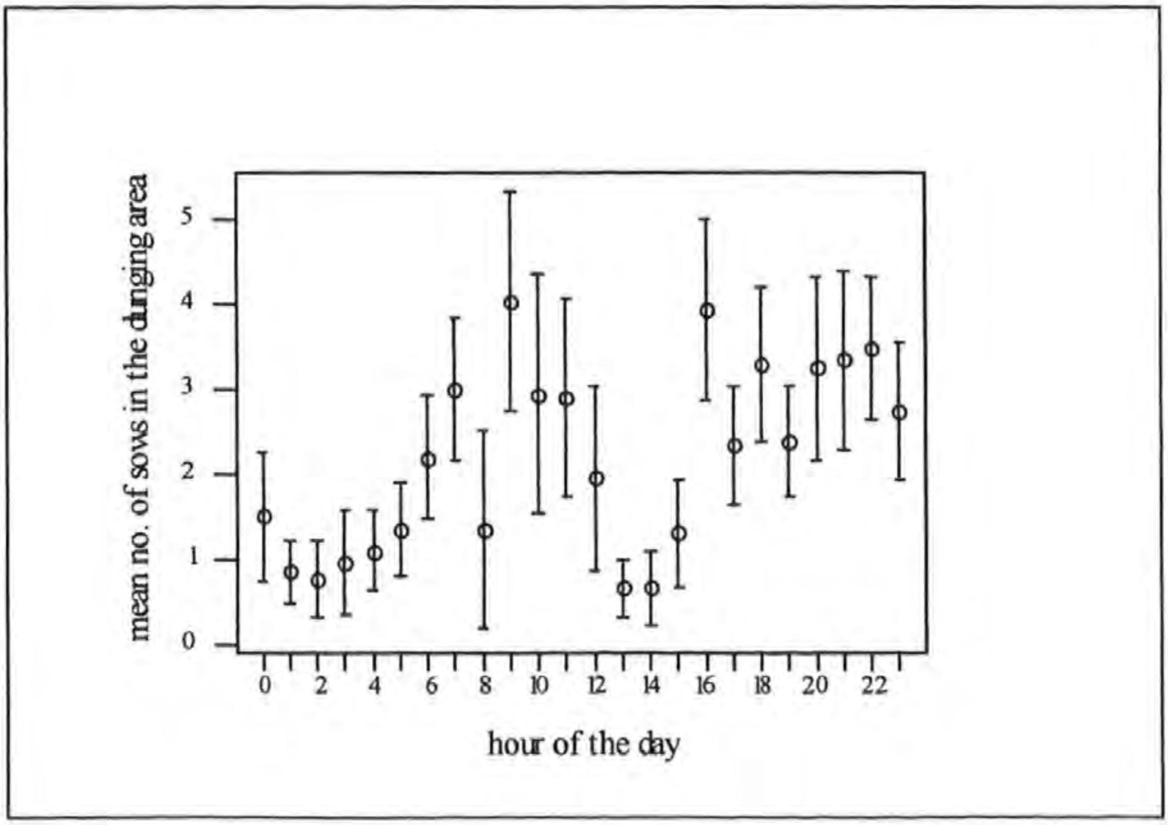


Figure 15c: The mean number of sows recorded in the dunging area



4.3.3 Interactions

The number of interactions recorded throughout the day is shown in Figure 16. A significant ($P<0.001$) increase was observed at the start of the feeding cycle. The number of interactions recorded in the lying, feeding and dunging areas throughout the day is shown in Figure 17. As expected, there were significantly ($P<0.001$) more interactions in the lying and feeding areas than in the dunging area. The relative occurrence of the different interactions observed is shown by the histogram in Figure 18. In a total of 1000 recorded interactions not all those described in the ethogram were performed. As illustrated, the most frequently observed interactions involved one sow directing its head towards the head of another, with or without attempting to bite.

Figure 16: The mean number of interactions observed.

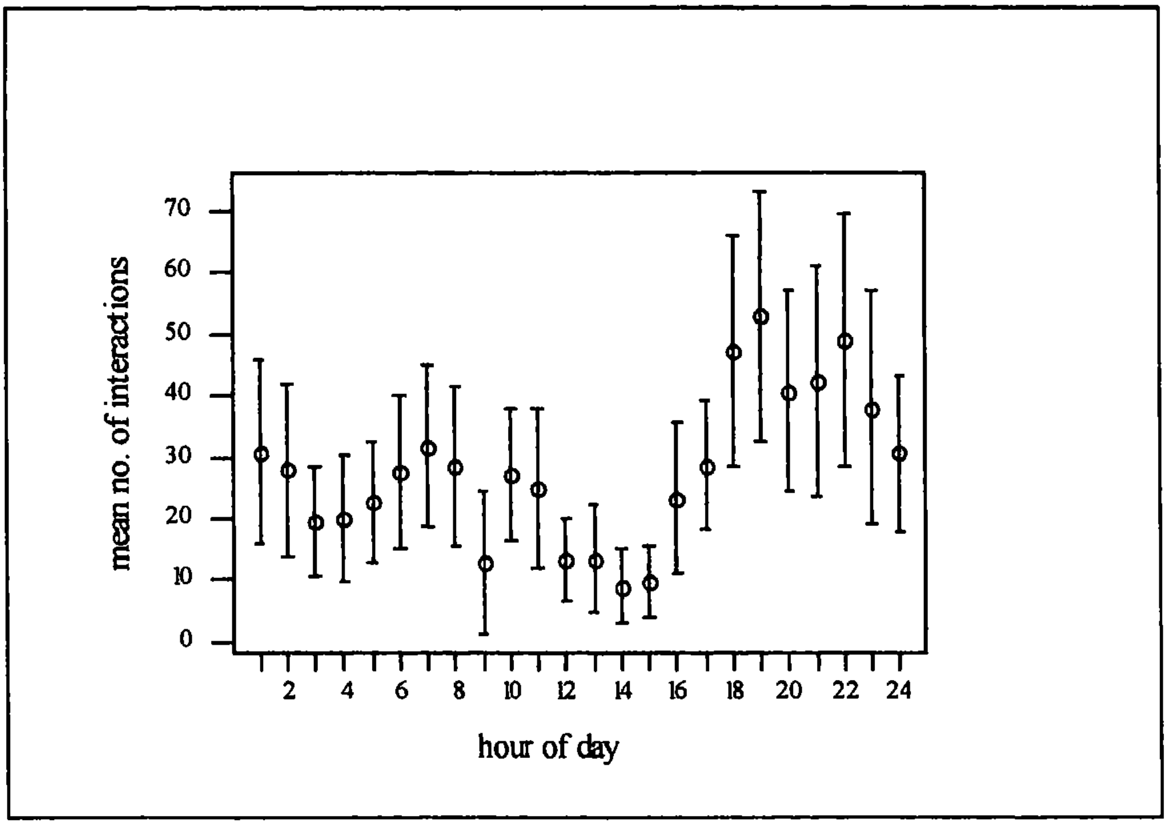


Figure 17: The mean number of interactions recorded in the lying, feeding and dunging areas.

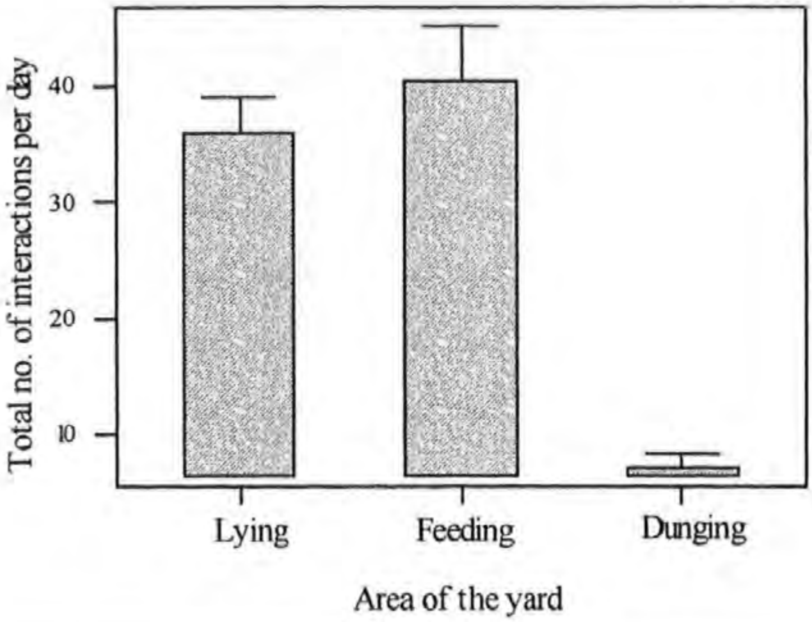
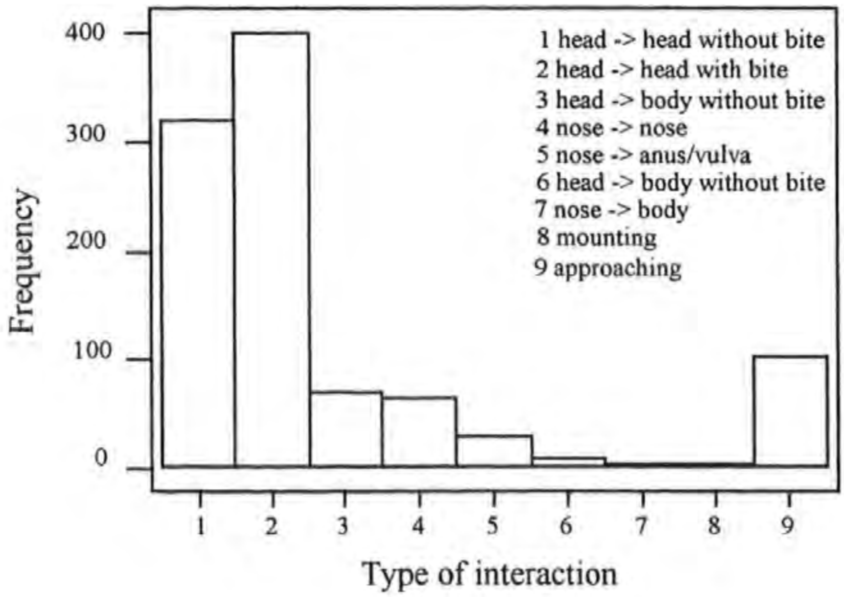


Figure 18: The frequency of the different types of interaction observed (n=1000).



4.4 Discussion

In this group housing system, sows were found to perform a number of exploratory, grooming, locomotory and displacement behaviours, to interact with other members of the group and to utilise all areas of the yard throughout the day. The activities and interactions described were similar to those observed by Fraser (1974) and Jensen (1980) in groups of growing pigs and dry sows, respectively.

Throughout the day, lying was the most commonly demonstrated behaviour. Abnormally low levels of activity and lack of response to novel stimuli have been suggested as indicators of a poor welfare status (Van Putten 1980; Wiepkema *et al.* 1983; Broom 1986). However, inactivity in this context refers to the animals being in a state of inanimation, often sitting or standing motionless for long periods and could be defined as stereotypic behaviour (Fraser 1975). Stereotypies have been described as having no obvious goal or function and this definition may be used to distinguish the inactivity shown by an animal lying in a bedded area from that described above.

When compiling the activity ethogram (Table 6) champing, licking and non-feeding visits were described as displacement behaviours. Whilst sows were observed to make non-feeding visits throughout the day, neither champing nor licking were recorded on any occasion during the 120 hour observation period.

Two events were observed to have a significant effect on activity patterns, frequency of interactions and space utilisation; the introduction of fresh straw to the yard and the start of the feeding cycle. Whilst acknowledging its role with respect to both recreation and bedding, Fraser (1975) and Lawrence, Appleby, Illius and MacLeod (1989) found the presence of straw to have no effect on the level of aggression in tethered or group housed sows, respectively.

However, in this study activity levels increased ($P<0.001$) and the frequency of interactions decreased ($P<0.001$) when fresh straw was introduced to the permanent deep litter lying area. This suggested that it was the introduction and novelty of *fresh* straw that was having a regulatory effect on interactive behaviour by providing a substrate for both manipulation and, possibly, ingestion. As an unacceptable level of aggression is commonly cited as the major criticism of group housing systems, the provision of this resource may have important implications on the success of such systems. Fraser (1975) observed similar benefits in tethered sows, housed on dry concrete. Animals were observed to spend long periods of time sitting or standing motionless. This behaviour, and other stereotypic activities such as bar biting decreased, whilst the time spent lying increased, when the animals were provided with straw either as bedding or as a feed supplement.

The frequency of interactions and the number of animals in the feed queue both increased at the start of the feeding cycle, although 73-90 % (S.D.=4.88%) of the herd still remained in the lying area. Aggressive interactions have been observed to arise when animals compete for limited resources (Rasmussen *et al.* 1962; Meese and Ewbank 1972). Although the space available in all areas of the yard exceeded recommendations and there were sufficient feeders and queuing space for the size of the group (Hunter 1989), sows could compete for favoured resting locations and for position in the feed queue.

The number of aggressive interactions at feeding time were found to be 20.1 $hour^{-1}$ in an indoor system (Jensen 1984) and six $hour^{-1}$ in a free-ranging system (Jensen and Wood-Gush 1984). Whilst the sows in this system were fed individually, there was a significant increase in the number of animals in the feed queue at the start of the feeding cycle. At this time a mean of 28.4 (S.D.=19.06) interactions $hour^{-1}$ was recorded. However, Jensen (1984) and Jensen and Wood-Gush (1984) defined interactions as aggressive. If only those interactions where the head of one sow was directed towards the head or body of another were considered, the mean number of interactions recorded in the first hour of the feeding cycle was 16.8 (S.D.=13.83).

As expected, there were significantly more interactions in the feeding and lying areas than in the dunging area where no obvious resource providing a stimulus for competition existed. The investigation was carried out in March when the ambient temperature would not have made this a favourable resting area: In subsequent studies, sows were observed to choose to rest in the dunging area in the summer months (personal observation).The fact that most interactions occurred in the lying area could also be explained by the fact that this was the most populated area throughout the day. This was to be expected as sows were attracted to this area by the presence of straw both as a bedding and a recreational material.

As observed by Rasmussen *et al.* (1962) and McBride *et al.* (1964), the most frequently observed interactions in this study were those involving the head of one sow being directed towards the head of another sow, with or without associated biting. Whilst other authors (Lambert *et al.* 1986; Van Putten and Van de Burgwal 1990; Bure 1991) have reported unacceptable levels of vulva biting in group-housing systems, there was little evidence of such behaviour in this investigation. The information collected on activity patterns and interactions in this study was used to plan some of the subsequent investigations:

- to assess the incidence of injuries arising from aggressive interactions in sows housed in this ESF system
- to investigate resting behaviour with respect to physical factors and social organisation within the herd
- to study feeding behaviour and motivation.

Chapter Five: The injury status of the gestating sows housed in a dynamic group and fed using an electronic sow feeding (ESF) system

5.1 Introduction

A number of methods exist to assess the welfare status of the pig (Sybesma 1981; Broom 1988; Barnett and Hemsworth 1990; Mason and Mendl 1993). All injury, defined by Baxter and Baxter (1984) as the "destruction of the physical structure of tissue ... manifested in cuts, bruises and abrasions", may be assumed to have a detrimental effect on an animal's welfare status. Whilst lesions arising from aggressive interactions have been found to be largely superficial and quick-healing (Dolf 1986), the advantages of using such an observable physical symptom of suffering as an indicator of welfare were discussed by Dawkins (1988). Ekesbo, cited by de Koning (1984), suggested that the state of the integument could be used as an easily assessed indicator of well-being. Subsequently, de Koning (1984) devised a scale for recording the site and intensity of injuries on the body of the sow and, in a study of the welfare status of a number of different housing systems, concluded that this was both an easily implemented and very valuable technique. Gloor (1986) similarly stated that the extent of lesions on the skin reflected the quality of the animal's physical and social environment. A number of assessment scales have since been based on de Koning's original system (McGlone 1985; Gloor 1986; Luescher *et al.* 1990; Edwards *et al.* 1993).

Social organisation has been shown to have a regulatory effect on aggressive behaviour in groups of growing pigs (Beilharz and Cox 1967), gilts (Rasmussen *et al.* 1962) and sows (Jensen 1980). However, most forms of organisation depend upon established, stable relationships between members of the group. In dynamic housing systems, the group is regularly disrupted with the potential for high levels of associated aggression (Bresser *et al.* 1993). Furthermore, social orders in pigs have only been identified in groups of up to 12 animals (Ewbank 1969a). Commercial group housing systems for gestating sows typically contain much larger numbers of animals. The possible existence of sub-groups within the main group has been discussed (Hunter 1989). Such groups may provide a mechanism for reducing the potential level of aggression within the main group by decreasing the amount of disruption experienced by each individual. However, animals housed in dynamic, commercial systems might be expected to sustain a high injury status.

Several other factors have been reported to have an effect on aggressive behaviour; the housing of a boar with the group (Barnett, Cronin, McCallum and Newman 1993) and the provision of straw both as a feed buffer (Arey 1993; Robert, Matte, Farmer, Girard and Martineau 1993; Brouns, Edwards and English 1994) and as a substrate for manipulation (Fraser 1975; Arey 1993; Jensen, Kyriazakis and Lawrence 1993) are commonly implemented techniques in groups of dry sows. However, Luescher *et al.* (1990), having reviewed a number of methods for reducing aggression at mixing, concluded that no solution existed for decreasing aggressive behaviour in dynamic groups and that perhaps a certain amount of fighting was required to establish a dominance hierarchy and that the extent of inevitable injury should be minimised by controlling the physical and social conditions at mixing.

There is conflicting evidence as to whether individual characteristics, such as parity, weight and age have any influence on aggressive behaviour. A relationship between parity and aggression in feral pigs was observed by Mauget (1981), whereas Mount and Seabrook (1993) found parity to have no effect on the amount of aggression displayed by individuals when mixing unacquainted sows. Whilst Mauget (1981) found weight to be related to aggression in feral pigs and McBride *et al.* (1964) and Beilharz and Cox (1967) observed heavier animals to win most social encounters in groups of growing pigs, Rasmussen *et al.* (1962) and Meese and Ewbank (1973) found no relationship between weight and aggression in groups of gilts and growing pigs, respectively.

In a dynamic group, there is a continuous need to re-establish the social order. Both the initial rank of an animal and the length of time that it is away from the group have been found to have a significant effect on the levels of disruption on its return. Ewbank and Meese (1971) found that top ranking animals could be returned to a group of growing pigs without being attacked after a separation period of 25 days; lower ranking animals were attacked on return if removed for only three days. A similar situation was observed by Fraser (1974). The incidence of aggression when mixing sows has been found to decrease when the animals were introduced in sub-groups, with the facility for these small groups to integrate gradually with the rest of the herd (Hunter 1989; Hunter *et al.* 1989; Moore *et al.* 1993). Spoolder, Burbidge, Edwards, Lawrence and Simmins (1996) found this assimilation process to take at least three weeks.

In groups of growing pigs and gilts most attacks are directed towards the head, neck and ears and consequently, the majority of injuries occur on the ears, head, neck and shoulders (Rasmussen *et al.* 1962; McBride *et al.* 1964; McGlone 1985; Luescher *et al.* 1990). However, it is the threat of injury to the vulva that has been cited as a potential major problem of dynamic group housing systems for dry sows (Edwards, Armsby and Large 1986; Lambert *et al.* 1986; Van Putten and Van de Burgwal 1990). Van Putten and Van de Burgwal (1990) defined the process and outcome of vulva-biting in the following way:

> "Vulva biting ... occurs when a sow approaches a pen-mate from the rear or when the pen-mate steps back towards the snout of a sow with the consequence that this sow bites the vulva of the other with her incisors... wounded vulva generally shows a deep cut; however there may be only a scratch. Sometimes part of the labia is nearly or entirely bitten off. It even occurs that a whole vulva is bitten off."

The vulva swells in the latter stages of pregnancy, as the sow prepares for parturition and consequently becomes more vulnerable to attack. Furthermore, as illustrated in Plate 3, once the vulva has been bitten, the resultant swelling, darkening in colour and possible presence of blood and pus are likely to attract further attention and thus the problem may be perpetuated (Van Putten and Van de Burgwal 1990). In a group of 80 sows, Lambert *et al.* (1986) found vulva biting to be at such a level that, on average, 6.6 (SE 4.1) sows required treatment each week; although it was not discussed what level of treatment was involved, the welfare of the animals was stated to be at risk. Van Putten and Van de Burgwal (1990) found vulva biting to originate around the feeding stations from where the incidence spread throughout the pen. They stated that pigs were foraging animals and conditioned to feeding simultaneously. Queuing for feed is an unnatural behaviour and the problem is compounded by the fact that, in a barren environment, feeding has become of exaggerated importance. This problem was reduced by providing chopped corn silage on the floor in the lying area twice a day. The silage provided an opportunity for the animals to feed simultaneously, thereby taking pressure away from the feeders. Bure (1991) also reported unacceptable levels of vulva biting in an ESF system, especially around the feed stations and, having observed the incidence to be reduced by providing straw pellets in the feed, suggested that this behaviour may be associated with a frustrated feeding motivation.

Although there is a lack of information on the injury status of dry sows housed in dynamic group housing systems, there is concern that animals may sustain a level of injury which would be unacceptable in welfare terms. The objectives of the study reported here were:

- to assess the injury status of individual sows housed in the system
- to relate injury score to specific characteristics of the sow such as parity, stage of pregnancy and body condition

- to quantify injuries to different parts of the body
- to investigate whether the vulva is more susceptible to attack as it swells in the latter stages of pregnancy

5.2 Methodology

5.2.1 Injury assessment

This study assessed the injury status of the sows when group housed in the dry sow yard and only injuries arising from aggressive interactions during this period were recorded. Sows also received injuries from other sources: boars at service; the bars of the farrowing crates; friction from their collars; yard surfaces. These various injuries were studied and found to be easily distinguishable (Table 8).

Table 8: Injuries received by the sows

Source	Description
Service	Abrasions to shoulders and flanks Large surface area affected Largely superficial with deep red colouring
Farrowing crates	Distinct wounds, often quite deep, sometimes resembling blood blisters Location easily associated with position of farrowing crate bars
Collars	Grazes, cuts or blisters on neck immediately beneath collar
Yard surfaces	Grazes or distinct cuts or bruises which may appear on any part of the body
Treading	Skin damage, usually manifested in deep cuts, typically found on the side of the udder
Aggressive interactions	Skin damage, ranging from superficial scratches to deep wounds Typically small, discrete sites of injury

For a period of 18 months (10/92-04/94), the gestating sows were assessed each week for injuries. To minimise stress and disruption to both the group as a whole and to the individual feeding behaviour of each sow, observation time was limited to the period towards the end of one feed cycle, when all the animals had consumed their entire ration (typically 1400 hours), but before the start of the next feed cycle (1630 hours). As shown in Figure 11, the majority of the herd were inactive during this period.

Due to the size of the group, it was necessary to devise a method that allowed the animals to be assessed quickly and efficiently. The sows were confined in the dunging area and walked through a weigh-crate back into the lying area. This allowed all areas of the body to be examined clearly by two observers and injuries to be assessed quickly. A scoring technique was devised for this study (Table 9 and Plates 3a-d). This was a simplification of the de Koning scale, a well-established method of injury assessment (de Koning 1984). The surface of the body was divided into twelve areas (ears (x2), snout, shoulders (x2), flanks -including sides of the udder (x2), hindquarters (x2), top of the back, tail, vulva) and each area given a score (0-3) depending on the severity of injury, if any. Preliminary observations of injury sites revealed that, typically, wounds started to heal by forming a scab within 12-24 hours of their occurrence, depending on their severity. Only injuries that had not started to heal and had thus occurred within the last 24 hours were recorded during each observation period. This ensured data independence in that each injury was only scored once. The animals were assessed before they re-joined the herd after service to identify any injuries that were received in the farrowing and/or service houses. These injuries were not recorded.

To ensure data consistency, all recordings were made by the same two observers. This method allowed up to 70 animals to be assessed within two hours.

Table 9: The injury scoring system

Score	Injury status	Description
0	No injury	Skin unmarked No evidence of injury from aggressive interactions
1	Slight injury	< 5 superficial wounds
2	Obvious injury	5-10 superficial wounds and/or < 3 deep wounds
3	Severe injury	> 10 superficial wounds and/or > 3 deep wounds

5.2.2 Sow condition

During the same experimental period dry sows were weighed weekly in a standard weigh crate fitted with an electronic universal weighhead (GHL Products, Cheshire). To gain further information on sow condition, backfat measurements (P2) were taken after weaning, in week eight of pregnancy and one week before farrowing using an ultrasonic probe (Meritronics livestock grader, Meritronics Ltd, Faversham).

5.2.3 Data analysis

Data on sow identity, parity, pregnancy stage, weight, backfat and injury scores was stored in the ORACLE database and analysed using the MINITAB statistics package (Release 10.5 Xtra).

A stratified random sample was taken across the herd to ensure data independence. Each sow was represented in only one parity.

Plate 3 Evidence of vulva biting

Plate 4a A sow with no injury; score 0.

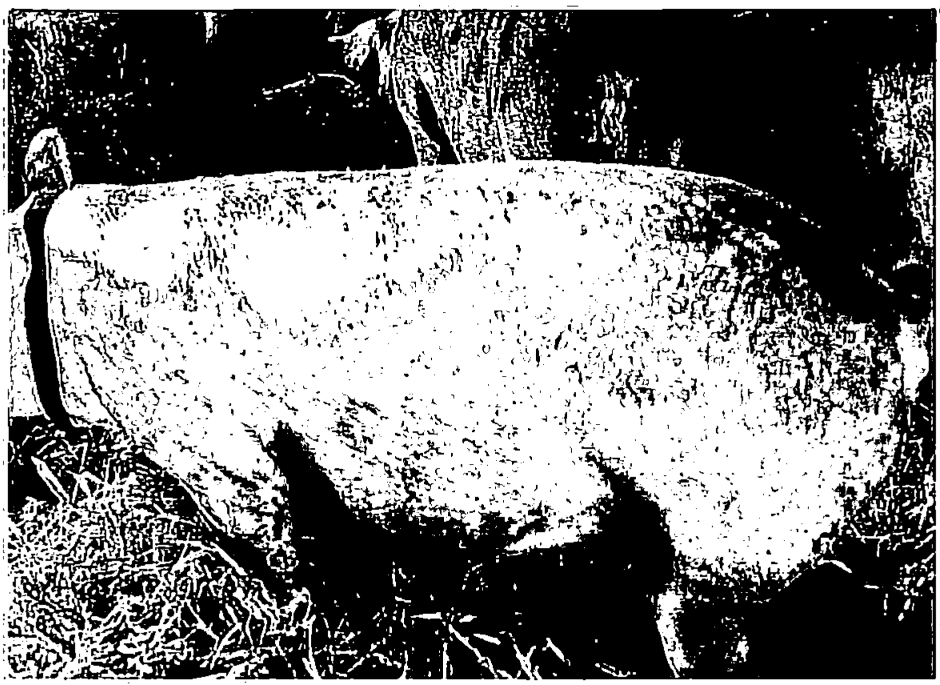


Plate 4b A sow with slight injuries; score 1.

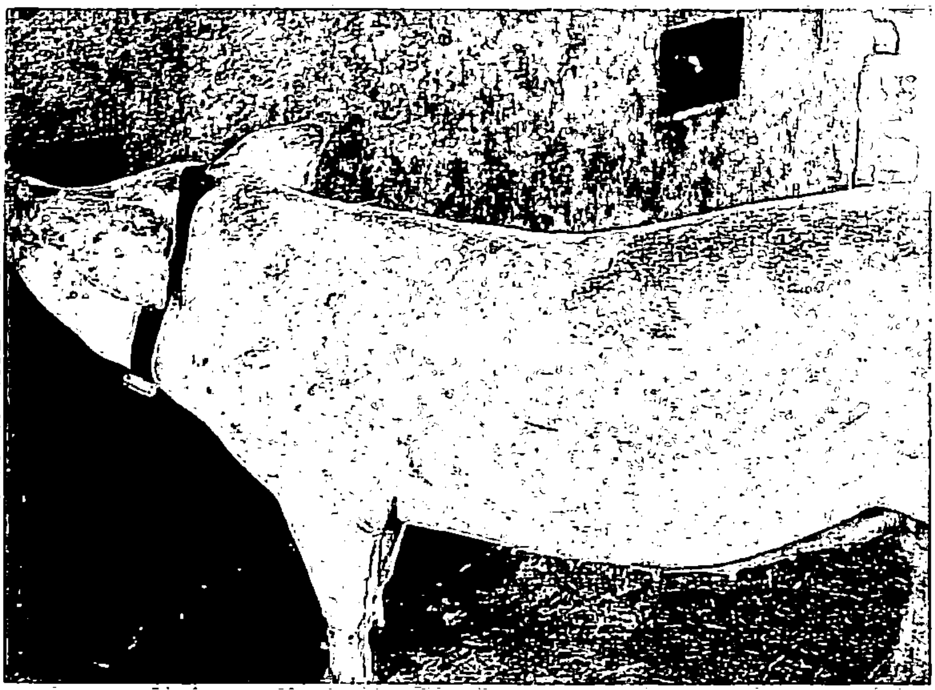


Plate 4c A sow with obvious injuries; score 2.

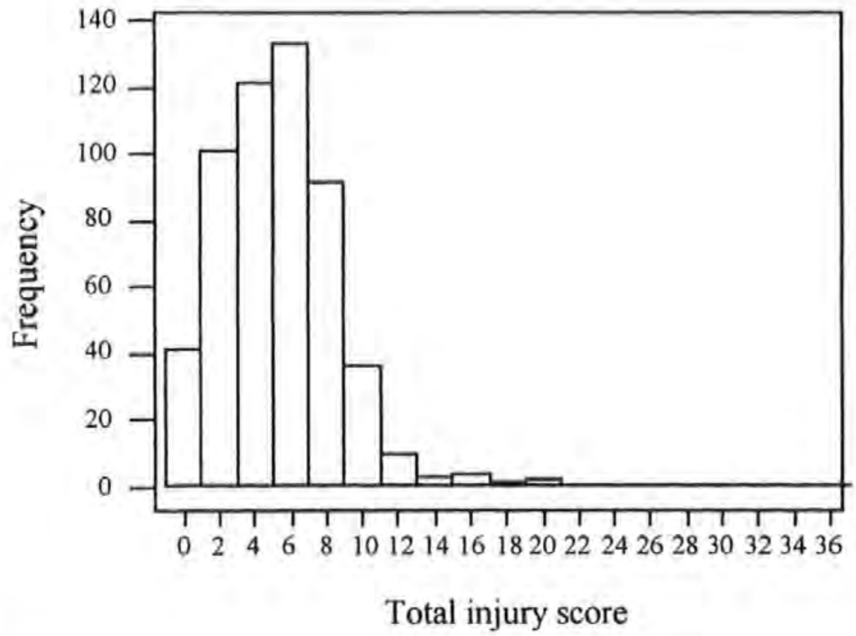
Plate 4d A sow with severe injuries; score 3.

5.3 Results

5.3.1 Injury status of sows housed in this system

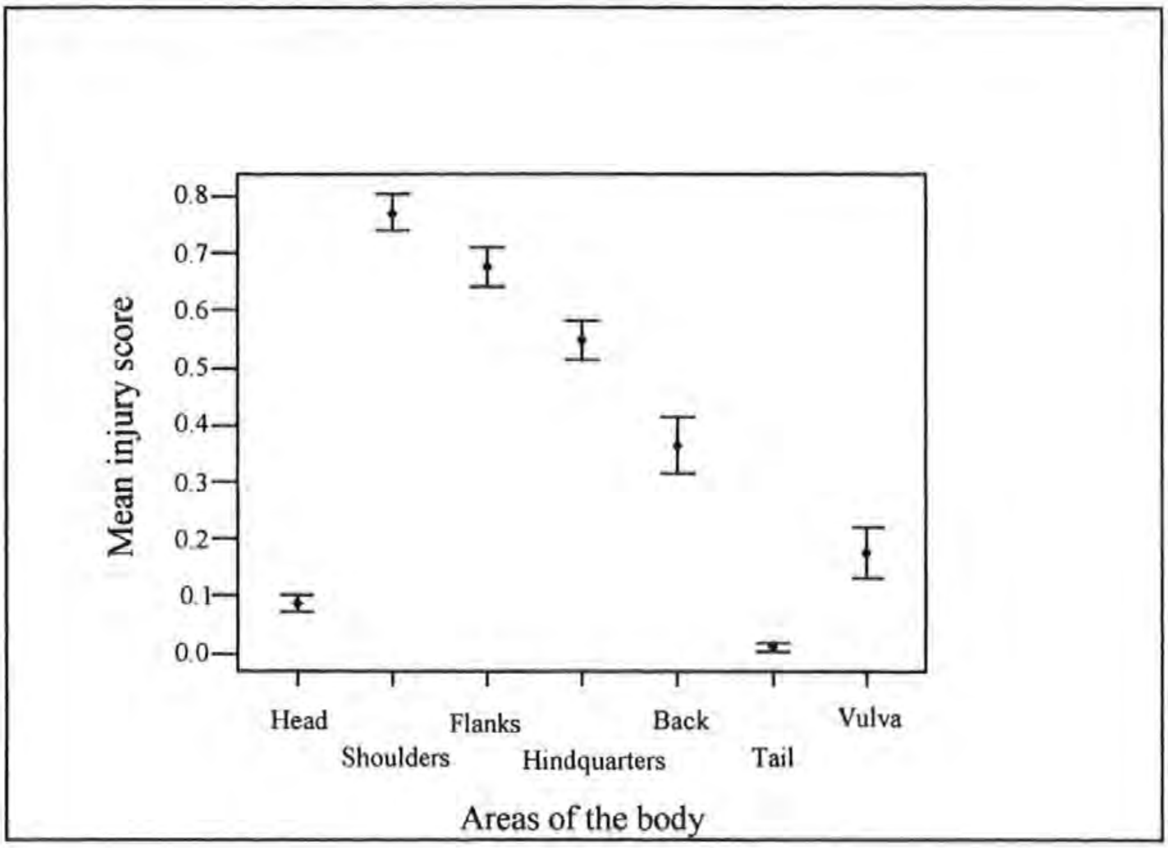
Analysis of the data revealed a low level of injury throughout the herd; with a potential maximum total injury score of 36 (i.e. sum of all area scores: 12 areas x maximum score of 3), the maximum score recorded was 19, with a median value of 5 (Figure 19).

Figure 19: Total injury score.



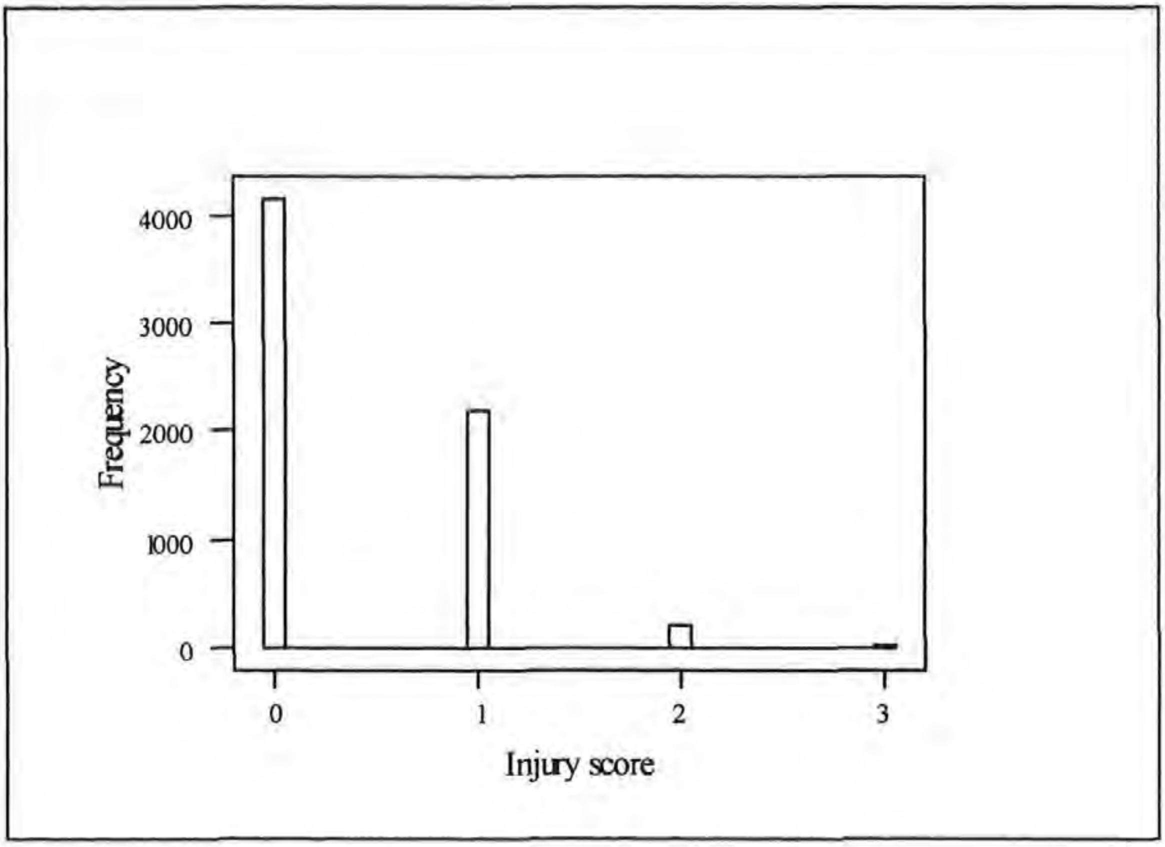
Significant differences in the extent of injuries to the various areas of the body were revealed using analysis of variance ($F=252.39$; $df=11, 6468$; $P<0.001$). Since very few injuries were observed on the ears and snout, these areas were combined to represent the facial region for analysis purposes. Furthermore, the scores for similar areas on the left and right sides of the body were added together. The shoulders, flanks and hindquarters received a significantly greater number of injuries than all other areas of the body (Figure 20).

Figure 20: Injuries received to various areas of the body.



A frequency histogram of the individual injury scores (Figure 21) illustrates the severity of the attacks, demonstrating that most injuries were slight, and very few scores of 2 or 3 were recorded. These observations suggested that a high total injury score was probably the result of slight injury to several regions of the body rather than localised areas of intense damage.

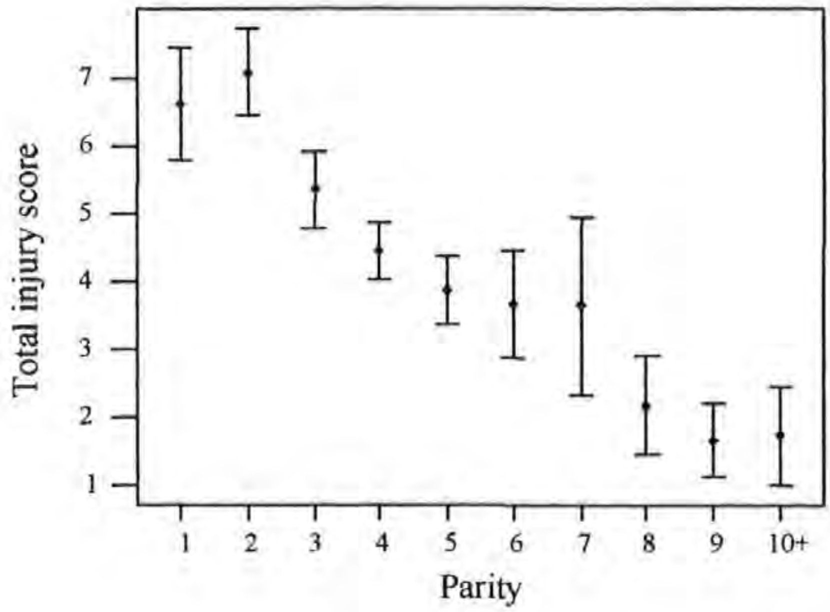
Figure 21: Frequency of injury score to illustrate the severity of injuries received by the sows.



5.3.2 The effect of parity, pregnancy stage, weight and backfat on injury score

The injury score of sows was compared between parities using a oneway analysis of variance (Zar 1984). A significant difference between parities was identified (F=20.74; df=12,533; P<0.001) with injury score declining with increasing reproductive experience as illustrated in Figure 22. Gilts and first parity sows sustained the greatest level of injury. The injury score of sows of parity 10 and above was very variable.

Figure 22: The effect of parity on total injury score



Multiple regression analysis (Zar 1984) was used to investigate the combined effect and relative importance of parity, days into pregnancy, weight and backfat on total injury score:

Total injury score = 16.1 - 0.26parity - 0.03weight - 0.08backfat - 0.01days into pregnancy

($F=17.58$; $df=4,123$; $Rsq(adj)=36.4\%$; $P<0.001$)

In combination, these factors accounted for 36.4% of the variation in the total injury score recorded. Of this 36.4%, parity contributed 63.94%, weight 31.06%, backfat 3.94% and days into pregnancy 1.06%. Therefore parity and weight had the most significant effect, with injury score decreasing as both these factors increased. Injury score decreased only very slightly as backfat and days into pregnancy both increased.

5.3.3 The extent of injury to the various areas of the body

Under hormonal control, a number of changes occur in the body of the sow as she prepares for parturition. The vulva swells in the latter weeks of pregnancy and thus may become more susceptible to attack. This has been cited as a potential problem of group housing systems with resultant problems including stress, infection and farrowing difficulties (Van Putten and Van de Burgwal 1990). Regression analysis did not reveal any increase in the extent of vulva damage in the latter stages of pregnancy ($F=3.00$; $df=1,544$; Rsq(ad)= 0.4%; $P > 0.05$). In fact, there was little evidence of vulva damage at all, most injuries occurring on the shoulders, flanks and hindquarters (Figure 20).

5.4 Discussion

5.4.1 Injury status of the sows

Dynamic group housing systems necessarily result in social disruption and associated aggression (Bressers *et al.* 1993) and, as such, the welfare of animals housed in such systems may be expected to suffer. However, the paramount finding of this study was the low injury status throughout the group, demonstrated by both the low incidence (Figure 19) and low severity (Figure 21) of injury. These results suggested that, as in previous studies with growing pigs (Beilharz and Cox 1967; Jensen 1982), fights were resolved quickly and that some social organisation was having a regulatory effect on aggressive behaviour although it was not possible to identify any such social order for a number of reasons:

- the group was dynamic, hence any hierarchy would have changed frequently
- the size of the group would have required the observation of a great number of interactions to stand any chance of establishing a hierarchy
- the frequency of interactions was low (Figure 16) and thus it would have been difficult to gather sufficient data

A number of other factors may explain the low level of aggression and resultant low injury status of the sows in this herd. The incidence of aggression has been found to increase when resources, such as food and space, are limited and defendable (Rasmussen *et al.* 1962; Bryant 1972; Meese and Ewbank 1972). In this electronic sow feeding system, the sows were protected whilst feeding in the feeding stall and there was no opportunity for any member of the group to access and consume the food allocation of another. It could be argued that sows could compete for their position in the feed queue and feed cycle but, as the data reported in chapters four and eight illustrates, this competition did not result in excessive levels of aggression as sows modified their feeding behaviour within the constraints imposed by the rest of the group.

The bedded area exceeded the lying space recommended for the size of the herd (Hunter 1989) and the sows were also able to rest in the dunging area and, during the summer months, in the field adjacent to the dry sow yard. Furthermore, the size and design of the yard allowed sows to escape from aggressive interactions and for conflicts to be resolved quickly; factors which have been shown to decrease the incidence of aggression (Bryant 1972; Bryant and Ewbank 1972; Ewbank and Bryant 1972; Meese and Ewbank 1973). As discussed in Chapter Six, certain resting areas were considered more favourable than others, and competition for such sites probably explained some of the aggression that occurred in the lying area (Figure 17). In this system the design of the feed stations and gates directed the sows away from the feeding area to the drinking/dunging area and then to the lying area. Such a one-way movement has been found to decrease the level of activity and subsequent aggression around the feeders (Hunter 1989).

Straw has been found to have a regulatory effect on aggressive behaviour, especially when the group is disrupted, for example, when sows are re-introduced into the herd following service (Ewbank and Meese 1971). In this system the sows were provided with a deep litter lying area, fresh straw being added two or three times a week. The straw provided both a feed buffer (Arey 1993; Robert *et al.* 1993; Brouns *et al.* 1994) and a medium for the sows to manipulate and thus perform comfort and exploratory behaviours (Fraser 1975; Arey 1993; Jensen *et al.* 1993). A boar was housed with the dry sows, a practice which has been shown to reduce the incidence of aggression, especially at mixing (Barnett *et al.* 1993).

5.4.2 The effect of different factors on injury score

The relationship between parity and total injury score may indicate that a learning process existed as well as the more obvious conclusion that higher parity sows were older and heavier and therefore more likely to initiate than receive aggressive behaviour (McBride *et al.* 1964; Beilharz and Cox 1967). Furthermore, older sows may have an established status, resting location and feeding pattern and thus integrate more easily and with less disruption when re-introduced to the group.

The trend for injury status to decrease with increasing parity was reversed in sows in parity ten and above. At this stage animals became less mobile and thus less capable of escaping from aggressive encounters. First parity sows received a greater injury score than gilts. This may be explained by the data on lying behaviour presented in Chapter Six which demonstrated that gilts tended to isolate themselves from the rest of the group, remaining predominantly in the dunging area, whereas first parity animals started to integrate with the herd. A similar situation was observed by Hunter (1989) and Moore *et al.* (1993).

Total injury score decreased gradually throughout pregnancy as, over time, the sows re-established their social position. In this dynamic group gilts and sows were regularly returned to and removed from the herd. Both the initial rank of an animal and the length of time that they are away from the group were found to have a significant effect on the levels of disruption on their return. Ewbank and Meese (1971) found that top-ranking animals could be returned to a group of growing pigs without being attacked after a separation period of 25 days; lower ranking animals were attacked on return if removed for only three days. A similar situation was observed by Fraser (1974). In this system animals were typically removed for up to 35 days, suggesting that, if sows behaved in a similar way to growing pigs, even higher ranking animals would have to fight to re-establish their social position on return. However, the results obtained from this study did not show this to be the case. Injury scores recorded in the first week after re-joining the herd were not significantly higher than in later weeks although there was a very gradual decline throughout pregnancy. This may be explained by the fact that newly introduced gilts and sows were found to rest in the dunging area for a while before integrating with rest of group (Chapter Six). This pattern was also recorded by Hunter (1989) and Moore *et al.* (1993), the latter observing integration to take place within 21 days. Hunter *et al.* (1989) further found the incidence of aggression at mixing to decrease if the pigs were introduced in sub-groups, with the facility for these animals to integrate gradually with the rest of the herd. In the Seale-Hayne system gilts were introduced in batches of six and sows returned after service in sub-groups of four to six. In the final stages of pregnancy sows increasingly tended to isolate themselves from the herd and avoided social interactions (personal observation).

Injury score was found to be significantly related to both weight and backfat with heavier, fatter sows sustaining lower scores than those in poorer condition. This information suggested that heavier sows received less aggressive attacks but did not necessarily imply they were more aggressive themselves - they may have avoided interacting with other sows. Mauget (1981), working with feral pigs, found weight to be related to aggression and McBride *et al.* (1964) and Beilharz and Cox (1967) observed that heavier animals won most encounters.

However, Rasmussen *et al.* (1962), working with gilts, and Meese and Ewbank (1973), studying mixed sex groups of growing pigs, did not find weight to be related to social aggression. Mount and Seabrook (1993) found the amount of aggression displayed when mixing unacquainted sows bore no relationship to age, weight or parity.

5.4.3 The extent of injury to the various areas of the body

In this study, most injuries were found on the shoulders, flanks and hindquarters, with little evidence of damage to the head or vulva. This conflicts with the findings of McGlone (1985) and Luescher *et al.* (1990) who found most fights to be directed towards the head, ears and neck in groups of prepubertal mixed sex pigs and gilts respectively and also Lambert *et al.* (1986) and Bure (1991) who cited vulva damage as the major problem in a group of dry sows. In the Seale-Hayne unit most aggressive encounters were found to occur in the lying and feeding areas (Figure 17). Throughout the day the majority of the herd occupied the lying area where agonistic interactions were initiated for a number of reasons including sows disturbing each other, competing for resources of straw and space and reinforcing their social relationships. Observations in the present study suggested that the majority of these attacks were directed towards the body. In the feeding area, the animals competed for access to the feeders. The sides of the feed station extended beyond the entrance gates (Plate 2) and thus the head and neck region of the animal waiting to access the feeder was largely protected. This may further explain the incidence of injury on the shoulders, flanks and hindquarters as these areas would be exposed to other animals fighting for access to the feed station.

A number of authors have cited vulva-biting in the latter stages of pregnancy as a potential problem in group-housing systems (Edwards *et al.* 1986; Lambert *et al.* 1986; Van Putten and Van de Burgwal 1990). Bure (1991) reported unacceptable levels of vulva biting in an ESF system, the problem being most prevalent in the feeding area as animals fought for both position in the feed queue and access to the feeders. It was suggested that this behaviour was linked to a frustrated feeding motivation and the incidence was significantly reduced by providing straw pellets at the feed station. The animals in the Seale-Hayne unit were fed similar amounts of concentrated feed in the feeding station as those in Bure's (1991) study, yet there was little evidence of vulva damage throughout pregnancy and no significant increase in the final weeks when the vulva became swollen and potentially more susceptible to attack. This suggested that whilst both fresh straw and straw pellets provided a feed buffer, the former further reduced the incidence of vulva biting by providing a substrate for manipulation. In the Seale-Hayne system the animals were protected whilst feeding and there was sufficient queuing space in front of the feeders. A high incidence of vulva biting was reported in the original ESF systems in which the sows had to reverse out of the feeders (Hunter 1989). As such the vulva was vulnerable to attack from queuing sows. The low level of interactions recorded in the dunging area (Figure 17) suggested that animals in this system were not vulnerable to attack as they exited the feeding stations.

In the introduction to this chapter the assessment of physical injury was discussed as a reliable indicator of welfare status. However, although the sows in this study were found to sustain a low injury score, it was not possible to determine a level above which welfare may be considered to have been compromised. Barnett and Hemsworth (1990) stated that if an animal was suffering its productivity would suffer as a consequence. However, Ewbank (1969b) discussed situations where this was not the case and the Brambell Committee (HMSO 1965) stated that factors such as high productivity and weight gain were not good measures of freedom from discomfort and stress. In Chapter Nine the inter-relationships between injury status, productivity and various aspects of the animals feeding and social behaviour are discussed in an attempt to further evaluate the welfare status of sows in this

ESF system. At this stage it can only be surmised that as the majority of injuries were superficial and quick healing the animals welfare was unlikely to be severely affected.

In conclusion, a dynamic, commercial group of dry sows fed through an ESF system sustained a low injury status throughout pregnancy. This was thought to be due to the provision of straw, the design of the yard and the feeding system. Parity, pregnancy stage and body condition were all found to have a significant effect on injury score. There was little evidence of vulva damage, even in the latter stages of pregnancy.

Chapter Six: Resting behaviour of dry sows housed in the Seale-Hayne electronic sow feeding (ESF) system

6.1 Introduction

In comparison with sows housed in confined stall and tether systems, loose-housed sows have some ability to control their own physical and social environment. Group housing systems should enable this freedom to be fully exploited to the benefit of individual sow welfare. One of the choices available to the loose housed sow is resting location. Sows have the ability to choose where and with whom they lie, within constraints imposed by other group members.

Domestic pigs have been shown to spend the majority of their time resting. Growing pigs were found by Randolph *et al.* (1981) to spend, on average, 67.4% of their time resting. Group size and space allowance were both shown to have an effect on lying behaviour. Hammel and Hurnik (1987) observed that gilts (mean weight 48kg) spent over 80% of the day resting, whether feed was provided in six meals or offered *ad lib.*, although there was a significant increase (P<0.01) in the time spent walking in the former treatment group. In the Seale-Hayne unit the sows were found to spend a mean of 76.38% (SD=10.73) of their time resting (Section 4.2.2).

Beckett *et al.* (1986) found that group-housed sows displayed preferences for particular lying sites. Sows housed in groups of four in a pen equipped with individual feeding stalls, a communal lying area and a dunging passage were found to spend 50% of their time lying in the stalls (Walker and Kilpatrick 1994). Although this apparent preference for isolation may be explained by the fact that the animals were previously housed in stalls, benefits may be accrued from providing group-housed sows with access to both individual and communal lying areas. Van Putten (1988) stated that, given a choice, "pigs will pick a strategic lying site, just as cats and dogs do", based upon a desire to "lie comfortably and survey the environment."

Typically, a dynamic group of sows will contain animals of various ages, weights and stages of pregnancy and these differences may have an effect on lying behaviour. In the last two weeks of pregnancy, sows have been observed to isolate themselves from the rest of the group, to avoid activities that may result in injury to the foetuses and to perform nest-building behaviours (Hurnik 1985; Stolba and Wood-Gush 1989; Stangel and Jensen 1991). Older and heavier pigs have been found to be more dominant than younger, lighter animals (Beilharz and Cox 1967; Mauget 1981) and the resting locations occupied by these animals may indicate those areas of the pen considered most favourable. The importance of perimeter and corners in the animals perception of space quality was discussed by Wiegand, Gonyou and Curtis (1994) although the attraction of a certain area will probably depend upon the prevailing physical and social environment.

Temperature and straw may be considered as two of the most important factors of the physical environment. The lower critical temperature (LCT) has been defined by Geuyen, Verhagen and Verstegen (1984) as:

> " the temperature of a homeothermic animal below which thermal regulatory heat must be generated in order to balance heat loss with heat production"

Whittemore (1993) estimated the lowest temperature at which a sow feels comfortable (T_c) to range from 14 - 20°C depending on housing conditions. Similar values for the LCT of sows housed in groups on straw were calculated as 14°C (Geuyen *et al.* 1984) and 15°C (Whittemore 1993). Geuyen *et al.* (1984) found the LCT of individually housed sows to be 20°C. Lynch (1977) stated the LCT of a gestating sow could vary from 10 - 20°C depending upon the stage of pregnancy and feed intake. The upper critical temperature (UCT), the temperature above which animals will start to suffer heat stress, has been found to be around 28 - 29°C (McGlone, Stansbury and Tribble 1988; Black, Mullan, Lorschy and Giles 1993).

The advantages of providing straw in group-housing systems have been widely discussed (Fraser 1975; Jensen *et al.* 1993; Brouns *et al.* 1994). Such environmental enrichment has been shown to increase the welfare status of the animals, providing both comfort and a material for manipulation.

As discussed in Section 1.3, the basis of the social structure in wild pigs is the matriarchal herd and their most recent offspring. Signoret *et al.* (1975) stated that these groups typically contain less than ten adult females, whilst Mauget (1981) found little evidence of groups with over four sows. Associations between feral animals in the same group have been found to persist throughout life (Graves 1984). Commercial group-housing systems for dry sows typically contain a larger number of animals than found in the wild and thus represent an unnatural social situation. However, the formation of small sub-groups within the main group has been widely observed (Bengtsson, Svendsen and Andersson 1984; Edwards *et al.* 1986; Hunter *et al.* 1989; Wiegand *et al.* 1994). This establishment of small sub-groups within a larger group bears resemblance to one of May's (1972) theories on ecological stability in which larger communities tend to be organised into loosely coupled smaller sub-units termed 'guilds', with most interactions occurring within rather than between guilds. The presence of these smaller groups may suggest that either the main group contains too many animals for each individual to distinguish between or that certain individuals are consciously choosing to associate with one another in preference to other members of the group. Whatever the explanation, Edwards *et al.* (1993) stated that an understanding of sub-group behaviour was integral to the successful design and management of dynamic group housing systems.

Distance to the nearest neighbour has been widely used as a measure of association in domestic animals (Stricklin, Graves and Wilson 1979; Keeling and Duncan 1989). Wiegand *et al.* (1994) considered recumbent pigs lying in physical contact (other than tail to tail) to belong to the same social group. Similarly, Edwards *et al.* (1986), in a study of a large group of sows, regarded animals that lay together in specific areas of the pen to form distinct sub-groups.

The stability of sub-groups depends upon some form of conscious association otherwise it could be argued that certain animals were simply choosing to lay in a similar area of the pen rather than actively choosing to lay with particular members of the group. Bradshaw (1992) found that groups of six 18-week old laying hens possessed the ability to discriminate between familiar and unfamiliar birds and to choose to spend more time aggregating with familiar conspecifics. In pigs, the stability and extent of the dominance hierarchy has been found to be dependent upon maintained recognition between the animals in the group (Rasmussen *et al.* 1962; Ewbank *et al.* 1974) suggesting that pigs also possess the ability to distinguish between group members.

In a commercial dynamic housing system small groups of gilts and sows will be regularly introduced into the main group. These newly introduced animals have been found to form sub-groups on the periphery of the main group, typically resting in the dunging area (Hunter *et al.* 1989; Edwards *et al.* 1993; Moore *et al.* 1993). Although this has been shown to be a temporary situation with some movement towards integration starting within 21 days after mixing (Moore *et al.* 1993; Spoolder *et al.* 1996), these animals may lie in association with other members of their original sub-group after they integrate with the main herd.

The physical environment has also been found to play a role in the establishment of sub-groups. Van Putten and Van de Burgwal (1990) found that new groups of sows remained separate from the resident group throughout gestation. Housing design probably encouraged this situation: the new sows were provided with access to an additional lying area and the main pen was partitioned. Similarly, Wiegand *et al.* (1994) found that corners encouraged growing pigs to form small social groups by providing semi-isolated areas within the pen.

The amount of space that an animal requires was defined by McBride (1968) as "the amount it occupies physically and the amount it requires to control the intensity of social stimuli". More simply, its physical and personal space (McBride 1971). Pen size and shape has been found to have an effect on spacing behaviour in animals (Stricklin *et al.* 1979; Wiegand *et al.* 1994). A mechanism based on the balance between attraction and repulsion was shown to explain the spacing behaviour of hens (Keeling and Duncan 1989). Groups of three hens were housed in two enclosures of different sizes. Those in the small enclosure were found to lie in corners and further than expected from their pen-mates, suggesting that repulsion was playing a greater role than attraction. In the larger pen, the opposite situation was observed, with animals tending to occupy the centre of the pen and to lie closer together than expected. Similarly, growing pigs were found to form a greater number of sub-groups when housed in a large pen than when housed in a smaller area (Wiegand *et al.* 1994). Group size and space allowance have been found to have the opposite effect on spacing behaviour in cattle (Kondo, Sekine, Okubo and Asahida 1989). In both mature cattle and calves, the mean distance of an animal from its nearest neighbour was found to increase as space allowance increased and group size decreased.

Pen design, essentially the length of walls and number of corners, has been shown to have an effect on the number of sub-groups formed within a group of growing pigs. Wiegand *et al.*

(1994) compared circular, triangular, square and rectangular pen shapes and found that circular pens provided the pigs with the greatest opportunity to separate into small groups.

Having identified that the animals spent the majority of their time resting and that the design of the housing system allowed the animals to rest where and with whom they chose, the resting location of sows housed in the Seale Hayne ESF system was investigated with the following objectives:

- to describe quantitatively patterns of resting behaviour
- to determine whether individuals demonstrated a preference for certain areas
- to investigate any effect of parity and stage of pregnancy on resting location

6.2 Methodology

As described in chapter two, the dynamic dry sow group, containing between 55-70 animals, ranging from gilts to sows of parity ten and above, was loose housed in a yard. For the purposes of recording resting behaviour, the yard was regarded as comprising six areas illustrated in Figure 23: LLA, LLB, LLC (Bedded lying areas with low roof), LH (Bedded lying area with high roof), F (Feeding area) and D (Dunging area). The identification of these areas was based solely on environmental characteristics and, as such, they were of varying sizes. This factor was taken into account in the analyses.

The preliminary investigative study (Chapter Four) revealed that the level of general activity declined in the latter part of the feeding cycle (1200 -1500 hours) when all the animals had fed (Figure 12). For a period of eight months (08/93-03/94), the herd was regularly scanned at 1400 hours by the same observer. The location of every resting sow was recorded, together with information on parity and days into pregnancy. Using the technique employed by Wiegand *et al.* (1994) for establishing the existence of sub-groups, the identity of any other sows with which each individual was in contact was recorded. Data independence was assured because all animals had fed and thus moved since the previous recording. Within this experimental time period a small-scale observational study was carried out to investigate further the theory that animals formed sub-groups within the main herd. Sixteen animals, selected at random, were observed on 30 occasions following their introduction into the yard as either gilts or recently served sows. The identity of any other recumbent sows with which the animal was in physical contact was recorded. Information was gathered to investigate whether these neighbouring animals belonged to the same original group of gilts as the selected sow or had been re-introduced into the yard at the same time from the service house.

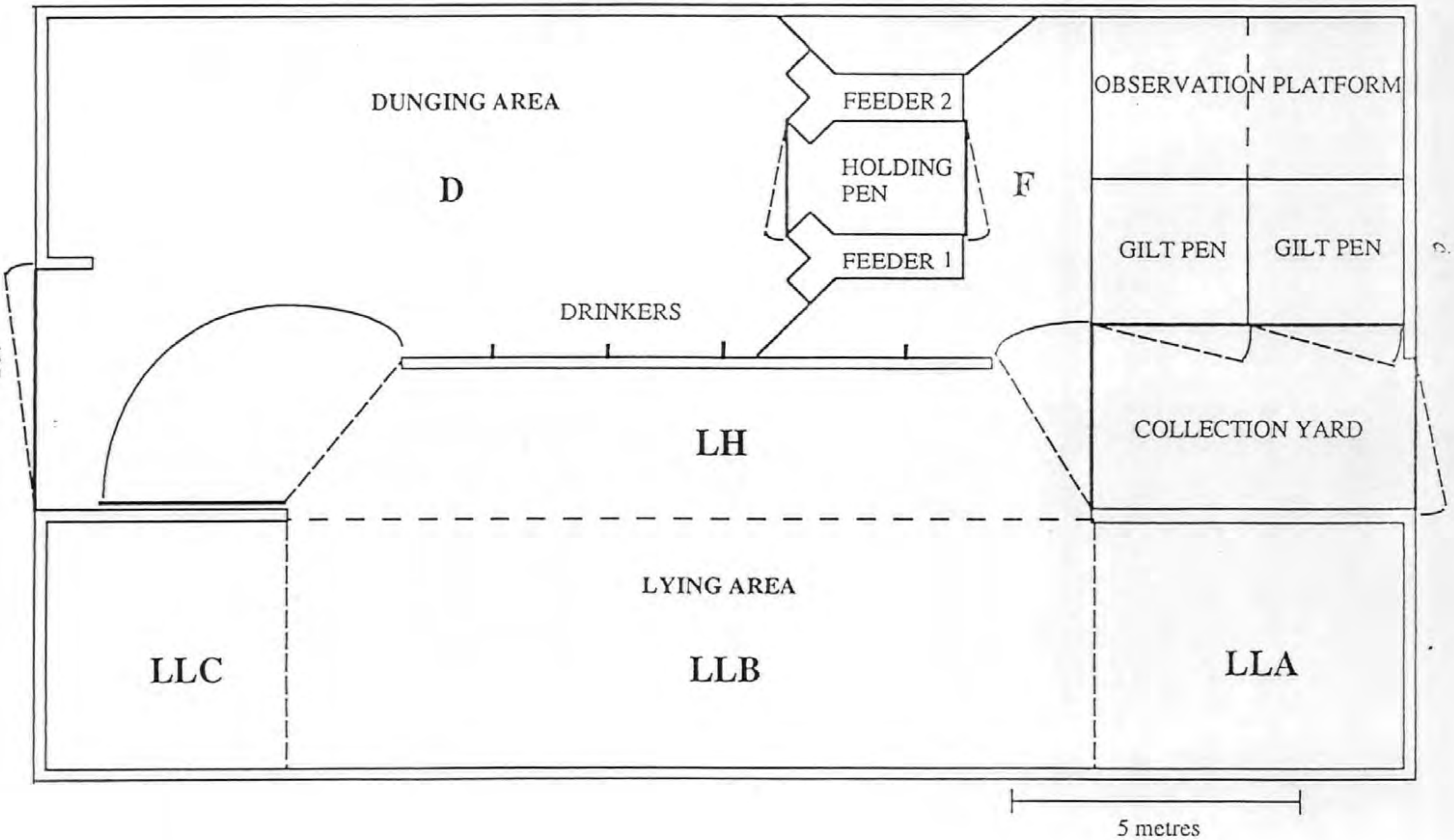
Thermometers were installed, approximately one metre above ground level, in each of the six areas and air temperature recorded immediately before the herd was scanned. However, ambient temperature may not be an accurate representation of the environmental temperature experienced by the sows. Whittemore (1993) discussed the concept of effective temperature (T_e), defining it by the following equation:

$$T_e = T(Ve)(Vl)$$

where T = ambient temperature; Ve = a factor representing air movement; Vl = a factor representing surface substrate.

A range of values for Ve and Vl were suggested by Whittemore (1993), dependent upon the prevailing housing conditions. In this investigation, the lying areas were neither draughty nor insulated and thus, according to Whittemore, Ve = 0.9. As a consequence of the deep litter system, Vl = 1.4. In the feeding and dunging areas, which were draughty and uninsulated, with no straw bedding, Ve = 0.6 and Vl = 0.9. Thus the effective temperature was higher than the ambient temperature in the lying areas and lower than the ambient temperature in the feeding and dunging areas.

Figure 23: The different areas of the sow yard.



6.2.1 Data analysis

All data were entered into the ORACLE database and analysed using MINITAB (Release 10.5 Xtra). Data were analysed using chi squared analysis and analysis of variance (Zar 1994).

6.3 Results

6.3.1 Resting locations

An initial analysis was carried out to investigate any effect of size of area on the distribution of animals. Chi-squared (goodness of fit) analysis revealed that the number of sows recorded in each of the six areas differed significantly from that expected if size of area alone was the only factor ($\chi^2 = 1965.68$; $P<0.001$). Further, within the lying area, the distribution of sows was not related to the size of the different locations LLA, LLB, LLC and LH ($\chi^2=220.96$; $P<0.001$).

On all occasions, the majority of the group were found to rest in the lying areas (LLA, LLB, LLC, LH), with only a few individuals being recorded resting in the feeding (F) and dunging (D) areas (Table 10). Within the bedded area (LLA, LLB, LLC, LH), individual sows were observed to display a preference for specific lying sites ($\chi^2=895.501$; df=171; $P<0.001$). There were insufficient data to investigate whether this preference was maintained over parities.

Chi-squared analysis demonstrated that animals in parities five, six and eight and above lay in contact with a surface on more occasions than expected, whilst gilts and sows in their first and second parities occupied such areas less than expected ($\chi^2=106.002$; df=9; $P<0.001$).

Analysis of variance was used to determine whether a difference existed between the areas of the yard with respect to both ambient and effective temperature. The analysis was performed as a randomised block in order to remove any effect of a difference between days. The analysis revealed a significant difference between areas (ambient temperature: $F=79.96$; $df=5,2518$; $P<0.001$; effective temperature $F=507.10$; $df=5,2518$; $P<0.001$). Subsequent Tukey tests showed that the mean temperatures in the bedded areas LLA, LLB, LLC and LH were significantly higher than those in the feeding (F) and dunging (D) areas (Table 10). Temperatures in the feeding (F) and dunging (D) areas were more variable than those recorded in the more enclosed lying areas (LLA, LLB, LLC and LH).

Table 10: The proportion of sows and the ambient and effective temperatures recorded in the six different areas (n=76).

Area	LLA	LLB	LLC	LH	F	D
Proportion of sows in each area	0.21^{a}	0.41^{b}	0.18^{c}	0.13^{d}	0.04^{e}	0.03^{e}
Mean ambient temperature in each area	14.26^{a}	14.42^{a}	14.50^{a}	13.70^{b}	10.03^{c}	11.02^{c}
Mean effective temperature in each area	17.97^{a}	18.17^{a}	18.27^{a}	17.27^{b}	5.42^{c}	5.95^{c}

Within each row, subscripts a, b, c, d, e illustrate a significant difference $P<0.001$

As discussed in Section 6.1, the LCT of the gestating sow housed in a group-housing system with straw is around 14°C. The distribution of sows when the temperature was above and below this value was investigated. However, as illustrated in Table 11, the resting location of sows in this investigation was not found to be related to their LCT. Whilst the greatest proportion of sows were found in LLB in both temperature ranges, the reverse situation to what was expected was found in the other areas: when the effective temperature was beneath the sows' LCT fewer sows were recorded in the warmer lying areas and more sows in the dunging area than when the temperature was greater than the sows' LCT.

Table 11: The proportion of sows recorded in each area at two effective temperature ranges.

Area/ Temperature	LLA	LLB	LLC	LH	F	D
< 14°C	0.13	0.41	0.10	0.20	0.07	0.09
14-20°C	0.23	0.43	0.18	0.11	0.04	0.01

6.3.2. The effect of parity and pregnancy stage on resting location

Chi-squared analysis revealed a significant relationship between parity and resting location (χ^2=797.85; df=45; P<0.001). A stratified random sample was taken across the herd to ensure data independence; each sow was represented in only one parity. Examination of the standardised residuals of the χ^2 contingency table showed that gilts rested in the dunging area before starting to integrate with the main group in areas LLB and LH in their second parity. In subsequent parities a greater proportion of the animals occupied the more favourable areas LLA and, to a lesser extent, LLC. This gradual progression is illustrated in Tables 12 and 13.

Table 12: The relationship between parity and the proportion of sows found in each area.

Parity/Area	LLA	LLB	LLC	LH	F	D
1	0.05	0.33	0.03	0.28	0.10	0.21
2	0.09	0.52	0.17	0.17	0.05	0.01
3	0.10	0.54	0.17	0.13	0.05	0.01
4	0.34	0.39	0.14	0.11	0.03	0.00
5	0.26	0.47	0.20	0.07	0.01	0.00
6	0.30	0.49	0.13	0.08	0.01	0.00
7	0.46	0.27	0.13	0.06	0.08	0.00
8	0.34	0.29	0.28	0.04	0.04	0.01
9	0.35	0.24	0.33	0.02	0.06	0.00
10+	0.18	0.41	0.27	0.08	0.03	0.02

Table 13: Summary of the results of the χ^2 analysis.

Deviation from expected	Parity			
	Gilt	1	2	3+
> expected	LH, D	LLB, LH	LLB	LLA, LLC
< expected	LLA, LLB, LLC	LLA	LLA	LLB, LH, D

Gilts were found on more occasions than expected in areas D and LH and less than expected in areas LLA, LLB and LLC. Parity 1 animals were found on more occasions than expected in areas LLB and LH and less than expected in area LLA. Parity 2 animals were found on more occasions than expected in area LLB and less than expected in area LLA. Animals in parity 3 and above were found on more occasions than expected in either LLA or LLC and less than expected in areas LLB, LH and D.

In order to investigate any association between days into pregnancy and resting location, pregnancy was divided into five stages: days 0-21; days 22-42; days 43-63; days 64-84; days 85-105 (when sows were removed to the farrowing accommodation). Chi squared analysis revealed a significant association between pregnancy stage and resting location (χ^2=77.072; df=20; P<0.001).

In the first 21 days of pregnancy, by the end of which the animals would have been in the yard for a minimum of 14 days, sows were found on more occasions than expected in LH and less than expected in the more favourable LLA. In the latter stage of pregnancy they were not found to be significantly associated with any particular area. Similarly, animals in the middle stages of pregnancy, although found less than expected in LH, were not found to rest in any particular area. The relationship between pregnancy stage and area is presented in Table 14.

Table 14: The relationship between pregnancy stage and the proportion of sows found in each area.

Pregnancy stage/Area	LLA	LLB	LLC	LH	F	D
0-21 days	0.14	0.41	0.15	0.24	0.05	0.01
22-42 days	0.17	0.46	0.17	0.12	0.06	0.02
43-63 days	0.24	0.41	0.17	0.09	0.05	0.03
64-84 days	0.24	0.47	0.14	0.09	0.05	0.02
85-105days	0.22	0.39	0.19	0.13	0.03	0.04

6.3.3. The influence of other group members on resting location

Wiegand *et al.* (1994) considered recumbent pigs lying in physical contact (other than tail to tail) to belong to the same social group. Using this technique it was not possible from the data available to distinguish whether animals were actively choosing to associate with particular other group members, irrespective of location, or whether certain animals were choosing simply to lay in the same area. Such an association could be investigated in the future by collecting data on a smaller group of animals over a longer time period. However, Edwards *et al.* (1986) regarded animals that lay together in specific areas of the pen to form distinct sub-groups. In this study, the relationship between parity and area revealed that groups of animals of similar parity were resting in particular areas and suggested that sub-groups, formed from animals of similar ages, may exist.

However, although it was not possible to prove statistically the existence of sub-groups using the method employed by Wiegand *et al.* (1994) the observational study, in which the neighbouring animals of 16 sows were identified and recorded, provided descriptive evidence to support the theory that animals were resting with particular companions. Personal observation suggested that these associations originated from when the animals were reared together as gilts or from when they were housed in sub-groups in the service house following weaning. The data in Table 15 show the proportion of occasions on which each of the sixteen selected sows were found resting in association with a member of their original gilt or service group and the proportion of occasions on which the animal was found resting in association with that animal identified as its most frequent companion. For fifteen of the sixteen sows, their most frequent companion was found to belong to either the same gilt (G) or service (S) group as the selected sow.

Table 15: The proportion of occasions (n=30) on which each of the sixteen selected sows were found resting in association with members of the same service or gilt group and the proportion of occasions on which they were in contact with their most frequent companion.

Sow	Sow from same service group	Sow from same gilt group	Most frequent companion	Identity of most frequent companion
1	0.37	0.01	0.23	S
2	0.63	0.63	0.57	S+G
3	0.20	0.37	0.20	S+G
4	0.30	0.10	0.20	S
5	0.10	0.30	0.13	G
6	0.30	0.37	0.23	G
7	0.10	0.13	0.13	-
8	0.23	0.60	0.17	S+G
9	0.23	0.17	0.17	S+G
10	0.13	0.13	0.13	S+G
11	0.33	0.10	0.17	G
12	0.23	0.03	0.20	S
13	0.07	0.37	0.17	G
14	0.33	0.63	0.27	S+G
15	0.37	0.17	0.23	S
16	0.27	0.10	0.27	S
mean	0.26	0.27	0.22	
SEmean	0.03	0.05	0.03	

6.5 Discussion

6.4.1 Resting locations

Data revealed that the majority of the sows rested in the bedded area and that within this area, animals displayed preferences for particular sites. A number of factors may explain this behaviour.

In order to avoid sows resting in the dunging area, Hunter (1989) recommended an overall space requirement of 2.3m^2 per sow, with the lying area being approximately one and a half times the size of the dunging area. By these criteria, adequate space was available in the Seale-Hayne unit for all the sows to lie in the bedded area. However, not all the animals were found to rest in this area, suggesting that certain sows were either choosing to lie in the dunging and feeding areas or were being prevented from lying in the bedded area. Alternatively, sows may require a greater amount of lying space than that suggested by Hunter (1989).

Sows may have chosen to lie in the dunging and feeding areas for a number of reasons. As shown in Table 10, both the ambient and effective temperature varied greatly throughout the building. The effective mean temperatures in the dunging and feeding areas were beneath the LCT of the sow whilst temperatures in the lying areas were within the animals' comfort range. Although the temperatures recorded throughout the investigation never exceeded the animals' UCT, on hot days the dunging area may have offered a more comfortable environment than the bedded lying area in which the animals were observed to dig up the deep litter system and reveal the moist substrate underneath. However, this theory was not supported by the results shown in Table 11, in which the proportion of sows recorded in the dunging area was greater when the temperature was below the sows' LCT than when it was higher. This finding could have been a consequence of the fact that the investigation was only carried out over an eight month time period (Section 6.2) and may not be a realistic indicator of the relationship between LCT and lying behaviour or that the moist substrate beneath the litter system did in fact offer a more favourable resting environment than the dunging area. However, although temperature had a significant effect on lying behaviour, the majority of the sows were always found in the bedded area. This suggested that other factors such as the presence of straw and levels of surrounding activity were perceived as more important than temperature in determining where the animals chose to rest.

The environmental enrichment provided by straw has been shown to increase the welfare status of the animals, offering both comfort and a material for manipulation (Fraser 1975; Jensen *et al.* 1993; Brouns *et al.* 1994). The fact that the majority of the herd rested in the bedded area throughout the investigation illustrated the perceived importance of this resource. Such behaviour has implications when designing a housing system. Animals may be encouraged to rest in certain areas by providing straw. Similarly, they may be deterred from lying in the dunging and feeding areas by the lack of bedding material.

Daily scans only revealed the resting location of the animals at a specific instant (1400 hours). Information was not available to measure either the timing (start and finish) or duration of each individuals rest period. Therefore, whilst the herd appeared settled and there was little or no activity at this time, it was not possible to determine how long each animal had occupied her present position. Hence, an animal recorded in the dunging area may have only just moved there in response to a recent occurrence (eg. aggressive interaction) and could only be resting in this area for a short while.

On a number of occasions, sows were observed to rest in the feeders. Although the entry gates unlocked after the occupants ration had been consumed, in the lying position a sow would push back against the gates and make them difficult to open. Hence, the feeders provided a relatively protected environment. Such behaviour may have implications on feeder use and some feed stations have been designed to prevent this from happening. Other animals were observed to lie at the feeder entrances. Two theories may explain this behaviour. Such a position would allow the resting animal immediate access to the feed station at the start of the feeding cycle. Alternatively, she could be preventing other animals from accessing the feeding station. Both these explanations suggest that such a location would be occupied by older and thus potentially more dominant sows. However, χ^2 analysis did not reveal any association between particular parities and the feeding area.

Due to the length of the recording period, it was not possible to determine whether an individual sow's preference for a particular area was sustained over successive parities. However, the relationship between parity and area showed that sows gradually moved from D to LH to LLB as they integrated with the herd in their first and second parities. From parity three to eight the greater proportion were found in LLB and LLA, with parity nine animals predominantly found in LLA and LLC and animals in parity ten and above favouring LLB and LLC. Whilst areas LLA and LLC had similar physical attributes, situated at either end of the bedded area (Figure 23) and LLC was slightly warmer than LLA (Table 10), a greater proportion of sows in parity three and above were found in LLA. This preference may be explained by the fact that LLA was situated nearer to the feeder entrances.

6.4.2 The effect of parity and pregnancy stage on resting location

As illustrated by the data in Tables 12 and 13, parity was found to have a significant effect on resting position. As observed by Hunter *et al.* (1989) and Edwards *et al.* (1993), gilts were found to rest in the dunging area when first introduced into the yard. These animals had to pass through the lying area to access the feeding stations and as such came into contact with the rest of the group. By their second parity, animals were resting in the lying area.

Older sows have been shown to be more dominant (Beilharz and Cox 1967; Mauget 1981) and as such may be expected to occupy the more favourable resting locations (Hunter 1989). Whilst the definition of the "best" area will depend upon the prevailing social and physical conditions, the areas LLA and, to a lesser extent, LLC were consistently occupied by the higher parity animals. As shown in Figure 23, these areas were situated at either end of the bedded area. As such, they provided a confined environment, with little disturbance. Areas LLB and LH were more open and areas of greater activity, providing access between the dunging and feeding areas. The temperature was significantly higher in all these bedded areas than in the feeding and dunging areas. Whilst possible reasons for sows occupying the dunging and feeding areas have been discussed, the lack of bedding and lower temperatures made these areas relatively unfavourable resting locations.

The data revealed a significant relationship between resting location and pregnancy stage. Sows were found to rest in LH during the first two weeks after being introduced in to the yard from the service house. After this period, pregnancy stage did not affect resting location. Sows would have been away from the group for 35 (±3) days and this suggested a gradual integration process took place, after which parity determined resting location for the rest of gestation. These findings supported those of Moore, Gonyou and Ghent (1993). In the latter stages of pregnancy, sows have been shown to lie away from the rest of the group (Hurnik 1985; Stolba and Wood-Gush 1989). Whilst data from this investigation did not show any change in lying position in the week before the sows were moved to the farrowing house (days 104-111 of pregnancy), this system provided sufficient space for such behaviour.

6.4.3 The influence of other group members on resting location

Although it was not possible to identify sub-groups using the method employed by Wiegand *et al.* (1994), Edwards *et al.* (1986) stated that animals found in similar areas of the pen belonged to the same sub-group. By this definition, a number of sub-groups existed within the Seale-Hayne herd. The relationship between parity and area suggested that these groups contained animals of similar parities. Gilts were raised in stable groups of six from when they entered the herd at between six and eight weeks of age and these data suggest that animals may continue to associate with their original gilt group members throughout their productive life. The data in Table 15 support this theory and further suggest that associations develop in the service accommodation that are maintained when the animals move into the dry sow yard.

A number of other authors have observed the existence of sub-groups within larger groups (Edwards *et al.* 1986; Hunter *et al.* 1989; Wiegand *et al.* 1994). Edwards *et al.* (1993) further stated that the presence of these smaller integrated groups was fundamental to the successful functioning of dynamic group-housing systems.

Results from this trial highlight the importance of providing straw as a bedding material and suggest that both the facility for sows to lie in sub-groups and the provision for gilts to integrate gradually with the herd should be incorporated into yard design and herd management.

Chapter Seven: The feeding motivation of the Seale-Hayne breeding herd

7.1 Introduction

In the wild, the pig spends a long time foraging for a low dry matter, bulky diet to meet its nutritional requirements. In commercial practice, the sow is offered a high dry matter, low bulk diet which it can consume very quickly. Thus, in this latter situation, although the sow's nutritional requirement is met, the animal may not feel satiated. In a barren physical environment she is unable to continue foraging and, as such, may suffer a frustrated feeding motivation which in turn may lead to the development of stereotypies. One solution to this problem may be to provide the sow with a bulky diet that has the potential to satisfy both its nutritional requirement and its feeding motivation without resulting in it consuming an excessive amount of energy.

7.1.1 Feed requirements during pregnancy

Before recommended feed intakes were published by the ARC (1981), sows were treated as a homogenous group and no account was taken of individual body condition, stage in the production cycle, environmental temperature or housing system. Emphasis was placed on the importance of keeping feed costs to a minimum and feed intakes were established at a level that would sustain the existing productivity figures (Brooks 1988). These proposals have since been revised to take into account a number of different criteria (AFRC 1990). The difficulty of deriving a single optimum feeding strategy due to the variety of production criteria was discussed by Elsley, Bannerman, Bathurst, Bracewell, Cunningham, Dodsworth, Dodds, Forbes and Laird (1969) and Close and Cole (1986). However, weight and backfat status throughout pregnancy have been used as indicators of reproductive performance (Whittemore, Franklin and Pearce 1980) and adequacy of the diet (Lodge *et al.* 1966; Young, King, Shaw, Quinton, Watson and McMillan 1991).

Pregnancy and lactation are not discrete stages of the production cycle. Whilst influencing birthweight, number of piglets born and sow condition (Close and Cole 1986), the feeding strategy throughout gestation has been shown to influence the sows appetite in lactation (Dourmad 1993). Excessive feed intake during pregnancy results in a consequent decrease in feed intake in lactation (Friend 1971; Dourmad 1993) with associated losses in weight and backfat and a subsequent decline in reproductive performance (O'Grady, Elsley, MacPherson and McDonald 1975; Reese, Moser, Peo , Lewis, Zimmerman, Kinder and Stroup 1982; Riley 1989; Baidoo, Aherne, Kirkwood and Foxcroft 1992). However, underfeeding in pregnancy has been shown to reduce productivity, an effect that may become increasingly pronounced at successive parities (Elsley and MacPherson 1970) and potentially result in anoestrus and a condition described as "thin sow syndrome" (Hovell and MacPherson 1977; Hovell, Gordon and MacPherson 1977).

During pregnancy, nutrients are necessary to maintain the sow (70%), to promote conceptus growth (5%) and to ensure an acceptable rate and pattern of maternal gain (25%) (Close 1990). These proportions change as pregnancy progresses. Restricted feeding in the early stages of pregnancy is important to ensure optimum embryo survival (Close 1990). Whilst it is common policy to increase the feed intake of sows in the last two weeks of pregnancy (Verstegen, Van Es and Nijkamp 1971), opinions differ as to the value of this practice. In similar trials, Fowler, Curran, Davies, Edwards, Ellis, Franklin, Hazeldine, Lee, Lynch, Petchey, Walker and Wood (1987) observed no subsequent benefits in productivity, whereas Cromwell, Hall, Clawson, Combs, Knabe, Maxwell, Noland and Orr (1989) observed significant improvements in reproductive performance.

The type of housing system has been shown to have an effect on the sows heat loss and physical activity and hence nutritional demand (Hovell *et al.* 1977). Geuyen *et al.* (1984)

stressed the importance of assessing thermal requirements and lower critical temperature (LCT) in sows in relation to housing and feeding and carried out an experiment to compare group-housing systems with individual housing. Group-housing and the provision of straw were found to decrease the lower critical temperature (LCT) and hence the animals' feed requirement necessary to maintain homeostasis. The amount of extra feed necessary per °C drop in temperature was calculated precisely for the two housing systems: 40g and 75g per °C in group and individually housed sows respectively. Brooks (1988) stated that, as a practical guide, a temperature drop of 5°C below thermoneutrality would necessitate a 15-20% increase in feed intake. Cole (1990) estimated that straw contributes approximately 2MJDE day^{-1} to a sow's diet depending on supply, freshness and frequency of feeding. As such, sows housed on straw have lower nutritional requirements than those housed on concrete (Simmins, Edwards and Spechter 1994). Stereotypies have been observed to occur as a consequence of environmental deprivation. Cronin, van Tartwijk, van der Hel and Verstegen (1986) found that tethered sows used up to 23% of their ME in stereotypic behaviour patterns resulting in an increased feed requirement.

Thus, for a combination of reasons, the nutritional requirements for maintenance have been shown to be lower for sows group-housed on straw than for sows housed in confinement on bare concrete (Simmins *et al.* 1994). Individual housing systems prevailed when feed recommendations (AFRC 1990) were published and these may be too high for group-housed animals.

In summary, the feeding strategy for the modern sow is to control weight gain during pregnancy and to maintain an adequate body condition throughout lactation (Close and Cole 1986). A dynamic herd will necessarily contain a wide range of animals with respect to body condition, parity, pregnancy stage and hence feed requirement. Where possible, the feeding system should allow the animals to be fed as individuals and not as a homogenous group

(Brooks 1988). For details of sow nutrient requirements and feeding recommendations see AFRC (1990) and NRC (1998).

7.1.2 Voluntary feed intake

Voluntary feed intake (VFI) has been defined as "the amount eaten by an animal or group of animals during a given period of time during which they have free access to food" (Forbes 1995). A number of physical, physiological, dietary and environmental factors determine the voluntary feed intake of the pig (Forbes 1983; Houpt 1985; Forbes 1986). Friend (1971) found the voluntary feed intake of a standard commercial diet by sows in gestation to average 7.6 kg day^{-1}. The concept of adapting the composition of the feed to be such as to match but not exceed both nutritional and appetite demands was discussed by Forbes (1986). However, if offered a high density feed *ad lib.*, sows have been found to overeat in pregnancy and undereat in lactation with respect to their nutritional requirements at these times (Friend 1971). A solution to this problem may be to offer animals a bulky diet that satisfies both their nutritional requirements and their physical requirement for gut fill.

7.1.3 The assessment of feeding motivation

Although recommended feed levels satisfy the animals nutritional requirements, data suggest that they do not meet the animals feeding motivation. Appleby and Lawrence (1987) showed that, although nutritionally satisfied, pigs fed to ARC (1981) recommendations remained hungry and found that their behaviour was strongly related to feed allowance. Stereotypic behaviours in tethered gilts being almost totally eliminated when feed intake was increased from 1.25 to 4 kg day^{-1}. Lawrence, Appleby and MacLeod (1988) used operant conditioning techniques to illustrate that pigs fed 1.3 x maintenance were still unsatisfied in terms of feeding motivation. Recommended feed intakes have been found to represent only 60% of the amount pigs would choose to consume if offered feed *ad lib.* and as a consequence animals feel motivated to feed for 19 hours of the day (Lawrence and Illius 1989). These findings were supported by Rushen and de Passille (1992) who stated that this highlighted the difference between an animals needs and desires.

In order to assess the extent of the sows feeding motivation, Hutson (1991) used operant conditioning techniques to measure hunger levels in pregnant sows fed a commercial diet at maintenance. Sows were fed 2.3 kg day^{-1} and were trained to work for extra feed rewards of 2.68g by operating a lever. The amount of work necessary to receive a reward was increased progressively throughout the experiment and it was found that sows on a restricted ration were prepared to sustain an energy deficit in order to gain more food. This highlighted the extent of the sows feeding frustration and has important implications for their welfare.
The strength of this motivation for food was highlighted in a later trial in which sows in the latter stage of pregnancy were offered the chance to work for either extra feed or straw (Hutson 1992). The motivation for feed completely overshadowed that for straw, despite its significance in nest building prior to farrowing. This finding contradicts that of Arey (1992) who found the desire for straw to be comparable with that for food in preparturient sows. However, the sows in Arey's study were closer to farrowing than those in the study by Hutson (1992).

High concentrate diets require little time to consume and hence increase occupational deprivation (Von Borell and Hurnik 1990a). Dawkins (1983) stated that stereotypies were not simply related to hunger and suggested that animals need to spend a certain amount of time searching for food. The Edinburgh Food Ball was designed as a potential solution to this problem. The Food Ball delivers small amounts of food rewards randomly with regard to space and time in response to a rooting action from the pig (Young, Carruthers and Lawrence 1994). The provision of straw to tethered sows has been found to decrease the incidence of stereotypic behaviour by allowing the pigs to perform foraging activities with beneficial effects on the levels of frustration experienced (Fraser 1975; Vestergaard 1984; Fraser and Broom 1990). Similar benefits were obtained by enriching the environment of confined growing pigs by providing toys (Wood-Gush and Beilharz 1983; Apple and Craig 1992). Straw has also been shown to decrease the evidence of apathy (Van Putten 1980; Wiepkema *et al.* 1983; Broom 1986). The incidence of stereotypic behaviour as a consequence of frustrated feeding motivation has been found to be compounded in consecutive parities (Robert *et al.* 1993). Appleby and Lawrence (1987) concluded that animals fed small amounts of food should not be confined and that confined animals should not be deprived of food.

7.1.3.1 The relationship between feeding events and subsequent feeding motivation

The incidence of stereotypic behaviour has been found to be related to the feeding period in tethered sows (Rushen 1984) and associated with frustrated feeding motivation in tethered gilts (Appleby and Lawrence 1987). Arellano *et al.* (1992) observed the incidence of stereotypic behaviour in sows to be higher before feeding than after whereas Lawrence and Terlouw (1993) and Terlouw and Lawrence (1993) found stereotypies to occur largely in the postprandial period and suggested a short term increase in feeding motivation existed after the animal had eaten. Similarly, Lawrence and Illius (1988) found that animals given a small meal were potentially more motivated to feed at the end of the meal than they were before it. Terlouw, Lawrence and Illius (1991) and Spoolder, Burbidge, Lawrence, Simmins and Edwards (1995) found that pigs given a feed allowance just above maintenance level spent a greater amount of time standing during the postprandial period than those given twice the maintenance ration. Bure (1991) recorded an increased incidence in the level of vulva biting when animals were fed smaller meals than when fed larger portions.

Rushen (1984) observed evidence of excessive water intake after the delivery of food and concluded that this adjunctive drinking was related to a frustrated feeding motivation. He further observed a difference in the type of stereotypies performed before and after the feeding period: those performed before included head waving, bar-biting and nosing behaviours whilst those performed in the period after feeding included manipulation of the drinker.

7.1.4 The effect of feeding high fibre diets

Theories differ as to whether sows are motivated to eat by a requirement for energy or a by a desire for a level of physical satiety. It has been suggested that increasing the fibre content of the diet may result in a decrease in feeding motivation (Arey 1993; Robert *et al.* 1993; Brouns *et al.* 1994) and hence the incidence of stereotypic behaviours (Fraser 1975; Lawrence and Terlouw 1993; Brouns *et al.* 1994), especially in the post-feeding period (Rushen 1985; Whittaker, Spoolder, Edwards, Corning and Lawrence 1997). Sources of fibre include straw (Fraser 1979), oat husks (Zoiopoulos, English and Topps 1982), alfalfa (Allee 1977), grass silage (Whittemore and Henderson 1977), chopped corn silage (Van Putten and Van de Burgwal 1990) and sugar beet pulp (Brouns *et al.* 1994).

Spoolder *et al.* (1995) found that abnormally high levels of chain manipulation in feed restricted (1.8 kg day^{-1}) sows housed in groups of six could be avoided by providing straw. Van Putten and Van de Burgwal (1990) discovered that feeding corn silage on the floor in the lying area decreased the incidence of vulva-biting in group-housed dry sows. Spoolder, Burbidge, Edwards, Lawrence and Simmins (1997) fed two feed levels, low (1.6 kg day^{-1}, parity one; 1.8 kg day^{-1}, parity two) and high (3.0 kg day^{-1}, parity one; 3.2 kg day^{-1}, parity two) to group-housed sows fed in a sequential feeding system. Whilst feed level was not related to the level of aggression or resultant injury, sows fed the low diet spent a significantly greater amount of time manipulating straw. Similarly, Fraser (1975) found that providing tethered and food restricted sows with straw decreased the incidence of stereotypies. Animals were observed to manipulate the straw suggesting it provided a recreational role as well as contributing to gut fill. However, whilst recognising its benefits with respect to both recreation and bedding Lawrence *et al.* (1989) found the provision of straw to have no effect on either the incidence of bar-biting at feeding time or the level of aggression within a group, concluding that short term satiety from gut distension does not decrease the feeding motivation of growing pigs.

Brouns *et al.* (1994) found that sows fed a conventional diet remained active for longer and spent more time performing oral behaviours than those fed a diet containing 500 g of unmolassed sugar beet pellets. It was suggested that the oral behaviours performed by the group fed the conventional diet could represent the beginnings of stereotypies. Braund, Edwards, Riddoch, Buckner, and Roden (1995) observed outdoor sows fed a diet containing unmolassed sugar beet pulp to perform less foraging behaviours than those fed a conventional diet.

Brouns, Edwards and English (1995) found the voluntary feed intake of dry sows offered a diet containing a high level of unmolassed sugar beet pulp to be low compared to that of diets containing high levels of other fibrous materials. This suggested some particular relationship between sugar beet pulp and VFI which may have been due to its palatability or its physical and/or a metabolic effect on the level of satiety experienced. Sugar beet pulp has a high water holding capacity and this may result in a marked increase in gastric distension and intestinal fill. A metabolic effect on appetite suppression has been observed in ruminants (Farningham and Whyte 1993). Brouns, Edwards, and English (1997) concluded that gastric distension appeared to be a major factor in regulating intake when feeding a diet containing sugar beet pulp.

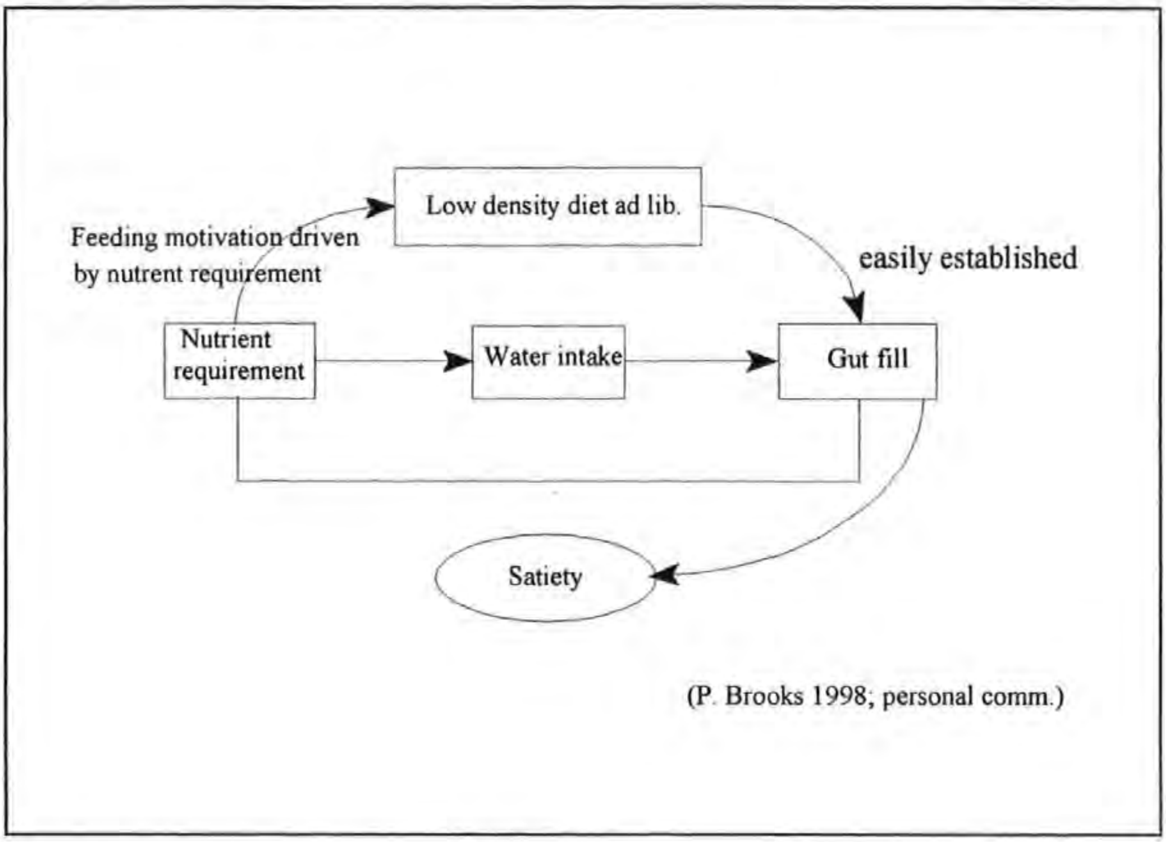
An explanation for this effect of increased fibre in the diet was suggested by Whittaker *et al.* (1997) who found sows fed high fibre diets to spend increased time eating and ingesting the food. There is evidence to suggest that pigs eat to a constant daily DE intake and, within limits, are able to compensate for variation in nutrient density of different diets by adapting their feed intake (Owen and Ridgman 1967, 1968; Cole *et al.* 1989). Cole (1972) suggested a mechanism whereby the pig attempts to adjust its daily intake by eating less of a high energy diet and more of a lower energy diet. This theory works until physical limitation prevents further intake and the diluting effect of a high fibre diet results in reduced energy intake (Fowler 1985).

Zoiopoulos *et al.* (1982) found the inclusion of either straw or oat husks in the diet of lactating sows resulted in a decrease in the intake of DE, although daily feed intake actually increased. Similar findings in pregnant animals were found by Allee (1977) and Pollmann, Danielson and Peo Jr. (1979). Close, Pettigrew, Sharpe, Keal and Harland (1990) demonstrated that sows fed a high fibre diet in pregnancy consumed more of a conventional diet in lactation than those fed a conventional diet throughout the production cycle. As sows typically undereat with respect to their nutritional requirements during lactation (Friend 1971) this may represent a further benefit of providing a high fibre diet in gestation.

Growing pigs fed, *ad lib.*, a diet deficient in crude protein were observed to spend increased periods of time standing and rooting straw compared to those fed a conventional diet (Jensen *et al.* 1993). These findings suggested that feeding motivation is related to specific nutritional needs and not just appetite.

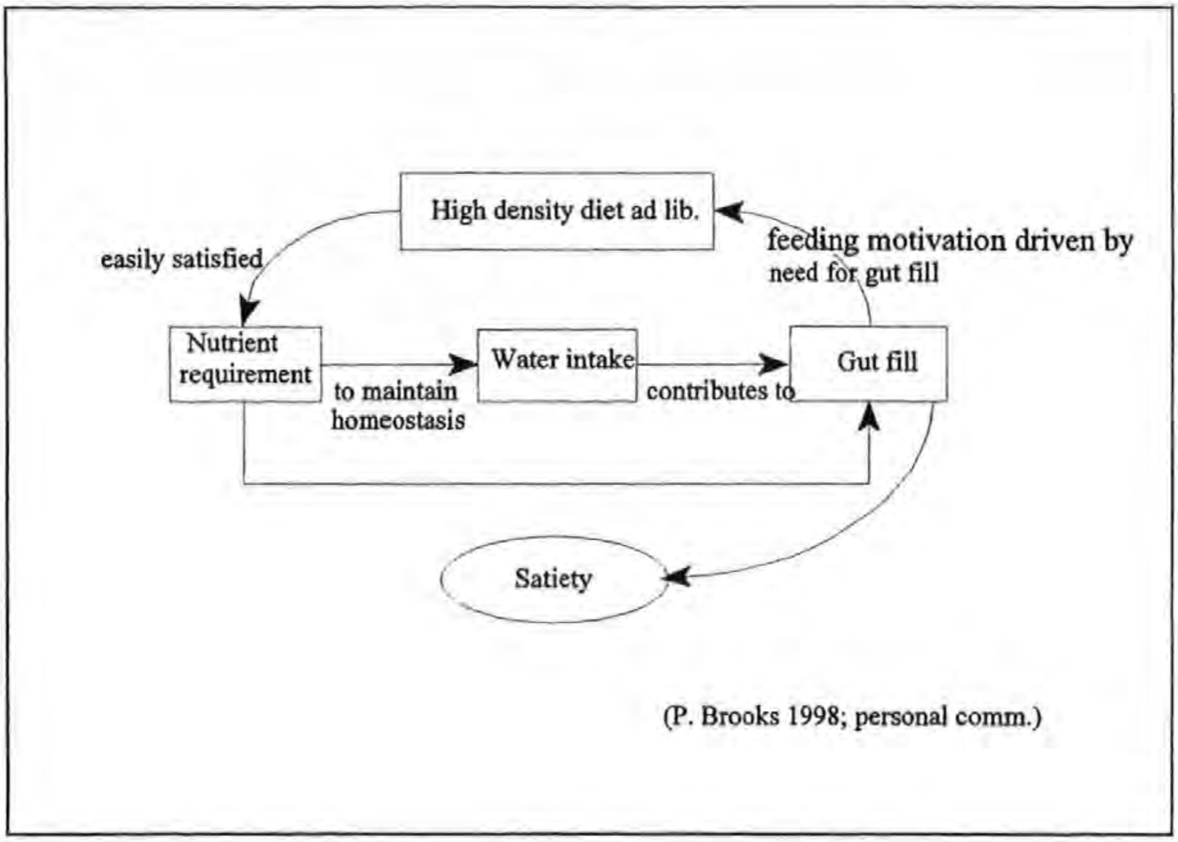
The current understanding of the relationships between diet density and feeding motivation may be described by Figures 24-26 (P. Brooks 1998; personal comm.).

Figure 24: Processes involved when feeding a low density diet *ad lib.*



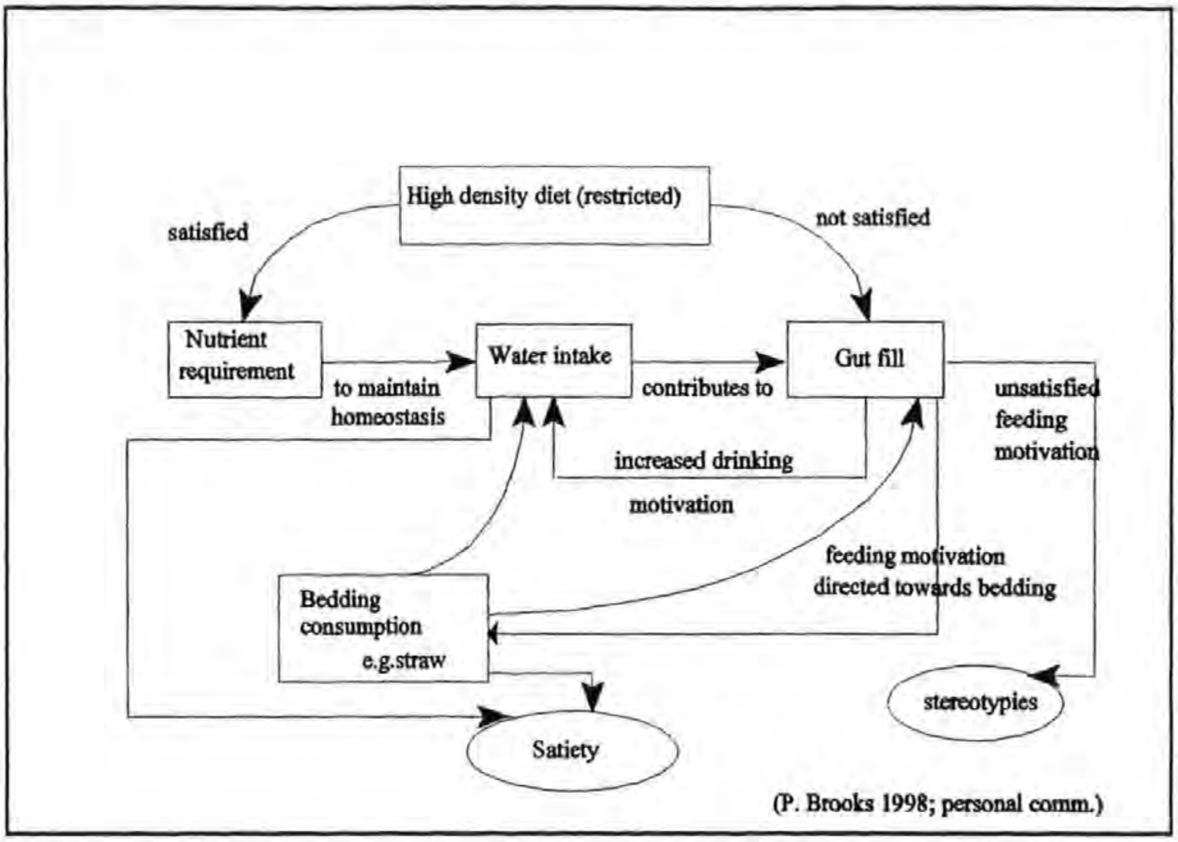
In this instance, whilst feeding motivation is driven by nutrient requirement, gut fill may restrict intake. Thus, although the animals will feel satiated, their nutrient requirements may not be met, *e.g.* animals foraging in the wild.

Figure 25: Processes involved when feeding a high density diet *ad lib.*



In this instance feeding motivation is driven by a need for gut fill and, as such, the animals nutrient requirements are likely to be exceeded as it strives to achieve a feeling of satiety. Water intake to maintain homeostasis contributes towards gut fill. e.g. animals fed a commercial ration *ad lib.*

Figure 26: Processes involved when feeding a high density diet at restricted level.



In this situation feeding motivation is driven by a need for gut fill. The animals nutrient requirement is satisfied but it does not fill physically satisfied. If available, the animal will redirect this frustrated feeding motivation firstly towards consumption of bedding material (e.g. straw) and then towards water intake. If these avenues are unavailable then this frustrated feeding motivation may result in the development of stereotypic behaviour. e.g. typical commercial situation with or without straw bedding.

7.1.5 The concept of volumetric fill

Abdominal fill describes the sum of water and food intake (Yang, Howard and MacFarlane 1981). Yang *et al.* (1981) did not find any constant relationship between food and water intake in growing pigs; water intake remained unchanged or decreased slightly as feed intake increased. This finding lead to the conclusion that pigs have a limited daily volumetric intake of food and water. Below this limit, feed is the first requirement, with water limited by volumetric fill; the pig will limit water intake in order to maximise feed intake (Yang *et al.* 1981). Mount, Holmes, Close, Morrison and Start (1971) found a linear relationship between feed and water intake although no clear correlation.

If the pig is allowed unrestricted access to food and water, it will maximise the proportion of food it consumes within its volumetric limit (gut fill) consistent with consuming adequate water to maintain its homoeostatic balance. Therefore, the pig appears to minimise its demand for water per unit of dry matter when fed *ad lib.* When feed intake is less than the level producing physical satiety, pigs will increase their water intake, thereby taking in water as a surrogate as food (Yang *et al.* 1981). This observation suggests that the regulation of intake is controlled by abdominal fill (Yang *et al.* 1981).

As a guide, Yang *et al.* (1981) suggested that the daily volumetric intake of total dry solids and water in growing pigs equals approximately 19% of the animals weight. If this theory applies in maturity, the daily volumetric intake of a 250kg sow may be expected to reach 47.5 kg.

In conclusion, although recommended feed levels (AFRC 1990) provide the animals' nutritional requirements, they do not satisfy their feeding motivation (Appleby and Lawrence 1987; Lawrence *et al.* 1988). The extent and consequences of this frustrated feeding motivation have been discussed (Lawrence *et al.* 1989; Lawrence and Illius 1989; Rushen and de Passille 1992) yet there is little actual data on the voluntary feed intake (VFI) of the modern sow.

Whilst increasing the fibre content of the diet has been widely found to have a regulatory effect on VFI (Lawrence and Terlouw 1993; Brouns *et al.* 1994; Whittaker *et al.* 1997), Brouns *et al.* (1995) suggested that sugar beet pulp may have a greater effect on reducing VFI than other fibrous raw materials. Brouns *et al.* (1994), Braund *et al.* (1995) and Brouns *et al.* (1997) all found the inclusion of sugar beet in the diet to decrease the feeding motivation of dry sows.

The aims of this investigation were:

- to determine the VFI of sows when offered a conventional diet (D73K, Appendix 2b) (C) and a high fibre diet (soaked molassed sugar beet pellets, Appendix 2d) (HF)
- to investigate any effect of parity, pregnancy stage, weight and temperature on VFI
- to calculate volumetric fill in an attempt to determine:

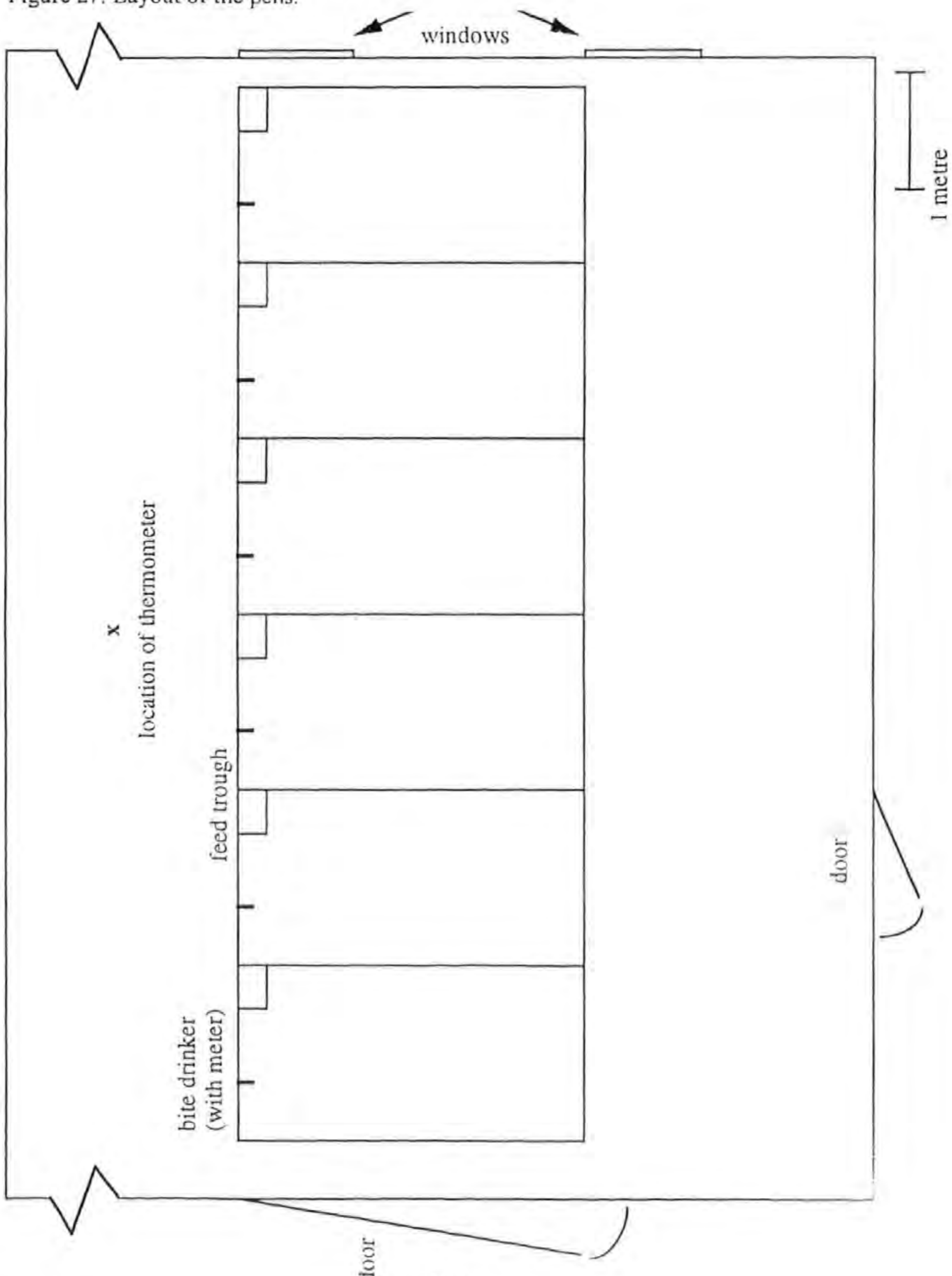
  (a) any relationship between dry matter and water intake

  (b) whether VFI is determined by energy intake or by physical capacity (gut-fill)

7.2 Methodology

Six sows were selected at random from the main herd. These were housed individually in straw-bedded pens (3m x 1.5m), assembled in an enclosed building (Figure 27). Water was provided by bite drinkers (Arato, Bernard Partridge, Wheely Heath) fitted with meters and feed was offered in troughs fixed to the floor. The pens were cleaned out twice a day. The animals were able to turn with ease, were able to see all the other sows and had olfactory and tactile contact with their immediate neighbours. Records were kept of parity, days into pregnancy, weight and backfat of each animal at the start of each trial. Initial exploratory trials were conducted over a period of five days, subsequent trials were performed over 12 days. A maximum/minimum thermometer was installed beside the pens. Ventilation was controlled by opening/shutting the doors of the building.

Figure 27: Layout of the pens.



7.2.1 Measurement of VFI

A series of trials were carried out to determine the voluntary feed intake of the dry sows. Sows were fed 2.5 kg day^{-1} of the conventional diet and then offered either this diet (C) or a high fibre diet (HF) *ad lib.* during the remainder of the 24 hours. The high fibre diet consisted of unmolassed sugar beet pellets soaked in water at a ratio of 1:4.

The animals were allowed two days to adapt to their new surroundings. Feed was offered *ad lib.* from the third day. Feed was weighed into the troughs which were checked regularly to ensure that fresh, unsoiled feed was always available. At 0800 hours each morning the refusals from the previous 24 hour period were weighed and discarded and daily feed intake calculated. Initial investigations were carried out for five days: trials were replicated four times (48 animals). However, this was found to be an insufficient time period to determine a stable daily feed intake and the trials were repeated over a 12 day period. These 12 day trials were replicated twice (24 animals). Daily water intake was recorded during the twelve day trials.

7.2.2 Measurement of volumetric fill

Volumetric fill was measured using the data gathered in the 12 day trials for the measurement of VFI. An additional trial was performed to calculate volumetric fill under restricted feed conditions. Six animals were fed 2.5 kg day^{-1} of the conventional diet with free access to water for a period of seven days. This trial was replicated twice (12 animals).

Total intake was separated into dry matter, moisture in the feed and water taken from the drinker. The ratio between dry matter and water intake was calculated.

7.2.3 Data analysis

Data were analysed using analysis of variance and regression analysis (Minitab Release 10.5 Xtra).

7.3 Results

7.3.1 Measurement of VFI

7.3.1.1 Five day exploratory study

Total daily intake of both the conventional (2.5 kg C + *ad lib.* C) and high fibre diets (2.5kg C + *ad lib.* HF) varied significantly between days as shown in Figure 28. Voluntary feed intake of the conventional diet was significantly lower on day two than on days one, four and five ($P<0.001$). For the high fibre diet, voluntary feed intake was significantly lower on day two than on the last three days ($P<0.001$). Voluntary intake of the high fibre diet was significantly greater than that of the conventional diet ($P<0.001$).

7.3.1.2 Twelve day study

As illustrated in Figure 29, total intake was again found to differ significantly between days ($P<0.001$). Intake of the conventional diet was significantly lower on the second day than on the first and third days of the trial ($P<0.001$). There were no significant differences in intake on days four to 12. For the high fibre diet, intake on the second day was significantly lower than on the last six days of the trial ($P<0.001$). There were no significant differences in intake on days six to 12. Voluntary intake of the high fibre diet was significantly greater than that of the conventional diet ($P<0.001$).

Figure 28: Daily intake of the conventional diet and the high fibre diet over a period of five days

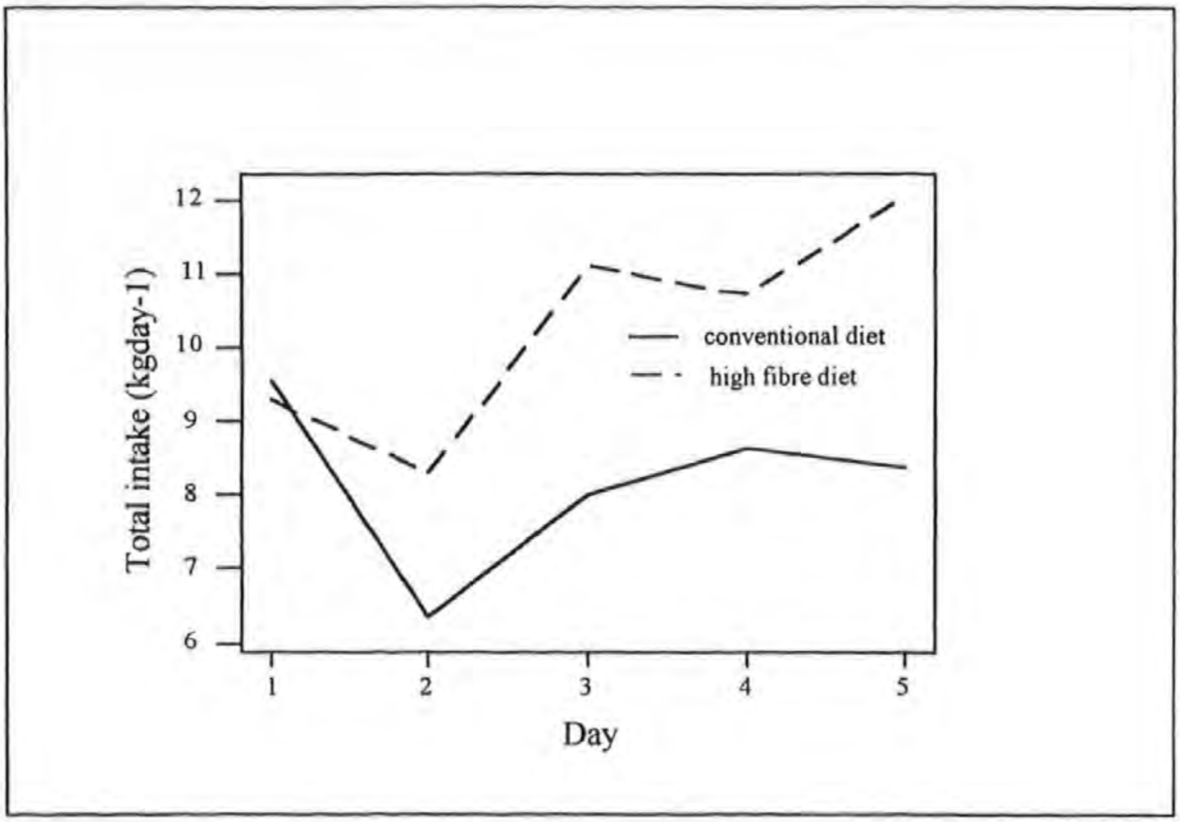
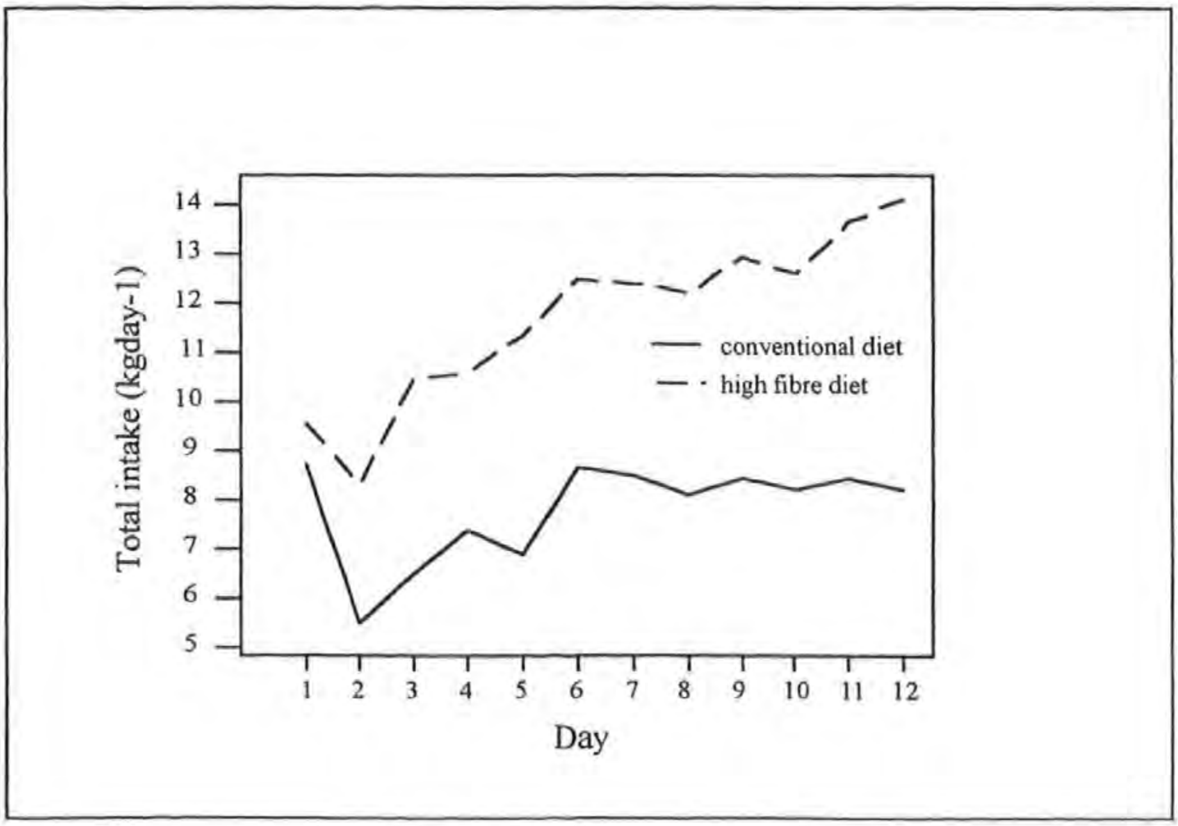


Figure 29: Daily intake of the conventional and high fibre diets over a period of 12 days.



Although, as shown in Table 16, mean daily feed intakes were found to be similar in the five and 12 day trials, it was concluded that five days was an insufficient time period to establish a reliable result. From Figures 28 and 29, it can be seen that the animals took five days to adapt to the *ad lib.* feeding regime and that feed intake started to stabilise after this initial period, there being no significant differences in intake on days six to 12.

Table 16: Mean total daily feed intakes (kg) of the conventional and high fibre diets.

Diet	C	HF	SE_D
Five day study	8.2	10.3	0.07
Twelve day study	7.8	11.8	0.14

Animals ate significantly more of the high fibre diet than the conventional diet. Although analysis of variance revealed no significant differences in intake of the high fibre diet from days six to 12, intake gradually increased throughout the trial. This suggested that animals were attempting to increase their consumption of dry matter and energy to equal that consumed when offered the conventional diet. Figures 30 and 31 illustrate dry matter and energy intakes for the two diets. Regression analysis revealed that those animals fed the high fibre diet gradually increased their dry matter (DM) intake as the trial progressed and they adapted to the diet:

DM intake = 1.57 + 0.113 day ($F = 71.42$; $df = 1,10$; Rsq adj = 86.5%; $P<0.001$)

Figure 30: Dry matter intake (kg day^{-1}) of the conventional and high fibre diets.

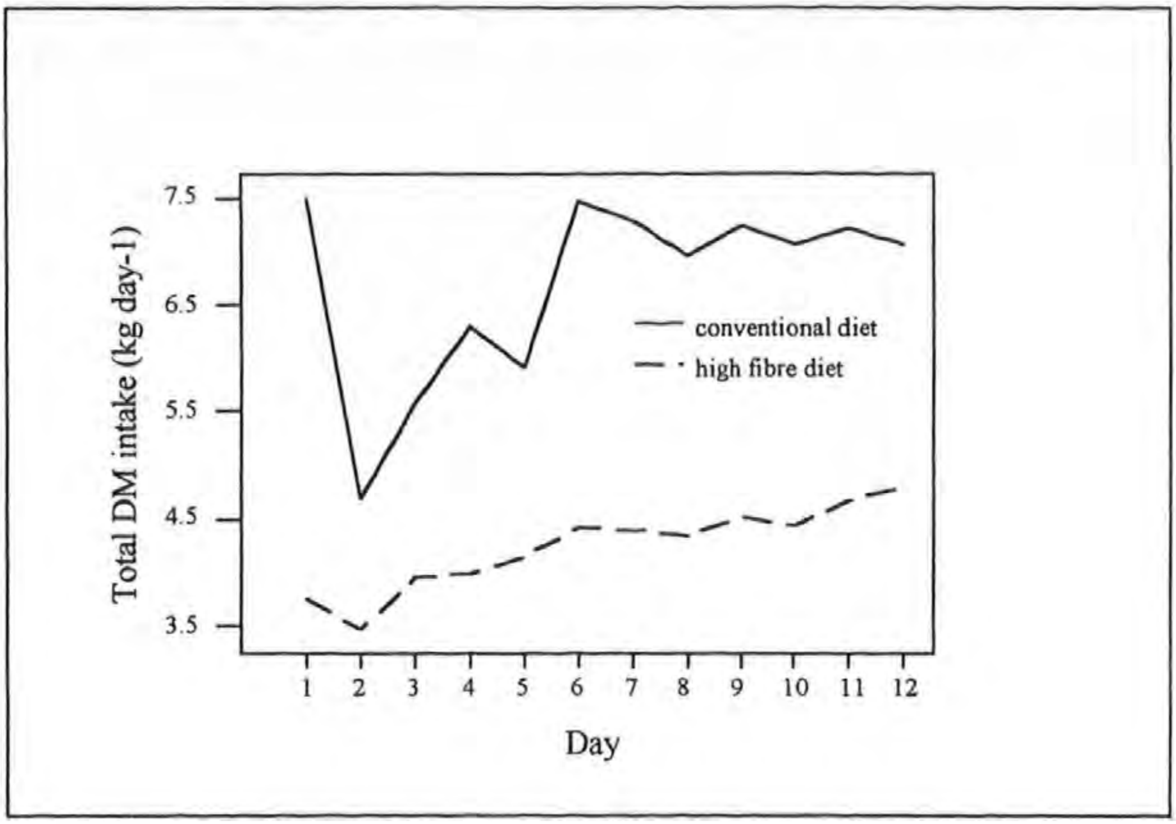
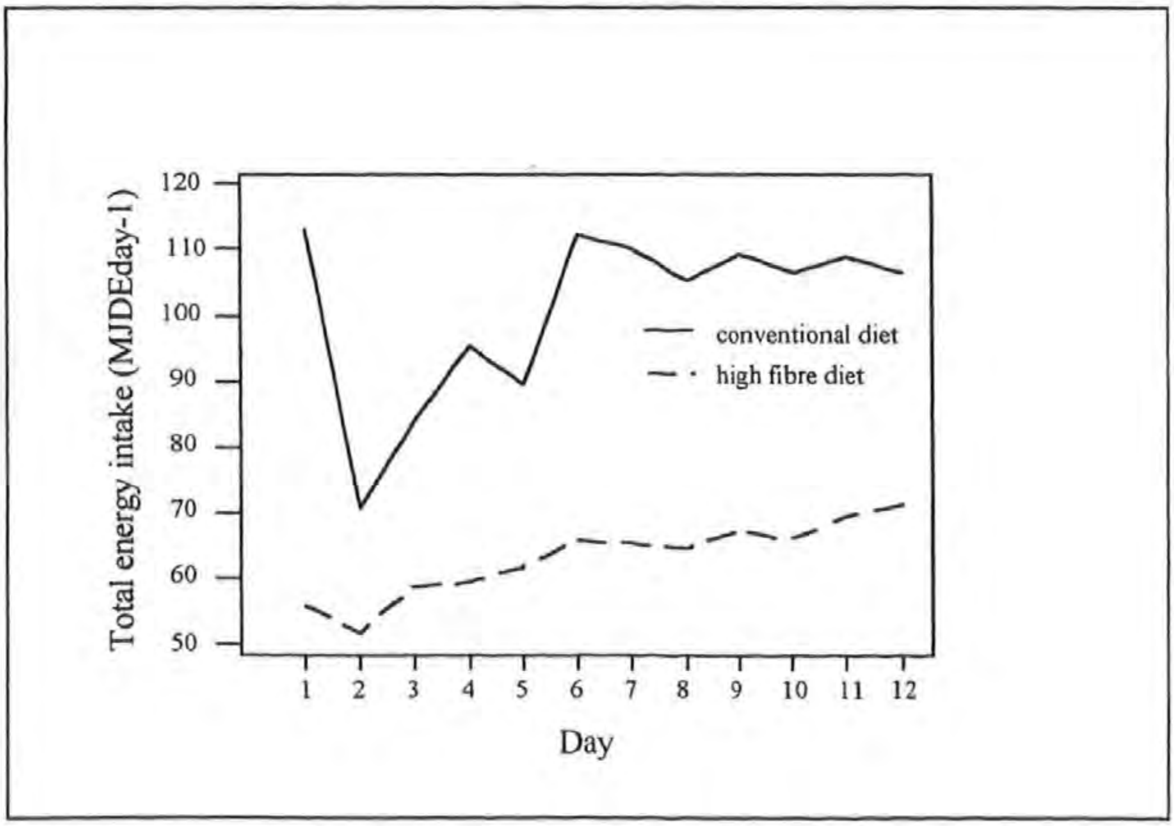


Figure 31: Energy intake (MJDE day^{-1}) of the conventional and high fibre diets.



7.3.1.3 Factors affecting voluntary feed intake

The possible effect of a number of factors on VFI were investigated using multiple regression analysis in the 12 days study. Voluntary feed intake was described by the following equation:

Feed intake = -4.51 + 0.042 sow + 0.308 day + 0.0428 weight - 0.0308 days into pregnancy + 2.5 diet + 0.0624 backfat - 0.112 parity - 0.0556 max. daily temp.

(F = 48.97; df = 8,279; Raq (adj) = 57.2%; P<0.001)

These factors collectively accounted for 57.2 % of the variation in daily feed intake. Within this 57.2 %, sow (51.0%), day of the trial (16.3%), weight (14.0%), days into pregnancy (9.1%) and diet (8.0%) had the greatest influence on daily feed intake. Backfat, parity and maximum daily temperature together accounted for only 1.6% of the collective variation.

7.3.2 Measurement of volumetric fill

The mean total volumetric intake when the animals were offered the conventional (C) and high fibre (HF) diets *ad lib.* is illustrated in Figure 32. The mean intake of the three components of the animals daily intake (feed dry matter; water in the feed; water from the drinkers) when animals were offered both the conventional diet and the high fibre diet *ad lib.* and the conventional diet at a restricted level are presented in Figure 33. Data is also presented for the days when the animals consumed the minimum and maximum amounts of the high fibre diet to highlight the relationship between feed and water intake.

Figure 32: Total feed and water intake.

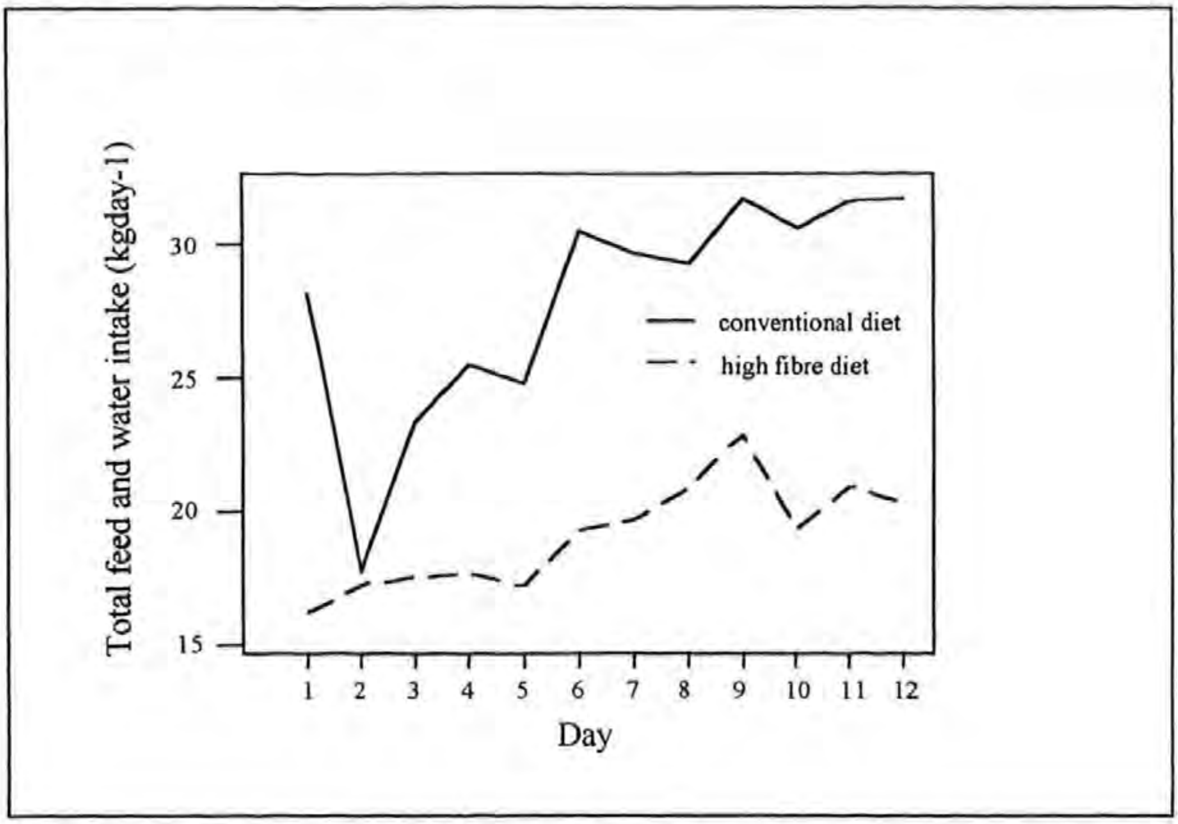
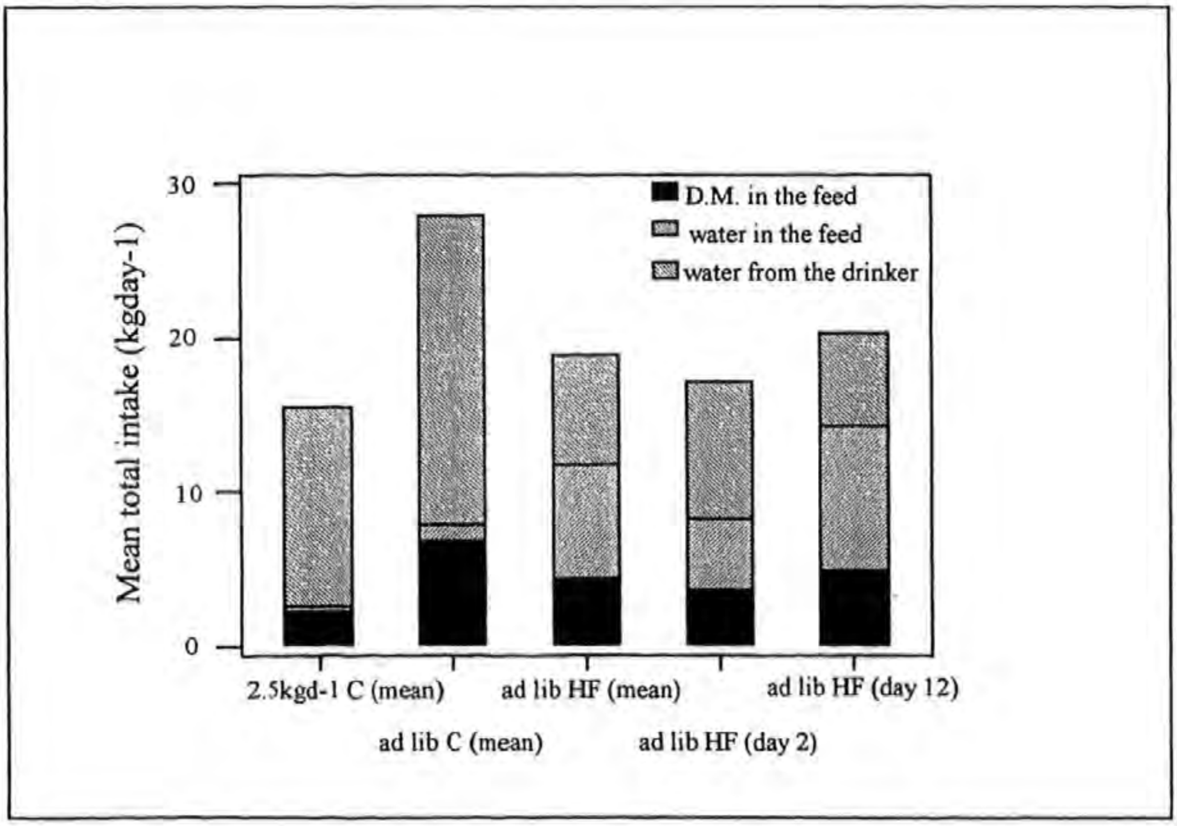


Figure 33: Total volumetric intake.



As expected, intake of dry matter was greatest when animals were fed the conventional diet *ad lib.* Table 17 illustrates the relationship between dry matter and water intake. The ratios were similar when animals were offered *ad lib.* both the conventional and high fibre diets. When feed intake was restricted, the ratio between feed and water intake almost doubled.

Table 17: Dry matter:water ratios.

Diet	D.M. : water
2.5kg C + water	1:6
(2.5kg C + *ad lib.* C) + water	1:3.2
(2.5kg C + *ad lib.* HF) + water	1:3.4

7.4 Discussion

7.4.1 Daily feed intake of the conventional (C) and high fibre (HF) diets

Mean total daily feed intakes of 7.8 kg day^{-1} and 11.7 kg day^{-1} were recorded in the 12 day study for the conventional and high fibre diets respectively. These figures are higher than that recorded by Friend (1971) who found the voluntary feed intake of a conventional diet by sows in gestation to average 7.1 kg day^{-1}.

As illustrated in Figure 25, a sow offered a commercial high density diet *ad lib.* will overeat with respect to her nutrient requirement as she attempts to achieve a feeling of physical satiety. In this study, this feeding motivation resulted in the animals offered the commercial diet *ad lib.* consuming over three times their calculated maintenance requirement. However, Friend's (1971) data suggest that animals are "programmed" to build up fat during gestation in order to create a reserve of energy to utilise in lactation when they may be unable to satisfy their nutrient requirements. As such the animals perceived energy requirement during gestation may be greater than that recommended by the nutritionists (AFRC 1990; NRC 1998) who do not consider fat deposition during this period to be necessary with the availability of high energy, palatable lactation diets.

Alternatively, when fed a high fibre diet, the animal's feeding motivation is driven by a need to satisfy its nutrient requirement (Figure 24). As discussed by Cole (1972), the pig attempts to adjust its daily feed intake by eating less of a high energy and more of a low energy diet. This process is feasible until intake is limited by gut fill (Fowler 1985) although gut capacity increases with time as the animal adapts to the diet. In this study, the feed intake of sows fed the high fibre, lower energy diet was found to increase significantly as the trial progressed suggesting that the animals' feeding motivation was not satisfied by gut fill and that animals were attempting to reach a similar energy intake as those fed the commercial diet. However, whilst the animals offered the conventional diet were consuming 106.74 M DE day^{-1} on the last day of the trial those fed the high fibre diet were only managing to consume 70.95 M DE day^{-1}.

The results from these trials imply that gestating sows may suffer a frustrated feeding motivation with the potential for subsequent high levels of stereotypic behaviour (Appleby and Lawrence 1987; Lawrence *et al.* 1988). However, as illustrated in Figure 26, unsatisfied animals will direct their feeding motivation towards bedding materials, such as straw, and water if available. In this herd, gestating sows were housed in a deep litter yard and offered fresh straw on a regular basis. Water was available freely from bite drinkers. As such, although it has been established that the provision of bulk, whilst providing gut fill does not satisfy the animals energy requirement, the degree of deprivation experienced by the animals was insufficient to result in a high incidence of stereotypic behaviour, aggression or non - feeding visits.

7.4.2 Factors affecting VFI

Individual differences between sows was found to account for the greatest amount of variation in voluntary feed intake. Consequently, feeding motivation also will vary amongst individuals. Whilst feed intake increased as weight increased and decreased slightly as pregnancy progressed, other factors such as backfat and temperature had little effect on VFI.

7.4.3 Volumetric fill

When offered unrestricted access to both feed and water, the pig will maximise its feed intake within its capacity for gut fill consistent with consuming sufficient water to maintain its homoeostatic balance (Yang *et al.* 1981). The mean dry matter to water intake ratio of animals offered the conventional diet *ad lib.* was 1:3.2. This was consistent with that recorded by Barber (1992) in growing pigs. A similar ratio (1:3.4) was found when the sows were fed the high fibre diet *ad lib.* When offered the commercial diet at a restricted level, the ratio of feed to water intake doubled to 1:6 as the animals took in water for gut fill.

Having established that the sows were motivated to consume more than their allocated ration, a subsequent study was carried out to investigate any evidence of this frustrated motivation in the sows feeding behaviour.

Chapter Eight The feeding behaviour of the Seale-Hayne breeding herd

8.1 Electronic sow feeding systems

Baxter (1986) stated that, by providing animals with some freedom to act as individuals, electronic sow feeding (ESF) systems represented a step forward in relation to the welfare of sows. Feed intake remains a critical factor in successful management of group-housing systems. A review of the welfare status of three different feeding regimes within group housing, based upon the *Five freedoms* (FAWC/1 1979), revealed individual feeders to be the best, ESF stations to be intermediate and group feeding to be the worst (Hunter 1990). In the wild, pigs have been observed to feed simultaneously. Individual feeding systems (e.g. Morris and Hurnik 1990) facilitate this behaviour, but are expensive to install on a commercial scale and require a lot of space. Dump and trickle feed systems do not allow individual rationing and less dominant and younger animals may be prevented from obtaining their basic AFRC (1990) recommended ration. Some of the benefits arising from group housing may then be lost. Electronic sow feeders allow the animals to be housed as groups but to be fed as individuals. Furthermore, they provide the sows protection whilst feeding and allow them to select their own feeding pattern within the constraints imposed by the other members of the group (Eddison and Roberts 1991). Competition for food is reduced because, although they can queue in front of the feeders, the sows can not access the system whilst another is feeding.

In a typical ESF system, sows are housed in a group in a yard separated into distinct lying, feeding and dunging areas. Commercial experience has led to the evolution of feed stations with forward entry, side exit gates with the animals directed from the feeding area to the dunging area (Hunter 1989; Figure 4). The sows are fitted with transponders either on a collar or, more recently, as ear tags or implants. Each sow's allowance becomes available at the beginning of a feed cycle. From this time the sow may enter a feeder and consume her ration in one or more visits. The sow is protected whilst feeding but, after a predetermined time period following expiry of her allowance, other sows may enter the feeder. Much research has been carried out on feeding behaviour in such systems (e.g. Edwards *et al.* 1988a; Bressers *et al.* 1993; Eddison and Roberts 1991, 1995).

8.1.1 Feeding behaviour in ESF systems

Many studies have been conducted in which the order in which sows feed has been examined (e.g. Edwards *et al.* 1988a; Hunter, Broom, Edwards and Sibly 1988; Bressers *et al.* 1993). The underlying rationale of these studies was that a predictable feeding order might be indicative of a social structure within the sow herd.

Hunter *et al.* (1988) studied a group of 20 sows and found a fairly stable feeding order over two periods of three to four days, two weeks apart and also over a period of seven consecutive days. This order was found to be positively related to parity. Parity was also discovered to account for some of the variability in individual feeding patterns by Eddison and Roberts (1995). Edwards *et al.* (1988a) recorded a relatively stable feeding order in a group of 39 sows, with each sow feeding at an interval of approximately 24 hours. Hunter *et al.* (1989) found a group of 40 sows to maintain their feed order positions throughout dynamic grouping, the position in the feed order being positively correlated with dominance rank. Recently introduced sows tended to avoid the feed station for the first 24 hours and those that made visits were easily displaced. Although no rigid feeding order was detected, Hunter (1991) observed sub-groups of early, intermediate and late feeding sows.

Bressers *et al.* (1993) suggested that, if a regular feed order existed, then any deviation from such a pattern could be indicative of potential problems. They observed groups of ten mixed parity sows as they were introduced into a gestation house. No regular feeding order was observed. However, feeding order was not random within subgroups and the most recently introduced sub-group fed last. The authors concluded that although patterns existed, they were not sufficiently stable for feeding order to be used as a management tool.

In a fifteen month investigation Eddison and Roberts (1995) found that, in the majority of cases (79%), the sows consumed all of their ration at the first feeding visit of each feed cycle. However, no sow ate all her allowance on the first visit on every occasion nor was there any relationship between feed allocation and number of visits. This lack of a consistent pattern in the individual feeding behaviour of a dynamic group of 70-80 sows fed in two ESF stations led to the conclusion that such feeding systems should be designed to accommodate this variability in behaviour. These findings support those of Edwards (1985) and Edwards, Armsby and Large (1984) who found individual sows, housed in groups of 40 to 50 and fed by a single ESF station, to make between none and ten feeding visits per day. Similar variations in individual feeding behaviour were recorded in a group of 37 sows using a single feeder (Smith, Gorman and Payne1986) and in groups of ten, 20 or 30 growing pigs fed through a single feed station (Walker 1991). Walker (1991) found feeding behaviour to be affected by group size: as group size increased, feeder occupation time increased, the number queuing increased but visit time decreased. These differences became less pronounced with time.

Brouns and Edwards (1994), in a study in which twelve sows were offered feed *ad lib.* from two troughs situated either side of a hopper, found the sows to show a clear preference for the feeding place on the right of the hopper. Evidence of sows displaying preference for a particular electronic feeding station was found by Eddison (1992). Over 50% of sows, group-housed in a straw yard, showed a preference for one of two ESF stations, having been trained to use both, although there was no difference in feeder use when all feeding visits were considered. This suggested that the animals were employing a mechanism such as an avoidance order (Jensen 1982) to minimise competition in the feeding area. In an earlier study, Knowles *et al.* (1989) found the animals to use the feeding stations to unequal extents but it was later concluded that this trial had been carried out for an insufficient time period with respect to the dynamics of the herd (Eddison 1992). Growing pigs have similarly been shown to demonstrate a preference for a particular feeder (Gonyou, Chapple and Frank 1992).

The majority of commercial systems in the UK, including Seale-Hayne, operate a 24 hour feeding cycle in which the animals may get all their feed in a single visit if desired. Such a practice has been found to result in the lowest levels of aggression in group-housed sows (Bengtsson *et al.* 1984; Edwards *et al.* 1984b; Edwards 1985; Lambert, Ellis and Rowlinson 1985) and permits low ranking animals to feed quietly after the other sows have fed. However, Gravas (1986) suggested that a number of cycles, the length of which being determined by the number of animals in the group, would benefit the feeding behaviour of lower ranking sows.

Beckett *et al.* (1986) found almost 90% of sows, housed in a group of 400 and fed through ten feed stations, to have taken their ration within eight hours from the start of the daily feed cycle. A similar situation was observed by Smith *et al.* (1986) who further found one third of the group to stand within five metres of the feeding station for the first three hours of the cycle; 60% of the group fed within the first six hours and 80% within the first 12 hours of start of the feeding cycle. A peak in the number of feeding visits at the beginning of the feed cycle was observed by Knowles *et al.* (1989) with an increase in the frequency of non-feeding visits in the latter two hours of the cycle. Occupation time of the feeding stations has been found to range from approximately 50-60% of the day (Beckett *et al.* 1986) to 88-94% of the day (Edwards 1985).

A feed station which recorded the voluntary feed intake of group-housed pigs was developed by de Haer, Merks, Kooper, Buiting and Van Hattum (1992). When the feeding behaviour of pigs fed in this system was compared to individually housed pigs, the group-housed animals were found to eat faster, have a higher feed intake per meal, take fewer meals per day, spend less time eating per day and have a lower daily feed intake (de Haer and Merks 1992). This suggested that the group fed animals felt that they had to eat quickly due to competition from other group members. The feeding behaviour of the group-housed animals was found to have adverse consequences on digestibility and to result in a significant decrease in subsequent growth rate and backfat thickness (de Haer and de Vries 1993). Growing pigs fed *ad lib.* have been shown to take several small discrete meals per day, the inter-meal interval depending on the amount eaten at the last meal. In support of the findings of de Haer and Merks (1992), Young and Lawrence (1994) observed growing pigs fed in an ESF station to modify their diurnal feeding behaviour in order to adapt to the social and physical constraints of the system.

8.1.2 Social facilitation

Social facilitation has been found to have an effect on feeding behaviour in growing pigs (Hansen, Hagelso and Madsen 1982; Hsia and Wood-Gush 1983; Brouns and Edwards 1994). This has been shown to result in increased competition and subsequent levels of aggression at feeding sites with the consequence that lower ranking animals may not be able to obtain their feed requirements (Hansen *et al.* 1982; Hsia and Wood-Gush 1983; Csermeley 1989; Csermeley and Wood-Gush 1990; Brouns and Edwards 1994).

In a simultaneous dump feeding system, dominant animals in a stable group of pregnant sows were observed to feed in the centre of the pile and actively defend the food whereas subordinate animals fed at the periphery (Csermeley 1986). However, when feed was offered *ad lib.*, Brouns and Edwards (1994) observed sows to prefer to eat singly, with most feeding bouts starting when no other pig was feeding. Similarly, Feddes, Young and DeShazer (1989) observed little evidence of social facilitation in groups of four growing pigs fed *ad lib.*, with only 30-40% of the feed being consumed when two or more animals were at the feeders. Young and Lawrence (1994) found that social facilitation resulted in competition for feeder access when a group of ten growing pigs were fed through an ESF system. These findings suggest that the problems associated with social facilitation only become apparent when feed is limited and defendable.

In the previous chapter it was demonstrated that the sows' feeding motivation was not satisfied by their restricted feed allowance. The purpose of this study was to investigate any evidence of this frustrated motivation in the sow's feeding behaviour. Data were collected on feeding and non-feeding visits along with feeder occupancy. Whilst the feeding system allowed individual rationing, this facility was little used and, in general, animals were fed 2.5 kg day^{-1} in the first 12 weeks of pregnancy and 3.5 kg day^{-1} in the last two weeks. As a consequence, older and heavier sows might be expected to be underfed and thus be more motivated to feed. In order to discover if this was the case, the relationship between feeding behaviour and parity was investigated.

8.2 Methodology

The data used in the analyses here were collected over a seven month time period, between July 1993 and February 1994. For a description of the design and management of the housing system during this period see Section 2.2 and Figure 3. The layout of the housing system differed to that described in previous published work from this herd (Knowles *et al.* 1989; Eddison 1992; Eddison and Roberts 1991; 1995) in that the feeders were originally located against the wall in the dunging area (Figure 2). A further difference was the swinging trough mechanism (Figure 4) which prevented sows accessing any feed refusals. In the previous studies the trough was static and thus there was more incentive for sows to visit the feeders as there was the potential for poaching feed. Each feeding visit made by a sow was recorded by means of a computer interface (Knowles *et al.* 1989). This recorded visit time and duration for all visits for each individual sow together with the corresponding amount of food delivered by the feeding system. Whilst on some occasions sows did not eat all of the delivered food, feed was dropped in 90 g aliquots and as such each drop represented proportionately less than 0.05 of the sows daily allowance.

As stated previously, whilst the ESF system allowed specification of individual food allowances, this facility was little used. A spot check was carried out to investigate the extent to which the allowance fed in the yard differed from the sows calculated requirement on a single day. The gestating sows maintenance requirement under thermo-neutral conditions has been calculated to be 0.44 MJ ME kg metabolic body weight $^{-1}$ (AFRC 1990). The requirement ncessary to sustain products of conceptus have been estimated as 0.8 MJ ME day^{-1} (Verstegen *et al.* 1987). The gain in maternal body tissue is higher in early pregnancy than in late pregnancy and thus the requirement for maternal body gain decreases from about 7 MJ DE day^{-1} to 3 MJ DE day^{-1} throughout gestation (Close 1992). Each sow's individual requirement was evaluated using these basic criteria. Whilst this is a very crude estimation of the sows' requirements and, due to a lack of data, does not include refinements for ambient temperature and individual body condition (AFRC 1990), it is sufficient to provide a basis for an approximate comparison. The difference between each animal's actual and calculated daily allowance was evaluated.

8.2.1 Data analysis

Analyses of variance were used to investigate the incidence of all visits to the feeders throughout the day. Occupancy time for each of the two feeders was compared using paired t-tests. The data were paired by day in order to overcome differences between days (such differences would occur because the number of sows present in the yard varied between days). Any influence of parity on feeding behaviour was investigated using analysis of variance.

8.3 Results

8.3.1 Feeding behaviour

Oneway analysis of variance demonstrated a significant difference in the mean number of visits (feeding and non-feeding) per hour recorded throughout the day ($F = 20.91$; $df = 23, 3380$; $P < 0.001$). A Tukey test revealed that significantly more visits were made in the three hours before the start of the feeding cycle (1330-1630 hours) than in the first seven hours after the cycle had started (1630-2330 hours) during which period the mean number of visits per hour ranged from 5.52 to 7.66 (Figure 34). As discussed in Section 2.2.2, it took 15-20 minutes for a sow to consume all her ration in a single feed. Thus two feeders had the capacity to feed between six and eight animals per hour if the animals were taking all their feed in a single visit. An earlier study demonstrated that the majority of sows (79%) took their daily allocation at their first visit (Eddison and Roberts 1995). This suggested that in the first seven hours of the feeding cycle visits to the feeders were feeding visits. The total number of visits increased significantly eight hours after the start of the cycle (0030 hours) suggesting a combination of feeding and non-feeding visits. Data from the preliminary observation study described in Section 4.1 revealed a similar pattern although the actual values recorded were different; this was thought to be due to the fact that the observational study was only carried out for a period of three weeks whereas data in this study were collected over a period of seven months. Analysis of variance of the data from the observational study revealed that sows made significantly more non-feeding visits at the end of the feeding cycle than in the first 12 hours of the cycle ($F = 27.94$; $df = 23,456$; $P < 0.001$). The number of feeding visits per hour decreased as the feeding cycle progressed. These findings are illustrated in Figures 35a and 35b.

Figure 34: The mean number of total visits per hour of the day.

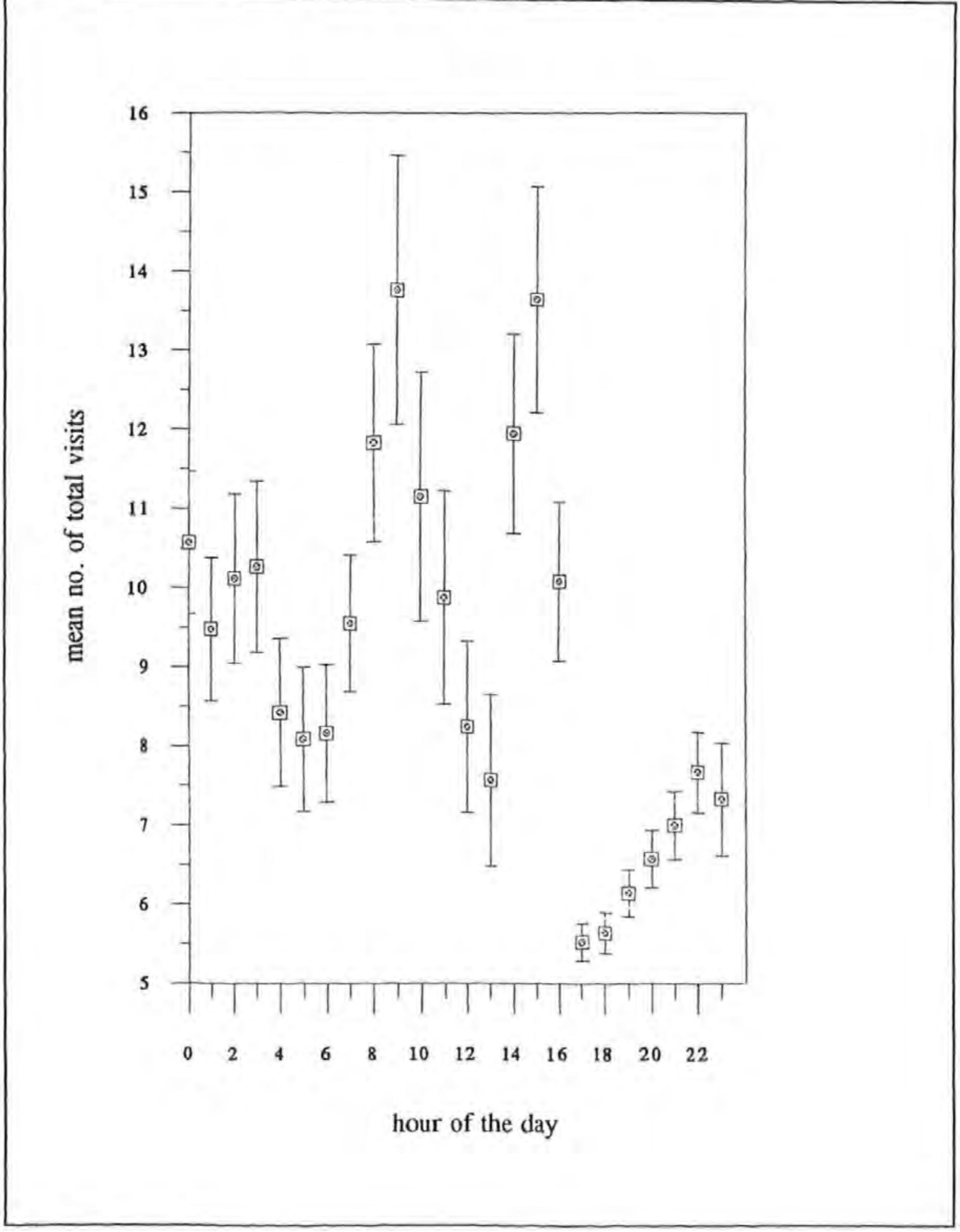


Figure 35a: The mean number of feeding visits per hour of the day (data from observational study)

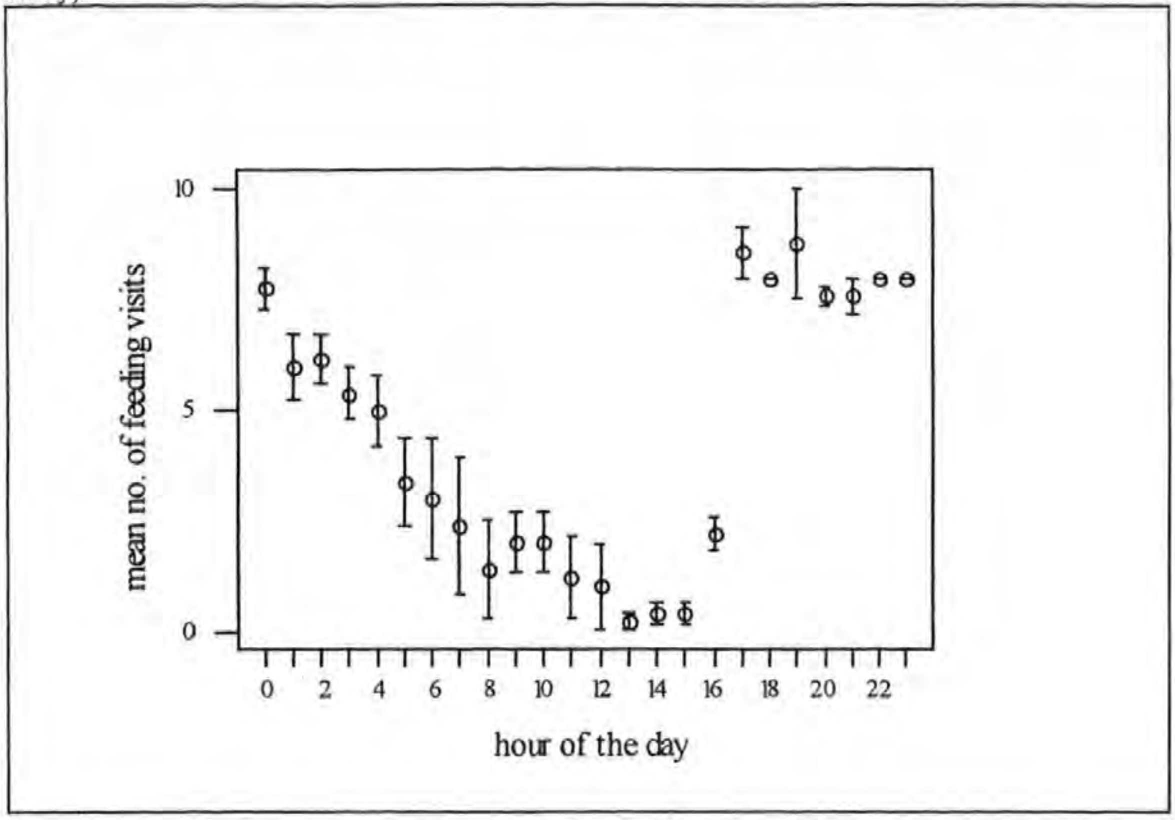
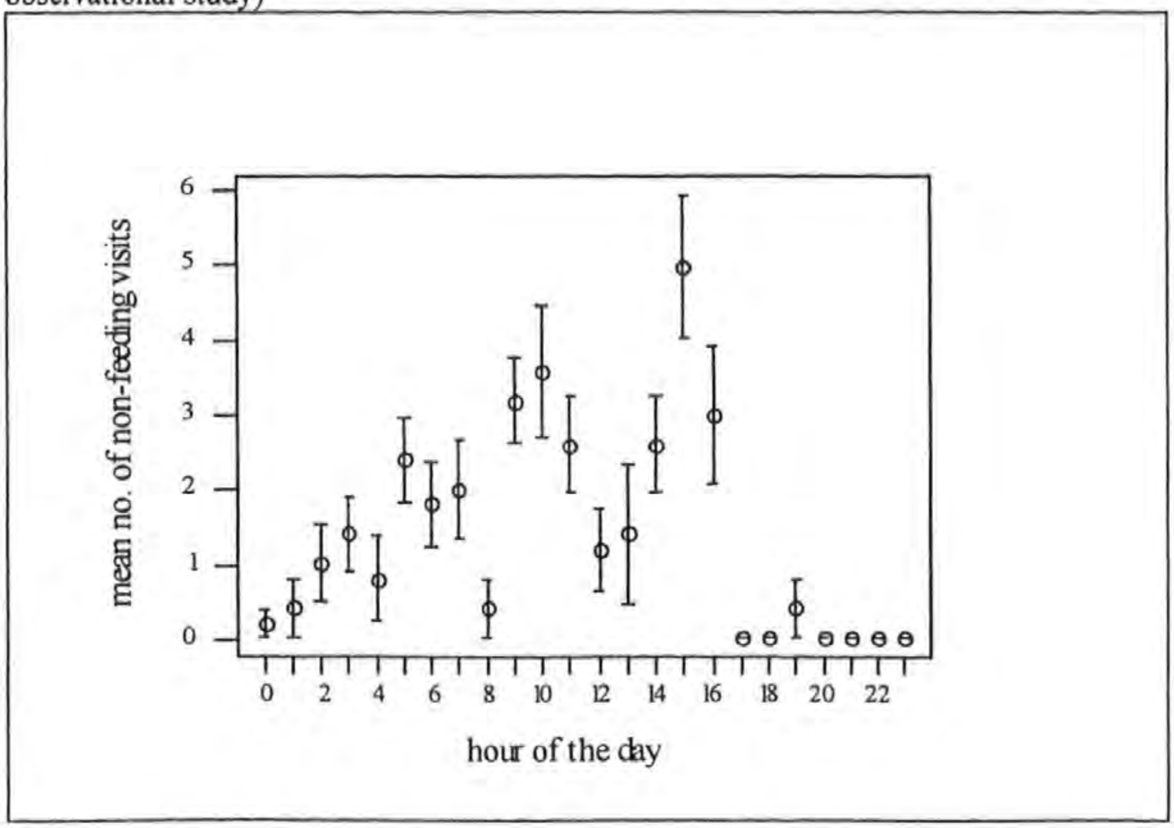


Figure 35b: The mean number of non-feeding visits per hour of the day (data from observational study)



As expected, data from the observational study revealed that there were significantly more animals in the feed queue between 1600-0000 hours than between 1100-1500 hours (Figure 14). The maximum mean number of animals recorded in the queue was 6.95 (SE_{mean}= 0.456) at 2100 hours. As there were between 55-70 animals in the yard at any time this represented a proportion of less than 0.13 of the herd. Smith *et al.* (1986) found a third of animals to stand within five metres of the feed station during the first three hours of the feeding cycle. In this study, less than 0.09 of the herd were queuing during the same period.

To enable comparison between data from both this study and the observational study with that of Beckett *et al.* (1986) and Smith *et al.* (1986) the mean proportions of feeding visits made in the first eight and twelve hours of the feeding cycle were calculated (Table 18).

Table 18: The mean proportion of feeding visits made in the first eight or twelve hours of the feeding cycle

	Eight hours after start of feeding cycle	Twelve hours after start of feeding cycle
Monitoring study	0.65 (sd = 0.21)	0.83 (sd = 0.15)
Observational study	0.63 (sd = 0.19)	0.83 (sd = 0.16)

8.3.2 Feeder occupancy time

A paired t-test (arcsine transformation; Zar 1994) revealed that feeders were used to an unequal extent: feeder one was occupied for 41.56% of the day whilst feeder two was occupied for 64.28% of the day. Feeder two was used more frequently than feeder one with respect to both total occupancy time ($P < 0.001$) and mean visit duration ($P < 0.01$). This unequal use of the feeders was in accordance with the study by Knowles *et al.* (1989) but contradicted that of Eddison (1992) who found two feeders to be used equally. However, the overriding finding from this analysis, was that as neither feeder was occupied at capacity the sows were provided with the freedom to display individual feeding behaviour patterns.

8.3.3 The effect of parity on feeding behaviour

On the day that the spot check was carried out, sows were fed a mean of 0.29 kg more than their calculated requirement. Differences ranged from one sow in parity two being overfed by 1.7 kg and a sow in parity nine being fed 0.6 kg less than she required. Regression analysis revealed a significant relationship between bodyweight and the difference beween an animal's actual and calculated intake:

Difference between actual and calculated intake = 1.91 - 0.00651 weight

($F = 12.07$; df=1,60; Rsq (adj) = 15.4%; $P < 0.001$).

This relationship is illustrated by the fitted line plot in Figure 36. Although there was much individual variation, the trend was for the difference between actual and calculated intake to decrease as weight increased. Animals weighing over 290 kg may be expected to suffer an increased feeding motivation as from this stage the actual allocation received in the yard was less than the calculated requirement. However, the histogram in Figure 37 demonstrates that for the majority of sows their actual intake was within 0.3 kg of their calculated requirement.

Figure 36: Fitted line plot to illustrate the difference between the sows actual and calculated intake (kg day^{-1})

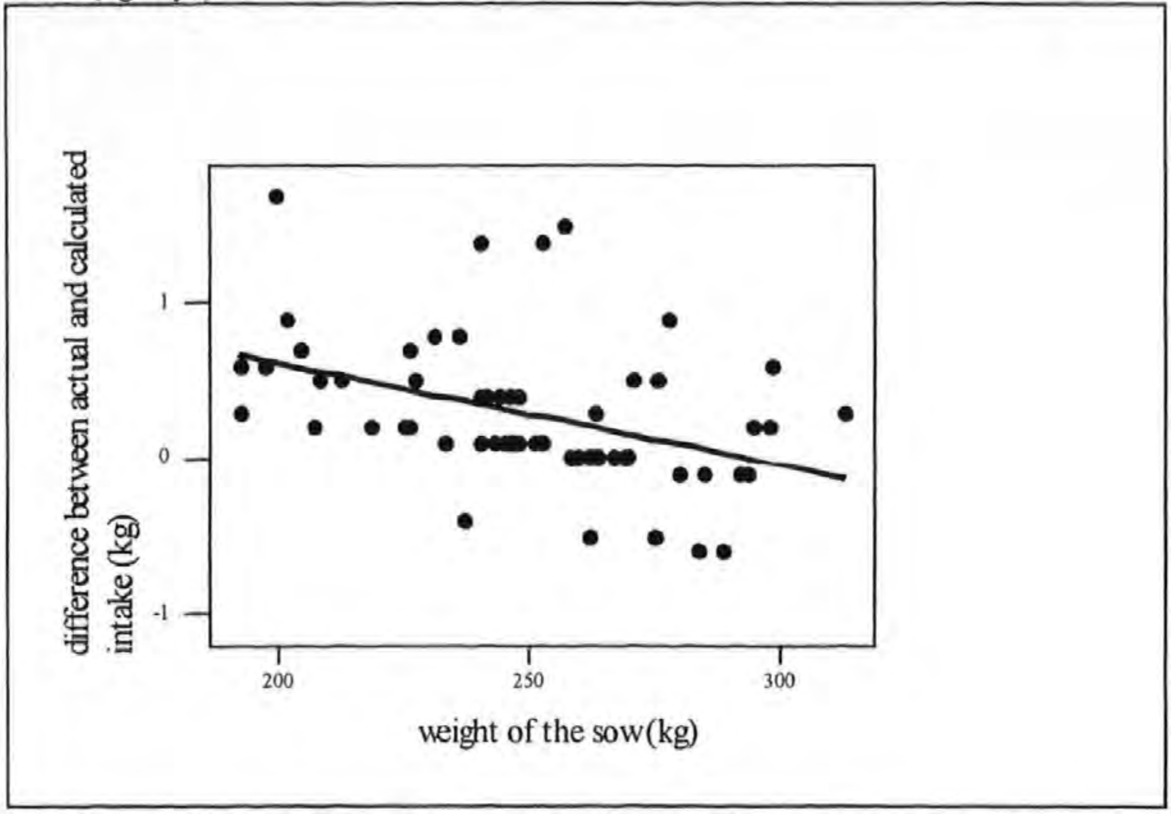
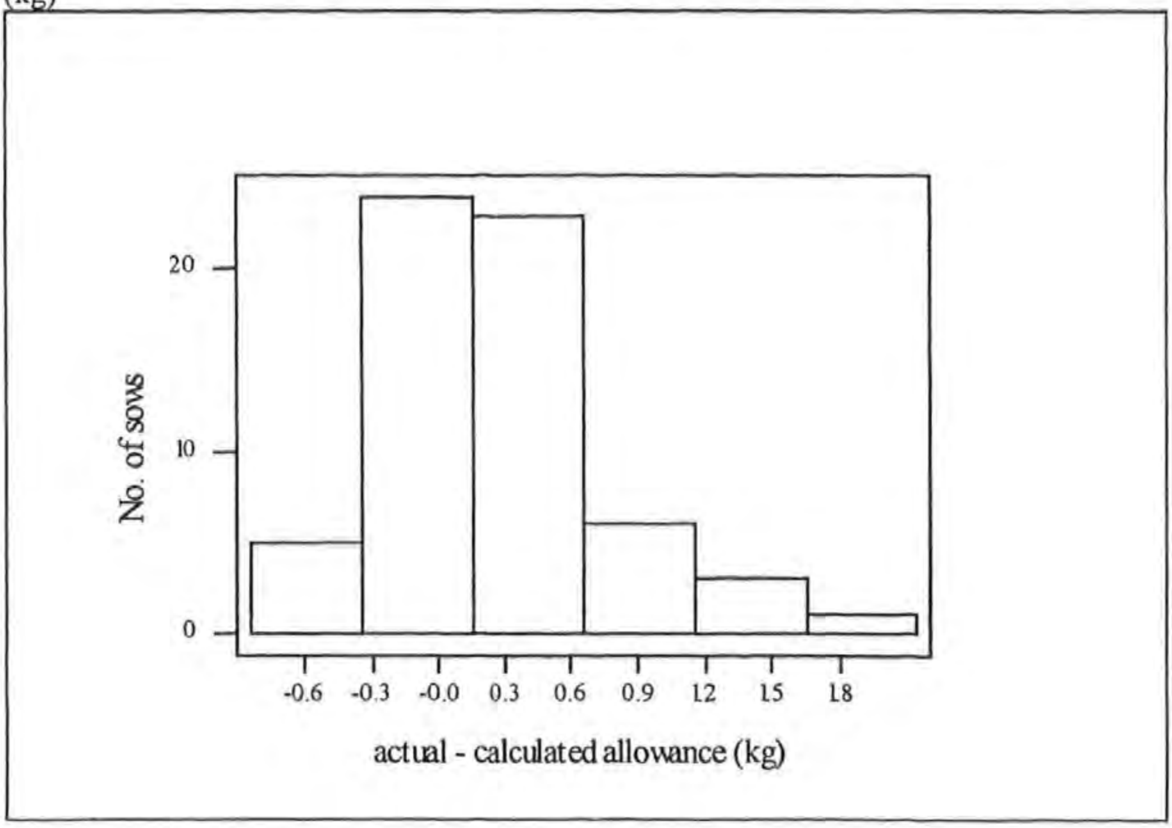


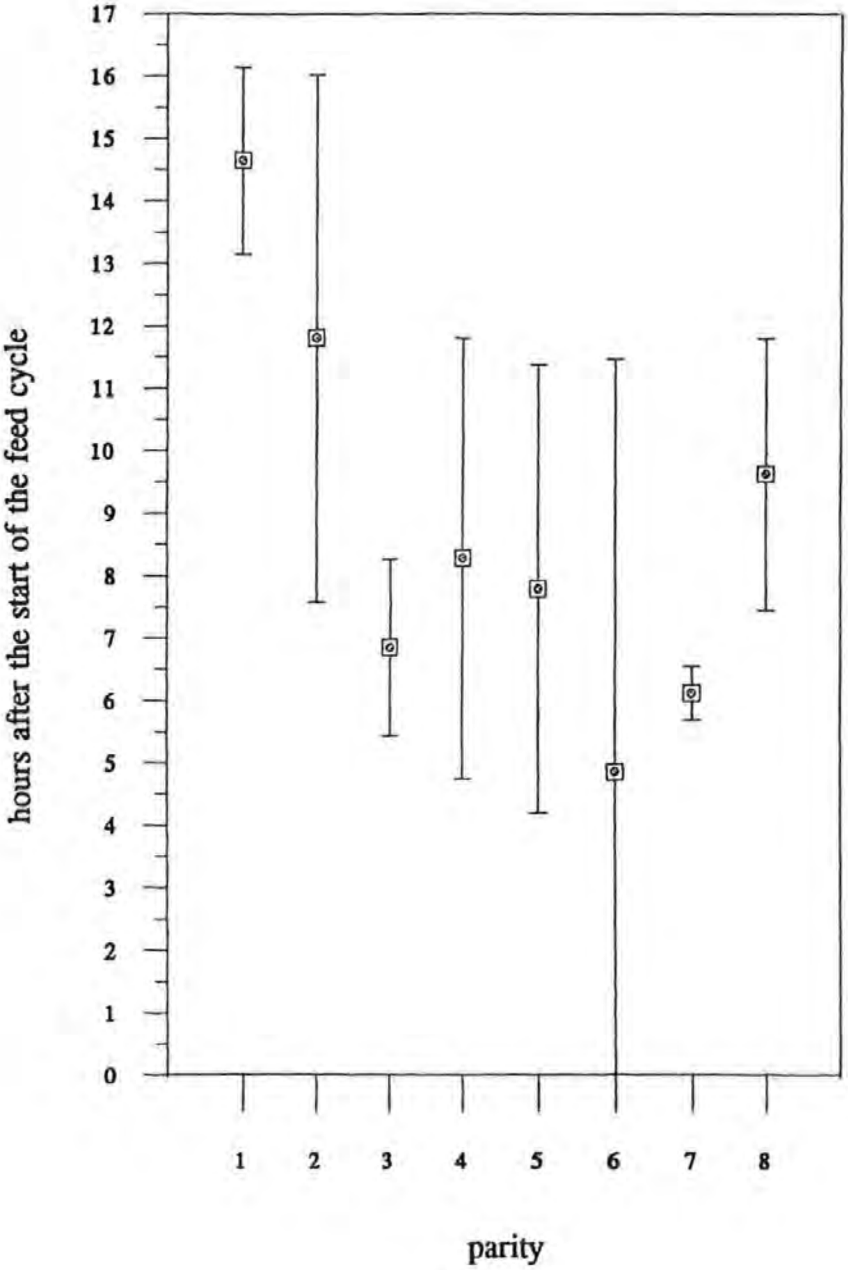
Figure 37: Frequency histogram of the difference between actual and calculated allowance (kg)



As weight tends to increase with parity a subsequent investigation was carried out to investigate any relationship between parity and feeding behaviour. A random sample of sows was selected; in order to ensure data independence, each sow was represented in only one parity Analysis of variance did not reveal any effect of parity on either the number of daily feeding visits ($F = 1.31$; $df = 7,30$; $P>0.1$) or the number of daily non-feeding visits ($F = 1.27$; $df = 7,30$; $P>0.1$).

The time of the first feeding visit made by each of the selected sows was recorded and expressed as hours after the start of the feeding cycle. Analysis of variance demonstrated a significant relationship between parity and starting time of the first feeding visit ($F = 4.84$; $df = 7,30$; $P=0.001$). A subsequent Tukey test revealed that gilts fed later in the cycle than animals in parities three to eight. Animals in parity eight fed after those in parity seven (Figure 38).

Figure 38: The relationship between parity and the time of the first feeding visit after the start of the cycle.



8.4 Discussion

8.4.1 Feeding behaviour

Data from this study demonstrated a significant difference in the mean number of total visits per hour made to the feeders throughout the day. This finding was supported by evidence from the observational study (Chapter Four). The mean proportion of feeding visits made in the first eight and twelve hours of the feeding cycle are illustrated in Table 18. Whilst these figures represented the number of visits made to the feeders and not the number of animals to have fed, they were similar to the findings of Beckett *et al.* (1986) and Smith *et al.* (1986). The fact that not all of the sows had fed in the first 12 hours of the cycle suggested that in this unit, with a ratio of 28-35 sows per feed station, a single daily feeding cycle was necessary to enable all the animals to feed.

In accordance with Knowles *et al.* (1989), there was a significant increase in the number of non-feeding visits at the end of the feeding cycle. This suggested that animals were anticipating the start of the next cycle. The increase in the number of sows in the feed queue immediately before the cycle started and during the first hours of the cycle supported this theory. As there was no physical signal to indicate to the animals that the cycle had started this behaviour suggested that the animals were either "conditioned" or motivated by hunger to feed at 24 hour intervals. Edwards *et al.* (1988) observed sows in an ESF system to feed at intervals of approximately 24 hours.

8.4.2 Feeder occupancy

Although animals were trained to use both feeders, feeder two was used more frequently than feeder one. The layout of the yard was such that sows would have to pass feeder one to access feeder two (Figure 3). This suggested that sows were choosing consciously to visit feeder two, possibly because, once reached, the area around the entrance to feeder two represented a less disturbed environment than the area around feeder one.

Feeder one was occupied for 41.56% of the day whilst feeder two was occupied for 64.28% of the day. Thus neither feeder was used to capacity. This supported Beckett *et al.* (1986) who observed feeders to be occupied for 50-60% of the day. Edwards (1985) found occupation time to reach 88-94% of the day. This discrepancy may be explained by the fact that in this herd the ratio of feeders to sows was 1:28-35, whereas in the study by Edwards (1985) the ratio was 1:40-50. Walker (1991) observed feeder occupation time by growing pigs to increase as group size increased.

The fact that the feeders were not used to capacity allowed the animals some freedom in their feeding behaviour (Eddison and Roberts 1995). However, it could be argued that this system could support more animals. Hunter (1989) concluded that up to 40 animals could be fed through a single feeder without any detriment to sow welfare.

8.4.3 The effect of parity on feeding behaviour

Sows were fed a mean of 0.3 kg day^{-1} more than their calculated requirement. Although there was a lot of individual variation, the trend was for the difference between a sow's actual and calculated intake to decrease as weight increased. As weight tends to increase with parity this suggested a relationship between parity and feeding motivation that could possibly have had consequences on feeding behaviour.

Whilst the VFI trials suggested that older and heavier animals in this system experienced the greatest feeding motivation, no relationship was observed between parity and the number of feeding or non-feeding visits made by a sow within a feeding cycle in the sow yard. This may have been a consequence of the swinging trough mechanism which removed any incentive for animals to visit the feeders by preventing them from obtaining any extra feed once they had consumed their daily allowance. Alternatively, due to the regular provision of straw providing a substrate for both recreation and gut-fill, the degree of frustration experienced by the older animals may have been insufficient to affect their behaviour.

Data revealed a significant relationship between parity and feed order with middle parity animals feeding before both younger animals with less experience and older sows who may have been less mobile. This suggested the presence of some social organisation within the herd based upon parity. Hunter *et al.* (1989) and Eddison and Roberts (1995) similarly observed reproductive experience to account for some of the variation in feed order.

In conclusion, there was little evidence of the frustrated feeding motivation predicted by the results of the VFI trials described in Chapter Seven. Feeders were not used to maximum capacity. Whilst the incidence of both non-feeding visits and queuing increased in the period around the start of the feeding cycle, the number of animals recorded performing such activities at this time represented only a small proportion of the herd that was considerably less than has been observed in other studies.

Much of the previous work on electronic sow feeding systems has been carried out over a short time period in controlled experimental conditions with small static groups of animals, often of similar parity, fed through a single feeder (e.g. Gravas 1986; Edwards *et al.* 1988; Simmins 1993). The gestating sow herd investigated in this study was part of an established commercial unit with production figures comparing favourably with those from other commercial herds (MLC Yearbook). The dry sow group contained animals ranging from gilts to sows of parity ten and above. Animals were fed using two electronic sow feeders. The system was dynamic with animals being added to and removed from the group on a weekly basis. Behavioural and physical measures were used to assess the welfare and productivity status of individual animals within the herd. In order to gather reliable data, studies were of a longer duration than many of those reported previously.

The major criticism of group-housing systems, especially dynamic systems, is the potential for high levels of aggression (Lambert *et al.* 1986; Van Putten and Van de Burgwal 1990; Bure 1991) initiated by a number of factors: competition for limited and defendable resources, mixing of unfamiliar animals and unsatisfied feeding motivation. All of these factors were present in the Seale-Hayne unit. Sows were able to compete for access to the feeders and favourable lying areas. The herd was disrupted regularly as individuals were removed from and returned to the group each week. Furthermore, as established by a series of voluntary feed intake trials, gestating sows suffered a frustrated feeding motivation. The allowance fed to animals in the dry sow yard represented less than a third of their VFI when offered feed *ad libitum*. A comparison between feed intake of a conventional high energy diet with that of a high fibre diet revealed that animals had a requirement for a particular level of energy as well as for bulk.

However, productivity figures for animals of all parities compared favourably with those from other units and there was little evidence of aggression with a corresponding low incidence and severity of injury being recorded throughout the herd. This implied that the small number of fights that did occur were resolved quickly and that some form of social organisation was having a regulatory effect on aggressive behaviour.

The basis of the social structure in pigs has been shown to be based upon a dominance hierarchy (Rasmussen *et al.* 1962; Beilharz and Cox 1967; Ewbank 1969a; Jensen 1982) the stability of which being dependent upon individual recognition (Rasmussen *et al.* 1962; Ewbank *et al.* 1974). Ewbank (1969a) stated that observational work on pig behaviour had been largely restricted to groups of less than 12 animals and, since then, there has been a lack of any more recent studies to suggest whether a hierarchy could have existed within this group of between 55-70 animals. The results reported in this study revealed significant relationships between parity and resting location, injury status and feed order. Middle parity animals rested in the more favourable lying areas (Table 12), sustained a lower injury status (Figure 23) and fed earlier in the feed cycle (Figure 38) than both lower parity sows and animals in parity ten and above. On the basis of these findings, it was suggested that some form of social organisation, based upon sub-groups containing individuals of similar parity, existed within the main sow herd. Several previous studies (Bengtsson *et al.* 1984; Edwards *et al.* 1986; Hunter *et al.* 1989) have reported the existence of sub-groups, and others have discussed the disruption caused by mixing (Luescher *et al.* 1990; Bresser *et al.* 1993; Moore *et al.* 1993). The results reported here are based upon a dynaimc sow herd where regular mixing occurred, and evidence has been presented that demonstrates differences in both feeding and resting patterns that are related to parity. Moreover, overall levels of injury occurring within the sow herd were very low, but were also related to parity to some extent. The results, therefore, are indicative of a social organsiation that decreased the level of disruption experienced by each individual within this dynamic system in a way that is related to parity. Although definitive evidence has not emerged from this study as to the exact nature of the social structure, the results reported here are consistent with a social system that is dynamic at the sub-group level (related to parity) but, at the individual level, each sow may have been perceiving the social system as relatively stable since they perceived themselves to exist within a small sub-group.

In support of previous studies (Fraser 1975; Jensen *et al.* 1993; Brouns *et al.* 1994), it was concluded that the regular addition of *fresh* straw played an important role as both a bedding and recreational material. This was exemplified by the data on lying behaviour which revealed that the majority of the herd rested consistently in the bedded lying area and also by the fact that, after lying, straw manipulation was the second most commonly observed activity. Furthermore, although the VFI trials illustrated that the sows feeding motivation was driven by a requirement for energy and not just bulk, providing animals in a restricted feeding system with a source of gut-fill may result in this frustrated motivation being reduced to a level insufficient to affect the animals behaviour.

As discussed previously, there was the potential for sows to compete for resources including access to the feeders and favourable resting locations. However, feeders were not occupied at capacity. This allowed animals to display individual feeding behaviour patterns and enabled gilts to feed at the end of the cycle. Lying space was not restricted and animals had the ability to choose where and with whom they rested, within constraints imposed by other group members. As such, the freedom provided by this system for animals to act as individuals may have resulted in the level of motivation to achieve a goal at a particular time being insufficient to initiate an aggressive encounter.

Several management factors contributed to the low level of aggression. Any movement of animals into or from the yard was carried out between 1030-1200 hours when the majority of the sows had fed and were lying in the bedded area. Sows were removed from the group within a week of their predicted farrowing date and, after a three to four week lactation period, were returned to the group immediately following service. As such, animals were typically separated from the main herd for a period of 35 days. If sows behave in the same way as growing pigs, such a period of separation would result in the potential for aggression when animals were returned (Ewbank and Meese 1971; Fraser 1974). However, the design of the sow yard and the 24 hour feed cycle allowed newly introduced sows and gilts to integrate gradually with the main group.

The design of the yard encouraged a one-way flow of movement. From the feed queue, animals were directed through the feeders to the dunging area from where they had to pass through the lying area to re-access the feed queue. This design, together with the swinging trough mecahanism which prevented animals from accessing any feed once they had consumed their allocation, dissuaded sows from making continuous feeder visits. The majority of the herd took their daily feed allocation in a single visit, the number in the feed queue throughout the day only represented a small proportion of the herd and the feeders were not occupied at capacity.

In conclusion, this system functioned successfully because it provided an environment in which sows could behave as individuals within limited physical and social constraints. Data from this study suggested the theory that animals formed sub-groups based on parity and that such a social organisation contributed to the low levels of aggression and subsequent injury recorded. Further work to investigate whether this theory is correct and whether such sub-groups can be identified in larger or smaller groups of sows may result in the ability to identify optimum group size / stocking density within physical constraints of space and feeder provision. In short, this study has increased the prevailing understanding of the key features that contribute to the success of ESF group-housing systems on a commercial scale and highlighted areas worthy of further research. When British welfare legislation outlawing individual housing systems comes into force on 1 January 1999 such a group-housing system, with the potential for combining competitive productivity figures with a high welfare status, may offer pig producers some confidence for the future.

Appendices

Appendix 1

The *FAWC Five Freedoms*

Farm Animal Welfare Council Press Release 92/7

The council wishes the revised Codes to provide farm animals with the following:-

1 FREEDOM FROM HUNGER AND THIRST

- by ready access to fresh water and a diet to maintain full health and vigour.

2 FREEDOM FROM DISCOMFORT

- by providing an appropriate environment including shelter and a comfortable resting area.

3 FREEDOM FROM PAIN, INJURY OR DISEASE

- by prevention or rapid diagnosis and treatment.

4 FREEDOM TO EXPRESS NORMAL BEHAVIOUR

- by providing sufficient space, proper facilities and company of the animal's own kind.

5 FREEDOM FROM FEAR AND DISTRESS

- by ensuring conditions and treatment which avoid mental suffering.

Appendix 2a

D76K Alpha Supersow 16 Cake. Product code: 3422. J. Bibby Agriculture Ltd., Peterborough.

Energy content: 16.0 MJ DE kg^{-1}

Oil 5.5%	Protein 16.0%	Fibre 7.5%	Ash 7.5%

Vitamin A	10000 iu/kg
Vitamin D3	2000 iu/kg
Vitamin E (alpha tocopherol)	70 iu/kg
Selenium (sodium selenite)	0.37 mg/kg
Copper (cupric sulphate)	29 mg/kg
Lysine	0.7 %
Moisture	13.8 %

This product contains raw materials from the following categories (in descending order by weight):

Cereal grain products and by-products, products and by-products of sugar production, products and by-products of legume seeds, oil seed products and by-products, products from the bakery and pasta industries, cereal grains, minerals, oils and fats.

Appendix 2b

D73K Alpha Drysow Plus Cake. Product code: 3410. J. Bibby Agriculture Ltd., Peterborough.

Energy content: 13.0 MJ DE kg^{-1}

Oil 5.0%	Protein 13.0%	Fibre 7.0%	Ash 7.5%

Vitamin A	10000 iu/kg
Vitamin D3	2000 iu/kg
Vitamin E (alpha tocopherol)	69 iu/kg
Selenium (sodium selenite)	0.35 mg/kg
Copper (cupric sulphate)	29 mg/kg
Lysine	0.5 %
Moisture	13.8 %

This product contains raw materials from the following categories (in descending order by weight):

Cereal grain products and by-products, products and by-products of sugar production, cereal grains, products and by-products of legume seeds, products from the bakery and pasta industries, minerals, oils and fats.

Appendix 2c

D79K Alpha Superlac Plus Cake. Product code: 3410. J. Bibby Agriculture Ltd., Peterborough.

Oil 6.0%	Protein 18.0%	Fibre 6.0%	Ash 6.5%

Vitamin A	10000 iu/kg
Vitamin D3	2000 iu/kg
Vitamin E (alpha tocopherol)	70 iu/kg
Selenium (sodium selenite)	0.33 mg/kg
Copper (cupric sulphate)	28 mg/kg
Lysine	0.9 %
Moisture	13.8 %

This product contains raw materials from the following categories (in descending order by weight):

Cereal grains, cereal grain products and by-products, oil seed products and by-products, products and by-products of legume seeds, products from the bakery and pasta industries, Products and by-products of sugar production, oils, fats and minerals.

Appendix 2d

Dried molassed sugar beet pellets. Trident Feeds, Peterborough.

Total sugar (sucrose)	14 %
Fibre	14.5 %
Energy content	13.2 MJ DE kg^{-1}

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