A COMPARISON OF DRY SOW HOUSING SYSTEMS ON THE BEHAVIOUR AND OCCURRENCE OF LAMENESS IN GESTATING GILTS

By

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A Thesis Submitted to the Faculty of Graduate

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ABSTRACT

Two studies were conducted to compare the effects of dry sow housing systems on the behaviour and occurrence and severity of lameness in gestating gilts. The three housing systems examined were: locked-stall (LS), stall-pen (SP) and straw (S). Housing systems differed in the level of confinement, individual or group housing, and provision of straw bedding. LS gilts were highly confined, individually housed gilts in standard gestation stalls. SP gilts were housed in groups of 4 in stalls on concrete flooring with access to a slatted exercise area. S gilts were kept in groups of 8-16 animals, and were housed for the latter half of gestation in larger pens that were deeply bedded with straw.

The aim of the first trial was to examine the postures assumed and behaviours performed by 61 gestating gilts. Behaviours and postures were recorded on videocassette during daylight hours. Data were obtained using scan sampling at ten-minute intervals. Observations were recorded in early and late gestation, and were further divided into morning and afternoon periods. A pattern was apparent in which ventral recumbency, resting, abnormal behaviour, standing idle, and inactive postures and behaviours were more frequently observed in LS than S gilts, with SP gilts exhibiting intermediate frequencies. The opposite pattern was found for locomoting, nosing the pen, and lying in lateral recumbency.

As housing became more physically and socially confining, gilts spent less time locomoting (LS: 1.9%, SP: 4.4%, S 6%; $P < 0.01$) and more time lying in ventral recumbency (LS: 5.5%, SP 3.5%, S 2.2%; $P < 0.01$). Increased ventral lying in LS gilts was attributed to reduced exercise, the physical risk of injury, and an inability to establish

dominance relationships with neighbouring gilts. The frequency of abnormal behaviour was also greater in LS gilts (0.7%) than SP (0.1%) and S (<0.1%) gilts ($P < 0.01$), potentially due to environmental inadequacies. S gilts spent less time standing idle (2.3%) than LS gilts (5.3%) ($P < 0.05$). Drinking tended to be higher in confinement housing (average 3.8%) compared to S housing (2.6%) ($P < P$ 0.05). Excessive drinking or playing with the drinkers has been identified as an abnormal behaviour, and as such it is considered to be a sign of reduced welfare. While resting, group-housed gilts tended to spend more time in lateral recumbency, indicating a greater level of comfort compared to LS gilts. Increased ventral recumbency, abnormal behaviours, drinking, and inactivity, combined with reduced locomotion seen in LS housed gilts indicates that the level of welfare experienced by these gilts was reduced compared to gilts housed on straw. As pregnancy progressed, gilts on straw spent less time resting and more time nosing at the straw. With advancing pregnancy, activity levels in all housing systems decreased.

Behavioural differences observed in this trial were consistent with reduced welfare in LS housed gilts, with some improvement in SP housing, although S housed gilts were considered to have the highest level of welfare. SP housing provided an alternative to LS housing, however, the level of welfare experienced by the gilts was not as high as in S housing.

The aim of the second study was to evaluate lameness in 73 gestating gilts. Lameness was assessed using a scoring system adapted from Main et al. (2001). All animals were evaluated at early (0-14 days), mid (48-62 days) and late (93-107) gestation. Three criteria were examined separately to evaluate lameness: the gilts' initial response to the observer (IR), the standing posture of the gilt (ST), gait (G), and a combined lameness

(CL) score. Animals were assigned a score, ranging from 0 to 5 in each category, with 0 representing a normal condition and 5 indicating severe lameness.

The majority of gilts in all housing systems and in all stages of gestation received scores of zero in all categories of lameness. In late gestation, significantly fewer S housed gilts received a G score of zero, compared with early and mid-gestation (χ^2=6.62, $P = 0.05$, 2 degrees of freedom), although when the zero category was expanded to include scores up to 0.5, no significant difference was found as gestation progressed. While no differences in lameness related to housing were found, the overall low level of lameness in this study precluded a rigorous assessment.

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DEDICATION

This thesis is dedicated to my family, but specifically my Mom, Sharon Shell, my Dad, Shep Shell, and especially to my husband, Dan, without whom there would be no point in doing anything. I love you all!

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LIST OF ABBREVIATIONS

ANI	Animal needs index
EU	European union
G	Gait
IR	Initial response
LS	Locked-stall
LWS	Leg weakness syndrome
OA	Osteoarthrosis
OC	Osteochondrosis
RCOP	Recommended codes of practice for the care and handling of farm animals
S	Straw
SP	Stall-pen
ST	Standing posture
UK	United Kingdom

1.0 GENERAL INTRODUCTION

To more efficiently utilize space in the dry sow barn, gestation stalls are widely used in commercial production. Currently, 75% of Manitoba hog producers use gestation stalls in their operations (Manitoba Pork Council 2002). As legislation has forced many European producers move away from confinement based housing for pregnant sows, it is inevitable that consumers will question the use of gestation stalls in North America.

One of the major concerns associated with commercial housing of gestating sows is the level of confinement. Sows housed in confinement systems are unable to perform a variety of behaviours, such as rooting, nest building, and complex social behaviours (Broom et al. 1995). This is a particular problem for swine due to the complexity of their behavioural repertoire and the intelligence of the animal. The absence of behavioural possibilities in gestation stalls leads to the emergence of stereotypies (Rollin 1995), such as bar biting and vacuum chewing. The incidence of abnormal or stereotypic behaviour has been shown to be greater in confined sows than in group-housed sows (Barnett et al. 1985; Broom 1983; Broom 1998; Broom and Potter 1984; Tarrant 1984; Vieuille-Thomas et al. 1995).

A major concern associated with confinement is that the opportunity for exercise in crates is severely limited, and negatively affects the sow's physical state (Marchant et al. 1997a). Physical effects of reduced exercise may include reduced muscle size and bone strength (Marchant and Broom 1996a), reduced muscle and bone growth (Marchant and Broom 1996b), and reduced cardiovascular fitness (Marchant et al. 1997a; Ratcliffe et al. 1969a). Insufficient exercise has been shown to exacerbate lameness due to reduced muscle strength and the development of bone lesions (Elliot and Doige 1973; Marchant and Broom 1996b) Osteochondrosis (OC) is the most common bone lesion seen in growing pigs (Grondalen 1974a; Grondalen 1974b; Nakano et al. 1979; Nakano et al. 1981b; Nakano et al. 1984). OC bone lesions are caused by many contributing factors, including growth rate, unyielding flooring, and insufficient exercise, and have been identified as playing an important causative role in the appearance of lameness (Grondalen 1974a; Grondalen 1974b; Nakano et al. 1981a).

Another concern arising from commercial housing practices is the absence of suitable bedding material. Provision of bedding in the form of straw has numerous advantages. Straw bedding offers a more cushioned floor material for moving and lying (Rollin 1995), while providing improved footing that may reduce injuries due to slipping and falling (Day et al. 2002; Edwards 1998). The insulating nature of straw, if deeply bedded, can also improve thermal comfort (Day et al. 2002; Edwards 1998). Straw also provides foraging opportunities to feed-restricted gestating sows that may otherwise develop abnormal behaviours (Broom 1983; Day et al. 2002; De Leeuw and Ekkel 2004; Edwards 1998; Ewing et al. 1999; Rollin 1995; Spoolder et al. 1995).

Because many factors associated with the use of gestation crates, such as social isolation, barren surroundings, insufficient exercise and hard concrete flooring, have been associated with the development of abnormal behaviours and the occurrence of lameness in breeding-age pigs, it can be inferred that housing plays an important role in the welfare of gestating sows. Conversion of gestation crates into pens housing a small group of pigs represents a potential compromise between housing gestating sows in individual crates, common in North America, and the larger straw based housing systems employed in

Europe. Housing small groups of pigs in a pen might address the major welfare issues created by confinement stalls. These include social isolation, reduced opportunity to exercise, prevention of expression of most normal behaviour, and subsequent development of abnormal behaviour. Additionally, groups of 4-6 pigs housed in pens may mitigate the chief concerns of the industry over the disadvantages of moving to large-scale, straw based housing systems. These include animal factors such as aggression, and management issues such as difficulty cleaning, lack of individual feeding, and ability to easily monitor dry sows throughout gestation.

The objectives of these experiments were:

1. To determine the effects of three dry sow housing systems (representing intensive commercial housing, straw housing, and a system corresponding to an intermediate between the two) on the behaviour and activity of gestating gilts.
2. To assess the occurrence and severity of lameness of gestating gilts in these dry sow housing systems.
3. To evaluate the relative level of welfare of gestating gilts housed in different dry sow housing systems.

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

The number of pork producers in the US has dropped from 3 million in the 1950's to 85,760 in 2001 (National Pork Producers Council 2002). Concurrently, the number of pigs per farm has risen dramatically as producers utilize new technologies in housing and management to capitalize on economies of scale (McGlone 2001). This intensification of livestock production has resulted in increased stocking densities and therefore less space per animal (Marchant and Broom 1996a; Marchant and Broom 1996b). In order to more efficiently utilize space in the dry sow barn, as well as for management purposes, gestation crates are widely used in commercial production. Currently, 75% of Manitoba hog producers use gestation stalls in their operations (Manitoba Pork Council 2002). Farmed Animal Watch (2002) estimates that 64% of US pig operations use gestation crates. As European producers move away from confinement based housing for pregnant sows, it is inevitable that consumers will question the use of gestation stalls in North America.

Conversion of gestation crates into pens housing a small group of pigs represents a potential compromise between housing gestating sows in individual crates, as is done in North America, and the larger straw based housing systems employed in Europe. Housing small groups of pigs in a pen (4-6) might address the major welfare issues created by confinement stalls. These include social isolation, reduced opportunity to exercise, prevention of expression of most normal behaviour, and subsequent development of abnormal behaviour. Additionally, groups of 4-6 pigs housed in pens may mitigate the chief concerns of the industry over the disadvantages of moving to large-scale, straw-based housing systems. These include animal factors such as aggression, and management issues such as increased labour, lack of individual feeding, and ability to easily monitor dry sows over their gestation.

2.2 WELFARE

2.2.1 Current legislation and regulation

In October 2001, the council of the European Union published directive 2001/88/EC amending directive 91/630/EEC, laying down minimum standards for the protection of pigs. They concluded that "pigs should benefit from an environment corresponding to their needs for exercise and investigatory behaviour", and that the "welfare of pigs appeared to be compromised by severe restrictions of space". They also stated that continuous close confinement housing of sows will be banned by 1 January 2013 due to its restriction of social interaction with other pigs. As of 1 January 2006 the use of tethers on sows and gilts will be prohibited (Department for Environment Food and Rural Affairs 2002). The UK in particular has been supportive of the EU rules, banning tethers and close confinement stalls as of 1 January 1999 (Department for Environment Food and Rural Affairs 2002). On 27 May 2004 Austria adopted a very strict anti-cruelty animal law banning all forms of confinement as well as any sort of mutilation (ear cropping, tail docking) for both commercial animals and pets, to go into effect 1 January 2005. Violators may face harsh fines equivalent to $3,200 to $24,500 Cdn and possible seizure of their animal(s) depending on the severity of the infraction (Associated Press 2004).

The UK and EU are not alone in legislating changes in animal husbandry practices for gestating sows. The Supreme Court of Florida passed Amendment 10 ('Animal Cruelty Amendment: Limiting Cruel and Inhumane Confinement of Pigs During Pregnancy') to the state's constitution in November 2002 (Ban Cruel Farms.org 2002; Farmed Animal Watch 2002; Grimes and Kelsey 2001; LSU AgCentre 2003). This amendment prohibits gestating sows from being housed in stalls too small to permit turning. Tethering or any other form of restraint that prevents the animal from turning around is also prohibited. The amendment is to take effect in 2008. Producers in violation of the new amendment could face fines up to $5000 and/or jail time for an offence, with each confined pig considered a separate offence (Ban Cruel Farms.org 2002; Grimes and Kelsey 2001). Florida is the first US state to constitutionally address the issue of intensively kept livestock.

Where the UK, EU and US adopt a legislative approach to improvements in farm animal welfare, Canada regulates industry practices by use of Recommended Codes of Practice (RCOP). The RCOP for swine (1993) recommends that producers consider using alternatives to standard gestation stalls. While recognizing that stalls represent a contentious welfare issue, detailed examples of alternative systems were not discussed. Tethers are specifically not recommended for use in Canada (Connor 1993). The recommended codes of practice advocate the necessity of additional research into the exercise and social requirements of dry sows, and how the industry might best meet those needs.

The RCOP are conservative recommendations for the care of animals and are regulated rather than legislated, and therefore are not strictly enforced. A potential advantage of this system is that it recognizes the need for additional research into contentious welfare issues, and is flexible enough to allow new research to be incorporated into animal husbandry practices. This helps to ensure that new systems adopted provide benefits to animals. This element of flexibility, inherent in the codes of practice, allows for variation in the recommendations to best suit local circumstances (Broom 1989). The RCOP are included in the Animal Care Regulations, part of the Manitoba Animal Care Act (established in1998), as enforceable standards for the care of animals (Government of Manitoba 2003). The act states that "A person shall not be convicted of an offence under [the act]...for treating an animal in a manner…consistent with a standard or code of conduct, criteria, practice or procedure specified as acceptable in the regulations…[and] consistent with generally accepted practices or procedures" (Government of Manitoba 1996). Manitoba Agriculture and Food, Veterinary Services Branch enforces the act and regulations (Government of Manitoba 2003). Most other provinces have similar animal protection laws (Alberta, British Columbia, Ontario, New Brunswick and Nova Scotia) (Government of Ontario 2002), although none specifically refer to the RCOP in the text of the act.

2.2.2 Consumer perception

Regardless of actual legislation and recommendations, North America is increasingly aware of the shift of perception of consumers around the world. Pressure is being applied to large corporate consumers of livestock products. McDonalds Inc. has recently contracted to pay an additional $0.15 per dozen eggs produced by hens allocated an extra 28% space allowance in their cages (McGlone 2001). This type of industry pressure is driven by consumer demand for animal products produced under higher welfare standards. This implies that consumers believe that standard production practices are less humane than they would like, and rightly or wrongly, they are imposing changes in farm animal husbandry practices. There is growing awareness in the pork industry of niche markets for pork produced under conditions of higher welfare. Broom (1997) identified pork produced under improved conditions, marketed as a distinguishable product, as a potential benefit to producers. He notes that consumers may be willing to pay more and travel further for such a product. Dave Wasylyshen (2001) described the idea of marketing 'natural pork'. He suggests creating an accredited Natural Pork Program in Manitoba to create and administer guidelines for humanely produced pork. While there may be some costs associated with changes in production of this niche product, producers would receive a premium on their product. A consumer base willing to pay extra for humanely produced pork already exists (Wasylyshen 2001). The Winnipeg Humane Society's Certified Labelling program offers meat, dairy and egg products from animals reared under specific farming practices designed to "assure animals a decent quality of life" (The Winnipeg Humane Society 2003). Specific production criteria that must be met to qualify for this special label includes animal production without unnecessary antibiotics or hormones, no caging of animals (particularly for egg and pork production), increased space requirements, no concrete/slatted floors (straw or other 'natural' materials), natural lighting, and mandatory farm inspections by the Independent Organic Inspectors Association in order to maintain Winnipeg Humane Society certification.

The inherent problem in creating a niche market for high welfare animal products is that objective assessment of welfare is very difficult to accomplish, and therefore these systems may be judged on inaccurate perceptions of welfare. Decisions regarding animal housing will consequently be based not only on scientific measures but also on ethical and political grounds (Webster 2001; Wechsler et al. 1997).

2.2.3 Welfare of gestating sows

The Brambell Commission (1965) recommended that all farm animals should be permitted the 'five freedoms'. These include the freedom to stand up, lie down, turn around, stretch limbs and groom. In the case of gestation crates, the freedom to turn around, to groom and to a lesser extent to stretch limbs is violated. These five freedoms were amended to include freedom from a) hunger, malnutrition and thirst; b) thermal or physical distress; c) fear and stress; d) pain, injury, and disease; and e) suppression of normal behaviours (Ewing et al. 1999; Webster 2001). According to the new freedoms, the practice of using gestation crates to house pregnant sows violates the sow's freedom from discomfort (i.e. physical distress) and to express normal behaviour.

2.2.3.1 Defining welfare

To determine whether or not the welfare of an animal is being compromised, it is first necessary to define welfare. However, welfare is a notoriously ambiguous term and is extremely difficult to characterize. From a purely evolutionary perspective, welfare might be considered to be the ability to survive and reproduce, termed 'fitness' (Webster 1998; Webster 2001). This however, is a narrow definition that ignores concerns such as short-term suffering occurring at slaughter. Scientists have attempted to improve this definition by defining welfare in terms of an animal's attempts to satisfy its needs or requirements with respect to its environment (Broom 1997), or the state of an individual in relation to its environment (Broom 1991). Broom (1991) defines welfare as an individuals "state as regards its attempts to cope with its environment". The relative success of an animal at meeting its needs, such as obtaining food and shelter, and performing certain behaviours, such as grooming, is considered to be how well (or poorly) the animal copes with its environment (Broom 1991). The more difficulty an animal has in coping with its environment, the lower its welfare standard is considered to be. Wechsler et al. (1997) hypothesized that an animal's inability to satisfy its needs would result in a deficiency that can be measured, such as a nutritional deficiency, however they conclude that measurement of welfare status is not easily accomplished.

Welfare has also been described in terms of satisfying requirements and avoiding harm or injury, thus maximizing survival and reproduction, similar to the concept of 'fitness' (Wechsler et al. 1997). According to this definition, an animal that is overtaxed by its environment would show a deficiency in a relevant area, which could then be measured. For example in a housing system with poor flooring, the animal may show an increase in injuries, a measure that is quantifiable.

Perhaps the most important definition of welfare is that described by Webster (1998, 2001) suggesting that the welfare of an animal is determined by its capacity to avoid suffering, in this case referring to mental welfare. Mental welfare, integrally important in our determination of welfare, is the most difficult to assess.

2.2.3.2 Assessing welfare

Dawkins (1980) described welfare as including the mental and physical well-being of the animal. Broom (1991) stresses, "Welfare is a characteristic of the animal, not something given to it". It is clear that the perception of the environment by the animal is integral to its welfare state.

However, it should not be assumed that just because researchers cannot access the subjective and private experiences and feelings of animals directly that they cannot measure welfare (Wechsler et al. 1997). While researchers cannot explicitly ask an animal how it is feeling, they can use indicators related to the subjective feelings of animals. Barnett et al. (1993) identify four criteria available to characterize the emotional state of the pig: a) health; b) behaviour; c) physiology and d) production. Dawkins (1980) likewise notes that no single method by itself can give information about the emotional experiences of animals. Among others, she identifies health, production, comparison with wild counterparts, physiological measures, behaviour, animal preference, and anthropomorphizing. The overwhelming conclusion, therefore, is that it is necessary to examine a wide range of indicators collectively in order to develop a picture of an animals' state of welfare (Barnett et al. 1984; Barnett et al. 1993; Bracke et al. 2001; Broom 1991; Broom et al. 1995; Broom 1997; Webster 1998; Webster 2001). Measurements of mortality, disease, injury, productivity, physiology, immunology and behaviour are often used as indicators of animal welfare (Barnett et al. 1985; Broom 1991; Dawkins 1988; Wechsler et al. 1997). There is considerable debate, however, over their meaning and how they should be used in the evaluation of welfare.

Finally, it is important to establish a cut-off point where good welfare ends and poor welfare begins. Measures of poor welfare, according to Broom (1993) include a) reduced life expectancy, b) reduced ability to grow and breed, c) tissue damage, d) disease and immunosuppression, e) extreme, prolonged or unsuccessful physiological and/or behavioural attempts to cope, f) self narcotization via stereotypies, g) change in normal behaviour (extent of aberration or suppression of normal behaviour), and h) extent of delay of development of physiological processes and anatomical development. Measures of good welfare include the variety of normal behaviours shown, the extent to which strongly preferred behaviours are shown, and physiological and behavioural indicators of pleasure. Quantification of how much performance of abnormal or preferred behaviours signal poor or good welfare respectively is not addressed in this list by Broom (1993). This highlights the ambiguity of assigning a well-defined point at which welfare progresses from good to poor. It is important to note that although specific measurements and indications can be assigned for both good and poor welfare, welfare is considered to be a continuum from very good to very poor (Broom 1991).

2.2.3.3 Problems assessing welfare

Bracke et al. (2001) remark that welfare is so poorly understood that any attempt to assess it might be pointless because the measures used in that assessment may not be a valid reflection of actual welfare. This illustrates the disagreement over means of assessing welfare in a systematic and objective way (i.e. production and health versus behaviour).

There are four main problems with assessment of welfare. The first is that, as humans, we do not have access to the private experiences of animals (or even other humans). The second is that many different measures have been used as indicators of welfare, and there is disagreement as to their validity and interpretation. The third is that it is difficult to justify a cut off point for poor or good welfare. Finally, the fourth is that different measures of welfare are not necessarily correlated.

2.2.3.4 *Welfare assessment systems currently in use*

Bracke et al. (2001, 2002a,b) are developing a computer model to assess the welfare of pregnant sows using an exhaustive list of the animals' 'needs'. These include physical as well as emotional requirements, and rely on a wide variety of welfare indicators. While they report initial success at evaluating welfare with this method, they caution that determining where good welfare ends and poor welfare begins is not yet clear.

Austria is currently using an animal needs index (ANI 35 L) to evaluate and grade livestock housing with respect to animal well-being. This system assesses five criteria related to the animal and its environment: a) possibility of mobility; b) social contact; c) floor condition; d) stable climate; and e) intensity of human care (Bartussek 1999). A facility is graded on each criterion and assessed a score. Extra points can be given for conditions considered to improve animal welfare. Scores from each of the five conditions are tallied, and the sum of these is the ANI-value. This gives each facility a numerical score that can indicate how well it is meeting the welfare needs of its livestock. The Austrian ANI 35 L has been compared with a German animal needs index (ANI 200). The two systems assess slightly different criteria, but a significant correlation ($r = 0.87$) was found between them (Bartussek 1999).

The Swiss Animal Welfare Act, ratified in 1981 depends heavily on behavioural methods of assessment of welfare. It states that animals must not be kept in environments that interfere with behaviour or bodily functions, or overtax their ability to adapt (Wechsler et al. 1997). The use of behaviour as a primary welfare indicator is justified as behavioural alterations may be an early indicator of an animal experiencing difficulty adapting to its' housing environment (Tschanz 1987). Behavioural changes may be apparent before pathological change or injury develops.

2.3 HOUSING

2.3.1 Defining an acceptable environment

There are several definitions of what constitutes an acceptable environment. Hurnik (1995) suggests that a good environment is one in which there is harmony between the genetic character of the individual and its environment, where the optimum environment is one that provides the most appropriate combination of factors meeting a variety of needs supporting normal biological function (Ewing et al. 1999). Similarly, Broom (1997) deemed an environment as appropriate for an animal if it "allows the animal to satisfy its needs". These needs can be a particular resource, or the ability to carry out actions whose function is to obtain an objective (Broom 1983; Broom 1991). According to Broom (1997) the main impediment to creating the optimum environment with respect to welfare is not that this optimum environment does not exist, but that it may not be financially obtainable.

2.3.2 Use of gestation crates from the producer's perspective

According to McGlone (2001) the leading reason producers choose to house dry sows in gestation stalls is economic pressure. Gestation crates provide many benefits to the producer by a) allowing more efficient use of barn space, b) increasing the ease of managing the breeding herd, c) requiring less labour to operate a breeding facility, d) protecting the animals from injury that might occur due to fighting in group housing, e) allowing for individual feeding based on body condition, and f) protecting the sow from certain types of social stress that might be experienced in a group (McGlone 2001). Tubbs and Zulovich (1995) identify several benefits of individual housing such as enhanced farrowing rate and other measures of reproductive efficiency, reduced fighting and social stressors, and control over environmental factors, such as temperature, feed intake and photoperiod (Tubbs and Zulovich 1995)

Producer requirements that should be satisfied by the housing system include: a) maximized biological performance, b) reduced labour input, c) increased ease of management, d) acceptable capital cost, and e) acceptable financial return (den Hartog et al. 1993). However, the requirements of the animal as described by the five freedoms (Webster 1987) may be incompatible with the requirements of the producer. The freedoms most often neglected are the expression of most normal behaviours, absence of physical discomfort, and absence of fear and stress.

2.3.3 Use of gestation crates from the animal's perspective

Gestation crates are not an ideal housing system for the sow. Standard gestation crates 0.61 m wide by 2.13 m long are based on the static space requirements of the sow (McGlone 2001). This does not take into account the increased requirement for space during dynamic posture changes such as lying down and standing up (Baxter and Schwaller 1983). De Koning (1984) observed that the number of skin lesions of confined sows increased when "the size of the system is not in good harmony with the body size [of the sow]". In addition to difficulties presented by insufficient crate space, modern sows are physically less able to perform these posture changes with ease due to selection for improved carcass characteristics over the last few decades (Marchant and Broom 1996a; Marchant and Broom 1996b).

The opportunity for exercise in crates is severely limited affecting the sow's physical state (Marchant et al. 1997a). Physical effects may include reduced muscle size and bone strength (Marchant and Broom 1996a), reduced muscle and bone growth (Marchant and Broom 1996b), and reduced cardiovascular fitness (Marchant et al. 1997a). Stall-housed sows are reported to suffer a greater incidence of cardiovascular disease (Ratcliffe et al. 1969b). The effects of lack of exercise in turn makes changing position in the stall more problematic for the sow (Marchant and Broom 1996b), reducing her ability to manoeuvre and to carry out normal behaviours, and increasing risk of injury.

Sows housed in confinement systems are unable to perform a variety of behaviours, such as rooting, nest building, and complex social behaviours (Broom et al. 1995). This is a particular problem in swine due to the complexity of their behavioural repertoire and the intelligence of the animal. The absence of behavioural choices in gestation stalls leads to the emergence of stereotypies (Rollin 1995), such as bar biting and vacuum chewing. The incidence of abnormal or stereotypic behaviour has been shown to be greater in confined sows than in group-housed sows (Barnett et al. 1985; Broom 1983; Broom 1998; Broom and Potter 1984; Tarrant 1984; Vieuille-Thomas et al. 1995). It is generally agreed that for these reasons, the welfare of sows in gestation stalls is poor (Barnett et al. 1985; Broom 1987; Broom 1989; Broom et al. 1995; Marchant and Broom 1996a; Marchant and Broom 1996b).

2.3.4 Alternative systems

The number and variety of housing systems providing an alternative to gestation crates is large. Alternative housing can be as simple as a single, open pen with group housing of sows, to a system as complex as the Hurnik-Morris housing system. Many have been evaluated for effects on behaviour and/or production in the literature. However, with such a wide range of systems, minor differences between similar systems make direct comparison difficult.

Group housing is considered to be better than individual housing as it provides a more enriched environment for the animal (Ewing et al. 1999). Compared to individually housed sows, group housed sows are reported to spend less of their time performing stereotypic behaviours (for example, rooting and chewing at pen components) (Broom et al. 1995; Ewing et al. 1999). Group housing of sows allows for increased exercise compared to confinement systems, reported to have a positive effect on foot and leg health, maintenance of muscle mass and cardiovascular fitness (Ewing et al. 1999; Marchant et al. 1997a; Rollin 1995).

Levels of aggression may be just as high in gestation stall housing. Compared to stall-housed sows, group-housed sows were found to be less aggressive, likely the result of a stable social hierarchy (Barnett et al. 1987; Broom et al. 1995). Individually housed gilts are unable to move away from a neighbouring pig (i.e. active avoidance behaviour), negatively affecting the formation of a stable social hierarchy and leading to unresolved aggression and chronic stress (Barnett et al. 1987; Broom et al. 1995). However, many studies have found that agonistic interactions in large groups were more severe, with animals receiving substantial injury due to fighting (Barnett et al. 1987; Broom et al. 1995; Edwards 1998; Edwards and Turner 2000).

Group size is an important consideration in any group housing system. Large groups may be advantageous in that they do not require complex and expensive building systems, but that may be offset by the higher standard of animal management required to maintain a larger group (Edwards 1998). Another problem with housing of large groups is the possibility of increased aggression during mixing, potentially leading to increased risk of pregnancy failure (Edwards 1998). Smaller group sizes of four to eight animals have been recommended due to the reduced incidence of aggression, and simpler management (Edwards 1998). A drawback is that this system is potentially more costly to set up than housing for large groups due to less efficient utilization of space and increased cost of penning.

Feeding management in groups of any size is an extremely important factor affecting aggression. Competition for feed in group-housed gestating pigs on limited intake will intensify aggressive interactions, especially in floor-fed or group-fed animals. A possible solution to this is to provide individual feeding stalls (Ewing et al. 1999). Overall, group housing may be more difficult to manage than gestation stall systems, requiring more individual attention and stockmanship to ensure production levels are maintained (Ewing et al. 1999).

Another alternative to gestation stall housing is housing sows and gilts in groups on deeply bedded straw. Provision of bedding in the form of straw has numerous advantages. Straw bedding offers a more cushioned floor material for moving and lying (Rollin 1995), while providing improved footing that may reduce injuries due to slipping and falling (Day et al. 2002; Edwards 1998). The insulating nature of straw, if deeply bedded, can also improve thermal comfort (Day et al. 2002; Edwards 1998). Straw also provides foraging opportunities to feed restricted gestating sows that may otherwise develop abnormal behaviours (Broom 1983; Day et al. 2002; De Leeuw and Ekkel 2004; Edwards 1998; Ewing et al. 1999; Rollin 1995; Spoolder et al. 1995).

Unfortunately, the major disadvantage of a straw-based housing system is it's incompatibility with current manure disposal practices in north america, requiring increased cost and labour requirements (Day et al. 2002; Rollin 1995), significantly limiting utilization by producers. Straw provision also appears to be incompatible with the practice of floor feeding, and has been shown to result in an increase in aggressive behaviours (Day et al. 2002; Whittaker et al. 1999b).

2.4 BEHAVIOUR

Behaviour is defined as a complex of observable, recordable or measurable activities of a living animal (Heymer 1977). Within the context of discussing animal well-being, behaviour has been defined as an action or pattern of actions in response to a stimulus, externally derived from the interaction of an animal with its environment and/or internally derived from the interaction of hormones and an animal's phenotypic make-up (Ewing et al. 1999). Ethology is the study of animal behaviour, from a zoological point of view (Ewing et al. 1999; Heymer 1977). According to Broom (1987), ethology is the investigation of biological mechanisms by observation and detailed description of behaviour. In addition, ethology is a very precise and rigorous field that depends on knowledge of normal behaviour and the ability to recognize behavioural abnormalities.

2.4.1 Behaviour as a measure of welfare

Behavioural information is widely considered useful in the evaluation of welfare. The Brambell Committee Report (1965) recognized that alteration of behaviour from normal patterns might be the first and possibly the only sign of distress shown by intensively housed livestock (Tarrant 1984). Ewing et al. (1999) state that if the animal's environment is lacking and it is unable to perform normal behaviours then the animal will respond by expressing behaviours that reflect the environmental inadequacy such as the development of oral stereotypies by confined, feed restricted sows. Generally, animal well-being is considered to be compromised when an animal demonstrates behavioural or physiological aberrations (Ewing et al. 1999). Likewise, Broom (1991) lists behavioural anomalies as one of several indicators that an animal may be experiencing poor welfare.

2.4.2 Abnormal behaviours

Abnormal behaviour is defined as behaviour that "differ[s] in pattern, frequency or context from that which is shown by most members of the species in conditions that allow a full range of behaviours" (Fraser and Broom 1990). Abnormal behaviour is a "consequence of certain conditions which have been imposed on the animal and is almost completely absent in good conditions" (Broom 1987). Abnormal behaviours occur when the individual is unable to carry out preferred behaviours, or is frustrated, frightened or depressed (Broom 1998). Expression of abnormal behaviour is considered to be a coping mechanism ameliorating the effects of an inappropriate environment (Broom 1991; Rollin 1995). Zanella et al. (1996) caution that the "causes of abnormal behaviour are, in general, poorly understood", however it is likely that conditions in the environment play a role in their development. Regardless of cause, "forcing an animal to the limits of its coping skills" is unacceptable (Rollin 1995), and the welfare of such an individual would be poorer than another animal not required to exercise coping skills to adjust to its environment (Broom 1991).

Abnormal behaviour may differ from normal behaviour quantitatively or qualitatively (Broom 1998). These behaviours can be classed as stereotypied and non-stereotypied behaviours (Ewing et al. 1999). Non-stereotypied behaviours include some postures, such as dog-sitting in sows that may indicate aberrant behaviour reflecting unsoundness (i.e. lameness) or inadequate space for normal lying or rising (Broom 1987; Ewing et al. 1999). Other non-stereotypied behaviours include inactivity, unresponsiveness, self mutilation and excessive aggression (Broom 1998). However, the majority of abnormal behaviours fall under the classification of stereotypies.

2.4.3 Stereotypies

A definition of stereotypies for welfare purposes was provided by Broom (1983) as a "relatively invariate sequence of movements occurring so frequently, in a particular context, that it could not be considered to form part of one of the normal functional systems of the animal". Other definitions of stereotypies are variations of the same theme—behaviour that is repeated, fixed, out of context of the animals natural behavioural repertoire, and without obvious function or purpose for the performer (i.e. useless) (Broom 1991; Cronin et al. 1984; Ewing et al. 1999; Rollin 1995; Vieuille-Thomas et al. 1995). Although some authors describe stereotypies as "vices" (for example, Edwards (1998)), this is inappropriate as it implies that the animal is responsible for the behaviour when in fact, it is likely the conditions imposed on the animal that are to blame (Broom 1987; Rollin 1995).

Stereotypies differ from other stereotyped behaviours in that they appear to be functionless, and seem to be performed extensively for long periods of time (Wiepkema et al. 1984). Stereotyped behaviour is defined as behaviour that is fixed (i.e. constant in form, duration and frequency) as a result of an evolutionary process (Wiepkema et al. 1984). These behaviours are seen in all animal species and have obvious functions, such as in elimination (for example, pre-dunging behavioural sequences), ritualistic agonistic behaviours, mating rituals, and behaviours involved in posture changing, among others (Cronin and Wiepkema 1984).

Stereotypies performed by sows are largely oriented towards oral activities (Cronin et al. 1984; Vieuille-Thomas et al. 1995) such as sham (or vacuum) chewing; tongue rolling; excessive drinking (polydipsia); and biting, chewing, licking or manipulating various pen implements including bars, feeders and drinkers (Broom 1983; Broom and Potter 1984; Spoolder et al. 1995; Vieuille-Thomas et al. 1995; Zanella et al. 1996). Sows explore and manipulate objects in their environment using their lips and tongue as prehensile appendages. Thus oral behaviours fulfil both appetitive and exploratory functions (Day et al. 1996; Ewing et al. 1999), although considering the integral nature of such behaviours it is unlikely that these functions can be separated in this context.

Performance of stereotypies is considered a sign of poor welfare, and the more waking time the animal devotes to performance of stereotypies, the worse its welfare is considered to be (Broom 1983; Broom 1991). According to McBride's adaptation model, as environmental demands intensify, the behavioural response from the animal will increase

(Barnett et al. 1985; McBride 1980). This effect is observed when increasing time spent in a demanding environment results in an increase in the level of stereotypy performance (Broom 1998; Cronin and Wiepkema 1984).

2.4.3.1 Development of stereotypies

Stereotypies are caused by a specific inadequacy in the environment (Cronin and Wiepkema 1984; Ewing et al. 1999). These include lack of foraging opportunities or insufficient feed, a barren environment, and confinement leading to physical restriction of movement, lack of exercise, limited ability to explore, and social isolation among others (Broom 1983; Cronin et al. 1984; Ewing et al. 1999; Hsia et al. 1991; Vieuille-Thomas et al. 1995). As well, individual differences in the character of the animal may play a role in differential expression of stereotypies in the same environment (Vieuille-Thomas et al. 1995).

Situations that cause frustration are widely identified in the literature as causes of stereotypies. These include prevention of goal achievement (Ewing et al. 1999; Wiepkema 1987) or performance of a preferred behaviour (Broom 1983; Broom 1998; Cronin et al. 1984; Spoolder et al. 1995; Spooler et al. 1995). Frustration can be adaptive in that it results in a high level of motivation to alter the cause of the frustration (Lewis 1999). However, if no possibility exists to alter the frustrating condition, the animal experiences a basic lack of control over the environment and may therefore be in severe conflict with its environment (Wiepkema et al. 1984). An animal prevented in this way from performing an essential component of a behavioural sequence compensates by performing the missing elements out of context (i.e. abnormally) resulting in ritualization of the behaviour, leading ultimately to development of a full stereotypy (Stolba et al. 1983; Wiepkema 1987).

2.4.3.2 Functional effects of stereotypies

While stereotypies appear purposeless (Broom 1991; Cronin et al. 1984; Rollin 1995), they may play an important role as behavioural strategies that facilitate coping with unfavourable circumstances (Broom 1983; Broom and Potter 1984; Cronin et al. 1984; Rushen et al. 1990; Wiepkema et al. 1984; Wiepkema 1987). The mechanism by which stereotypies are presumed to do this is by causing or facilitating endogenous opioid release (Broom 1983; Broom 1991; Zanella et al. 1996). However, Rushen et al. (1990) found no evidence supporting a link between stereotypy performance and opioid induced analgesia.

Endorphins (endogenous opioids), play a role in the reinforcing mechanism underlying self-stimulating behaviours such as stereotypies and have analgesic effects in situations of stress or pain (Wiepkema et al. 1984). Wiepkema et al. (1984) postulated a link between performance of stereotypies and release of endorphins after observing stereotypic behaviour of tethered gestating sows. They suggest that performance of the stereotypy is a self-stimulating activity, and has characteristics of an addictive behaviour. Indeed, the repetitive nature of the behaviour suggests some reward is gained from the performance (Cronin et al. 1984).

Endorphin release resulting from the performance of stereotypies may also protect the animal from stress-related injury. For example, Wiepkema et al. (1984) found that veal calves that spent more time performing oral stereotypies had significantly reduced abomasal damage at slaughter compared to veal calves that spent less time performing stereotypies.

Their conclusion was that stereotypies were a useful mechanism causing release of endogenous endorphins, preventing internal damage following stress. Although this conclusion has not been substantiated, it may indicate some underlying advantage for the performance of stereotypies.

Another potential functional effect of the performance of stereotypies is that it may provide some level of control of the sensory input experienced by the sow or gilt. Performance of stereotypies produces sensory input, which can a) increase input when the animal is subjected to a deprived environment where it experiences a low level of sensory input; and b) increase the average predictability of sensory input in situations where events are highly unpredictable, such as irregular or delayed feeding of tethered sows (Broom 1983). Stereotypies may provide the animal with the ability to 'tune-out' external input and decrease the necessity to respond to and process inputs from unpleasant stimuli (Broom 1983). It has been suggested that stereotypy performance might temporarily suspend higher central nervous system function in pigs (causing the low sensory input and unpredictability of the environment to be ignored), thus reducing suffering in an adverse environment (Dantzer 1986). However, it is of foremost importance to remember that even though an animal is coping with adverse conditions, its welfare is worse than an animal that does not need to cope at such a high level (Broom 1991). According to Ewing et al. (1999) stereotypies "must be viewed as a reflection of suffering that is the basis for their development."

2.4.3.3 *Association of stereotypic behaviour with feeding*

Standard feeding practice for the gestating sow restricts energy intake to 60% of *ad libitum* consumption (Whittaker et al. 1998) in order to limit excessive weight gain (National Research Council 1998; Patience et al. 1995). Feed is generally provided in a concentrated form once or twice daily, and is consumed rapidly by the sow (Rollin 1995; Whittaker et al. 1998). The sow is subsequently "food motivated" throughout most of the day (Spoolder et al. 1995; Whittaker et al. 1999b).

This system differs substantially from the natural feeding behaviour of the sow, where a sizable portion of time is spent engaged in food seeking behaviours, most notably by rooting in its environment with the snout (Rollin 1995). Additionally the natural diet of the sow is high in roughage, whereas the commercially fed diet is very low in fibre and contains highly concentrated nutrients and energy (Rollin 1995; Whittaker et al. 1998).

Food related behaviours are among the most important behaviours in an animal's repertoire within a 'natural' context, where all food acquisition is entirely up to the animal (Rollin 1995). In an animal's natural environment, the motivation to gather food and to eat is extremely high, owing to their integral association with survival (Dawkins 1988). Although commercial feeding practices meet the nutritional requirements of the sow, they do not allow the expression of food related appetitive behaviours that the sow is highly motivated to perform (Rollin 1995; Spoolder et al. 1995; Whittaker et al. 1998). As a result, food restriction and the inability to perform foraging behaviours are identified as important causal factors of stereotypic behaviours in sows (Hsia et al. 1991; Rollin 1995; Rushen 1984b; Spoolder et al. 1995; Whittaker et al. 1998; Whittaker et al. 1999b).

The limited amount of feed offered in such restricted diets elicits positive feedback effects on hunger in the early stages of feeding. Such positive feedback effects are stronger than the negative feedback of ingestion of nutrients. This leads to an increased expression of feed-related behaviours following the short meal (Spoolder et al. 1995). Dailey and McGlone (1997) suggest that oral-nasal-facial behaviours of sows, both stereotypical and non-stereotypical might be normal feeding related behaviours of commercially reared sows fed a limited ration. However, in their measurement of heart rates of stall- and group-housed sows, Marchant et al. (1997) conclude that feeding represents a more important event in the day of the stall-housed sow compared to the group-housed sow as indicated by a greater response in heart rate to feeding in stall-housed sows. This indicates that the sow's housing environment, in addition to feeding level, plays an important role in the development of stereotypies.

2.4.3.4 Association of stereotypic behaviour with confinement

As stated earlier, confinement of pregnant sows in gestation crates or stalls is a common practice in commercial swine facilities, and is commonly associated with increased incidence of stereotypic behaviour (Broom 1983; Broom 1987; Broom et al. 1995; Ewing et al. 1999; Hsia et al. 1991; Vieuille-Thomas et al. 1995). According to Spoolder et al. (1995) restriction of movement in addition to feed limitation, may prevent the sow from performing important food related behaviours. This leads to 'channelling' of the complex behaviour of foraging into a few repeated sequences, and ultimately into stereotypies (Dantzer 1986).

In addition to movement restriction, confinement can also reduce the complexity of the animal's environment by isolating it from social interaction with its peers and reducing opportunities for exploration (Barnett et al. 1987; Broom 1983; Broom et al. 1995; Ewing et al. 1999). Expression of stereotypic behaviours also differs depending on the housing system. Vieuille-Thomas et al. (1995) report that stall-housed sows typically perform bar-biting stereotypies and group-housed sows exhibit vacuum chewing and wall licking. This suggests that there are other factors that interact with housing system and feeding level to influence the development and expression of stereotypies (Vieuille-Thomas et al. 1995).

2.4.3.5 Effect of straw provision on stereotypic behaviour

Provision of straw has been suggested by many as a means of preventing the development of, or reducing the incidence of unwanted behaviours that may otherwise arise in commercial environments (Broom 1983; Day et al. 2002; Edwards 1998; Ewing et al. 1999; Rollin 1995; Spoolder et al. 1995). Straw improves the welfare of pigs housed in barren environments by providing opportunities for exploration as well as improving physical and thermal comfort (Broom 1983; Day et al. 2002; Rollin 1995). Straw acts as a substrate on which the sow can express foraging behaviours that might otherwise be directed to pen components such as feeders, drinker nozzles, bars, concrete floors and conspecifics (Rollin 1995; Spoolder et al. 1995). This may facilitate the expression of chewing and rooting behaviours not normally expressed by commercially reared sows on restricted feed (Dailey and McGlone 1997).

Provision of straw may also improve welfare by allowing sows to redirect aggression to the manipulation of straw (Day et al. 2002). However, Whittaker et al. (1999) found that the overall incidence of aggressive behaviours rose significantly during and immediately following floor feeding in group-housed sows provided with straw. The increase in aggression is most likely a consequence of the feeding system utilized in their trial. Sows in this type of housing system were thought to have a more difficult time finding food compared to sows fed in individual stalls (Whittaker et al. 1999b). The author did note that increasing the fibre content of the sows' feed (by providing straw) reduced the incidence of vulva biting, a severe behavioural abnormality potentially experienced in group housing systems.

While many authors combine oral-nasal-facial behaviours together into a single grouping, sows may perceive these as having different value based on their surroundings. Sows in a semi-natural environment are exposed to a variety of substrates, and can express a full range of rooting behaviour. Sows in outdoor commercial housing may experience deficiencies in substrates on which to express rooting and foraging behaviours. Sows housed in more intensive indoor environments may experience different or multiple deficiencies in the expression of rooting and foraging behaviours. Dailey and McGlone (1997) found that the particular characteristic of oral-nasal-facial behaviour preferentially performed by sows was related specifically to their environment. In response to an environment that under-stimulates the mouth, snout or face, sows increased behaviours that provide the most compensatory stimulation of these neglected areas. For example, outdoor-housed sows stimulated the roof of their mouths more compared to indoor sows that are able to use aspects of their pens such as the bars to stimulate this area. Conversely, indoor sows without soil or straw to root in were observed stimulating the region on the top of the snout most often (Dailey and McGlone 1997).

2.4.4 Behaviours observed in commercially housed gestating pigs

2.4.4.1 Activity

Pregnant sows housed outdoors are reported to spend 21.7% of their day in active behaviours, including walking, standing, foraging, feeding and drinking (Buckner et al. 1998). These findings are considered to be comparable with indoor-housed sows, reported to spend 18-24% of their day engaging in active behaviours (Barnett et al. 1985). Vestergaard and Hansen (1984) found that individually housed and tethered gestating sows were active for less than 17% of the day. Loose, outdoor or straw-housed gestating gilts were more active than confined gilts (Barnett et al. 1985).

Gestating sows were observed to be more active than sows in other stages of their reproductive cycle, likely as a result of increased foraging behaviour (Buckner et al. 1998). Increased foraging can be attributed to the practice of restriction feeding during pregnancy (Buckner et al. 1998; Hsia et al. 1991). Barnett et al. (1985) found the predominant active behaviours of loose, outdoor-housed gestating gilts consisted of rooting and grazing. Rooting has been reported to constitute 10-20% of the active time of sows kept outdoors in a semi-natural environment (Stolba and Wood-Gush 1989), with food seeking and exploration reported to constitute 40-60% of active time (Studnitz and Jensen 2002). Indoor stall-housed sows were observed spending more time rooting at their environment than indoor group-housed sows, however rooting in this instance refers to forceful contact of the snout with the floor (Hsia et al. 1991). However, Weng et al. (1998) found that the level of rooting behaviour progressively increased with increasing space allowance of straw-housed sows.

The level of activity increases substantially with provision of straw or bedding (Morgan et al. 1998; Whittaker et al. 1999b), with most of the active time spent manipulating the straw (Spoolder et al. 1995). Weng et al. (1998) observed that loose-housed sows on straw spent 37% of their active time engaged in rooting behaviour. Provision of straw can redirect excessive levels of pen component directed behaviours into foraging and rooting behaviours (Whittaker et al. 1999b).

The predominant active behaviours in confined gestating gilts not provided with straw bedding are oral-nasal-facial behaviours such as licking, nosing and biting (Barnett et al. 1985). Behaviours such as these are commonly considered abnormal or inappropriate (Barnett et al. 1985; Dailey and McGlone 1997; Vieuille-Thomas et al. 1995), and may be a reflection of an inadequacy in the environment preventing the sow from expressing normal foraging behaviours.

Pigs spend 21% of a 24-hour period standing, although standing during a 12-hour day time period was found to be higher at 31.9% (Ruckebusch 1972). Pigs on straw were found to spend more time standing (Morgan et al. 1998), possibly as a result of a general increase in activity overall. Spoolder et al. (1995) however, found no difference in frequency of standing in group-housed sows with or without straw. Standing was observed to be highest in all treatments just before feeding (at 0800h), gradually declining throughout the day until evening (1800h) (Spoolder et al. 1995).

Physical attacks or threat of attack are defined as aggressive behaviours (Ewing et al. 1999). Examples of aggressive behaviours include biting, butting, kicking, pawing and stomping. Numerous causes of aggressive behaviours are identified in commercially housed swine, including competition for food, crowding, fear or pain, and establishment of a stable social hierarchy (Ewing et al. 1999). Provision of straw to growing pigs was found to redirect negative interactions with other pigs (i.e. nosing, aggression, ear chewing, licking, biting, belly nosing, tail biting and play fighting) towards rooting and nosing at the straw (Day et al. 2002).

Social interactions are mainly associated with individual recognition (for example, nose-to-nose and nose-to-body contact) and comfort (for example, positioning in order to be with preferred pen mates). These can be distinguished from aggressive encounters by the type of contact. Generally speaking, social encounters involve body, head or snout contact (Jensen 1984), and aggressive encounters involve biting and threat displays (Ewing et al. 1999). However, social behaviour and aggressive or antagonistic behaviours are rarely distinguished from each other in the literature (Bradshaw et al. 1999). An increasing level of confinement was found to result in a decreasing frequency of social activity and a more limited repertoire of social behaviours (Jensen 1984).

Drinking was found to occupy an average of 1% of the gestating sow's day, with no differences between group-housed sows with or without straw (Spoolder et al. 1995). Excessive levels of drinking (>10% of the pig's day) are considered stereotypic, and have been noted in restriction fed gilts (Spoolder et al. 1995; Terlouw et al. 1991). Whether or not water was actually ingested is questionable as distinguishing between abnormal levels of drinking and excessive manipulation of the drinking equipment is difficult with behavioural observations.

2.4.4.2 *Inactivity*

Inactive behaviour includes resting and sitting or standing while not engaged in other behaviours. Resting is an important behaviour as it accounts for the majority of the gestating gilts' day, reported as 82% by Weng et al. (1998). Other reports found resting to occupy 88.9% of a 24-hour period, although the proportion of time resting during a 12-hour daytime interval was somewhat lower at 68.1% (Ruckebusch 1972). Only 32% of resting time is spent in actual sleep, while drowsing accounts for 21% (Ruckebusch 1972). Gestating gilts spend most of their day lying down and resting, regardless of housing, although gilts confined to stalls and tether stalls were found to spend significantly more time resting than loose-housed gilts. (Barnett et al. 1985). Findings by Hsia et al. (1991), demonstrating that group-housed sows spend more time lying down than stall housed sows are not consistent with this conclusion.

Pre-parturient gilts in stalls spent less time lying in lateral recumbency than gilts on straw (Cronin et al. 1994; Vestergaard and Hansen 1984). Similarly, tethered and individually housed dry sows were observed lying on their side for 54.2-62.5% of their day, while belly lying was only observed for 21-29.2% of their day (Vestergaard and Hansen 1984). Decreased lateral recumbency was associated with an increased frequency of posture changes in stall-housed gilts, indicating a lower level of comfort in the stall-housed sows. Tethered sows were observed changing positions more frequently than sows individually housed in larger pens (Vestergaard and Hansen 1984). Frequency of postural change can be interpreted as a measure of comfort, with more time spent in a posture, and fewer posture changes indicating a greater level of comfort. However, Marchant and Broom (1996) interpret differences in posture changing in confined and unconfined sows as a measure of the ease or difficulty with which the sows are able to change position. The posture changes from standing to lying were found to be reduced in sows housed in gestation stalls compared with loose-housed sows (Anil et al. 2002). The increased frequency of postural change and duration of posture may actually represent a greater level of comfort, indicating that the animal can adjust freely to maximize comfort (Anil et al. 2002). It is possible that there exists an optimal amount of postural changes, with too many or too few indicating discomfort.

Idle behaviour, consisting of sitting and standing inactive was found to be greater in stalls compared with group housing systems (Barnett et al. 1985). As well, time spent sitting and standing inactive were found to increase progressively in group housing systems when space per sow was reduced from $4.8m^2$ to $3.5m^2$ to $2.4m^2$ to $2.0m^2$ (Weng et al. 1998). Zanella et al. (1996) found that prolonged confinement results in excessive inactivity, representing an abnormal behaviour. They found that highly inactive sows had an increased density of opioid receptors in the frontal cortex, potentially indicating genetic differences in endogenous opioid release and/or response in a chronic stress situation.

2.5 LAMENESS

2.5.1 Description

Lameness, also referred to as locomotor dysfunction, has been generally described as a disturbance in gait (Nakano et al. 1981a; Nakano et al. 1987), difficulty walking (Yamasaki et al. 1989; Yamasaki and Itakura 1988), or an awkward gait (White 1994). This can also manifest as shortened stride length (Hill 1994) with the animal taking short, stiff steps (Yamasaki et al. 1989; Yamasaki and Itakura 1988). Walking is usually hindered, and one or more limbs are usually not fully weight bearing (Hill 1994).

In addition to the effects of lameness on locomotion, an affected animal may experience difficulty standing, or show reluctance to stand (Blowey 1994; Hill 1994; Yamasaki et al. 1989; Yamasaki and Itakura 1988). Problems standing create immediate welfare implications for the sow. Access to feed and water may be restricted, and the sow may experience problems defecating normally. Difficulty standing may also have repercussions on the sows and gilts, as they may be unable to support the weight of the boar during mating (Blowey 1994). Nakano et al. (1981) observed that lame boars spent more time lying down than control (non-lame) animals. Animals who are lame may also perform abnormal activities such as eating while sitting, rather than standing (Yamasaki et al. 1989; Yamasaki and Itakura 1988). Animals in extreme pain may refuse to move, or animals may be unable to move due to paralysis (Hill 1994).

Onset of lameness can be insidious or acute, and may appear episodic, especially when caused by bone/joint lesions (Hill 1994). Other than the disturbance in gait, movement and posture, an animal with non-infectious lameness appears otherwise normal (eating, temperature normal) (Yamasaki et al. 1989; Yamasaki and Itakura 1988), unless in severe pain or distress.

In the literature, lameness of breeding animals has been commonly referred to as leg weakness syndrome (LWS). LWS is a general term used to describe impairment of locomotor ability, structural unsoundness or lameness (Nakano et al. 1987). Hill (1994) states that LWS is not a specific syndrome, but actually describes a broad range of lameness. It was originally used to describe the inability of boars to remain mounted during mating.

Later it was applied to locomotor deficiencies in general. It is most commonly used with reference to lameness in adolescent breeding pigs (Hill 1994; Reiland 1976). Grondalen (1977, 1979a,b) notes that the diagnosis of LWS was made based on observation of the ability of the animal to move, and as such it cannot be considered to be a conclusive diagnosis, being subject to the same problems of any subjective scoring system. The major causes of LWS are the same as those identified for lameness. Joint lesions, caused by many contributing factors, including growth rate, unyielding flooring, and insufficient exercise, have been identified as playing an important causative role in the appearance of the lameness (Elliot and Doige 1973; Grondalen 1974a; Grondalen 1974b; Nakano et al. 1981a). Additionally, osteochondrosis (OC) has been identified as playing a significant role in the etiology of leg weakness syndrome (Pointillart and Gueguen 1978). Nakano et al. (1981) suggested that OC could be an important predisposing factor in LWS.

Most papers that describe lameness do so in a purely descriptive and mechanistic manner. It can be inferred from these descriptions that animals showing signs of lameness should be considered to be experiencing some degree of pain or discomfort (Hill 1994). As such, an animal experiencing lameness can be said to have reduced welfare.

2.5.2 Economic impact of lameness

In addition to being a welfare concern, lameness in sows and gilts is a serious economic problem in swine herds all over the globe, posing particular problems to breeding herds (Grondalen 1979a; McCaw and Mitten 1980). The average annual culling rate of gilts and sows due to lameness in Ontario in 1985 was 10%, ranging from 0-38% (Dewey et al. 1992; Friendship et al. 1986). In the US, culling rates due to lameness were 6% for gilts, and

20% for boars in 1989-90 (Hill 1994). With replacements estimated at $65 US per gilt and $345 US per boar, the cost to the US swine industry in one year (1989-90) was estimated at $48,103,933 (Hill 1994). In a more recent study (December 1999 through May 2000) the U.S. Department of Agriculture (USDA 2001) reported the current culling rate of breeding-age female pigs due to lameness at 16%. In the UK, 10.7% of all sows were culled due to lameness (Blowey 1994). In addition, 20% of first parity gilts were culled for lameness. Overall this resulted in a loss of £3.0 million. Yamasaki et al. (1989) reported that lameness represents a serious economic loss to the pig industry in Japan.

The losses due to lameness are both overt, such as culling for lameness, and covert. Covert costs can include reduced reproductive performance of replacement gilts compared to older sows (Dewey et al. 1993; Hill 1994), a reduced pool from which to select replacement stock and increased farrowing mortality (Hill 1994).

2.5.3 Causes of lameness

2.5.3.1 Injury, infection and disease

There are many factors that contribute to lameness in breeding-age female pigs. Generally, lameness is identified as being caused by injury, infection (Tubbs 1988; White 1994), or degeneration of joints in the limbs (Dewey et al. 1993; Grondalen 1974b; Grondalen 1974c; Nakano et al. 1981a; Nakano et al. 1987). There exists, however, considerable disagreement over which of these factors is responsible for causing the majority of lameness.

Tubbs (1988) suggests that trauma and infection are likely the underlying causes of most lameness observed in swine, although Hogg et al. (1975) states that lameness is often mistakenly attributed to *Mycoplasma hyosynoviae* infection, when it is actually caused by other factors, such as trauma, conformation, or nutritional deficiencies. McCaw and Mitten (1980) report on a herd with severe lameness in which osteochondrosis (OC) was observed simultaneously with *M. hyosynoviae* and *M. hyorhinis* infection, although these were identified as secondary to the OC.

While Yamasaki and Itakura (1988) and Yamasaki et al. (1989) were unable to link osteochondrosis with locomotor dysfunction, many other studies have identified joint disease or degeneration as a major cause of lameness (Dewey et al. 1993; Grondalen 1974b; Grondalen 1974c; Nakano et al. 1981a; Nakano et al. 1987).

2.5.3.1 Osteochondrosis

Osteochondrosis (OC) has been widely defined as a non-infectious disturbance in endochondral ossification of joint cartilage and epiphyseal plates (growth plates) (Grondalen 1974c; Grondalen 1979a). This results in disruption of normal ossification of cartilage leading to cartilage necrosis and disturbed bone growth (McCaw and Mitten 1980). Nakano et al. (1979) observed softening and fracture of cartilage with OC lesions. OC has also been described as a generalized dyschondroplasia of growing pigs (Dewey et al. 1993; Hill 1994).

A condition linked with OC is osteoarthrosis (OA), also called osteoarthritis. OA refers to the degeneration of articular cartilage. OA differs from OC in that OC affects the subarticular growth cartilage involved in growth of epiphyseal bone via endochondral ossification (Nakano and Aherne 1993). As the animal matures, the subchondral growth cartilage disappears. Therefore, OC lesions do not develop in adult animals, although the damage due to OC lesions may remain in the adult joint. Much of the confusion surrounding the definition of OC is due to alternative names that are commonly used in place of OC and OA. These include arthropathy, arthritis, polyarthritis, degenerative joint disease (DJD), dyschondroplasia, and metaphyseal dysplasia (Hill 1994). Hill (1994) suggests that the names of both OC and OA are inaccurate because lesions are initiated in growth cartilage, and bones are affected secondarily. He suggests that OC should be used to define a group of syndromes that cause limb deformities or degenerative joint diseases in young, fast growing swine. This definition will be used in the rest of this thesis. OC is believed to be the most common joint abnormality of immature, growing pigs (Nakano et al. 1979). This joint condition has been suggested to be the major cause of LWS (Grondalen 1974a; Grondalen 1974b; Grondalen 1974c; Nakano et al. 1981b; Nakano et al. 1984).

In young growing animals the joint cartilage consists of subarticular growth cartilage, below a layer of articular cartilage. The subarticular growth cartilage is important in the growth of epiphyseal bone via endochondral ossification. This increases the length of long bones (Hill 1994). In pigs, skeletal growth continues (i.e. growth plates continue to function) until the animal is 3 to 3.5 years of age. Generally, OC is considered to be a disease of growing animals only. Lesions can appear by the time the animal reaches 20 kg body weight (Grondalen 1974c; Grondalen 1979a). McCaw and Mitten (1980) report that OC lesions first appear at 4 months of age, but can clinically manifest later in life. Gross pathological lesions initially appear at 4-5 months of age, presenting as a yellowing of overlying cartilage in the joint. By 6-8 months, the joint surface appears visibly flattened. From 6-12 months, fissures with hyperaemic bases start to form (McCaw and Mitten 1980).

2.5.3.2 Nutritional effects and rapid growth

Nutritional deficiencies have been suggested to cause lameness (2003; Hogg et al. 1975; Pointillart and Gueguen 1978; White 1994), although excess nutrients can result in lameness as well. Grondalen (1974a,b; 1979a) and Nakano et al. (1987) found that a high plane of feeding has a very large positive effect on growth rate, causing long bone development to outstrip joint maturation and muscle development, resulting in lameness. Rapid growth, resulting in an imbalance between growth of the limb bones and growth of the trunk, has been suggested as the major cause of widening of the angle between the long axis of the femoral head and the greater trochanter, significantly associated with lameness in pigs (Yamasaki et al. 1989; Yamasaki and Itakura 1988). Others have also identified rapid growth as a potential contributing factor for lameness in swine (Grondalen 1974a; Grondalen 1974c; Grondalen 1979a; Grondalen 1979b; McCaw and Mitten 1980; White 1994)

2.5.3.3 *Lack of exercise*

Lack of sufficient exercise has been suggested to exacerbate lameness. Elliot and Doige (1973) found that bone lesion frequency was higher in individually housed pigs, compared to pigs housed in small groups. They concluded that the lameness observed was due to reduced muscle strength from confinement. With poor muscle control of basic movements, there is a greater chance that the sow might slip or fall, incurring physical injury (Marchant and Broom 1996a). Sufficient injury to a limb can cause the sow to shift weight off of the affected limb to reduce pain (Hill 1994). This provides an opportunity for the injury to heal. However, shifting weight onto less painful limbs increases the load the other joints must carry, which can potentially increase the mechanical damage to those joints. Toe and claw problems have also been implicated in the development of joint lesions (Fritschen 1977). Fritschen (1977) found that pigs with unequal inner and outer claw lengths distributed their weight unequally among their legs, and identified this as a factor in bone lesion distribution and development.

Not all are in agreement on the effects of exercise on underlying causes of lameness. When exercised on a treadmill, the lameness of pigs was found to improve, however, the incidence and severity of bone lesions was unchanged (Hill 1994). Grondalen (1974a,c; 1977; 1979a,b) noted that exercised pigs appeared to be more agile, allowing them to remain standing after slipping more easily. This was attributed to increased muscle strength with exercise, and experience. However, in these papers Grondalen states that the degree of joint lesion was not influenced by exercise.

Exercise is important to the overall health of the sow, and insufficient exercise can compromise the sow's cardiovascular fitness (Ratcliffe et al. 1969a). Exercise is also important in growth, development and maintenance of muscle and bone. Sows confined to gestation stalls as gilts, with reduced opportunity to exercise, were found to have significantly shorter body length than loose-housed sows (Marchant and Broom 1996a). These sows were also found to have a reduced proportional weight of some of the muscles involved in locomotion, and a decrease in strength of the humeri and femurs compared to loose-housed sows (Marchant and Broom 1996a). Reduced muscle weight is presumed to be associated with decreased muscle strength. The consequences of this reduction in muscle weight would be increased difficulty in performing basic movements, such as standing and lying (Marchant and Broom 1996b). Increased difficulty in changing posture in the stall would likely result in less time standing and more time lying down, or abnormally long periods of standing and lying due to reluctance to change posture. This would further reduce the amount of exercise, or muscle strengthening behaviours, leading to even weaker muscles, continuing the vicious circle. In addition to compromising the sow's welfare (increased risk of injury and increasing muscle weakness), this can result in increased piglet mortality due to crushing during farrowing (Boyle et al. 2002; Marchant and Broom 1996a; Marchant and Broom 1996b), and dystocia.

3.4.2.1.1 Mechanical pumping—maintenance of healthy joints

Exercise in the form of joint motion plays an important role in normal maintenance of articular cartilage through mechanical pumping via joint loading (Nakano and Aherne 1993). Normal cartilage tissue is composed of two constituent molecules: collagen fibres give the tissue tensile strength, and proteoglycans—hydrophilic molecules immobilized in the collagen network—protect the tissue from compressive and shear stresses (Nakano and Aherne 1993). Mechanical pumping occurs via the repetitive process of exudation and intake of joint fluid through the proteoglycan molecules. This facilitates transportation of nutrients into tissue and removal of waste products from chondrocytes into the joint space. Confinement in stalls and subsequent reduction in exercise may result in impaired mechanical pumping (Nakano and Aherne 1993), and therefore cell death. Cell death, if abnormally high, will lead to clinically apparent lesions.

3.4.2.1.2 Joint Loading

Exercise contributes to joint loading, which is very important in the maintenance of healthy joint tissue. A high frequency of joint loading stimulates protein and proteoglycan synthesis, where static or low frequency of joint loading decreases the synthesis rate of protein and proteoglycan synthesis (Larsson et al. 1991). Additional destruction of the cartilage matrix may result from derangement of enzymatic systems following mechanical failure (i.e. cell death) of cartilage. Prolonged standing may contribute to local overloading of joint tissue and static compression of articular cartilage (Nakano and Aherne 1993). Local overloading has been identified as a possible cause of joint lesions (osteoarthrosis) due to inability of joint tissue to withstand mechanical stress, resulting from excessive loading or underlying weakness of the tissue (Nakano and Aherne 1993; Yamasaki and Itakura 1988). Poor conformation can also contribute to development of joint lesions by causing abnormal loading on improper joint surfaces.

An optimum amount of loading is necessary for joint health. Excessive joint loading results in local overloading and static compression of articular cartilage, as described above. Insufficient joint loading results in inadequate mechanical pumping to move nutrients through the cartilage matrix. Both of these may contribute to the development of lameness. Confinement gestation housing restricts the sows ability to exercise freely (Broom et al. 1995; Marchant and Broom 1996a; Marchant and Broom 1996b; Nakano and Aherne 1993; Rollin 1995), and may contribute to suboptimal joint loading and lameness.

2.5.3.4 Housing

Many factors related to housing can be linked with the development or exacerbation of lameness. Confining sows in gestation crates severely limits the opportunity to exercise, shown to exacerbate lameness due to reduced muscle strength and the development of bone lesions (Elliot and Doige 1973; Marchant and Broom 1996a; Nakano et al. 1981a). Reduced muscle strength has been shown to cause lameness by increasing the difficulty in changing position in the stall, reduced ability to manoeuvre and to carry out normal behaviours, and increased risk of injury (de Koning 1984; Marchant and Broom 1996b). Another concern regarding commercial housing is the use of concrete flooring, suggested to be a major contributing factor to lameness through the development of bone and joint lesions (Elliot and Doige 1973; Nakano et al. 1981a) and foot lesions (Mouttotou et al. 1999). Provision of bedding in the form of straw offers a more cushioned floor material for moving and lying (Rollin 1995), while providing improved footing that may reduce injuries, and subsequent lameness, due to slipping and falling (Day et al. 2002; Edwards 1998).

2.5.4 Assessing lameness

Assessing lameness is important in both clinical and applied settings. Rapid diagnosis of lameness is important for treatment. Early identification of animals with locomotory problems is also essential to reduce culling of bred gilts and sows. Only animals able to withstand the production environment should be placed in the breeding herd.

There are inherent difficulties with scoring lameness in modern domestic sows. The first is the unusual locomotion of domestic swine. Main et al. (2000) observed that pigs have a stilted gait, taking short, rapid steps as opposed to steady walking. They also note that pigs display limited vertical head movement, a key indicator of lameness in other species. The second difficulty in quantitatively assessing lameness in any species is the subjectiveness of the scoring system. Hill (1994) comments that the lameness exam is dependant on consistent methodology. Grondalen (1977) acknowledges that the diagnosis of lameness is based on the observer's visual impression of the pig's ability to move, and is not an exact diagnosis. Main et al. (2000) tested the reliability of their scoring system with trained and naive operators. They found that there was good accuracy when scoring was conducted by trained observers, but reliability was compromised when unfamiliar operators used their system to evaluate lameness in swine.

2.5.4.2 Lameness scoring systems

Lameness assessment systems for pigs described in the literature involve a subjective evaluation of the gait (Brennan and Aherne 1986; Grondalen 1977; Hill 1994; Nakano et al. 1981a). Much variation in the criteria used to evaluate lameness and the detail describing those criteria exists between systems in the literature. In a system described by Grondalen (1977), gait was scored on a scale of 3 to 8, where 3 represented pigs unable to rise and 8 represented pigs with very good gait. Aspects other than gait that were assessed included ability to stand, ability to trot, ease of movement and 'springiness' of movement, stiffness or swaying gait, and stability while walking (Grondalen 1977). Some gait score systems were described in less detail. For example, the subjective gait assessment method described by Brennan and Aherne (1986) includes only the criteria that a score of 1 is given to normal pigs, and a score of 5 is assigned to very lame animals. In the system described by Nakano (1981) boars with normal locomotion were scored zero, slight to moderately lame animals received scores of 1-3, scores of 4-6 were given to animals displaying moderate to severe lameness, and a score of 7 was reserved for animals unable to stand.

The lameness scoring system developed by Main et al. (2000) differs from other scoring systems described in the literature by providing a detailed list of criteria to evaluate lameness that was simple to use, repeatable, and capable of quantifying the lameness observed, despite being a subjective system. Main et al. examined several aspects contributing to lameness, including behaviour, posture while standing, and gait. The system ranks pigs with scores ranging from zero to 5, with zero representing pigs with no signs of lameness, and 5 assigned to pigs that are suffering from severe lameness. Each aspect of lameness (behaviour, standing posture and gait) has specific defining criteria for assigning the lameness score. When tested, the scoring system was found to have a high level of repeatability between trained observers, although repeatability decreased when the system was utilized by untrained observers (Main et al. 2000). One way in which the scoring system developed by Main et al. (2000) is similar to other systems is that it was developed to evaluate gait in finishing pigs, rather than sows and gilts, however it remains the most detailed and quantifiable scoring system available to assess lameness in pigs.

2.5.4.3 Criteria in assessing lameness

The essential criterion used in assessment of lameness is evaluation of gait. Evaluation of gait is difficult for the reasons specified above. Therefore it is important to have simple but specific guidelines available to assist the observer in identifying those qualities that represent both normal and abnormal gait. Another criterion important to the assessment of lameness is evaluation of standing posture. Attention to the posture of the animal while standing is important as this can assist the observer to identify if the sow is shifting weight off of a painful limb. A normal pig will stand squarely on all four legs. A mildly lame animal may to be shifted off centre, or appear to be standing on the toes of one or more feet. A severely lame animal may refuse to place weight on the affected limb, or elevate it off the floor (Main et al. 2000). A very important and undervalued criterion in many lameness scoring systems is observation and evaluation of behaviour. When approached by an observer in its pen a normal to mildly lame pig will appear bright, alert and responsive and approach inquisitively (Main et al. 2000). A moderate to severely lame pig may not respond as quickly to an approaching observer, and may remain in a sitting or recumbent posture (Main et al. 2000). Another aspect of behaviour useful in assessing lameness is how the animal interacts with pen-mates in the pen. A normal animal will freely participate in group activities in the pen, while a lame animal may remain separate from other members of the group (Main et al. 2000). A final criterion important in lameness evaluation includes examining the animal for signs of illness and infection. This is useful to determine a probable cause of lameness (i.e. infection) and a specific location (e.g. withdrawal of painful limb on examination). Feet and legs can be examined for swelling, heat, and skin lesions, indications of inflammation or injury to the joints.

3.0 MANUSCRIPT 1

A comparison of dry sow housing systems, locked-stall, stall-pen and straw on the behaviour and activity of gestating gilts.

3.1 ABSTRACT

Currently in North America, the gestation stall is the standard commercial housing for pregnant sows and gilts. A major concern with the use of gestation stalls is the level of confinement imposed on sows. Confinement is associated with a reduced opportunity for exercise, increased performance of abnormal behaviours, and limited social interaction. A further concern with standard commercial housing is the absence of bedding material. Provision of straw bedding is a means of improving the welfare of pigs housed in barren environments.

The aim of this study was to examine the postures assumed and behaviours performed by 61 gestating gilts in three types of housing: locked-stall (LS), stall-pen (SP) and straw (S). Housing systems differed in the level of confinement, individual or group housing, and provision of straw bedding. LS gilts were highly confined, and housed individually in standard gestation stalls. SP gilts were housed in groups of 4 on concrete flooring with access to a slatted exercise area. S gilts were housed in groups of 8-16, and were on straw for the latter half of gestation. Behaviours and postures were recorded on videocassette during daylight hours. Data were obtained using scan sampling at ten-minute intervals. Observations were recorded in early and late gestation, and were further divided into morning and afternoon periods.

Ventral recumbency, resting, abnormal behaviour, standing idle, and inactive postures and behaviours were more frequently observed in LS than S gilts, with SP gilts exhibiting intermediate frequencies. The opposite pattern was found for locomoting, nosing the pen, and lying in lateral recumbency.

As housing became more physically and socially confining, gilts spent less time locomoting (LS: 1.9%, SP: 4.4%, S 6%; $p<0.01$) and more time lying in ventral recumbency (LS: 5.5%, SP 3.5%, S 2.2%; $p<0.01$). Increased ventral lying in LS gilts was attributed to reduced exercise, the physical risk of injury, and an inability to establish dominance relationships with neighbouring gilts. The frequency of abnormal behaviour was also greater in LS gilts (0.7%) than SP (0.1%) and S (<0.1%) gilts ($p<0.01$). S gilts spent less time standing idle (2.3%) than LS gilts (5.3%) ($p<0.05$). Drinking tended to be higher in confinement housing (average 3.8%) compared to S housing (2.6%) ($p<0.05$), which may be a sign of reduced welfare. While resting, group-housed gilts tended to spend more time in lateral recumbency, indicating a greater level of comfort compared to LS gilts. Increased ventral recumbency, abnormal behaviours, drinking, and inactivity, combined with reduced locomotion seen in LS gilts indicates that the level of welfare experienced by these gilts was reduced compared to gilts housed on straw. As pregnancy progressed, gilts on straw spent less time resting and more time nosing at the straw. With advancing pregnancy, activity levels in all housing systems decreased.

Behavioural differences observed in this trial were consistent with reduced welfare in LS gilts, with some improvement in SP gilts, although S gilts were considered to have the highest level of welfare. SP housing provided an alternative to LS housing, however, the level of welfare experienced by the gilts was not as high as in S housing.

3.2 INTRODUCTION

The number of pork producers in the US has dropped from 3 million in the 1950's to 85,760 in 2001 (National Pork Producers Council 2002). Concurrently, the number of pigs per farm has risen dramatically as producers utilize new technologies in housing and management to capitalize on economies of scale (McGlone 2001). This intensification of livestock production has resulted in increased stocking densities and therefore less space per animal (Marchant and Broom 1996a; Marchant and Broom 1996b). To more efficiently utilize space in dry sow barns, gestation crates are widely used in commercial production. Currently, 75% of Manitoba hog producers use gestation stalls in their operations (Manitoba Pork Council 2002). Farmed Animal Watch (2002) estimates that 64% of US pig operations use gestation crates. As legislation demands European producers move away from confinement based housing for pregnant sows, it is inevitable that consumers will question the use of gestation stalls in North America.

One of the major concerns of using gestation stalls is the level of confinement of the animals. Sows housed in confinement systems are unable to perform a variety of normal behaviours, such as rooting, nest building, and complex social behaviours (Broom et al. 1995). This is a particular problem in swine due to the complexity of their behavioural repertoire and the intelligence of the sow (Ewing et al. 1999). The absence of behavioural possibilities in gestation stalls can lead to the emergence of stereotypies (Rollin 1995), such as bar biting and vacuum chewing. The incidence of abnormal or stereotypic behaviour has been shown to be greater in confined sows than in group-housed sows (Barnett et al. 1985; Broom 1983; Broom 1998; Broom and Potter 1984; Tarrant 1984; Vieuille-Thomas et al. 1995). Confinement housing also severely limits the animal's opportunity for exercise, affecting the sow's physical state (Marchant et al. 1997a). Physical effects may include reduced muscle size and bone strength (Marchant and Broom 1996a), reduced muscle and bone growth (Marchant and Broom 1996b), and reduced cardiovascular fitness (Marchant et al. 1997a; Ratcliffe et al. 1969a). The effects of lack of exercise in turn makes changing position in the stall more problematic for the sow (Marchant and Broom 1996b), reducing her ability to manoeuvre and to carry out normal behaviours, and increasing risk of injury. There is general consensus in the literature that, for these reasons, the welfare of sows in gestation stalls is poor (Barnett et al. 1985; Broom 1987; Broom 1989; Broom et al. 1995; Marchant and Broom 1996a; Marchant and Broom 1996b).

Another concern arising from commercial housing practices is the absence of suitable bedding material. Provision of bedding in the form of straw has numerous advantages. Straw bedding offers a more cushioned floor material for moving and lying (Rollin 1995), while providing improved footing that may reduce injuries due to slipping and falling (Day et al. 2002; Edwards 1998). The insulating nature of straw, if deeply bedded, can also improve thermal comfort (Day et al. 2002; Edwards 1998). Most importantly, straw provides foraging opportunities to feed-restricted gestating sows that may otherwise develop abnormal behaviours (Broom 1983; Day et al. 2002; De Leeuw and Ekkel 2004; Edwards 1998; Ewing et al. 1999; Rollin 1995; Spoolder et al. 1995).

Conversion of gestation crates to include an exercise area for a small group of pigs represents a potential compromise between housing gestating sows in individual crates, as is done in North America, and the larger straw-based housing systems employed in Europe. Housing small groups of pigs in a pen, while maintaining some of the advantages of stalls, might address the major welfare issues created by confinement stalls. These include social isolation, reduced opportunity to exercise, prevention of expression of most normal behaviour, and subsequent development of abnormal behaviour. Additionally, groups of 4-6 pigs housed in pens may mitigate the chief concerns of the industry over the disadvantages of moving to large-scale, straw-based housing systems. These include animal factors such as aggression, and management issues such as difficulty cleaning, lack of individual feeding, and the ability to easily monitor dry sows during gestation.

The first objective of this experiment was to determine if postures assumed and behaviours performed by gestating gilts varied in three different housing systems representing intensive commercial housing, extensive straw housing, and a system corresponding to an intermediate between the two. The second objective was to determine if decreasing confinement is associated with increased exercise as determined by time spent locomoting and overall activity. The third objective was to determine the effect that provision of straw would have on the behaviour of gestating gilts. This trial was conducted in conjunction with a study on lameness of gestating gilts in the same three housing systems (manuscript 2).

3.3 MATERIALS AND METHODS

3.3.1 Animals

Seventy-three Cotswold (Cotswold Canada Inc.) nulliparous gilts were placed on trial at Glenlea Research Station over a period of 20 months (April, 2001 to November, 2002). Gilts arrived approximately two months prior to estrus, weighing an average of 111.4 kg, and were individually identified with numbered ear tags. Once gilts went into estrus, they were bred using artificial insemination. A total of 23 gilts failed to breed successfully at first estrus and were rebred in the following breeding period 1.5 - 2 months later. Gilts successfully rebred were treated as first gestation gilts. Twelve gilts failed to breed or reproduce successfully in the following breeding period, and were culled from the herd. A total of 61 gilts were used in this trial. Thirty days following breeding, the average gilt weight was 133.7 kg, and at farrowing gilts weighed 191.1 kg on average.

The lighting schedule was 9L:15D from 0800 to 1700 hours, to allow for normal estrus cycling. Gilts were fed 2 kg per day of a barley based gestation ration with 16% protein, meeting or exceeding NRC guidelines. Gilts had *ad libitum* access to water. All animals were cared for according to CCAC guidelines (Canadian Council on Animal Care 1993) and recommended codes of practice (Connor 1993).

3.3.2 Housing Treatments

Gilts were housed for breeding in groups of 4 (Figure 1). Breeding pens were 3.7 m deep by 1.73 m wide with partially slatted concrete floors, providing 1.6m^2 per animal, which is slightly greater than the 1.5 m^2 recommended in the RCOP for gilts of equivalent weight (Connor 1993). Nipple drinkers were located on the rear wall over the slatted portion of the floor. After breeding, gilts were randomly assigned to locked-stall [LS], stall-pen [SP] or straw [S] housing treatments in groups of four, based on the order in which they were bred. Using groups of four ensured that each pen of animals had similar farrowing dates for management purposes. Gilts assigned to LS were moved into treatment housing within 24 hours of final breeding. Pregnancy was confirmed at 30 days post-breeding by transcutaneous ultrasonography. Gilts assigned to SP housing were moved into treatment pens after confirmation of pregnancy to avoid the necessity of remixing. Gilts assigned to S

FIGURE 1

Breeding pen, 3.7m deep by 1.73m wide, housing 4 bred gilts, with partially slatted concrete floor and one drinker in the rear of the pen

housing remained in breeding pens in groups of four until animals assigned to this larger group were confirmed pregnant (approximately 60 days). At this time they were moved to a separate barn and housed in a large pen in groups of 8-16 animals. At day 110 of gestation, all gilts were moved into farrowing crates.

3.3.2.2 Locked-Stall Housing (LS)

LS housing consisted of groups of four standard gestation stalls (Figure 2, green arrows). Each stall was 1.85m deep by 0.62m wide with solid concrete flooring, providing 1.15 m^2 floor space for each animal, less than was recommended in the RCOP (Connor 1993).Each crate was equipped with a feeder at the front of the stall next to a nipple and cup drinker. Social interactions were limited to animals in adjacent stalls. Movement within the stall was limited to a maximum of three strides from back to front, which decreased to two as the gilts grew. A total of 19 gilts were placed in LS housing.

3.3.2.3 Stall-Pen Housing (SP)

SP housing consisted of four standard gestation stalls opening into a slatted-floor pen area (Figure 2). The gestation stalls were as described for the LS treatment. The pen area (Figure 2, red arrows) was 1.85m deep by 2.5m wide with slatted concrete flooring. The total floor space was 2.3 m^2 per gilt, considerably more than recommended (Connor 1993). An additional drinker was located on the back wall of each pen area. Feed was provided in the stall feeders. Pigs were free to move within the pen area, and from stall to stall. Interaction with pen-mates was unrestricted. Interactions with pigs in neighbouring pens were limited to contact through the bars. Twenty gilts were assigned to SP housing.

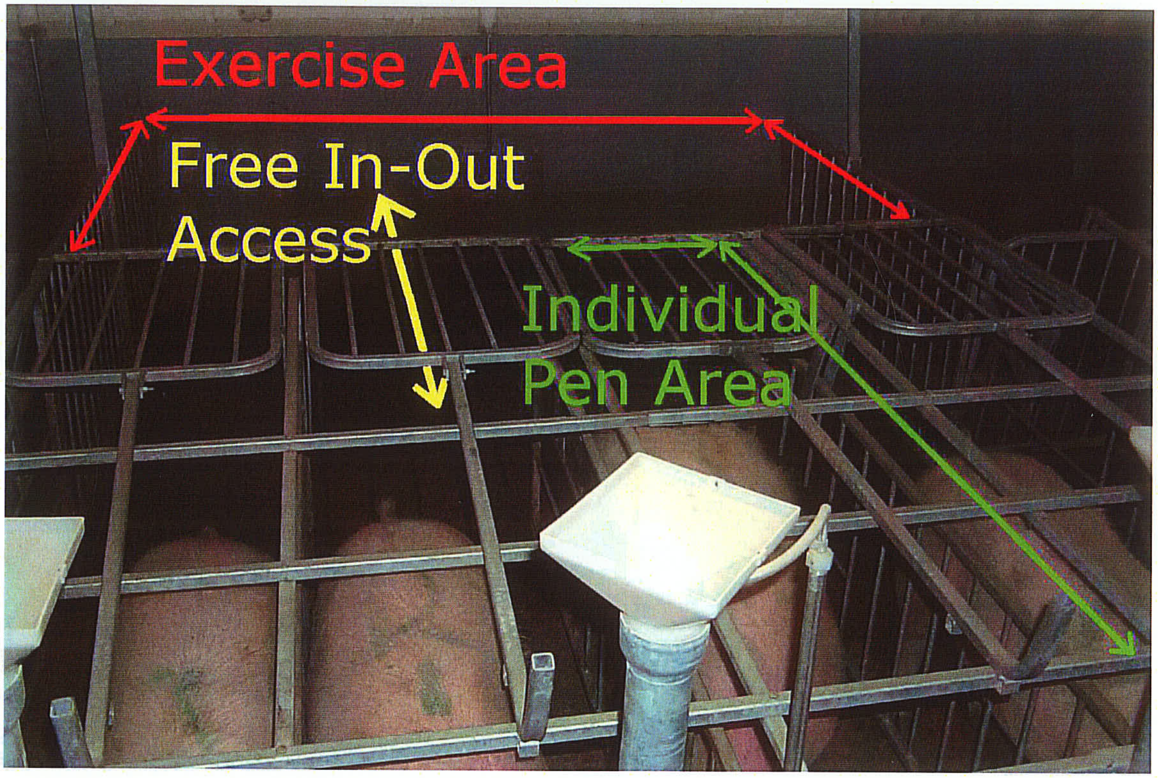

FIGURE 2

Stall-pen and locked-stall housing, for 4 pregnant gilts using standard gestation stalls, 1.85 m long by 0.62 m wide. Stalls could be closed to create the locked-stall housing treatment. With the gate open, animals had free access to a rear exercise area (1.85 m deep by 2.5 m wide), containing one drinker. The flooring was solid concrete in the stall area, and slatted concrete in the rear group area.

3.3.2.4 Straw Housing (S)

S housing (Figure 3) was located in a separate building containing four large group pens, each with a maximum capacity of 16 animals, although animals were housed in groups ranging from 8-16. Experimental gilts were always housed in the same pen from trial to trial. Straw pens were 8.53 m long by 3.05 m wide, providing a maximum of 3.25m^2 per animal when 8 animals were housed, and a minimum of 1.63m^2 per gilt when 16 animals were housed in the pen. The RCOP suggests that the space allowance provided for gilts on a solid bedded floor should be at least 1.7m^2 (Connor 1993), indicating that at the maximum of 16 animals, the space provided was inadequate according to the RCOP. The pen was bordered on three sides with PVC rails; the remaining side was concrete, with two water nipples. The pen floor was solid concrete, deeply bedded (20-40cm) with straw. Gilts were free to interact with pen mates and to move without restriction throughout the pen. Gilts were moved out of the straw pen once daily for individual feeding in an adjacent stall area. While out of the pen for feeding, behavioural observations could not be recorded, however the time out of the pen was accounted for in the 'other' category. There were 22 gilts assigned to S housing.

3.3.2.5 Differences between housing treatments

Five major differences between housing treatments were recognized: flooring, social environment, exercise, management of feeding and time spent in breeding pens (Table 1). Gilts assigned to LS and SP-housing remained on concrete flooring throughout gestation. Due to management and space restrictions, S-housed gilts were moved onto straw in

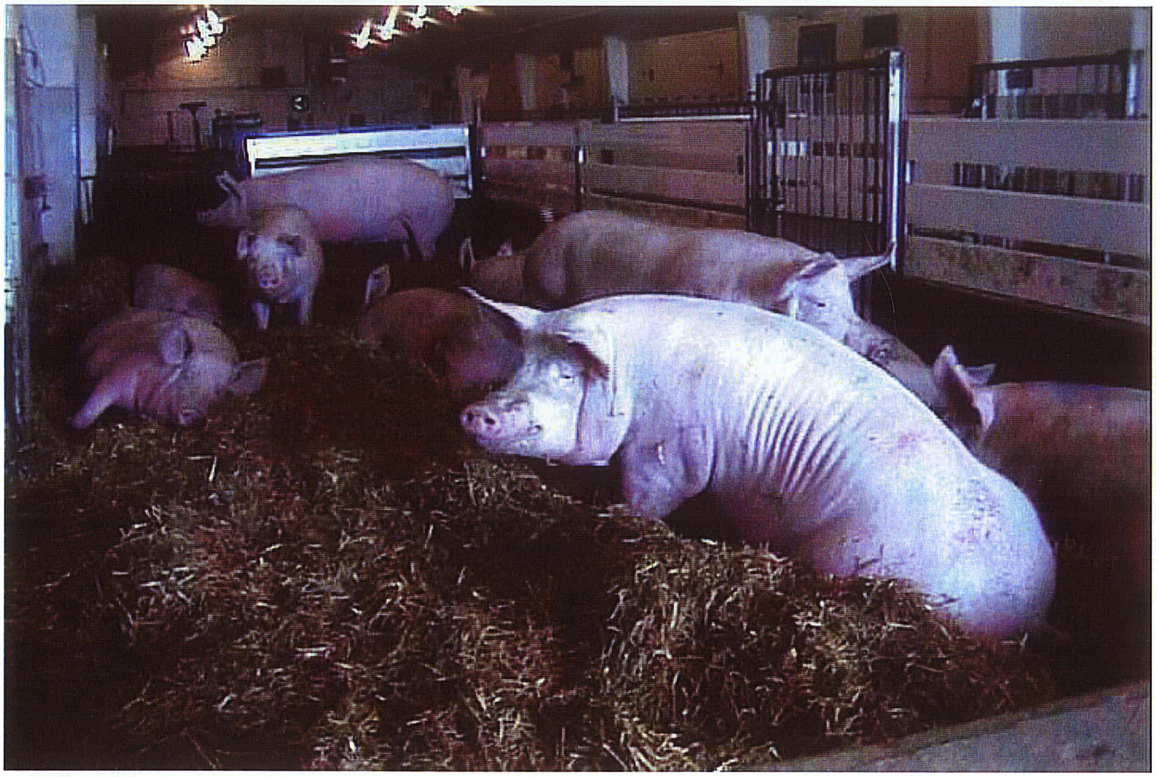

FIGURE 3

Straw housing, in a pen 8.53 m deep by 3.05 m wide, holding 10 pregnant sows

TABLE 1 Description of housing treatments including size, number of animals per pen, pen components and layout, and feeding management

Housing	Size	Pigs in pen	Description of pen	Description of floor	Feeding and water
Breeding pens	3.7m x 1.73m	4 (1.6m^2/gilt)	Open pen design Steel bars	Partially slatted concrete floors	Drop/floor feeding twice daily Drinker(s) in rear
Locked-stall [LS]	1.85m x 0.62m	1 (1.15m^2/gilt)	Standard gestation stalls (steel bars)	Solid concrete floor	Individual feeding twice daily Nipple drinker with cup
Stall-pen [SP]	3.7m x 2.5 m	4 (2.3m^2/gilt)	Free access stalls with a rear pen	Stalls: solid concrete; Pen: slatted concrete	Individual feeding (as for LS) in stall area twice daily Drinker in stalls and rear portion of pen
Straw [S]	8.53m x 3.05m	min 8 (3.25 m^2/gilt) max 16 (1.63m^2/gilt)	Open pen design Plastic and concrete rails	Solid concrete floor with straw bedding (20-40 cm)	Individual feeding in separate stall area once daily 2 drinkers on concrete wall.

mid-gestation. Social environment differed between housing types. SP and S gilts were group housed, with smaller groups of 4 per pen in SP, and larger groups of 8-16 pigs per pen in S, while LS gilts were individually penned. Opportunity to exercise was severely limited for LS gilts confined to gestation stalls. SP and S-housed gilts could move freely within their pens. However, gilts in S housing had the largest enclosure, and consequently had the greatest opportunity to exercise. Differences in feeding management among housing systems were recognized. While in breeding pens, gilts were floor fed. Once moved into their treatment pens, all gilts were individually fed. Straw-housed gilts were fed once a day outside of the range of the video cameras in the latter half of their pregnancy. As a result no behavioural observations could be made during this time, and no feeding behaviour was recorded for the straw-housed gilts in late gestation. LS and SP gilts were fed twice a day, with feeding behaviour recorded on videotape. Finally, duration of housing in breeding pens differed between treatments. LS gilts were moved to treatment pens immediately after breeding. SP gilts remained in breeding pens until they were confirmed pregnant at 30 days. Gilts assigned to S housing remained in breeding pens until mid-gestation before being moved into S housing due to management constraints at the Glenlea facility.

Other minor differences that existed between housing systems included location of treatment housing, provision of heated flooring, and season. Breeding pens, LS and SP treatments were all located within the same barn. The straw treatment, however was located in a separate building approximately 1/2 kilometer away, requiring the gilts to be transported by truck. In LS and SP treatments, the solid concrete portion of the floor was heated in the winter, providing a warm lying area within the stall portion of the pens. Gilts in breeding pens and in straw housing did not have access to heated concrete flooring, however, deeply bedded straw provides thermal insulation in cold temperatures (Edwards 1998). Finally, gilts were bred in eight groups over a period of 2 years. As a result, each group of gilts was bred, and housed in conditions that were variable with the season. Such conditions include temperature and relative humidity, which would have been higher than normal during summer months, but would not have varied significantly during winter months as all barns were heated.

3.3.3 Behavioural Observations

The behaviour of the gilts in all housing treatments was assessed for 3 consecutive days in early gestation (30 ± 5 days) and in late gestation (100 ± 7 days). For recording purposes, a number or letter was marked with oil crayon onto the back and both flanks of each gilt. Black and white video cameras[1] with wide-angle lenses[2] were mounted on the ceiling above each experimental pen. Each camera fed into a multiplexer[3] that allowed simultaneous recording of multiple pens by a time-lapse video-recorder[4] on 24 h mode. Video-taping was conducted during the hours when barn lights were on, from 0800 hours to 1700 hours. Behavioural data were obtained during playback using scan sampling at 10-minute intervals. At each sampling interval one mutually exclusive posture (Table 2) and one mutually exclusive behaviour (Table 3) were recorded. Because gilts assigned to S housing could not be recorded during their feeding period, feeding behaviour for all housing treatments was included in the 'other' behaviour category.

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[1] Panasonic WV-BP144 Video Camera

[2] Panasonic 1/3 TV Lens WV-LA2R 8C3B 2.8mm 1:1.3

[3] Panasonic Digital Video Multiplexer WJ-FS 216

[4] Panasonic Time Lapse Video Cassette Recorder AG-6730

TABLE 2 List of postures observed and operational descriptions

Posture	Description
Locomotion	Moving between 2 points; moving a minimum of 2 steps forward or backwards
Sitting	'Dog-sitting' posture with rear end and hind limbs on the ground and fore limbs straightened so that the front end was upright
Standing	Body supported by all 4 legs in an upright position
Sternal recumbency	Sternum in full contact with the floor; having 1 or both hind leg(s) and pelvis at an angle with floor
Lateral recumbency	Lying on the side with 4 legs extended or folded
Ventral recumbency	Lying on the sternum and belly with pelvis resting parallel to the floor
Other	Gilt was removed from pen for that recording period; or gilt assumed a posture not described in the above list

TABLE 3 List of behaviours observed and operational descriptions

Behaviour	Description
Resting	Lying down and not interacting or nosing at the pen
Drinking	(Apparent) drinking with head contacting drinker nozzle
Interacting	Physical contact with another animal involving nudging or nosing at the body, reciprocated or otherwise, not involving retreat, aggressive or submissive postures, or biting
Fighting	Interacting with another animal involving biting, chasing, retreat or aggressive/submissive postures
Standing idle	Standing without engaging in any other activity
Sitting idle	Sitting without engaging in any other activity
Nose pen	Pushing at or manipulating fixtures of the pen environment, including bedding material (if any) with snout, head or closed mouth
Abnormal	Biting the bars of the pen; repetitive and prolonged chewing, biting or sucking of belly, vulva, tail or ear of another animal.
Other	Gilt was removed from the pen for the recording period; or feeding with head in feeder or to ground (if floor fed); or engaging in a behaviour not described in the above list

Observations were recorded in early and late gestation, and further divided into time of day: AM (0800 – 1150 hours) and PM (1200 – 1700 hours). Postures and behaviours were subdivided into active and inactive classes based on a subjective assessment of muscular effort and joint loading. Locomotion and standing were considered active postures, while sitting and all recumbent positions were considered inactive postures. Sitting, although providing some joint loading and muscular effort to raise the front end of the pig, required minimal joint loading as the weight of the animal was supported on the hind-quarters, and as such was designated as an inactive posture. Active behaviours included nosing the pen, drinking, standing idle, interacting with pen-mates, performing abnormal behaviours and fighting with other pigs. Inactive behaviours included resting and sitting idle.

3.3.4 Statistical analysis

The statistical model used in this trial was a split-split plot in time. The main plot included gilts within housing treatments. The first subplot included two stages of gestation, early and late. Within each gestation period, sows were observed in the morning (AM) and afternoon (PM) forming the basis for the second subplot. The model for analysis was as follows:

$$Y_{ijkl} = \mu + T_i + p_{ij} + G_k + (T \times G)_{ik} + r_{ijk} + D_l + (T \times D)_{il} + (G \times H)_{kl} + e_{ikjl}$$

Y_{ijkl} = observation of the j^{th} gilt in the i^{th} housing treatment, at the k^{th} stage of gestation in the l^{th} time of day

μ = overall mean

T_i = effect of i^{th} housing treatment; i = LS, SP, S

p_{ij} = error term representing the effect of the j^{th} sow in the i^{th} housing treatment

G_k = effect of the k^{th} gestation period; k = early, late

$(T \times G)_{ik}$ = interactive effect of i^{th} housing treatment during the k^{th} gestation period

r_{ijk} = error term representing the effect of the j^{th} sow in the i^{th} housing treatment and k^{th} gestation

D_l = effect of the l^{th} time of day; l =AM, PM

$(T \times H)_{il}$ = interactive effect of the i^{th} housing treatment at the l^{th} time of day

$(G \times H)_{kl}$ = interactive effect of the k^{th} gestation period at the l^{th} time of day

e_{ijkl} = the residual error

Housing treatment, gestation period, time of day and their interactions were considered fixed effects; sow effects (p_{ij}), other effects involving sows (r_{ijk}) and the residual error were considered to be random effects. The behavioural data were analysed with SAS 8.2 (SAS Institute 2001) using general linear models (GLM) analysis of variance procedure for repeated measures. As data were binomial and expressed as decimal fractions, an arc sine square root transformation was applied (Steel et al. 1997). Data were presented as the means of the non-transformed data. For main effect differences (housing treatment, stage of gestation, or time of day) means comparisons were carried out using the Tukey-Kramer test. In order to control for overall type 1 error rate for all comparisons, the Bonferroni inequality test was used in the analysis of interactive effects (SAS Institute Inc. 1988).

3.4 RESULTS

3.4.1 Individual postures and behaviours

3.4.1.1 Daily time budget

Gestating gilts were most frequently observed in recumbent postures, with sternal and lateral recumbency accounting for almost all lying postures observed (Table 4). Ventral recumbency was observed infrequently and accounted for only 5.6% of time spent lying. Standing occupied 25% of an average day. Locomotion was seldom observed and gilts were least often observed sitting.

Resting was the behaviour most frequently performed by gestating gilts (Table 4). Gilts were observed nosing at pen components for 13% of their day. Drinking, sitting idle, standing idle and interaction with pen-mates and pigs in neighbouring pens were infrequent (11.9% total). Behaving abnormally and fighting were rare (<0.5%).

Certain postures were closely associated with observed behaviours, particularly time spent in recumbent postures (64.2%) and time spent resting (63.7%) (Table 4). Gilts were observed standing 25% of the day. While standing, they nosed pen components, ate, drank, stood idle, interacted, fought and engaged in abnormal behaviour. Gilts spent only 3.4% of the day sitting, and were idle for 75% of that time. Gilts nosed pen components, ate, drank, interacted and engaged in abnormal behaviour during the remainder of the time spent sitting.

3.4.1.2 Housing

Housing had a significant effect on the percentage of time gilts spent in locomotion and ventral recumbency (Table 5). Locomotion was least frequent in LS-housed gilts, was more frequent in SP-housed gilts, and tended to be most frequent in S-housed gilts ($p<0.01$).

TABLE 4 Daily time budget: the percentage of time gestating gilts, assigned to locked stall (LS), stall-pen (SP) and straw (S) housing, spent in a particular posture, or engaged in a particular behaviour

Behaviour	%	Mean*	Residual SD
Posture			
Sternal recumbency	30.7	0.579	0.079
Lateral recumbency	29.9	0.555	0.121
Standing	25.7	0.520	0.076
Locomoting	4.2	0.177	0.066
Ventral recumbency	3.6	0.149	0.074
Sitting	3.4	0.139	0.071
Other	2.5		
Total	100.0		
Behaviour			
Resting	63.7	0.931	0.099
Nosing pen	13.0	0.343	0.072
Drinking	3.4	0.155	0.090
Standing idle	3.3	0.153	0.081
Sitting idle	2.6	0.123	0.067
Interacting	2.6	0.132	0.074
Stereotypies	0.3	0.013	0.037
Fighting	0.2	0.017	0.035
Other	10.9		
Total	100.0		

Behavioural data were collected on videotape and obtained during playback using scan sampling at 10-minute intervals from 0800 to 1700 hours. Mutually exclusive postures and mutually exclusive behaviours were collected simultaneously.

* Least squares means before arc sin square root transformation are shown.

TABLE 5 The effect of three housing treatments, locked-stall (LS), stall-pen (SP) and straw (S) on the behaviour and postures of gestating gilts

	Treatment			
Behaviour (%)	LS (n=19)	SP (n=20)	S (n=22)	p
Posture				
Locomoting	1.9[a]	4.4[b]	6.0[b]	<0.01
Ventral recumbency	5.5[b]	3.5[ab]	2.2[a]	<0.01
Behaviour				
Nosing pen	11.3[a]	9.4[a]	17.7[b]	<0.01
Drinking	3.5[ab]	4.1[b]	2.6[a]	<0.05
Abnormal behaviour	0.7[b]	0.1[a]	<0.1[a]	<0.01

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root) using Tukey's tests.

NS: not statistically significant ($p > 0.05$)

[ab] Different superscripts within a row indicate that the means are significantly different using Bonferroni's inequality test.

Gilts housed in the S treatment remained in breeding pens until mid-gestation, and then were moved into straw housing. SP-housed gilts remained in breeding pens until 30 days post breeding, and then were moved into treatment housing. LS gilts spent the entire gestation in treatment housing.

The opposite trend was seen with time spent lying in ventral recumbency. Ventral lying was observed least in S gilts, more often in SP gilts, and most often in LS gilts ($p<0.01$). However, significance was reached only between S and LS housing treatments. No significant housing effect was observed in the frequency of standing, sitting, sternal recumbency or lateral recumbency.

The behaviour of gestating gilts was also affected by housing. The level of drinking observed tended to rise from S to LS to SP-housed gilts (Table 5). Statistical significance was reached between S and SP housed gilts only ($p<0.05$). Abnormal behaviour was observed more often in LS-housed gilts than gilts housed in SP and S treatments ($p<0.01$). No significant housing effect was observed in the frequency of resting, standing idle, sitting idle, interacting or fighting.

As housing for gilts became more physically and socially confining, there was a shift in posture from locomotion to lying in ventral recumbency. In housing in which locomotion was lower and ventral recumbency higher, abnormal behaviour was also more frequently observed.

3.5.3.4.1 Housing and stage of gestation

An interactive effect between housing treatment and stage of gestation was identified (Table 6). In early gestation, standing idle was less frequently observed in S-housed gilts than LS-housed gilts ($p<0.05$). The frequency of standing idle exhibited by gilts in SP housing was intermediate and not significantly different than either of the other housing types. It should be noted that in early gestation S gilts were still in breeding pens. In late gestation, housing did not affect the frequency of standing idle.

TABLE 6 The effect of three housing treatments, locked-stall (LS), stall-pen (SP) and straw (S) during progressing pregnancy (early or late gestation) on the behaviour of gestating gilts

		Treatment			
Behaviour (%)	Gestation	LS (n=19)	SP (n=20)	S (n=22)	p
Standing Idle	Early	5.3^{b}	3.8^{ab}	2.3^{a}	<0.05
	Late	2.7	2.5	3.2	NS
Resting	Early	61.4	66.0	64.2	NS
	Late	66.6^{b}	68.1^{b}	56.8^{a}	<0.05
Nosing Pen	Early	12.9	10.4	14.5	NS
	Late	9.7^{a}	8.3^{a}	20.9^{b}	<0.05

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root).

NS: not statistically significant ($p > 0.05$)

[ab] Different superscripts in a row indicate that the means are significantly different ($p<0.05$) using Bonferroni's inequality test.

Gilts housed in the S treatment remained in breeding pens until mid-gestation, and then were moved into straw housing. SP-housed gilts remained in breeding pens until 30 days post breeding, and then were moved into treatment housing. LS gilts spent the entire gestation in treatment housing.

No difference in resting or nosing behaviour was observed in the three housing treatments in early gestation (Table 6). In late gestation however, the frequency of resting behaviour in gilts housed on straw was significantly less than that of gilts in stall housing ($p<0.05$). Gilts on straw were observed nosing at the pen significantly more often than LS and SP-housed gilts in late gestation ($p<0.05$). Gilts on straw spent less time resting in late gestation (56.8%) than in early gestation (64.2%) ($p<0.05$) and more time nosing at the pen and bedding material in late gestation (20.9%) than early gestation (14.5%) ($p<0.05$). As gestation progressed gilts on straw appeared to decrease resting in order to spend more time nosing at the pen.

3.5.3.4.2 Housing and time of day

The diurnal variation of lateral recumbency and resting varied with housing (Table 7). In the morning, gilts in SP housing were observed lying in lateral recumbency more often than gilts in LS and S housing ($p<0.05$). In the afternoon however, straw-housed gilts were observed lying in lateral recumbency more often than gilts in stall housing ($p<0.05$). In the morning, gilts on straw spent significantly less time resting than gilts in stall housing ($p<0.05$). There was no difference between housing treatments in the afternoon. Gilts on straw rested least in the morning (54.8%), however when the proportion of resting time dedicated to lateral recumbency was calculated it appeared that S gilts spent the same proportion of resting time (25.4/54.8 = 46%) in lateral recumbency as SP gilts (31.8/66.8 = 48%), and more time than LS gilts (41%).

TABLE 7 The effect of three housing treatments, locked-stall (LS), stall-pen (SP) and straw (S) and time of day (AM or PM) on the percentage of time gestating gilts spent in lateral recumbency or resting

		Treatment			
Behaviour (%)	Time of day	LS (n=19)	SP (n=20)	S (n=22)	p
Lateral recumbency	AM	25.7[a]	31.8[b]	25.4[a]	<0.05
	PM	28.1[a]	30.4[a]	37.5[b]	<0.05
Resting	AM	63.3[b]	66.8[b]	54.8[a]	<0.05
	PM	64.7	67.3	66.1	NS

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root).

NS: not statistically significant (p > 0.05)

[ab] Different superscripts in a row indicate that the means are significantly different (p<0.05) using Bonferroni's test.

Gilts housed in the S treatment remained in breeding pens until mid-gestation, and then were moved into straw housing. SP-housed gilts remained in breeding pens until 30 days post breeding, and then were moved into treatment housing. LS gilts spent the entire gestation in treatment housing.

3.4.1.3 Stage of gestation

As gestation progressed gilts tended to become less active (Table 8). Gilts spent 3.3% less time standing as farrowing approached. At the same time, the time gilts spent lying in ventral recumbency increased by 2.3% from early to late gestation ($p<0.01$). Similarly, gilts were observed sitting 2.6% more often in late gestation (<0.01). No significant gestational effect was observed with locomotion, sternal or lateral recumbency.

Behaviours that differed significantly as gestation progressed included sitting idle and interacting with pen mates. Gilts were observed sitting idle in late gestation 2.6% more often than in early gestation ($p<0.01$) (Table 8). Time spent interacting with pen mates and pigs in neighbouring pens was observed to decrease by 1.1% as gestation progressed ($p<0.01$). No significant differences in drinking, standing idle, behaving abnormally or fighting were observed as gestation progressed.

Progressing pregnancy appeared to be associated with a shift from standing to sitting and lying in ventral recumbency (Table 8). When the proportion of time sitting idle while sitting was calculated, it seemed that gilts tended to be idle while sitting more often in late gestation (3.8/4.7 = 81%) than in early gestation (1.5/2.1 = 71%). Simultaneously, time spent interacting with other pigs was being exchanged for time spent sitting idle, contributing to an overall decrease in activity with advancing pregnancy.

TABLE 8 The effect of stage of gestation (early and late) on performance of postures and behaviours by gestating gilts

	Gestation		
Behaviour (%)	Early	Late	p
Posture			
Standing	27.4	24.1	<0.05
Ventral recumbency	2.6	4.9	<0.01
Sitting	2.1	4.7	<0.01
Behaviour			
Sitting idle	1.5	3.8	<0.01
Interacting	3.2	2.1	<0.01

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root).

3.4.2.1.1 Gestation and time of day

While gilts spent less time standing in late gestation than in early gestation (Table 8) this was only significant in the afternoon (Late: 22.3%, Early: 27.3%, $p<0.05$). In late gestation gilts spent significantly more time standing in the morning than in the afternoon ($p<0.01$) (Table 9). There was no difference however, in time spent standing from morning to afternoon in early gestation.

Advancing pregnancy was associated with a shift towards resting later in the day (Table 9). In early gestation, gilts were observed resting equally in the morning and afternoon. However, in late gestation gilts spent considerably less time resting in the morning than afternoon ($p<0.0001$).

While standing, gilts were active and observed to drink, stand idle, interact, fight and exhibit abnormal behaviour, but were not able to rest. As a result, it is possible to comparestanding, a posture, to resting, a behaviour, even though they are classed in separate categories. Within this context it seems that advancing pregnancy was associated with a shift from the behaviours associated with standing, observed more frequently in the morning, to resting in the afternoon.

3.4.1.4 Time of day

Sitting was observed more frequently in the afternoon (3.7%) than in the morning (3.1%) ($p<0.05$). Standing was found to significantly decrease in frequency from the morning (26.7%) to the afternoon (24.8%) ($p<0.05$). Sitting idle was less frequent in the morning (2.3%), compared with the afternoon (3%) ($p<0.01$). As the day progressed gilts became less active, spending less time standing and more time sitting. When the proportion

TABLE 9 The effect of time of day (AM or PM) and progressing pregnancy (early and late gestation) on the performance of standing and resting by gestating gilts (n=61)

Posture or behaviour (%)	Gestation	Time of day AM	PM	p
Standing	Early	27.6[a]	27.3[a]	NS
	Late	25.8[b]	22.3[a]	<0.01
Resting	Early	63.7[a]	63.9[a]	NS
	Late	59.6[a]	68.1[b]	<0.0001

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root).

NS: not statistically significant ($p > 0.05$)

[ab] Different superscripts in a row indicate that the means are significantly different ($p<0.05$) using Bonferroni's inequality test.

of sitting time dedicated to sitting idle was calculated it appeared that gilts were idle while sitting for a greater proportion of the time in the afternoon (3/3.7 = 81%) than in the morning (2.3/3.1 = 74%), resulting in overall decrease in activity.

3.4.2 Active and inactive postures and behaviours

3.4.2.1 Daily time budget of activities

As expected, inactive postures (67.6%) were observed more frequently than active postures (29.9%) in the gilts (Table 10). Inactive behaviours (66.3%) were also observed more often than active behaviours (28.7%). Frequencies of postures and behaviours in both active and inactive categories coincide strongly with one another in all analyses.

3.5.3.4.1 Housing and stage of gestation

Gilts in straw housing exhibited fewer inactive postures and behaviours than gilts in stall housing in late gestation (Table 11) ($p<0.05$). In early gestation, gilts in all three housing treatments were observed in inactive postures equally frequently. The frequency of inactive behaviours followed a similar pattern. Inactive behaviours observed in early gestation did not vary in frequency in different housing. In late gestation, gilts in stalls were observed to perform significantly more inactive behaviours than gilts on straw ($p<0.05$). Performance of inactive postures were not found to significantly increase as pregnancy progressed ($p\geq0.05$), however the frequency of inactive postures of gilts assigned to LS housing were significantly greater in late (67.2%) compared to early gestation (62.7%) ($p<0.05$). No significant housing effects were found following analysis of active postures and behaviours.

TABLE 10 Daily time budget of activity: mean amount of time (%) gestating gilts spent in active or inactive postures or behaviours

Activity	%	Mean*	SD
Posture			
Active	29.9	0.57	0.17
Inactive	67.6	0.94	0.17
Other	2.5		
Total	100.0		
Behaviour			
Active	28.7	0.55	0.16
Inactive	66.3	0.96	0.17
Other	5.0		
Total	100.0		

* Proportions were transformed to arc sin square root before analysis. Least square means for percentage data are shown, however means comparisons were carried out using Tukey's test.

TABLE 11 The effect of housing treatment (locked-stall [LS], stall-pen [SP] and straw [S]), and progressing pregnancy (early or late gestation) on the performance of inactive postures and behaviours by gestating gilts

		Treatment			
Behaviour (%)	Gestation	LS (n=19)	SP (n=20)	S (n=22)	p
Inactive Posture*	Early	62.7	66.3	64.6	NS
	Late	67.2^b	68.2^b	57.0^a	<0.05
Inactive Behaviour**	Early	62.5	67.7	65.7	NS
	Late	71.2^b	71.2^b	60.6^a	<0.05

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root).

NS: not statistically significant (p > 0.05)

^{ab} Different superscripts in a row indicate that the means are significantly different (p<0.05) using Bonferroni's test.

* Inactive postures include sitting, and sternal, lateral and ventral recumbency.
** Inactive behaviours include resting and sitting idle.

Gilts housed in the S treatment remained in breeding pens until mid-gestation, and then were moved into straw housing. SP-housed gilts remained in breeding pens until 30 days post breeding, and then were moved into treatment housing. LS gilts spent the entire gestation in treatment housing.

3.4.2.1.2 Housing and time of day

In the morning, gilts housed in LS and SP-housing performed more ($p<0.05$) inactive postures and behaviours than straw housed gilts (Table 12). However, no difference was seen between housing treatments in the afternoon. Inactive behaviours followed a similar pattern. In the morning, gilts housed in LS and SP treatments performed significantly more inactive behaviours than S-housed gilts ($p<0.05$). No differences between treatments were noted in the afternoon. Active postures and behaviours did not differ between housing treatments in the morning or afternoon ($p>0.05$).

3.4.2.2 Stage of gestation

Gilts were observed to be less active as they progressed in pregnancy (Table 13). The frequency of active postures decreased from early gestation to late gestation ($p<0.02$). The performance of active behaviours also decreased significantly as gestation progressed ($p<0.01$).

3.5.3.4.1 Stage of gestation and time of day

In early gestation, time of day was not a significant factor determining the frequency of activities (Table 14). However a shift from activity in the morning to inactivity in the afternoon was demonstrated in late gestation. More active postures were observed in the morning than in the afternoon ($p<0.05$). Significantly fewer inactive postures were performed in the morning than in the afternoon ($p<0.05$). The same pattern was observed in the performance of inactive behaviours. Inactive behaviours were observed equally in the morning and afternoon in early gestation. In late gestation, inactive behaviours were observed less frequently in the morning than in the afternoon ($p<0.05$). Active behaviours were affected by time of day, performed more often in the morning than afternoon ($p<0.01$), but not by progression of pregnancy.

3.5 DISCUSSION

Three dry sow housing systems were studied in this trial: locked-stall, straw, and stall-pen, representing intensive commercial housing, straw housing, and a housing system corresponding to an intermediate between the two. Three main differences were identified between housing systems: opportunity to exercise as a reflection of confinement, opportunity to interact socially as a reflection of group size, and provision of straw bedding. Opportunity for exercise and social interaction was highly restricted in LS housing, intermediate in SP housing and least constrained in S housing. S gilts were housed in deep-bedded straw in the second half of gestation, but otherwise gilts were housed on concrete. It is clear that these differences affected the activity and often the welfare of the gilts studied.

Locomotion, an important component of exercise, increased from LS to SP to S housing while ventral recumbency was observed to decrease following the same pattern. It appeared that as the level of physical and social confinement increased, there was a shift in activity from locomotion to lying in ventral recumbency, leading to a decrease in exercise. Lack of exercise in confinement housing has been identified as a welfare concern, resulting in physical deconditioning of muscles, bone and cardiovascular fitness, and an increased susceptibility to lameness (Ewing et al. 1999; Marchant et al. 1997b; Marchant and Broom 1996a; Marchant and Broom 1996b).

TABLE 12 The effect of housing treatment (locked-stall [LS], stall-pen [SP] and straw [S]), and time of day (AM or PM) on the performance of inactive postures and behaviours by gestating gilts

		Treatment			
Behaviour (%)	Time of day	LS (n=19)	SP (n=20)	S (n=22)	p
Inactive	AM	64.5[b]	67.3[b]	55.2[a]	<0.05
Posture*	PM	65.4	67.2	66.5	NS
Inactive	AM	65.8[b]	68.5[b]	57.6[a]	<0.05
Behaviour**	PM	67.9	70.4	68.7	NS

[ab] Different superscripts indicate that the means within an activity grouping are significantly different (p<0.05) using Bonferroni's test.

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root).

Gilts housed in the S treatment remained in breeding pens until mid-gestation, and then were moved into straw housing. SP-housed gilts remained in breeding pens until 30 days post breeding, and then were moved into treatment housing. LS gilts spent the entire gestation in treatment housing.

TABLE 13 The effect of progressing pregnancy (early and late gestation) on the performance of active postures and behaviours of gestating gilts

	Gestation		
Behaviour (%)	Early	Late	p
Active postures	31.9	27.7	0.02
Active behaviours	31.1	26.1	<0.01

NS: not statistically significant (p > 0.05)

TABLE 14 The effect of time of day (AM or PM) and progressing pregnancy (early and late gestation) on the frequency of active and inactive postures or behaviours of gestating gilts

		Time of day		
Behaviour (%)	Gestation	AM	PM	p
Active Posture	Early	32.1	31.7	NS
	Late	29.8^{b}	25.6^{a}	<0.01
Inactive Posture	Early	64.6	64.4	NS
	Late	60.0^{a}	68.3^{b}	<0.0001
Active Behaviour*	Throughout	29.8	27.4	NS
Inactive Behaviour	Early	64.9	65.7	NS
	Late	63.0^{a}	72.3^{b}	<0.0001

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root).

NS: not statistically significant ($p > 0.05$)

^{ab} Different superscripts in a row indicate that the means are significantly different ($p<0.05$) using Bonferroni's test.

*Active behaviour reported here did not show an interactive effect of progression of gestation ($p<0.01$).

Gilts housed in the S treatment remained in breeding pens until mid-gestation, and then were moved into straw housing. SP-housed gilts remained in breeding pens until 30 days post breeding, and then were moved into treatment housing. LS gilts spent the entire gestation in treatment housing.

The effects of confinement can also be seen in the increased time spent in ventral recumbency. It seems possible that ventral recumbency is an abnormal posture, indicating either an unwillingness or inability to assume one of the more normal postures of sternal or lateral recumbency. Confinement in gestation stalls has been shown to result in reduced muscle strength, causing the animals to experience difficulty when lying down or standing up (Marchant and Broom 1996a; Marchant and Broom 1996b). Thus the increased incidence of ventral lying may represent an inability of the gilt to easily manoeuver into more comfortable lying positions due to muscle and joint problems, although the exact mechanism underlying this effect was unclear. Increased ventral lying may also represent a posture choice by the gilts. In gestation stalls, gilts may choose positions during resting that limit contact with adjacent animals. In ventral recumbency, the gilt's legs are tucked underneath the body, maximizing the space between themselves and neighbouring animals. Contact with neighbouring animals may be undesirable due to the physical risk of injury from being stepped on. Contact with adjacent animals may also be undesirable due to incompatibility of social rank or an inability to establish the rank of neighbouring gilts occurring when social interactions are limited as in locked-stall housing. Individually housed gilts were unable to engage in a full range of social behaviours, particularly active avoidance behaviours, with neighbouring animals (Broom et al. 1995; Jensen 1984). This negatively affects the formation of a stable social hierarchy (Barnett et al. 1987; Broom et al. 1995). Animals unable to establish a stable social structure through physical interaction with pen-mates are more likely to have unresolved aggression and suffer from stress as a result (Barnett et al. 1987; Broom et al. 1995). The fact that SP-housed gilts displayed an intermediate level of ventral recumbency may indicate that the limited space available compared to S-housed gilts had a negative effect on the development of a stable social hierarchy, however, not as severe an effect as on the LS-housed gilts. Broom et al. (1995) observed that sows in small groups had a greater proportion of unresolved agonistic encounters compared to sows housed in a large pen, and may have experienced frustration as a result of this. It is important to note that although Broom et al. found the agonistic encounters to be reduced, the intensity of the aggression that was noted was considerably more severe in the larger groups. Incompatibility of social rank was more likely to influence frequency of ventral lying compared to risk of injury as gilts in all housing treatments were at a similar risk for physical injury, and gilts in this study were small enough to prevent their feet from protruding into the adjacent stall.

The frequency of abnormal behaviour was significantly greater in LS housing compared to SP and S-housed gilts. Hsia et al. (1991) reported similar findings in which the level of abnormal chewing behaviours in stall-housed sows was four times as high as in sows housed in groups. Due to the scan sampling technique used in this trial it was unlikely that the absolute percentage of abnormal behaviours observed represents all the abnormal behaviour present. However, it is likely that the trend reported was accurate, given the supporting findings of other trials. Hsia et al. (1991) continuously observed sows for 24 hours and found that abnormal behaviours in stall-housed sows occupied 161.7 minutes out of 24 hours observed, or 11% of the sows' day, compared with group-housed sows, where only 3% of the day was spent in abnormal behaviours. Abnormal behaviour has been reported to develop as a result of a specific inadequacy in the environment of the animal, such as lack of foraging opportunities, insufficient feed, barren environment and confinement, leading to physical restriction of movement, lack of exercise, limited ability to explore and social isolation (Broom 1983; Broom 1987; Broom et al. 1995; Cronin et al. 1984; Cronin and Wiepkema 1984; Ewing et al. 1999; Hsia et al. 1991; Vieuille-Thomas et al. 1995). All of these factors were present to some degree in all housing treatments, however the levels experienced by LS gilts were greater compared to S and SP gilts. S housing provided the greatest opportunity to exercise, explore, forage and socially interact with pen mates. Gilts in SP housing may have experienced an intermediate level of restriction leading to an intermediate level of abnormal behaviour. It is widely agreed upon in the literature that performance of abnormal behaviours is a sign of compromised welfare (Broom 1987; Broom 1991; Ewing et al. 1999; Tarrant 1984).

Polydipsia is considered to be an abnormal behaviour (Ewing et al. 1999), more common in confined sows than sows on straw or in groups (Broom et al. 1995; Whittaker et al. 1999a). Although the level of drinking observed in this experiment tended to be higher in confinement housing compared to S housing, drinking was highest in SP gilts. While gilts in SP housing in this trial had the greatest access to water, both in stalls and in the pen area, and drinker placement may facilitate development of excessive drinking (Spoolder et al. 1995), it seems unlikely that additional drinkers in the pen area would result in the production of abnormal behaviour. Although excessive drinking or playing with the drinkers has been identified as an aberrant behaviour (Ewing et al. 1999) and more specifically as a stereotypy (Broom and Potter 1984; Rushen 1984a; Spoolder et al. 1995) and the welfare of animals engaged in excessive drinking can be said to be reduced, the level of drinking observed in this trial was not necessarily considered to be excessive.

In early gestation, increasing confinement was associated with greater time spent standing idle, with LS gilts spending the most time idle, SP gilts spending an intermediate amount of time, and S gilts spending the least time standing idle. Idle behaviour can be considered a result of an inadequate environment (Cronin et al. 1984), possibly due to reduced opportunity for other activities. LS housing provides the least opportunity for exercise, social interaction, and exploration, making it the most barren of the three systems, which is consistent with this hypothesis.

As pregnancy progressed, there was a tendency in late gestation for gilts assigned to S housing to spend less time resting (10.6% less) and more time nosing at the pen and straw (11.9% more) than gilts in housing without straw. Given the opportunity, gilts with access to straw exchanged resting time for time spent nosing in the straw. This shift can be hypothesized to result from a number of environmental differences. Nosing at the pen and pen environment is a behaviour that is strongly dependent on external stimuli (i.e. the presence of the straw), and in the absence of straw the behaviour may not be seen as frequently (Dawkins 1988). This is consistent with the findings in this trial, where the frequency of resting was exchanged for nosing in S gilts, and no difference was found in housing systems without straw.

Straw may act as a preferred substrate on which the sow expresses increased foraging behaviours (Dailey and McGlone 1997). In barren environments such behaviours can only be directed to less favourable substrates such as conspecifics and pen components, including feeders, drinker nozzles, bars, and concrete floors (Rollin 1995; Spoolder et al. 1995). Increased time spent nosing in S housing may also be due to an overall increase in activity, although analysis of activity in this study found no difference in the performance of active behaviours or postures. Provision of straw or bedding material such as wood shavings has been shown to directly and substantially increase the level of activity observed in pigs

(Morgan et al. 1998; Whittaker et al. 1999b), with most of the active time spent manipulating the straw (Spoolder et al. 1995). Space allowance may have been a factor in the increased time spent nosing at the pen in S housing, compared to LS or SP housing. Weng et al. (1998) found that rooting progressively increased with increasing pen size, while inactive sitting and standing both decreased. Similar results were found in this trial, with sows housed in large straw pens spending the least time in inactive behaviours compared with sows in smaller pens (SP and LS). As sows approach the end of their pregnancy, they begin to express behaviours associated with preparation for farrowing such as nest building. This may have influenced the increase in pen nosing in S gilts. Provision of straw was found to be associated with an increase in the occurrence of pre-partum nesting-like behaviours compared to sows housed without straw (Cronin et al. 1994). Although Cronin et al. (1994) found that nesting behaviour increased substantially 24-hours prior to parturition, some form of nest-building behaviour may be present earlier as well.

S gilts spent the greatest proportion of resting time lying in lateral recumbency when compared to LS and SP gilts. In the afternoon, although no difference in total resting existed between gilts in different housing types, S gilts spent more time lying in lateral recumbency than gilts in LS and SP housing. Other studies have found similar results, with pre-parturient gilts in stalls reported to spend less time lying in lateral recumbency than gilts on straw (Cronin et al. 1994; Vestergaard and Hansen 1984). Lying posture may be related to level of comfort, and lateral recumbency is also associated with deep sleep (Ruckebusch 1969). Since S and SP gilts performed a higher level of lateral lying than LS gilts, it can be inferred that gilts in those housing treatments were able to engage in deep sleep more often, and may have experienced a higher level of comfort and welfare, than LS gilts. Another difference that may have affected activity level in the morning and afternoon was related to feeding management. As gilts on straw were fed their entire ration in the morning, unlike LS and SP gilts that were fed twice a day, it is possible that the level of activity in S gilts would be reduced in the afternoon in the absence of a PM feeding period, compared to LS and SP gilts. However, as the level of resting did not differ in the afternoon among housing treatments, it is unlikely that this played a significant role in the proportion of the time spent resting in lateral recumbency.

Differences in inactive behaviour and postures were noted in late gestation, with SP and LS gilts exhibiting more inactive behaviour than gilts housed on straw. Barnett et al. (1985) also found that inactivity, consisting of sitting and standing, was greater in stalls compared with group-housing systems. It has been suggested that prolonged confinement results in excessive inactivity, representing an abnormal behaviour (Zanella et al. 1996), and thus indicating a reduced level of welfare.

These behavioural changes indicate a consistent pattern in which LS gilts performed significantly different levels of behaviours and postures than S gilts. SP gilts were observed to be intermediate. The housing characteristics; group size, social interaction and possibility of exercise, reflect the same relationship demonstrated between LS, SP and S gilts, and are therefore likely to be implicated in influencing this pattern. In LS housing gilts traded time in lateral recumbency for time in ventral recumbency and generally stood idle more in early gestation, and rested more in late gestation, with a concomitant reduction in locomotion. Abnormal behaviour was more common in LS gilts. In general, LS gilts exhibited more inactive postures and behaviours. S-housed gilts spent more time locomoting, nosing at the pen environment and lying in lateral recumbency. In general, S gilts performed less inactive postures and behaviours.

The results of this trial consistently indicate that the welfare of gilts housed in gestation crates was reduced, compared to gilts housed on straw, with the welfare of SP gilts at an intermediate level. Reduced locomotion, as seen in LS gilts, was suggestive of compromised welfare in those animals as a consequence of reduced exercise. Abnormal behaviours, a clear indication of compromised welfare, were performed more frequently in LS housing compared with SP and S-housed gilts. Time spent standing idle, considered to be a consequence of an inadequate environment, decreased from LS to SP to S gilts, indicating that the welfare of LS-housed gilts may be reduced compared to SP and S gilts. Gilts on straw and in SP housing rested in lateral recumbency most often, a sign of deep sleep, compared to LS gilts. This suggests that S and SP gilts experienced a higher level of welfare than LS gilts. Inactive behaviour, a result of prolonged confinement, seen more frequently in LS and SP gilts than S gilts, indicated a level of reduced welfare for gilts in LS and SP housing. Ventral resting in this study also appeared to be an indicator of reduced welfare due to its relationship with characteristics of LS housing, such as reduced exercise, risk of injury and unstable social structure.

Gilts on straw spent significantly less time resting and more time nosing at the straw than gilts housed without straw. Provision of straw, as in other studies, was found to reduce abnormal behaviours, signifying improved welfare of S gilts compared to LS gilts.

As gilts progressed in their pregnancy, behavioural changes were observed that were attributed to advancing pregnancy. Decreases in standing, interacting, active postures and behaviours, and increases in ventral recumbency, sitting, sitting idle, and inactive postures and behaviours indicates an overall trend for decreasing activity with advancing pregnancy.

3.6 CONCLUSION

Behaviour varied between LS and S gilts, with SP gilts occupying an intermediate position. Locomotion, nosing at the straw and lateral recumbency were observed to increase as space and the opportunity for social contact increased. Ventral recumbency, abnormal behaviours, time spent idle, resting and inactive behaviours were observed more frequently as the level of social and physical confinement increased. These are consistent with reduced welfare in LS housing, with some improvement in SP housing, although S housing was considered to provide the highest level of welfare. Behavioural differences were apparent as gestation advanced, and were attributed to an overall decrease in activity. SP housing was considered to be an improvement over LS housing, however, the level of welfare experienced by the gilts was not as high as in S housing.

4.0 MANUSCRIPT 2

A comparison of dry sow housing systems, locked-stall, stall-pen and straw on the occurrence of lameness in gestating gilts

4.1 ABSTRACT

Currently in North America, the gestation stall is the standard commercial housing for pregnant sows and gilts. A major concern with using gestation stalls is the level of confinement of the animals. Confinement in gestation crates severely limits the opportunity for exercise, resulting in adverse effects on muscle, bone and cardiovascular fitness. This may contribute to the onset and exacerbation of lameness due to reduced muscle strength and the development of osteochondrotic bone lesions. With poor muscle control of basic movements, there is a greater chance that the sow might slip or fall, incurring physical injury. Another concern in standard commercial housing is the absence of bedding material. Provision of straw bedding offers a more cushioned floor material for moving and lying, while providing improved footing that may reduce injuries due to slipping and falling.

The aim of the present study was to evaluate lameness in gestating gilts in three types of housing: locked-stall (LS), stall-pen (SP) and straw (S). Housing systems differed in the level of confinement, individual or group housing, and provision of straw bedding. LS gilts were highly confined, individually-housed gilts in conventional gestating crates. SP gilts were housed in groups of 4 on concrete flooring with access to a slatted exercise area. S gilts were kept in groups of 8-16 animals, and were housed for the latter half of gestation in larger pens that were deeply bedded with straw. Lameness was assessed using a scoring

system adapted from Main et al. (2001). All animals were evaluated at early (0-14 days), mid (48-62 days) and late (93-107) gestation. Three criteria were examined separately to evaluate lameness: the gilt's initial response to the observer (IR), the standing posture of the gilt (ST), gait (G), and a combined lameness (CL) score. Animals were assigned a score, ranging from 0 to 5 in each category, with 0 representing a normal condition and 5 indicating severe lameness.

Overall, the vast majority of gilts in all housing systems in all stages of gestation received scores of zero in all categories of lameness. In late gestation, significantly fewer S-housed gilts received a G score of zero, compared with early and mid-gestation (χ^2=6.62, $p<0.05$, 2 degrees of freedom), although when the zero category was expanded to include scores up to 0.5, no significant difference was found as gestation progressed. While no differences in lameness related to housing were found, the overall low level of lameness in this study precluded a rigorous assessment.

4.2 INTRODUCTION

To more efficiently utilize space in the dry sow barn, and for ease of management, gestation stalls are widely used in commercial production. Currently, 75% of Manitoba hog producers use gestation stalls in their operations (Manitoba Pork Council 2002). As legislation forces European producers to move away from confinement based housing for pregnant sows, it is inevitable that consumers will question the use of gestation stalls in North America.

One of the major concerns of commercially housed gestating sows is the level of confinement of the animals. The opportunity for exercise in crates is severely limited, affecting the sow's physical state (Marchant et al. 1997a). Physical effects may include reduced muscle size and bone strength (Marchant and Broom 1996a), reduced muscle and bone growth (Marchant and Broom 1996b), and reduced cardiovascular fitness (Marchant et al. 1997a; Ratcliffe et al. 1969a). Lack of sufficient exercise has been shown to exacerbate lameness due to reduced muscle strength and the development of bone lesions (Elliot and Doige 1973; Marchant and Broom 1996a). Reduced muscle strength has been shown to contribute to the development of lameness by increasing the difficulty in changing position in the stall (Marchant and Broom 1996b). This results in a reduced ability to manoeuver and to carry out normal behaviours, and an increased risk of injury. Osteochondrotic bone lesions have also been linked to lameness in breeding-age pigs. Osteochondrosis (OC) is the most common bone lesion seen in growing pigs (Grondalen 1974a; Grondalen 1974b; Nakano et al. 1979; Nakano et al. 1981b; Nakano et al. 1984). OC results in disruption of normal ossification of cartilage leading to cartilage necrosis and disturbed bone growth (McCaw and Mitten 1980). These joint lesions, caused by many contributing factors, including growth rate, unyielding flooring, and insufficient exercise, have been identified as playing an important causative role in the appearance of lameness (Grondalen 1974a; Grondalen 1974b; Nakano et al. 1981a).

Another concern arising from current commercial housing practices is the absence of suitable bedding material. Provision of bedding in the form of straw offers a more cushioned floor material for moving and lying (Rollin 1995), while providing improved footing that may reduce injuries due to slipping and falling (Day et al. 2002; Edwards 1998).

Because many factors associated with the use of gestation crates, such as insufficient exercise and hard concrete flooring, have been associated with lameness in breeding-age pigs, it can be inferred that housing plays an important role in the development of lameness. Lameness, also referred to as locomotor dysfunction, has been generally described as a disturbance in gait (Nakano et al. 1981a; Nakano et al. 1987), difficulty walking (Yamasaki et al. 1989; Yamasaki and Itakura 1988), or awkward gait (White 1994). This can manifest as shortened stride length (Hill 1994) with the animal taking short, stiff steps (Yamasaki et al. 1989; Yamasaki and Itakura 1988). Walking is hindered, and one or more limbs are usually not fully weight bearing (Hill 1994).

In addition to the effects of lameness on locomotion, an affected animal may experience difficulty standing, or show reluctance to stand (Blowey 1994; Hill 1994; Yamasaki et al. 1989; Yamasaki and Itakura 1988). Problems standing create immediate welfare implications for the sow. Access to feed and water may be restricted, and the sow may experience problems defecating normally. Difficulty standing may also have repercussions on the reproductive performance of sows and gilts, as they may be unable to support the weight of the boar during mating (Blowey 1994). Nakano et al. (1981) observed that lame boars spent more time lying down than control (non-lame) animals. Animals who are lame may also perform abnormal activities such as eating while sitting, rather than standing (Yamasaki et al. 1989; Yamasaki and Itakura 1988). Animals in extreme pain may refuse to move (Hill 1994).

Lameness in gestating sows and gilts is a serious welfare and economic concern in swine herds world wide, posing particular problems in breeding herds (Grondalen 1979a; McCaw and Mitten 1980). With replacements estimated at $65 US per gilt and $345 US per boar, currently $300 and $1200 CDN respectively (Connor 2004, Personal Communication), the cost to the US swine industry in one year (1989-90) was estimated at $48,103,933 US

(Hill 1994). In a more recent study (December 1999 through May 2000) the U.S. Department of Agriculture (USDA 2001) reported the current culling rate of breeding-age female pigs due to lameness at 16%. In the UK, 20% of first parity gilts were culled for lameness (Blowey 1994), resulting in a loss of £3.0 million.

Conversion of gestation crates into pens housing a small group of pigs represents a potential compromise between housing gestating sows in individual crates, as is done in North America, and the larger straw-based housing systems employed in Europe. Housing small groups of pigs in a pen (4) might address the major welfare issues created by confinement stalls. These include social isolation, reduced opportunity to exercise, prevention of expression of most normal behaviour, and subsequent development of abnormal behaviour. Additionally, groups of 4-6 pigs housed in pens may mitigate the chief concerns of the industry over the disadvantages of moving to large-scale, straw-based housing systems. These include animal factors such as aggression, and management issues such as difficulty cleaning, lack of individual feeding, and a reduced ability to easily monitor dry sows over their gestation.

The aim of this experiment was to assess the occurrence and severity of lameness in gestating gilts in three different housing systems representing intensive commercial housing, extensive straw housing, and a system corresponding to an intermediate between the two, using a modified version of the lameness scoring system developed by Main et al. (2000). This trial was conducted in conjunction with a study on behaviour and activity of gestating gilts in the same three housing systems (Manuscript 1).

4.3 MATERIALS AND METHODS

4.3.1 Subjects

Eighty-four Cotswold (Cotswold Canada Inc.) nulliparous gilts were placed on trial at Glenlea Research Station over a period of 20 months (April, 2001 to November, 2002). Gilts arrived approximately two months prior to estrus, weighing an average of 111.4 kg, and were individually identified with numbered ear tags. Once gilts went into estrus, they were bred using artificial insemination. A total of 23 gilts failed to breed successfully at first estrus and were rebred in the following breeding period 1.5 - 2 months later. Gilts successfully rebred were treated as first gestation gilts. Twelve gilts failed to breed or reproduce successfully in the following breeding period, and were culled from the herd. A total of 73 animals were used in this trial. Thirty days following breeding, the average gilt weight was 133.7 kg, and at farrowing gilts weighed 191.1 kg on average.

The lighting schedule was 9L:15D from 0800 to 1700 hours, to allow for normal estrus cycling. Gilts were fed 2 kg per day of a barley based gestation ration with 16% protein, meeting or exceeding NRC guidelines. Gilts had *ad libitum* access to water. All animals were cared for according to CCAC guidelines (Canadian Council on Animal Care 1993) and recommended codes of practice (Connor 1993).

4.3.2 Housing Treatments

Gilts were initially housed for breeding in groups of 4-6 (Figure 1 in Manuscript 1). Breeding pens were 3.7 m deep by 1.73 m wide with partially slatted concrete floors, providing 1.6m^2 per animal, which is slightly greater than the 1.5 m^2 recommended in the RCOP for gilts of equivalent weight (Connor 1993). Nipple drinkers were located on the rear wall over the slatted portion of the floor. After breeding, gilts were randomly assigned to locked-stall [LS], stall-pen [SP] or straw [S] housing treatments (Table 1 in Manuscript 1) in groups of four, based on the order in which they were bred. Using groups of four ensured that each pen of animals had similar farrowing dates for management purposes. Gilts assigned to LS were moved into treatment housing within 24 hours of final breeding. Pregnancy was confirmed at 30 days post-breeding by transcutaneous ultrasonography. Gilts assigned to SP housing were moved into treatment pens after confirmation of pregnancy to avoid the necessity of remixing. Gilts assigned to S housing remained in breeding pens in groups of four until all animals assigned to this larger group were confirmed pregnant (approximately 60 days). At this time they were moved to a separate barn and housed in a large pen in groups of 8-16 animals. At day 110 of gestation, all gilts were moved into farrowing crates.

4.3.2.2 Locked-Stall Housing (LS)

LS housing consisted of groups of four standard gestation stalls (Figure 2 in Manuscript 1, green arrows). Each stall was 1.85m deep by 0.62m wide with solid concrete flooring, providing 1.15 m^2 floor space for each animal, less than was recommended in the RCOP (Connor 1993). Each crate was equipped with a feeder at the front of the stall next to a nipple and cup drinker. Social interactions were limited to animals in adjacent stalls. Movement within the stall was limited to a maximum of three strides from back to front, which decreased to two as the gilts grew. A total of 19 gilts were placed in LS housing.

4.3.2.3 Stall-Pen Housing (SP)

SP housing consisted of four standard gestation stalls that opened into a rear slatted-floor pen area (Figure 2 in Manuscript 1). The gestation stalls were as described for the LS treatment. The pen area (Figure 2, red arrows) was 1.85m deep by 2.5m wide with slatted concrete flooring. The total floor space was 2.3 m^2 per gilt, considerably more than recommended (Connor 1993). An additional drinker was located on the back wall of each pen area, and feed was provided in the stall feeders. Pigs were free to move within the pen area, and from stall to stall. Interaction with pen-mates was unrestricted. Interactions with pigs in neighbouring pens were limited to contact through the bars. Twenty-four gilts were assigned to SP housing.

4.3.2.4 Straw Housing (S)

S housing (Figure 3 in Manuscript 1) was located in a separate building containing four large group pens, each with a maximum capacity of 16 animals, although animals were housed in groups ranging from 8-16. Experimental gilts were always housed in the same pen from trial to trial. Straw pens were 8.53 m long by 3.05 m wide, providing a maximum of 3.25m^2 per animal when 8 animals were housed, and a minimum of 1.63m^2 per gilt when 16 animals were housed in the pen. The RCOP suggests that the space allowance provided for gilts on a solid bedded floor should be at least 1.7m^2 (Connor 1993), indicating that at the maximum of 16 animals, the space provided was inadequate according to the RCOP. The pen was bordered on three sides with PVC rails; the remaining side was concrete, with two water nipples. The pen floor was solid concrete, deeply bedded (20-40cm) with straw. Gilts were free to interact with pen mates and to move without restriction throughout the pen.

Gilts were moved out of the straw pen once daily for individual feeding in an adjacent stall area. There were 30 gilts assigned to S housing.

4.3.2.5 Differences between housing treatments

Five major differences between housing treatments were recognized: flooring, social environment, exercise, management of feeding and time spent in breeding pens (Table 1 in Manuscript 1). Gilts assigned to LS and SP-housing remained on concrete flooring throughout gestation. Due to management and space restrictions, S-housed gilts were moved onto straw in mid-gestation. Social environment differed between housing types. SP and S gilts were group housed, with smaller groups of 4 per pen in SP, and larger groups of 8-16 pigs per pen in S, while LS gilts were individually penned. Opportunity to exercise was severely limited for LS gilts confined to gestation stalls. SP and S-housed gilts could move freely within their pens. However, gilts in S housing had the largest enclosure, and consequently had the greatest opportunity to exercise. Differences in feeding management among housing systems were recognized. While in breeding pens, gilts were floor fed. Once moved into their treatment pens, all gilts were individually fed. Straw-housed gilts were fed once a day outside of the range of the video cameras in the latter half of their pregnancy. As a result no behavioural observations could be made during this time, and no feeding behaviour was recorded for the straw-housed gilts in late gestation. LS and SP gilts were fed twice a day, with feeding behaviour recorded on videotape. Finally, duration of housing in breeding pens differed between treatments. LS gilts were moved to treatment pens immediately after breeding. SP gilts remained in breeding pens until they were confirmed pregnant at 30 days. Gilts assigned to S housing remained in breeding pens until mid-gestation before being moved into S housing due to management constraints at the Glenlea facility.

Other minor differences that existed between housing systems included location of treatment housing, provision of heated flooring, and season. Breeding pens, LS and SP treatments were all located within the same barn. Straw housing was located in a separate building approximately 1/2 kilometer away, requiring the gilts to be transported by truck. In LS and SP treatments, the solid concrete portion of the floor was heated in the winter, providing a warm lying area within the stall portion of the pens. Gilts in breeding pens and in straw housing did not have access to heated concrete flooring, however, deeply bedded straw provides thermal insulation in cold temperatures (Edwards 1998). Finally, gilts were bred in eight groups over a period of 2 years. As a result, each group of gilts was bred, and housed in conditions that were variable with the season. Such conditions include temperature and relative humidity, which would have been higher than normal during summer months, but would not have varied significantly from normal during winter months as all barns were heated.

4.3.3 Lameness scoring

All animals were evaluated at early (0-14 days), mid (48-62 days) and late (93-107) gestation. Three criteria were examined separately to evaluate lameness: the gilt's initial response to the observer (IR), the standing posture of the gilt (ST) and gait (G). Animals were assigned a score, ranging from 0 to 5 in each category, with 0 representing a normal condition and 5 indicating severe lameness (Table 15). Each category was scored separately,

TABLE 15 Three categories of lameness in gestating gilts (initial response, standing posture and gait) and the criteria determining the score, adapted from Main et al. (2000)

Lameness Score	Initial Response	Standing Posture	Gait
0	Highly responsive. Rises immediately.	Standing pig distributes weight evenly on all 4 legs.	Even strides. Accelerates and changes direction rapidly. (Minor changes evident when pig is heavily pregnant were scored as 0.5)
1	Stays down but will rise if encouraged.	Slightly uneven posture, with very minimal body shift.	Abnormal stride length. Just noticeable limp or stiffness. Good mobility.
2	Gets up, but is dog-sitting.	Uneven posture. Weight unevenly distributed on 4 legs. Some body shift.	Obvious limp. Favours one or more leg(s) (90% weight bearing). Minimal hindrance in agility.
3	Pig is lying down or dog-sitting. Reluctant to rise.	As for score 2. Pig stands forward on toes with an arched back. May paddle feet.	Pronounced limp. Moderate weight bearing on affected limb (25-89%). Shortened stride.
4	May be unresponsive. Requires assistance to leave pen.	Affected limb elevated off floor. Pig will return to dog sitting when left alone. Will stand and walk if assisted.	Minimum weight bearing on affected limb(s) (0-24%) while walking. Head bucking when walking is pronounced.
5	Dull and unresponsive. Will not leave pen.	Will not stand even if helped up (sinks back down).	Does not move.

resulting in three scores for each animal per observation. Between 2 and 3 observers conducted scoring at each session, and all scores were averaged.

Lameness was assessed using a scoring system adapted from Main et al. (2001). The main departures from Main et al. (2001) were a) the incorporation of the categories 'Initial response to human presence' and 'Pig's response after opening gate' into a single category—'Initial response'; b) exclusion of the category 'Behaviour of the individual within the group'; and c) adaptation of the 'Gait' category to include changes in gait that are observed in heavily pregnant animals, but are not abnormal or associated with lameness. This last alteration was necessary as the system developed by Main et al. (2001) was designed for growing and finishing pigs. Additional changes to the scoring system included expanding several lameness category scoring criteria to include more specific characteristics of animals in those score categories. Categories expanded include those for scores of 1 and 2 in IR and ST lameness categories.

4.3.3.2 Initial response (IR)

IR was evaluated as the gilt was released from her stall or pen. A normal gilt (scoring zero) would be alert, immediately stand if lying or sitting, and have no difficulty leaving the pen or stall. If minimal encouragement was required for the gilt to stand, the gilt received a score of one. Gilts that rose from lying but remained dog sitting, rather than standing, received a score of two. Gilts observed to be lying down or sitting, and were reluctant to rise despite encouragement were given a score of three. Gilts that required assistance to leave the pen or stall were assessed as a four. A score of five was reserved for gilts unable to leave the pen, and that appeared dull and unresponsive, although no animals received a score of five in this trial.

4.3.3.3 Standing posture (ST)

ST was assessed visually in a collecting pen adjacent to the weigh scale. Observers examined the gilt from multiple angles while she was standing. Normal gilts (scoring zero) stood evenly on all four limbs. A score of one was recorded if a slightly uneven posture was observed. This was usually seen as a minimal shift in the angle of the gilts' back. Obvious shifting of weight off one or more limbs resulted in an easily observed uneven stance, and received a score of two or higher, depending on the severity. Shifting of stance included one of: arched back, standing on the toes, or paddling of the affected foot, and would result in a score of three. Limbs held entirely off of the floor resulted in a score of four. An animal unable to remain standing even when assisted, received a score of five. No gilts were scored a five in this trial.

4.3.3.4 Gait (G)

Once out of their home pen, animals walked down an 18.7m long hallway to a weigh scale. Gait was assessed at this time. Observers walked behind or beside the gilt, observing smoothness of stride, and evenness of steps. Normal gilts displayed smooth gait, with good agility and acceleration, and received a score of zero. In late pregnancy, gait and agility were occasionally hampered. Such heavily pregnant gilts displaying minor gait alterations were scored as 0.5. Gilts showing some stiffness, evidenced by shortened or stilted steps, or a mild limp (with minimally uneven weight bearing) received a score of one. Obviously shortened stride and decreasing amounts of weight borne on affected limb(s) (90% weight bearing) resulted in a score of two. Gilts with a pronounced limp, displaying shortened stride and moderate weight bearing (25-89%), were scored as a three. Severely lame animals (scoring four) bore weight on the affected limb(s) minimally or not at all (0-24%) while walking. Pronounced bucking of the head was often observed. Animals unable or unwilling to move would have received a score of five. Gilts were also assessed on the return journey in order to allow for initial stiffness that might loosen up after movement. The lower score was accepted as accurate.

4.3.4 Statistical analysis

Observer scores were averaged for each animal in each observation period (early, mid and late gestation). Due to averaging, scores greater than zero no longer fit into discrete categories (0-5) necessitating the use of a sliding scale. Zero scores remained in category zero. Averaged scores of 0.1-1.49 were placed into category 1; 1.5-2.49 into category 2; 2.5-3.49 into category 3; 3.5-4.49 into category 4; and 4.5-5 into category 5. This returned all values to the original scale for analysis.

Adding the IR, ST and G scores together created the combined lameness (CL) score. Similar to the IR, ST and G sliding scale, CL scores were set on a sliding scale (Table 4). A zero score remained in category zero. Scores of 0.1-3.49 were placed into category 1; 3.5-6.49 into category 2; 6.5-9.49 into category 3; 9.5-12.49 into category 4; and 12.5-15 into category 5.

Chi-square analyses were performed on count data for IR, ST, G and CL. Because very few gilts scored above one (0.1-1.49) (often less than five individuals) the categories were collapsed for analysis into gilts with a score of zero, and gilts with a score greater than zero. Additional analysis was performed on the G and CL portion of scoring categories, in order to determine if the difference in lameness was due to marginally higher or substantially higher scores. This was accomplished by expanding the zero category to include scores of 0.5, and comparing these to scores greater than 0.5.

4.4 RESULTS

4.4.1 Initial response (IR)

The majority of gilts in all housing treatments and in all stages of gestation received scores of zero for initial response (Table 16). Non-zero scores tended to occur in categories 1 and 2. No gilts were observed with a category 5 IR score.

No significant difference between housing systems was apparent over the study (χ^2=0.77, P = 0.05, 2 d.f.). In early gestation, most gilts in all housing systems received a score of zero. There was a non-significant tendency for the number of gilts scoring zero in early gestation to increase from LS (79%) to SP (87.5%) to S (93.3%) (χ^2=2.23, critical χ^2=5.99, P = 0.05, 2 d.f.) (Table 16). In early gestation, non-zero IR scores for gilts in all housing treatments were recorded in categories 1 or 2. These gilts required minimal encouragement in order to stand, or readily rose from lying but remained dog sitting.

In mid gestation, as in early gestation, the majority of gilts were assigned IR scores of zero, with no difference between housing (χ^2=0.55, P = 0.05, 2 d.f.) (Table 16). Non-zero scores in mid gestation were category 1 or 2 in LS gilts, category 2 in SP gilts, and categories 1 and 3 in S-housed gilts. Category three included gilts initially lying down or dog sitting that were reluctant to rise despite encouragement.

TABLE 16 Number and percentage of gestating gilts in initial response (IR) score categories (0-5) in three housing treatments (locked-stall [LS], stall-pen [SP], and straw [S]), at early, mid and late gestation

		Initial response score categories													
						Breakdown of non-zero category									
		0		>0		1		2		3		4		5	
Treatment	Gestation	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Locked stall (LS)	Early (n=19)	15	79.0	4	21.0	2	10.5	2	10.5	0	0.0	0	0.0	0	0.0
	Mid (n=19)	17	89.5	2	10.5	1	5.3	1	5.3	0	0.0	0	0.0	0	0.0
	Late (n=16)	15	93.8	1	6.3	0	0.0	0	0.0	1	6.3	0	0.0	0	0.0
Stall-pen (SP)	Early (n=24)	21	87.5	3	12.5	1	4.2	2	8.3	0	0.0	0	0.0	0	0.0
	Mid (n=22)	21	95.5	1	4.5	0	0.0	1	4.6	0	0.0	0	0.0	0	0.0
	Late (n=24)	20	83.3	4	16.7	4	16.7	0	0.0	0	0.0	0	0.0	0	0.0
Straw (S)	Early (n=30)	28	93.3	2	6.7	1	3.3	1	3.3	0	0.0	0	0.0	0	0.0
	Mid (n=29)	27	93.1	2	6.9	1	3.5	0	0.0	1	3.5	0	0.0	0	0.0
	Late (n=30)	24	80.0	6	20.0	2	6.7	3	10.0	0	0.0	1	3.3	0	0.0

Score categories (0-5) are based on a sliding scale of averaged observer scores (Appendix Table A1).

Gilts housed in the S treatment remained in breeding pens until mid-gestation, and then were moved into straw housing. SP-housed gilts remained in breeding pens until 30 days post breeding, and then were moved into treatment housing. LS gilts spent the entire gestation in treatment housing.

Chi-square analysis was performed using count data. Significance was accepted at $p<0.05$.

The number of gilts receiving a score of zero in late gestation was consistent with the pattern demonstrated in early and mid-gestation, with a majority of gilts in all housing systems scoring zero. The percentage of gilts scoring zero tended to increase from S (80%) to SP (83.3%) to LS (93.8%), although this difference was not significant (χ^2=1.52, P=0.05, 2 d.f.) (Table 16). Non-zero scores for gilts in S housing were observed in categories 1, 2 and 4. A score of four was assigned when a gilt required assistance to leave the pen or stall. Non-zero scores for SP-housed gilts were recorded in category 1, while LS gilts were assigned non-zero scores in category 3.

No significant differences in the number of gilts scoring zero versus greater than zero were demonstrated as pregnancy progressed (χ^2=2.52, P = 0.05, 2 d.f.). Comparison of IR scores in early, mid, and late gestation within housing treatments was similar to that observed across housing treatments. A majority of gilts were noted to have IR scores of zero (Table 16).

The number of gilts scoring zero in LS housing tended to increase as gestation progressed, from 79% in early gestation to 89.5% in mid gestation to 93.8% in late gestation. However, this was not significant (χ^2=1.84, P = 0.05, 2 d.f.) (Table 16). This trend was not observed in SP or S gilts. In SP gilts, the highest scores were seen in early and late gestation, however this was not significant (χ^2=1.71, P = 0.05, 2 d.f.). S-housed gilts displayed a non-significant trend opposite to that seen in LS gilts, with the number of gilts scoring zero decreasing as pregnancy progressed (χ^2=3.49, P = 0.05, 2 d.f.).

4.4.2 Standing posture (ST)

The majority of gilts in all housing treatments and in early, mid and late gestation received scores of zero for standing posture (Table 17). Non-zero scores tended to occur in categories 1 and 2. No gilts were observed with a category 5 ST score.

ST scores did not differ between housing treatments in this study (χ^2=1.17, P =0.05, 2 d.f.). In early gestation, the majority of gilts in all housing systems received a score of zero. Although more gilts in SP and S than LS housing scored zero, the difference was not statistically significant (χ^2=2.06, P = 0.05, 2 d.f.). The non-zero ST scores for gilts in SP and S housing consist only of lameness category 1, while LS-housed gilts received scores in categories 1 and 2. A score of 1 was recorded for gilts with a slightly uneven posture, usually seen as a minimal shift in the angle of the gilts' back. Gilts with obvious shifting of weight off 1 or more limbs, resulting in an easily observed uneven stance, received a score of 2.

In mid gestation, most gilts were assigned ST scores of zero. The number of gilts with zero scores was the same in SP (86.4%), LS (89.5%) and S (93.1%) housing (Table 17) (χ^2=0.64, P = 0.05, 2 d.f.). Non-zero scores in mid gestation were seen in lameness category 1 in LS gilts, 1 and 2 in SP gilts, while S-housed gilts received scores in categories 1 and 3. Gilts in category 3 were likely to display a combination of arched back, shifting of stance, standing on toes, and paddling of the affected foot.

The number of gilts assigned a score of zero in late gestation tended to increase from LS (83.3%) to SP (91.7%) and S (92.9%) housing (Table 17), however this trend was not significant (χ^2=1.22, P = 0.05, 2 d.f.). Non-zero scores in SP and S housing were observed only in lameness category 1, while LS-housed gilts scored in lameness categories 1 and 2.

TABLE 17 Number and percentage of gestating gilts in standing posture (ST) score categories (0-5) in three housing treatments (locked stall, stall-pen, and straw), at early, mid and late gestation

		Standing posture score categories													
						Breakdown of non-zero category									
		0		>0		1		2		3		4		5	
Treatment	Gestation	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Locked stall (LS)	Early (n=19)	16	84.2	3	15.8	1	5.3	2	10.5	0	0.0	0	0.0	0	0.0
	Mid (n=19)	17	89.5	2	10.5	2	10.5	0	0.0	0	0.0	0	0.0	0	0.0
	Late (n=18)	15	83.3	3	16.7	1	5.6	2	11.1	0	0.0	0	0.0	0	0.0
Stall-pen (SP)	Early (n=24)	23	95.8	1	4.2	1	4.2	0	0.0	0	0.0	0	0.0	0	0.0
	Mid (n=22)	19	86.4	3	13.6	2	9.1	1	4.6	0	0.0	0	0.0	0	0.0
	Late (n=24)	22	91.7	2	8.3	2	8.3	0	0.0	0	0.0	0	0.0	0	0.0
Straw (S)	Early (n=30)	28	93.3	2	6.7	2	6.7	0	0.0	0	0.0	0	0.0	0	0.0
	Mid (n=29)	27	93.1	2	6.9	1	3.5	0	0.0	1	3.5	0	0.0	0	0.0
	Late (n=28)	26	92.9	2	7.1	2	7.1	0	0.0	0	0.0	0	0.0	0	0.0

Gilts housed in the S treatment remained in breeding pens until mid-gestation, and then were moved into straw housing. SP-housed gilts remained in breeding pens until 30 days post breeding, and then were moved into treatment housing. LS gilts spent the entire gestation in treatment housing.

Chi-square analysis was performed using count data. Significance was accepted at $p<0.05$.

No statistically significant difference in ST was observed from early (95.7%) to mid (90%) and late (90%) gestation (χ^2=0.18, P = 0.05, 2 degrees of freedom). A majority of gilts received scores of zero, and no significant differences were observed as gestation progressed (Table 17). No discernible trend in the number of gilts scoring zero in LS, SP, or S housing was found as gestation progressed (LS χ^2=0.34, SP χ^2=1.32, S χ^2=0.01, P = 0.05, 2 d.f.).

4.4.3 Gait (G)

The majority of gilts in all housing treatments and in early, mid and late gestation received scores of zero for gait (Table 18). Non-zero scores tended to occur in categories 1, 2 and 3. No gilts were observed with categories 4 and 5 gait.

G scores did not differ between housing systems in this trial (χ^2=0.058, P = 0.05, 2 d.f.). In early gestation, a majority of gilts in all housing systems were assigned a score of zero (Table 18). Although more gilts in S (73.3%) than LS (63.2%) and SP (63.5%) housing received a score of zero, the difference was not found to be significant (χ^2=0.89, P = 0.05, 2 d.f.). Non-zero scores for gilts in LS and S housing consisted of lameness categories 1 and 2, while SP-housed gilts received scores in lameness category 1. A score of 1 was recorded for gilts showing some stiffness, evidenced by shortened or stilted steps, or a mild limp with minimally uneven weight bearing. Obviously shortened stride and decreasing amounts of weight borne on affected limb(s) (90-99% weight bearing) resulted in a score of 2.

As in early gestation, most gilts in mid-gestation received a gait score of zero (Table 18). More SP gilts scored non-zero, while more S housed gilts scored zero. Differences between housing systems in mid-gestation were not found to be significant (χ^2=1.31,

TABLE 18 Number and percentage of gestating gilts in each gait score categories (0-5) in three housing treatments (locked stall, stall-pen, and straw), at early, mid and late gestation

		Gait score categories													
						Breakdown of non-zero category									
		0		>0		1		2		3		4		5	
Treatment	Gestation	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Locked stall (LS)	Early (n=19)	12	63.2	7	36.8	6	31.6	1	5.3	0	0.0	0	0.0	0	0.0
	Mid (n=19)	13	68.4	6	31.6	6	31.6	0	0.0	0	0.0	0	0.0	0	0.0
	Late (n=18)	12	66.7	6	33.3	4	22.2	2	11.1	0	0.0	0	0.0	0	0.0
Stall-pen (SP)	Early (n=24)	15	62.5	9	37.5	9	37.5	0	0.0	0	0.0	0	0.0	0	0.0
	Mid (n=21)	12	57.1	9	42.9	7	33.3	1	4.8	1	4.8	0	0.0	0	0.0
	Late (n=23)	13	56.5	10	43.5	9	39.1	1	4.3	0	0.0	0	0.0	0	0.0
Straw (S)	Early (n=30)	22	73.3	8	26.7	6	20.0	2	6.7	0	0.0	0	0.0	0	0.0
	Mid (n=29)	21	72.4	8	27.6	6	20.7	0	0.0	2	6.9	0	0.0	0	0.0
	Late (n=29)	13	44.8	16	55.2	15	51.7	0	0.0	1	3.5	0	0.0	0	0.0

Gilts housed in the S treatment remained in breeding pens until mid-gestation, and then were moved into straw housing. SP-housed gilts remained in breeding pens until 30 days post breeding, and then were moved into treatment housing. LS gilts spent the entire gestation in treatment housing.

Chi-square analysis was performed using count data. Significance was accepted at $p<0.05$.

$P = 0.05$, 2 d.f.). Non-zero scores in mid gestation were seen over a wider range than those in early gestation, with LS gilts scoring in category one, S gilts scoring in categories 1 and 3, and SP gilts receiving scores of 1, 2 and 3. Gilts scoring 3 displayed a pronounced limp, with shortened stride and exhibited moderately reduced weight bearing (25-89%).

A tendency for the number of gilts assigned a score of zero in late gestation to decrease from LS (66.7%) to SP (56.5%) to S (44.8%) housing was noted, although this trend was not demonstrated to be significant (χ^2=2.20, $P = 0.05$, 2 d.f.) (Table 18). Gilts in LS and SP housing received non-zero scores in G categories 1 and 2, while SP housed gilts scored in categories 1 and 3.

Stage of gestation was not found to differ significantly in this trial (χ^2=3.39, P=0.05, 2 d.f.) (Table 18). When comparing stage of gestation within housing treatment, no significant difference was observed in LS and SP-housed gilts (LS χ^2=0.12, SP χ^2=0.21, $P = 0.05$, 2 d.f.). However, in late gestation, significantly more S housed gilts received a non-zero score (55.2%), compared with early (26.7%) and mid-gestation (27.6%) (χ^2=6.62, $P = 0.05$, 2 d.f.). Reanalysis was performed, with an expanded zero category that included scores up to 0.5, to account for minor gait alterations due to advanced pregnancy. No significant difference was found in S gilts as gestation progressed when comparing number of gilts scoring 0-0.5, and greater than 0.5 (χ^2=2.00, $P = 0.05$, 2 d.f.).

4.4.4 Combined lameness (CL)

The comparison of zero and non-zero CL scores indicated that there was no difference due to housing systems over the first gestation. No significant difference was found when comparing zero and non-zero CL scores with progressing pregnancy.

No significant difference between housing treatments was noted in this study (χ^2=2.00, P = 0.05, 2 d.f.). The overall pattern observed when all measures of lameness were combined (IR, ST and G) is summarized in Table 19. In early gestation, greater than half the gilts in all housing systems were assigned a CL score of zero. A tendency for the number of gilts scoring zero to increase from LS (57.9%) to SP (62.5%) to S (73.3%) housing was observed, however this trend was not statistically significant (χ^2=1.40, P = 0.05, 2 d.f.). Non-zero scores for gilts in LS and S housing consisted of scores in lameness categories 1 and 2, while SP housed gilts received scores in lameness category 1.

Similar to early gestation, in mid-gestation, at least half of the gilts received a CL lameness score of zero (Table 19). More LS gilts scored higher than zero, while most S-housed gilts were scored zero, although this difference was not significant (χ^2=1.65, P = 0.05, 2 d.f.). Non-zero CL scores in mid-gestation were more variable than those of early gestation, with LS gilts scoring in category 1, SP gilts scoring in categories 1 and 2, and S gilts receiving scores of 1, 2 and 3.

In late gestation, half or fewer of the gilts in SP and S housing received scores of zero compared with greater than 50% in early and mid-gestation (Table 19). As seen in gait scores, there appeared to be a tendency for the number of gilts assigned a score of zero in late gestation to decrease from LS (68.4%) to SP (50%) to S (46.7%), however this trend did not reach significance (χ^2=2.30, P = 0.05, 2 d.f.). Gilts in LS housing were assigned CL scores of 1 and 2, SP gilts scored in categories 1 only, and gilts assigned to S housing received scores of 1 and 3.

No significant difference was found as gilts progressed from early to mid to late gestation in this study (χ^2=2.40, P = 0.05, 2 d.f.) (Table 19). As pregnancy advanced, no

TABLE 19 Number and percentage of gestating gilts in combined lameness (CL) score categories (0-5) in three housing treatments (locked stall, stall-pen, and straw), at early, mid and late gestation

		Combined lameness score categories													
						Breakdown of non-zero category									
		0		>0		1		2		3		4		5	
Treatment	Gestation	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Locked stall (LS)	Early (n=19)	11	57.9	8	42.1	6	31.6	2	10.5	0	0.0	0	0.0	0	0.0
	Mid (n=19)	10	52.6	9	47.4	9	47.4	0	0.0	0	0.0	0	0.0	0	0.0
	Late (n=19)	13	68.4	6	31.6	3	15.8	3	15.8	0	0.0	0	0.0	0	0.0
Stall-pen (SP)	Early (n=24)	15	62.5	9	37.5	9	37.5	0	0.0	0	0.0	0	0.0	0	0.0
	Mid (n=24)	14	58.3	10	41.7	8	33.3	2	8.3	0	0.0	0	0.0	0	0.0
	Late (n=24)	12	50.0	12	50.0	12	50.0	0	0.0	0	0.0	0	0.0	0	0.0
Straw (S)	Early (n=30)	22	73.3	8	26.7	7	23.3	1	3.3	0	0.0	0	0.0	0	0.0
	Mid (n=30)	21	70.0	9	30.0	7	23.3	1	3.3	1	3.3	0	0.0	0	0.0
	Late (n=30)	14	46.7	16	53.3	15	50.0	0	0.0	1	3.3	0	0.0	0	0.0

Adding the initial response (IR), standing posture (ST) and gait (G) scores together created the CL score. Similar to the IR, ST and G sliding scale, CL score categories (0-5) are based on a sliding scale of averaged observer scores (Appendix Table A2).

Gilts housed in the S treatment remained in breeding pens until mid-gestation, and then were moved into straw housing. SP-housed gilts remained in breeding pens until 30 days post breeding, and then were moved into treatment housing. LS gilts spent the entire gestation in treatment housing.

Chi-square analysis was performed using count data. Significance was accepted at $p<0.05$.

significant difference was observed in LS and SP housed gilts (LS χ^2=1.02, SP χ^2=0.79, P = 0.05, 2 d.f.). Similar to the pattern observed in the G component of lameness in late gestation, significantly fewer S-housed gilts received a CL score of zero, compared with early and mid-gestation (χ^2=6.11, P = 0.05, 2 d.f.). When the zero category was expanded to include scores of 0.5, as in gait, no significant difference was found in S gilts as gestation progressed.

4.5 DISCUSSION

Assessing lameness is important in both clinical and applied settings. Rapid diagnosis of lameness is important for treatment. Early identification of animals with locomotory problems is also essential to reduce culling of bred gilts and sows. Onset of lameness can be insidious or acute, and may appear episodic, especially when caused by bone/joint lesions (Hill 1994). Other than the disturbance in gait, movement and posture, an animal with non-infectious lameness appears otherwise normal (eating, temperature, etc.) (Yamasaki et al. 1989; Yamasaki and Itakura 1988), unless in severe pain or distress. However, animals showing signs of lameness should be considered to be experiencing some degree of pain or discomfort (Hill 1994). As such, an animal experiencing lameness can be said to have reduced welfare.

Lameness observed in this trial could be divided into three categories. The first was represented by the zero lameness category, indicating that the animal was sound. The second was mild lameness, represented by categories 1 and 2. This degree of lameness did not constitute sufficient lameness to warrant treatment or culling of the affected animal, and was observed to resolve. The third category of lameness included scores of 3 and greater, which represented definite lameness that would have a direct welfare implication for the animal, and may have resulted in culling due to lameness. In this trial, most animals fell into the first category, receiving CL scores of zero, and were considered to display a sound gait. A smaller proportion were observed to be mildly lame, and were assessed CL scores of 1 or 2. A very small proportion of gilts (4%) received a CL score of 3, indicating severe lameness. Overall, the occurrence of lameness in this trial was considerably less than expected. The proportion of animals with high lameness scores was expected to reflect the culling rates of gilts and sows due to lameness. The average annual culling rate of gilts and sows due to lameness in Ontario in 1985 was 10%, ranging from 0-38% (Dewey et al. 1992). In the US, culling rates due to lameness were 6% for gilts in 1989-90 (Hill 1994). More recently (December 1999 through May 2000), the U.S. Department of Agriculture (USDA 2001) reported the current culling rate of breeding-age female pigs due to lameness at 16%. In the UK, 10.7% of all sows were culled due to lameness (Blowey 1994). In addition, 20% of first parity gilts were culled for lameness. Very low levels of lameness in this trial may have been due to characteristics of the Cotswold breed of pigs, to management factors or to other factors at the time of the study. The low level of lameness observed in this trial substantially reduced the ability of statistical tests to detect differences between housing treatments. The scoring system used was not designed to be sensitive enough to detect subtle differences between mild lameness consequently these were not tested.

In late gestation, significantly more gilts housed on straw were assessed gait scores greater than zero, compared to LS and SP gilts. However, the majority of non-zero scores seen in late gestation in S gilts were in score category 1 (94%). When reanalysis was performed using a zero category that was expanded to include scores of 0.5, no significant difference was found between housing systems. A gait score of 0.5 seen in late gestation may have represented minor alterations in gait that were a result of altered locomotion due to advanced pregnancy. A possible reason why this was seen more frequently in S housed gilts may be related to the subjectivity of the scoring system. With an increase in opportunity to exercise in S housing compared to SP and LS housing, and with the addition of straw bedding providing a more cushioned floor material, it is reasonable to assume that the gait of gilts housed on straw would be more fluid than gilts housed on concrete and in confinement (Day et al. 2002; Edwards 1998; Elliot and Doige 1973; Fritschen 1977; Marchant and Broom 1996b; Rollin 1995), and in fact this was observed. Against a background of animals with very smooth gait, any minor locomotory alterations might be more apparent. It is probable, and was observed, that gilts housed in LS and SP housing consistently exhibited a base level of stiffness that provided a background on which the minor gait changes due to pregnancy were not discerned.

4.6 CONCLUSION

Lameness of gilts in this experiment was mild, and most animals scoring higher than zero would not have been considered to be clinically lame. No differences in lameness were found between housing systems, however, the low levels of lameness observed made detection of differences unlikely.

5.0 GENERAL DISCUSSION

Three dry sow housing systems were studied in this trial: locked-stall, straw, and stall-pen, representing intensive commercial housing, straw housing, and a housing system corresponding to an intermediate between the two respectively. Three main differences were identified between housing systems: opportunity to exercise as a reflection of confinement, opportunity to interact socially as a result of group size, and provision of straw bedding. Opportunity for exercise and social interaction was highly restricted in LS housing, intermediate in SP housing and least constrained in S housing. S gilts were housed in deep-bedded straw in the second half of gestation, but otherwise gilts were housed on concrete. It was clear that these differences affected the behaviour and often the welfare of the gilts studied, however no differences in lameness were observed between housing systems.

Locomotion, an important component of exercise, increased from LS to SP to S housing while ventral recumbency was observed to decrease following the same pattern. It appeared that as the level of physical and social confinement increased, there was a shift in activity from locomotion to lying in ventral recumbency, leading to a decrease in exercise. Lack of exercise in confinement housing has been identified as a welfare concern, resulting in physical deconditioning of muscles, bone and cardiovascular fitness, and an increased susceptibility to lameness (Ewing et al. 1999; Marchant et al. 1997b; Marchant and Broom 1996a; Marchant and Broom 1996b).

The effects of confinement can also be seen in the increased time spent in ventral recumbency. It seems possible that ventral recumbency was an abnormal posture, indicating either an unwillingness or inability to assume one of the more normal postures of sternal or lateral recumbency. Confinement in gestation stalls has been shown to result in reduced muscle strength, causing the animals to experience difficulty when lying down or standing up (Marchant and Broom 1996a; Marchant and Broom 1996b). Thus the increased incidence of ventral lying may represent an inability of the gilt to easily manoeuver into more comfortable lying positions due to muscle and joint problems, although the mechanism underlying this effect was unclear.

Increased ventral lying may also represent a posture choice by the gilts. In gestation stalls, gilts may choose positions during resting that limit contact with adjacent animals. In ventral recumbency, the gilt's legs are tucked underneath the body, maximizing the space between themselves and neighbouring animals. Contact with neighbouring animals may be undesirable due to the physical risk of injury from being stepped on or bitten through the bars of the stall. Contact with adjacent animals may also be undesirable due to incompatibility of social rank or an inability to establish the rank of neighbouring gilts occurring when social interactions are limited as in locked-stall housing. Gilts housed individually have been shown to be unable to engage in a full range of social behaviours, particularly active avoidance behaviours, with neighbouring animals (Broom et al. 1995; Jensen 1984). This negatively affects the formation of a stable social hierarchy (Barnett et al. 1987; Broom et al. 1995). Animals unable to establish a stable social structure through physical interaction with pen-mates are more likely to have unresolved aggression and suffer from stress as a result (Barnett et al. 1987; Broom et al. 1995). The fact that SP-housed gilts displayed an intermediate level of ventral recumbency may indicate that the limited space available compared to S-housed gilts had a negative effect on the development of a stable social hierarchy, however, not as severe an effect as on the LS-housed gilts. Broom et al. (1995) observed that sows in small groups had a greater proportion of unresolved agonistic encounters compared to sows housed in a large pen, and may have experienced frustration as a result of this. It is important to note that although Broom et al. found the agonistic encounters to be reduced, the intensity of the aggression that was noted was considerably more severe in the larger groups. Incompatibility of social rank was more likely to influence frequency of ventral lying compared to risk of injury as gilts in all housing treatments were at a similar risk for physical injury, and gilts in this study were small enough to prevent their feet from protruding into the adjacent stall.

The frequency of abnormal behaviour was significantly greater in LS housing compared to SP and S-housed gilts. Hsia et al. (1991) reported similar findings in which the level of abnormal chewing behaviours in stall-housed sows was four times as high as in sows housed in groups. Due to the scan sampling technique used in this trial it was unlikely that the absolute percentage of abnormal behaviours observed represents all the abnormal behaviour present. However, it is likely that the trend reported was accurate, given the supporting findings of other trials. Hsia et al. (1991) continuously observed sows for 24 hours and found that abnormal behaviours in stall-housed sows occupied 161.7 minutes out of 24 hours observed, or 11% of the sows' day, compared with group-housed sows, where only 3% of the day was spent in abnormal behaviours. Abnormal behaviour has been reported to develop as a result of a specific inadequacy in the environment of the animal, such as lack of foraging opportunities, insufficient feed, barren environment and confinement, leading to physical restriction of movement, lack of exercise, limited ability to explore and social isolation (Broom 1983; Broom 1987; Broom et al. 1995; Cronin et al.

1984; Cronin and Wiepkema 1984; Ewing et al. 1999; Hsia et al. 1991; Vieuille-Thomas et al. 1995). All of these factors were present to some degree in all housing treatments, however the levels experienced by LS gilts were greater compared to S and SP gilts. S housing provided the greatest opportunity to exercise, explore, forage and socially interact with or avoid pen mates. Gilts in SP housing may have experienced an intermediate level of restriction leading to an intermediate level of abnormal behaviour. It is widely agreed upon in the literature that performance of abnormal behaviours is a sign of compromised welfare (Broom 1987; Broom 1991; Ewing et al. 1999; Tarrant 1984).

Polydipsia is considered to be an abnormal behaviour (Ewing et al. 1999), more common in confined sows than sows on straw or in groups (Broom et al. 1995; Whittaker et al. 1999a). Although the level of drinking observed in this experiment tended to be higher in confinement housing compared to S housing, drinking was highest in SP gilts. While gilts in SP housing in this trial had the greatest access to water, both in stalls and in the pen area, and drinker placement may facilitate development of excessive drinking (Spoolder et al. 1995), it seems unlikely that additional drinkers in the pen area would result in the production of abnormal behaviour. However, as excessive drinking or playing with the drinkers has been identified as an aberrant behaviour (Ewing et al. 1999) and more specifically as a stereotypy (Broom and Potter 1984; Rushen 1984a; Spoolder et al. 1995) it was considered to be a sign of reduced welfare in the SP and LS gilts.

In early gestation, increasing confinement was associated with greater time spent standing idle, with LS gilts spending the most time, SP gilts spending an intermediate amount of time, and S gilts spending the least time standing idle. Idle behaviour can be considered a result of an inadequate environment (Cronin et al. 1984), possibly due to reduced opportunity for other activities. LS housing provides the least opportunity for exercise, social interaction, and exploration, making it the most barren of the three systems, which is consistent with this hypothesis.

As pregnancy progressed, there was a tendency in late gestation for gilts assigned to S housing to spend less time resting (10.6% less) and more time nosing at the pen and straw (11.9% more) than gilts in housing without straw. Given the opportunity, gilts with access to straw exchanged resting time for time spent nosing in the straw. This shift can be theorized to result from a number of environmental differences. Nosing at the pen and pen environment is a behaviour that is strongly dependant on external stimuli (i.e. the presence of the straw), and in the absence of straw the behaviour may not be seen as frequently (Dawkins 1988). This is consistent with the findings in this trial, where the frequency of resting was exchanged for nosing in S gilts, and no difference was found in housing systems without straw.

Straw may act as a preferred substrate on which the sow expresses increased foraging behaviours (Dailey and McGlone 1997). In barren environments such behaviours can only be directed to less favourable substrates such as conspecifics and pen components, including feeders, drinker nozzles, bars, and concrete floors (Rollin 1995; Spoolder et al. 1995). Increased time spent nosing in S housing may also be due to an overall increase in activity, although analysis of activity in this study found no difference in the performance of active behaviours or postures. Provision of straw or bedding material such as wood shavings has been shown to directly and substantially increase the level of activity observed in pigs (Morgan et al. 1998; Whittaker et al. 1999b), with most of the active time spent manipulating the straw (Spoolder et al. 1995). Space allowance may have been a factor in the increased time spent nosing at the pen in S housing, compared to LS or SP housing. The greatest floor space available per gilts was found in straw housing with an average of $2.44m^2$ per gilt. A slightly lower floor space per gilt was seen in SP housing at $2.3m^2$ per gilt, although this is still exceeds the recommended space allowance of $1.63m^2$ per gilt as stated in the RCOP (Connor 1993). The least amount of floor space was present in LS housing, with on y $1.153m^2$ available per gilt, considerably less than the recommended amount. Weng et al. (1998) found that rooting progressively increased with increasing pen size, while inactive sitting and standing both decreased. Similar results were found in this trial, with sows housed in large straw pens spending the least time in inactive behaviours compared with sows with less available floor space as in LS housing. However, as levels of resting and nosing at the pen did not differ between LS and SP housing despite the large difference in available floor space, it is unlikely that provision of space is the only or main causative factor influencing the increased activity observed in S gilts. As sows approach the end of their pregnancy, they begin to express behaviours associated with preparation for farrowing such as nest building. This may have influenced the increase in pen nosing in S gilts. Provision of straw was found to be associated with an increase in the occurrence of pre-partum nesting-like behaviours compared to sows housed without straw (Cronin et al. 1994). Although Cronin et al. (1994) found that nesting behaviour increased substantially 24-hours prior to parturition, some form of nest-building behaviour may be present earlier as well.

SP gilts spent the greatest proportion of resting time lying in lateral recumbency when compared to LS and S gilts. In the afternoon, although no difference in total resting existed between gilts in different housing types, S gilts spent more time lying in lateral recumbency than gilts in LS and SP housing. Other studies have found similar results, with pre-parturient gilts in stalls reported to spend less time lying in lateral recumbency than gilts on straw (Cronin et al. 1994; Vestergaard and Hansen 1984). Lying posture may be related to level of comfort, and lateral recumbency is also associated with deep sleep (Ruckebusch 1969). Since S and SP gilts performed a higher level of lateral lying than LS gilts, it was inferred that gilts in those housing treatments were able to engage in deep sleeping more often, and may have experienced a higher level of comfort and welfare, than LS gilts.

Differences in inactive behaviour and postures were noted in late gestation, with SP and LS gilts exhibiting more inactive behaviour than gilts housed on straw. Barnett et al. (1985) also found that inactivity, consisting of sitting and standing, was greater in stalls compared with group housing systems. It has been suggested that prolonged confinement results in excessive inactivity, representing an abnormal behaviour (Zanella et al. 1996), and thus indicating a reduced level of welfare.

These behavioural changes indicate a consistent pattern in which LS gilts performed significantly different levels of behaviours and postures than S gilts. SP gilts were observed to be intermediate. The housing characteristics; group size, social interaction and possibility of exercise, reflect the same relationship demonstrated between LS, SP and S gilts, and are therefore likely to be implicated in influencing this pattern. In LS housing, gilts traded time in lateral recumbency for time in ventral recumbency and generally stood idle more in early gestation, and rested more in late gestation, with a concomitant reduction in locomotion. Abnormal behaviour was more common in LS gilts. In general, LS gilts exhibited more inactive postures and behaviours. S-housed gilts spent more time locomoting, nosing at the pen environment and lying in lateral recumbency. In general, S gilts performed less inactive postures and behaviours.

The results of this trial consistently indicate that the welfare of gilts housed in gestation crates was reduced, compared to gilts housed on straw, with the welfare of SP gilts at an intermediate level. Reduced locomotion, as seen in LS gilts, was suggestive of compromised welfare in those animals as a consequence of reduced exercise. Abnormal behaviours, a clear indication of compromised welfare, were performed more frequently in LS housing compared with SP and S-housed gilts. Time spent standing idle, considered to be a consequence of an inadequate environment, decreased from LS to SP to S gilts, indicating that the welfare of LS-housed gilts may be reduced compared to SP and S gilts. Gilts on straw and in SP housing rested in lateral recumbency most often, a sign of deep sleep, compared to LS gilts. This suggests that S and SP gilts experienced a higher level of welfare than LS gilts. Inactive behaviour, a result of prolonged confinement, seen more frequently in LS and SP gilts than S gilts, indicated a level of reduced welfare for gilts in LS and SP housing. Ventral resting in this study also appeared to be an indicator of reduced welfare due to its relationship with characteristics of LS housing, such as reduced exercise, risk of injury and unstable social structure.

Gilts on straw spent significantly less time resting and more time nosing at the straw than gilts housed without straw. Provision of straw, as in other studies, was found to reduce abnormal behaviours, signifying improved welfare of S gilts compared to LS gilts.

As gilts progressed in their pregnancy, behavioural changes were observed that were attributed to advancing pregnancy. Decreases in standing, interacting, active postures and behaviours, and increases in ventral recumbency, sitting, sitting idle, and inactive postures and behaviours indicate an overall trend for decreasing activity with advancing pregnancy.

Assessing lameness is important in both clinical and applied settings. Rapid diagnosis of lameness is important for treatment. Early identification of animals with locomotory problems is also essential to reduce culling of bred gilts and sows. Animals showing signs of lameness should be considered to be experiencing some degree of pain or discomfort (Hill 1994). As such, an animal experiencing lameness can be said to have reduced welfare.

Lameness observed in this trial could be divided into three categories. The first was represented by the zero lameness category, indicating that the animal was sound. The second was mild lameness, represented by categories 1 and 2. This degree of lameness did not signify sufficient lameness to warrant treatment or culling of the affected animal, and was observed to resolve. The third category of lameness included scores of 3 and greater, which represented severe lameness that would have a direct welfare implication for the animal, and may have resulted in culling due to lameness. In this trial, most animals fell into the first category, receiving CL scores of zero, and were considered to display a sound gait. A smaller proportion were observed to be mildly lame, and were assessed CL scores of 1 or 2. A very small proportion of gilts (4%) received a CL score of 3, indicating severe lameness. Overall, the occurrence of lameness in this trial was considerably less than expected. The proportion of animals with high lameness scores was expected to reflect the culling rates of gilts and sows due to lameness. The average annual culling rate of gilts and sows due to lameness in Ontario in 1985 was 10%, ranging from 0-38% (Dewey et al. 1992). In the US, culling rates due to lameness were 6% for gilts in 1989-90 (Hill 1994). More recently

(December 1999 through May 2000), the U.S. Department of Agriculture (USDA 2001) reported the current culling rate of breeding-age female pigs due to lameness at 16%. In the UK, 10.7% of all sows were culled due to lameness (Blowey 1994). In addition, 20% of first parity gilts were culled for lameness. Very low levels of lameness in this trial may have been due to characteristics of the Cotswold breed of pigs, to management factors or to other factors at the time of the study, such as age of the animal or duration in treatment housing. The low level of lameness observed in this trial substantially reduced the ability of statistical tests to detect differences between housing treatments. The scoring system used was not designed to be sensitive enough to detect subtle differences between mild lameness, consequently these were not tested.

In late gestation, significantly more gilts housed on straw were assessed gait scores greater than zero, compared to LS and SP gilts. However, the majority of non-zero scores seen in late gestation in S gilts were in score category 1 (94%). When reanalysis was performed using a zero category that was expanded to include scores of 0.5, no significant difference was found between housing systems. A gait score of 0.5 seen in late gestation may represent minor alterations in gait that were a result of altered locomotion due to advanced pregnancy. A possible reason why this was seen more frequently in S housed gilts may be related to the subjectivity of the scoring system. With an increase in opportunity to exercise in S housing compared to SP and LS housing, and with the addition of straw bedding providing a more cushioned floor material, it is reasonable to assume that the gait of gilts housed on straw would be more fluid than gilts housed on concrete and in confinement(Day et al. 2002; Edwards 1998; Elliot and Doige 1973; Fritschen 1977; Marchant and Broom 1996b; Rollin 1995). Against a background of animals with very smooth gait, any minor locomotory alterations might be more apparent. It is probable that gilts housed in LS and SP housing consistently exhibited a base level of stiffness that provided a background on which the minor gait changes due to pregnancy were not discerned.

Behavioural differences observed in gilts housed in three dry-sow housing systems indicate that reduced opportunity for exercise and other aspects of confinement have a negative effect on the welfare of gestating gilts. However the incidence and severity of lameness in these gilts was extremely low, and as a result no differences in lameness were observed between these housing systems.

6.0 GENERAL CONCLUSION

Behaviour varied between LS and S gilts, with SP gilts occupying an intermediate position. Locomotion, nosing at the straw and lateral recumbency were observed to increase as space and the opportunity for social contact increased. Ventral recumbency, abnormal behaviours, time spent idle, resting and inactive behaviours were observed more frequently as the level of social and physical confinement increased. These are consistent with reduced welfare in LS housing, with some improvement in SP housing, although S housing was considered to have the highest level of welfare. Behavioural differences were apparent as gestation advanced, and were attributed to an overall decrease in activity. Lameness of gilts in this experiment was mild, and most animals showing signs of lameness would not have been considered to be clinically lame. No differences in lameness were found between housing systems, however, the low levels of lameness observed made detection of differences unlikely. SP housing provided an alternative to LS housing, however, the level of welfare experienced by the gilts was not as high as in S housing.

7.0 REFERENCES

Anonymous, 2003. Pen protest. Winnipeg Free Press, Winnipeg, pp. A9.

Anil, L., Sukumarannair, S., Anil, S., and Deen, J., 2002. Relationship between postural behaviour and gestation stall dimensions in relation to sow size. Applied Animal Behaviour Science 77, 173-181.

Associated Press, 2004. Austria adopts anti-cruelty animal law. Winnipeg Free Press, pp. A9.

Ban Cruel Farms.org 2002. The Florida animal cruelty act. http://www.bancruelfarms.org/act_text.htm (accessed 5-6-2003).

Barnett, J. L., Cronin, G. M., Hemsworth, P. H., and Winfield, C. G., 1984. The welfare of confined sows: physiological, behavioural and production responses to contrasting housing systemts and handler attitudes. Annales de Recherches Vétérinaires 15, 217-226.

Barnett, J. L., Hemsworth, P. H., and Cronin, G. M., 1993. Does intensive pig farming have a viable future?--Concerns over housing and welfare. Proceedings of the New Zealand society of animal production, pp. 219-221.

Barnett, J. L., Hemsworth, P. H., Winfield, C. G., and Fahy, V. A., 1987. The effects of pregnancy and parity number on behavioural and physiological responses related to the welfare status of individual and group-housed pigs. Applied Animal Behaviour Science 17, 229-243.

Barnett, J. L., Winfield, C. G., Cronin, G. M., Hemsworth, P. H., and Dewar, A. M., 1985. The effect of individual and group housing on behavioural and physiological responses related to the welfare of pregnant pigs. Applied Animal Behaviour Science 14, 149-161.

Bartussek, H., 1999. A review of the animal needs index (ANI) for the assessment of animals' well-being in the housing systems for Austrian proprietary products and legislation. Livestock Production Science 61, 179-192.

Baxter, M. R. and Schwaller, C. E., 1983. Space requirements for sows in confinement. Current Topics in Veterinary Medicine and Animal Science 24, 181-195.

Blowey, R. W., 1994. Trochanter fracture and patellar osteochondrosis as causes of lameness in pigs. Veterinary Record 134, 601-603.

Boyle, L. A., Leonard, F. C., Lynch, P. B., and Brophy, P., 2002. Effect of gestation housing on behaviour and skin lesions of sows in farrowing crates. Applied Animal Behaviour Science 76, 119-134.

Bracke, M. B. M., Metz, J. H. M., Dijkhuizen, A. A., and Spruijt, B. M., 2001. Development of a decision support system for addressing farm animal welfare in relation to husbandry systems: strategy and prototype. Journal of Agricultural and Environmental Ethics 14, 321-327.

Bradshaw, R. H, Skyrme, J., Brenninkmeijer, E. E., and Broom, D. M, 1999. Consistency of measurement of social status in dry-sows group-housed in indoor and outdoor systems. Animal Welfare 9, 75-79.

Brennan, J. J. and Aherne, F. X., 1986. Effect of dietary calcium and phosphorus levels on performance, bone bending moment and the severity of osteochondrosis and lameness in boars and gilts slaughtered at 100 or 130 kg body weight. Canadian Journal of Animal Science 66, 777-790.

Broom, D. M, 1983. Stereotypies as animal welfare indicators. Current Topics in Veterinary Medicine and Animal Science 81-87.

Broom, D. M, 1987. The veterinary relevance of farm animal ethology. Veterinary Record 121, 400-402.

Broom, D. M, 1989. Overview of British animal welfare legislation. In: Blackman, D. E., Humphreys, P. N., and Todd, P. (Eds.), Animal welfare and the law, Cambridge University Press, New York, pp. 271-280.

Broom, D. M, 1991. Animal welfare: concepts and measurement. Journal of Animal Science 69, 4167-4175.

Broom, D. M, 1997. Welfare evaluation. Applied Animal Behaviour Science 54, 21-23.

Broom, D. M, 1998. Psychological indicators of stress and welfare. In: Ethics, welfare, law and market forces: the veterinary interface. Proceedings of a symposium organised on behalf of the Royal College of Veterinary Surgeons, Wheathampstead, pp. 167-175.

Broom, D. M, Mendl, M. T., and Zanella, A. J, 1995. A comparison of the welfare of sows in different housing conditions. Animal Science 61, 369-385.

Broom, D. M and Potter, M. J., 1984. Factors affecting the occurrence of stereotypies in stall-housed dry sows. In: Unshelm, J., van Putten, G., and Zeeb, K. Proceedings of the international congress on applied ethology in farm animals, Kiel, pp. 229-231.

Buckner, L. J., Edwards, S. A., and Bruce, J. M., 1998. Behaviour and shelter use by outdoor sows. Applied Animal Behaviour Science 57, 69-80.

Canadian Council on Animal Care, 1993. Guide to care and use of experimental animals. Olfert, E. D., Cross, B. M., and McWilliam, A. A. (Eds.), Canadian Council on Animal Care, Ottawa, pp.

Connor, L., 1993. Recommended code of practice for the care and handling of farm animals: pigs. Agriculture and Agri-Food Canada Communications Branch, Publication number 1898/E, Ottawa, ON.

Connor, L., 2004. Personal communication regarding the current Canadian price of replacement breeding stock for swine, 8/26/2004.

Cronin, G. M., Smith, J. A., Hodge, F. M., and Hemsworth, P. H., 1994. The behaviour of primiparous sows around farrowing in response to restraint and straw bedding. Applied Animal Behaviour Science 39, 269-280.

Cronin, G. M. and Wiepkema, P. R., 1984. An analysis of stereotyped behaviour in tethered sows. Annales de Recherches Vétérinaires 15, 263-270.

Cronin, G. M., Wiepkema, P. R., and Hofstede, G. J., 1984. The development of stereotypies in tethered sows. Proceedings of the International Congress on Applied Ethology in Farm Animal, Kiel, pp. 97-100.

Dailey, J. W. and McGlone, J. J., 1997. Oral/nasal/facial and other behaviors of sows kept individually outdoors on pasture, soil or indoors in gestation crates. Applied Animal Behaviour Science 52, 25-43.

Dantzer, R., 1986. Behavioural, physiological and functional aspects of stereotyped behavior: a review and a re-interpretation. Journal of Animal Science 62, 1776-1786.

Dawkins, M. S., 1988. Behavioural deprivation: a central problem in animal welfare. Applied Animal Behaviour Science 20, 209-225.

Day, J. E. L, Kyriazakis, I., and Lawrence, A. B., 1996. An investigation into the causation of chewing behaviour in growing pigs: the role of exploration and feeding motivation. Applied Animal Behaviour Science 48, 47-59.

Day, J. E. L., Burfoot, A., Docking, C. M., Whittaker, X., Spoolder, H. A. M., and Edwards, S. A., 2002. The effects of prior experience of straw and the level of straw provision on the behaviour of growing pigs. Applied Animal Behaviour Science 76, 189-202.

de Koning, R., 1984. Injuries in confined sows. Incidence and relation with behaviour. Annales de Recherches Vétérinaires 15, 205-214.

De Leeuw, J. A. and Ekkel, E. D., 2004. Effects of feeding level and the presence of a foraging substrate on the behaviour and stress physiology response of individually housed gilts. Applied Animal Behaviour Science 86, 15-25.

den Hartog, L. A., Backus, G. B. C., and Vermeer, H. M., 1993. Evaluation of housing systems for sows. Journal of Animal Science 71, 1339-1344.

Department for Environment Food and Rural Affairs 2002. Welfare of pigs. http://www.defra.gov.uk/animalh/welfare/farmed/pigs/ (accessed 19-12-2002).

Dewey, C. E., Friendship, R. M., and Wilson, M. R., 1992. Lameness in breeding age swine--a case study. Canadian Veterinary Journal 33, 747-748.

Dewey, C. E., Friendship, R. M., and Wilson, M. R., 1993. Clinical and postmortem examination of sows culled for lameness. Canadian Veterinary Journal 34, 555-556.

Edwards, S., 1998. Housing the breeding sow. In Practice 339-343.

Edwards, S. A. and Turner, S. P., 2000. Housing and management of pigs in large social groups. The Pig Journal 45, 45-54.

Elliot, J. I. and Doige, C. E., 1973. Effects of type of confinement on performance and on the occurrence of locomotory disturbances in market pigs. Canadian Journal of Animal Science 53, 211-217.

Ewing, S. A., Lay, D. C. Jr., and Rollin, B. E, 1999. Farm animal well-being: stress physiology, animal behavior, environmental design. Prentice Hall, Upper Saddle River, New Jersey, pp. 333.

Farmed Animal Watch 2002. Gestation crate ban passes. http://www.farmedanimal.net/Newsletters/Newsletter92.htm (accessed 5-6-2003).

Fraser, A. F. and Broom, D. M, 1990. Farm animal behaviour and welfare. Bailliere Tindall, London, pp. 437.

Friendship, R. M., Wilson, M. R., Almond, G. W., McMillan, I., Hacker, R. R., Pieper, R., and Swaminathan, S. S., 1986. Sow wastage reasons for and effect on productivity. Canadian Journal of Veterinary Research 50, 205-208.

Fritschen, R. D., 1977. Housing and its effects on feet and leg problems. Proceedings of the Ontario Pork Congress, pp. 26-34.

Government of Manitoba 1996. The animal care act: chapter A84 of the continuing consolidation of the statutes of Manitoba. http://web2.gov.mb.ca/laws/statutes/ccsm/a084e.php (accessed 5-6-2003).

Government of Manitoba 2003. Regulations and approval processes: Manitoba regulations and guidelines. http://www.gov.mb.ca/agriculture/news/lsteward/stewardship7.html#Animal%20Care%20Act (accessed 5-6-2003).

Government of Ontario 2002. Ontario Ministry of Agriculture and Food: animal welfare legislation and regulations. http://www.gov.on.ca/OMAFRA/english/livestock/animalcare/anwellegreg.htm (accessed 5-6-2003).

Grimes, S. H. and Kelsey, S. L. 2001. In the supreme court of Florida, case no. SC 01-1367, advisory opinion to the Attorney General, re: limiting cruel and inhumane confinement of pigs during pregnancy. http://www.law.fsu.edu/library/flsupct/sc01-1367/01-1367ini.pdf (accessed 6-5-2003).

Grondalen, T., 1974a. Leg weakness in pigs. I. Incidence and relationship to skeletal lesions, feed level, protein and mineral supply, exercise and exterior conformation. Acta Veterinaria Scandinavica 15, 555-573.

Grondalen, T., 1974b. Osteochondrosis and arthrosis in pigs. I. Incidence in animals up to 120 kg live weight. Acta Veterinaria Scandinavica 15, 1-25.

Grondalen, T., 1974c. Osteochondrosis, arthrosis and leg weakness in pigs. Nord.Vet.-Med. 26, 534-537.

Grondalen, T., 1977. Viewpoints on the porcine leg weakness syndrome. Proceedings of the International Conference on Production disease in farm animals, pp. 214-218.

Grondalen, T., 1979a. Osteochondrosis, arthrosis and leg weakness in pigs. The American Landrace July, 34-37.

Grondalen, T., 1979b. The role of the muscle in the porcine leg weakness syndrome. Acta Agriculturae Scandinavica Supplementum 21, 482-485.

Heymer, A., 1977. Ethological Dictionary. Garland Publishing, Inc., New York.

Hill, M. A., 1994. Skeletal system and feet. In: Leman, A. D., Straw, B. E., Mengeling, W. L., D'Allaire, S., and Taylor, D. J. (Eds.), Diseases of swine, Iowa State University Press, Ames, Iowa, pp. 163-178.

Hogg, R., Ross, R. F., and Cox, D. F., 1975. Joint changes in lameness of confined swine. American Journal of Veterinary Research 36, 965-976.

Hsia, L. C, Weng, R. C., Chen, C. H., Wang, C. P., and Li, Y. L, 1991. The effect of pen design and feeding level on dry sow behaviour. Journal of the Chinese Society of Animal Science 20, 443-454.

Jensen, P., 1984. Effects of confinement on social interaction patterns in dry sows. Applied Animal Behaviour Science 12, 93-101.

Larsson, T., Aspden, R. M., and Heinegard, D., 1991. Effects of mechanical load on cartilage matrix biosynthesis in-vitro. Matrix 11, 388-394.

Lewis, N. J., 1999. Frustration of goal-directed behaviour in swine. Applied Animal Behaviour Science 64, 19-29.

LSU AgCentre 2003. Animal industry news update. http://www.louisianalivestock.org/pdf%20files/Newsletters/AnimalScienceNovember2002.pdf (accessed 6-5-2003).

Main, D. C. J., Clegg, J., Spatz, A., and Green, L. E., 2000. Repeatability of a lameness scoring system for finishing pigs. Veterinary Record 147, 574-576.

Manitoba Pork Council 2002. How pigs are raised. http://www.manitobapork.com/pdf/pigsraised.pdf (accessed 19-12-2002).

Marchant, J. N. and Broom, D. M, 1996a. Effects of dry sow housing conditions on muscle weight and bone strength. Animal Science 62, 105-113.

Marchant, J. N. and Broom, D. M, 1996b. Factors affecting posture-changing in loose-housed and confined gestating sows. Animal Science 63, 487-485.

Marchant, J. N., Rudd, A. R., and Broom, D. M, 1997a. The effects of housing on heart rate of gestating sows during specific behaviours. Applied Animal Behaviour Science 55, 67-78.

Marchant, J. N., Rudd, A. R., and Broom, D. M, 1997b. The effects of housing on heart rate of gestating sows during specific behaviours. Applied Animal Behaviour Science 55, 67-78.

McBride, G., 1980. Adaptation and welfare at the man-animal interface. In: Wodzicka-Tomaszewska, M., Edey, T. N., and Lynch, J. J. (Eds.), Behaviour in relation to reproduction, management and welfare of farm animals, University of New England, Armidale, pp. 195-198.

McCaw, M. and Mitten, R., 1980. Osteochondrosis or leg weakness syndrome in swine. Iowa State Veterinarian 10-12.

McGlone, J., 2001. Alternative sow housing systems: driven by legislation, regulation, free trade and free market systems (but not science). In: Seddon, I. Proceedings of the Manitoba Swine Seminar, Winnipeg, MB, pp. 43-53.

Morgan, C. A., Deans, L. A., Lawrence, A. B., and Nielsen, B. L., 1998. The effects of straw bedding on the feeding and social behaviour of growing pigs fed by means of single-space feeders. Applied Animal Behaviour Science 58, 23-33.

Mouttotou, N., Hatchell, F. M., and Green, L. E., 1999. Foot lesions in finishing pigs and their associations with the type of floor. Veterinary Record 144, 629-632.

Nakano, T. and Aherne, F. X., 1993. Articular cartilage lesions in female breeding swine. Canadian Journal of Animal Science 73, 1005-1008.

Nakano, T., Aherne, F. X., Brennan, J. J., and Thompson, J. R., 1984. Effect of growth rate on the incidence of osteochondrosis in growing swine. Canadian Journal of Animal Science 64, 139-146.

Nakano, T., Aherne, F. X., and Thompson, J. R., 1981a. Effect of housing system on the recovery of boars from leg weakness. Canadian Journal of Animal Science 61, 335-342.

Nakano, T., Aherne, F. X., and Thompson, J. R., 1979. Changes in swine knee articular cartilage during growth. Canadian Journal of Animal Science 59, 167-179.

Nakano, T., Aherne, F. X., and Thompson, J. R., 1981b. Mineralization of normal and osteochondrotic bone in swine. Canadian Journal of Animal Science 61, 343-348.

Nakano, T., Brennan, J. J., and Aherne, F. X., 1987. Leg weakness and osteochondrosis in swine: a review. Canadian Journal of Animal Science 67, 883-901.

National Pork Producers Council 2002. Today's U.S. pork industry. http://www.nppc.org/about/pork_today.html) (accessed 19-12-2002).

National Research Council, 1998. Nutrient requirements of swine. National Academy Press, Washington, pp.

Patience, J. F., Thacker, P. A, and de Lange, C. F. M., 1995. Swine Nutrition Guide. Prairie Swine Centre Inc., Saskatoon.

Pointillart, A. and Gueguen, L., 1978. Ostéochondrose et faiblesse des pattes chez le porc. Ann.Biol.anim.Bioch.Biophys. 18, 201-210.

Ratcliffe, H. L., Luginbuhl, H., Schnarr, W. R., and Chacko, K., 1969b. Coronary arteriosclerosis in swine: evidence of a relation to behavior. Journal of Comparative Physiology and Psychology 68, 385-392.

Reiland, S., 1976. Osteochondrosis in swine. Morphologic and experimental studies. International Pig Veterinary Society; Proceedings of the International Congress, pp. Q.2.

Rollin, B. E 1995. Farm animal welfare: social, bioethical, and research issues. In. Iowa State University Press, Ames, Iowa.

Ruckebusch, Y., 1969. Sur les alternances veille-sommeil et certaines particualrités hépato-digestives du porc. Revue de Médecine Vétérinaire 32, 713-735.

Ruckebusch, Y., 1972. The relevance of drowsiness in the circadian cycle of farm animals. Animal Behaviour 20, 637-643.

Rushen, J., 1984b. Stereotyped behaviour, adjunctive drinking and the feeding periods of tethered sows. Animal Behaviour 32, 1059-1067.

Rushen, J., 1984a. Stereotyped behaviour, adjunctive drinking and the feeding periods of tethered sows. Animal Behaviour 32, 1059-1067.

Rushen, J., de Passille, A. M. B., and Schouten, W., 1990. Stereotypic behavior, endogenous opioids, and postfeeding hypoalgesia in pigs. Physiology & Behaviour 48, 91-96.

SAS Institute Inc., 1988. SAS/STAT® User's Guide. SAS Institute Inc., Cary, NC, pp. 1028.

Spoolder, H. A. M., Burbridge, J. A., Edwards, S. A., Simmins, P. H., and Lawrence, A. B., 1995. Provision of straw as a foraging substrate reduces the development of excessive chain and bar manipulation in food restricted sows. Applied Animal Behaviour Science 43, 249-262.

Spooler, H. A. M., Burbridge, J. A., Edwards, S. A., Simmins, P. H., and Lawrence, A. B., 1995. Provision of straw as a foraging substrate reduces the development of excessive chain and bar manipulation in food restricted sows. Applied Animal Behaviour Science 43, 249-262.

Steel, R. G. D., Torrie, J. H., and Dickey, D. A., 1997. Principles and procedures of statistics: a biometric approach. WCB/McGraw-Hill, Boston.

Stolba, A., Baker, N., and Wood-Gush, D. G. M., 1983. The characterisation of stereotyped behaviour in stalled sows by informational redundancy. Behaviour 87, 157-182.

Stolba, A. and Wood-Gush, D. G. M., 1989. The behaviour of pigs in a semi-natural environment. Animal Production 48, 419-425.

Studnitz, M. and Jensen, K. H., 2002. Expression of rooting motivation in gilts following different lengths of deprivation. Applied Animal Behaviour Science 76, 203-213.

Tarrant, V., 1984. Second topic: Chairman's summary and concluding remarks. Annales de Recherches Vétérinaires. 15, 205-214.

Terlouw, E. M. C., Lawrence, A. B., and Illius, A. W., 1991. Relationship between agonistic behaviour and propensity to develop excessive drinking and chain manipulation in pigs. Physiology & Behaviour 50, 493-498.

The Winnipeg Humane Society, 2003. An exciting new choice!

Tschanz, B., 1987. Ethology and animal protection. In: Fölsch, D. W. and Nabholz, A. (Eds.), Ethical, Ethological and Legal Aspects of Intensive Farm Animal Management, Birkhäuser, Basel, pp. 41-47.

Tubbs, R. C., 1988. Lameness in sows: solving a preventable problem. Veterinary Medicine 610-616.

Tubbs, R. C. and Zulovich, J., 1995. Designing a swine facility: breeding, gestation, and farrowing areas. Veterinary Medicine 893-898.

USDA, 2001. Part I: Reference of swine health and management in the United States, 2000. http://www.aphis.usda.gov/vs/ceah/cahm/Swine/Swine2000/finalswoodes1.pdf (accessed 19-12-2002).

Vestergaard, K. and Hansen, L. L., 1984. Tethered versus loose sows: ethological observations and measures of productivity. I. Ethological observations during pregnancy and farrowing. Ann.Rech.Vèt. 15, 245-256.

Vieuille-Thomas, C., Le Pape, G., and Signoret, J. P., 1995. Stereotypies in pregnant sows: indication of influence of the housing system on the patterns expressed by the animals. Applied Animal Behaviour Science 44, 19-27.

Wasylyshen, D. 2001. Niche markets - natural pork. http://www.gov.mb.ca/agriculture/livestock/pork/swine/pdf/bab14s05.pdf (accessed 14-11-2003).

Webster, A. J. F., 1998. What use is science to animal welfare. Naturwissenschaften 85, 262-269.

Webster, A. J. F., 2001. Farm animal welfare: the five freedoms and the free market. The Veterinary Journal 161, 229-237.

Wechsler, B., Fröhlich, E., Oester, H., Oswald, T., Troxler, J., Weber, R., and Schmid, H., 1997. The contribution of applied ethology in judging animal welfare in farm animal housing systems. Applied Animal Behaviour Science 53, 33-43.

Weng, R. C., Edwards, S. A., and English, P. R., 1998. Behaviour, social interactions and lesion scores of group-housed sows in relation to floor space allowance. Applied Animal Behaviour Science 59, 307-316.

White, M., 1994. Joint diseases in the pig. In Practice 16, 37-40.

Whittaker, X., Edwards, S. A., Spoolder, H. A. M., Lawrence, A. B., and Corning, S., 1999a. Effects of straw bedding and high fibre diets on the behaviour of floor fed group-housed sows. Applied Animal Behaviour Science 63, 25-39.

Whittaker, X., Edwards, S. A., Spoolder, H. A. M., Lawrence, A. B., and Corning, S., 1999b. Effects of straw bedding and high fibre diets on the behaviour of floor fed group-housed sows. Applied Animal Behaviour Science 63, 25-39.

Whittaker, X., Spoolder, H. A. M., Edwards, S. A., Lawrence, A. B., and Corning, S., 1998. The influence of dietary fibre and the provision of straw on the development of stereotypic behaviour in food restricted pregnant sows. Applied Animal Behaviour Science 61, 89-102.

Wiepkema, P. R., 1987. Behavioural aspects of stress. Current Topics in Veterinary Medicine and Animal Science 42, 113-133.

Wiepkema, P. R., Cronin, G. M., and van Ree, J. M., 1984. Stereotypies and endorphins: functional significance of developing stereotypies in tethered sows. Proceedings of the International Congress on Applied Ethology in Farm Animals, Kiel, pp. 93-96.

Yamasaki, K., Ikeda, Y., and Itakura, C., 1989. Bone lesions in pigs with locomotor dysfunction of hind legs. Journal of Comparative Pathology 100, 10-322.

Yamasaki, K. and Itakura, C., 1988. Bone lesions in clinically normal and in lame pigs. Journal of Comparative Pathology 98, 415-432.

Zanella, A. J, Broom, D. M, Hunter, J. C., and Mendl, M. T., 1996. Brain opioid receptors in relation to stereotypies, inactivity, and housing in sows. Physiology & Behaviour 59, 769-775.

8.0 APPENDIX

TABLE A1 Sliding scale of lameness scores used when averaging multiple observer scores of initial response (IR), standing posture (SP) and gait (G) of nulliparous gestating gilts

	Lameness scores					
Score category	0	1	2	3	4	5
Averaged scores	0	0.1-1.49	1.5-2.49	2.5-3.49	3.5-4.49	4.5-5

TABLE A2 Sliding scale of lameness scores used when averaging multiple observer scores for initial response (IR), standing posture (SP) and gait (G) of nulliparous gestating gilts, added to form a combined lameness score (CLS)

	Lameness scores					
Score category	0	1	2	3	4	5
Averaged scores	0	0.1-3.49	3.5-6.49	6.5-9.49	9.5-12.49	12.5-15

TABLE A3 The *F*-value and significant variables representing time spent in a particular posture by 61 gestating gilts in three housing treatments (locked-stall [LS], stall-pen [SP] and straw [S]), in early and late gestation, and in the morning (AM) and afternoon (PM)

Source	Locomotion	Sitting	Standing	Ventral lying	Lateral lying	Sternal lying
Treatment (T)	15.85**	0.48 NS	0.36 NS	8.55**	1.03 NS	2.41 NS
Gestation period (G)	2.19 NS	24.27**	4.45*	8.54**	2.89 NS	0.10 NS
T * G	0.92 NS	1.13 NS	1.59 NS	0.30 NS	1.98 NS	0.12 NS
Time of day (H)	0.13 NS	5.71*	6.26*	0.14 NS	11.84**	0.10 NS
T * H	0.70 NS	1.16 NS	1.92 NS	0.14 NS	11.22**	1.29 NS
G * H	0.41 NS	2.15 NS	4.44*	1.63 NS	15.93**	0.00 NS
Transformed mean	0.18	0.14	0.52	0.15	0.56	0.58
Residual standard deviation	0.07	0.07	0.08	0.07	0.12	0.08

NS: statistically not significant ($p > 0.05$)
** $p < 0.01$
* $p < 0.05$

TABLE A4 The *F*- value and significant variables representing time spent engaging in a particular activity by 61 gestating gilts in three housing treatments (locked-stall [LS], stall-pen [SP] and straw [S]), in early and late gestation, and in the morning (AM) and afternoon (PM)

Source	Behavioural activity								
	Feeding	Drinking	Resting	Fighting	Interacting	Sitting idle	Standing idle	Nosing pen	Stereotypies
Treatment (T)	180.77**	3.66*	1.52 NS	0.23 NS	2.10 NS	0.07 NS	1.32 NS	5.83**	6.65**
Gestation period (G)	219.33**	1.52 NS	0.03 NS	2.01 NS	11.92**	29.03**	3.09 NS	0.19 NS	0.05 NS
T * G	212.80**	3.10 NS	4.11 *	0.10 NS	2.41 NS	2.83 NS	4.14*	7.59**	1.12 NS
Time of day (H)	46.49**	0.19 NS	14.18**	0.17 NS	0.16 NS	6.48 *	2.19 NS	0.16 NS	0.02 NS
T * H	5.72**	0.81 NS	9.30**	1.60 NS	0.20 NS	1.77 NS	0.83 NS	1.88 NS	0.15 NS
G * H	0.07 NS	0.99 NS	13.16**	0.39 NS	0.09 NS	0.80 NS	11.23 **	0.60 NS	2.50 NS
Transformed mean	0.22	0.16	0.93	0.02	0.13	0.12	0.15	0.34	0.01
Residual standard deviation	0.03	0.09	0.10	0.04	0.07	0.07	0.08	0.07	0.04

NS: statistically not significant ($p > 0.05$)
** $p < 0.01$
* $p < 0.05$

TABLE A5 The percentage of time gestating gilts (n=61) spent in postures or behaviours in each of three housing treatments, locked-stall (LS), stall-pen (SP) and straw (S)

Behaviour (%)	Treatment LS (n=19)	SP (n=20)	S (n=22)	p
Posture				
Sternal recumbency	32.6	32.7	27.2	NS
Lateral recumbency	26.9	31.1	31.4	NS
Standing	27.5	24.6	25.1	NS
Locomoting	1.9^{a}	4.4^{b}	6.0^{b}	<0.01
Ventral recumbency	5.5^{b}	3.5^{ab}	2.2^{a}	<0.01
Sitting	4.3	2.6	3.2	NS
Behaviour				
Resting	64.0	67.1	60.5	NS
Nosing pen	11.3^{a}	9.4^{a}	17.7^{b}	<0.01
Drinking	3.5^{ab}	4.1^{b}	2.6^{a}	<0.05
Standing idle	4.0	3.2	2.8	NS
Sitting idle	2.9	2.4	2.7	NS
Interacting	3.0	2.8	2.1	NS
Stereotypies	0.7^{b}	0.1^{a}	<0.1^{a}	<0.01
Fighting	0.2	0.2	0.3	NS

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root) using Tukey's tests.

NS: statistically not significant (p > 0.05)

^{ab} Different superscripts indicate that the means across the row are significantly different using Bonferroni's test.

Behavioural data were collected on videotape and obtained during playback using scan sampling at 10-minute intervals from 0800 to 1700 hours. Mutually exclusive postures and mutually exclusive behaviours were collected simultaneously.

F-values, transformed means and residual standard deviations are reported in Appendix Tables A1 and A2 for postures and behaviours. Effect of housing treatment, gestational stage and time of day are shown.

TABLE A6 The effect of stage of gestation on percentage of time gestating gilts (n=61) engaged in postures and behaviours

Behaviour (%)	Gestation Early	Late	p
Posture			
Sternal recumbency	30.5	31.1	NS
Lateral recumbency	31.4	28.2	NS
Standing	27.4	24.1	<0.05
Locomoting	4.5	3.7	NS
Ventral recumbency	2.6	4.9	<0.01
Sitting	2.1	4.7	<0.01
Behaviour			
Resting	63.9	63.8	NS
Nosing pen	12.6	13.0	NS
Drinking	3.7	3.1	NS
Standing idle	3.8	2.8	NS
Sitting idle	1.5	3.8	<0.01
Interacting	3.2	2.1	<0.01
Stereotypies	0.4	0.2	NS
Fighting	0.3	0.1	NS

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root).

NS: statistically not significant ($p > 0.05$)

TABLE A7 The effect of time of day (morning and afternoon) on performance of postures and behaviours by gestating gilts (n=61)

	Time of day		
Behaviour (%)	AM	PM	p
Posture			
Sternal recumbency	31.0	30.6	NS
Lateral recumbency	27.6	32.0	<0.01
Standing	26.7	24.8	<0.05
Locomoting	4.3	3.9	NS
Ventral recumbency	3.7	3.8	NS
Sitting	3.1	3.7	<0.05
Behaviours			
Resting	61.6	66.0	<0.01
Nosing pen	12.6	12.9	NS
Drinking	3.6	3.2	NS
Standing idle	3.7	3.0	NS
Sitting idle	2.3	3.0	<0.01
Interacting	2.7	2.5	NS
Stereotypies	0.3	0.3	NS
Fighting	0.2	0.2	NS

Least square means for percentage data are shown, however means comparisons were carried out on transformed data (arc sin square root).

NS: statistically not significant ($p > 0.05$)

Behavioural data were collected on videotape and obtained during playback using scan sampling at 10-minute intervals from 0800 to 1700 hours. Mutually exclusive postures and mutually exclusive behaviours were collected simultaneously.

TABLE A8 Chi-squared values comparing zero and non-zero lameness scores (initial response (IR), standing posture (ST), gait (G), and combined lameness (CL) scores) of 73 nulliparous gestation gilts in early, mid, and late gestation, compared in three different housing systems (locked-stall [LS], stall-pen [SP], and straw [S])

	Gestation χ^2					
Lameness scoring criteria	Early	p	Mid	p	Late	p
Initial response	2.23	NS	0.55	NS	1.52	NS
Standing posture	2.06	NS	0.64	NS	1.22	NS
Gait	0.89	NS	1.31	NS	2.20	NS
Combined lameness	1.40	NS	1.65	NS	2.30	NS

Chi square analyses performed on count data, comparing gilts receiving lameness scores of zero with gilts assessed scores greater than zero.
NS: statistically not significant ($p \geq 0.05$)
* $p < 0.05$, critical $\chi^2 = 5.99$; df = 2

TABLE A9 Chi-squared values comparing zero and non-zero lameness scores (initial response (IR), standing posture (ST), gait (G), and combined lameness (CL) scores) of 73 nulliparous gestation gilts within each housing system (locked-stall [LS], stall-pen [SP], and straw [S]) over early, mid and late gestation

	Gestation χ^2					
Lameness scoring criteria	Locked stall (n=19)	p	Stall-pen (n=24)	p	Straw (n=30)	p
Initial response	1.84	NS	1.71	NS	3.49	NS
Standing posture	0.34	NS	1.32	NS	0.01	NS
Gait	0.12	NS	0.21	NS	**6.62**	*
Combined lameness	1.02	NS	0.79	NS	**6.11**	*

Chi square analyses performed on count data, comparing gilts receiving lameness scores of zero with gilts assessed scores greater than zero.
NS: statistically not significant ($p \geq 0.05$)
* $p < 0.05$, critical $\chi^2 = 5.99$; df = 2

TABLE A10 Chi-squared values comparing zero and non-zero lameness scores (initial response (IR), standing posture (ST), gait (G), and combined lameness (CL) scores) of 73 nulliparous gilts over the course of the gestation

Lameness scoring criteria	Chi square	p
Initial response	2.52	NS
Standing posture	0.18	NS
Gait	3.39	NS
Combined lameness	2.40	NS

Chi square analyses performed on count data, comparing gilts receiving lameness scores of zero with gilts assessed scores greater than zero.
NS: statistically not significant ($p \geq 0.05$)
* $p < 0.05$, critical $\chi^2 = 5.99$; df = 2

TABLE A11 Chi-squared values comparing zero and non-zero lameness scores (initial response (IR), standing posture (ST), gait (G), and combined lameness (CL) scores) of 73 nulliparous gestating gilts within each housing system (locked-stall [LS], stall-pen [SP], and straw [S]) over the entire gestation

Lameness component	0 vs. >0	p	0-0.5 vs >0.5*	p
Initial response	0.770	NS	1.380	NS
Standing posture	1.171	NS	4.347	NS
Gait	0.058	NS	2.004	NS
Combined lameness	2.004	NS	0.892	NS

Chi square analyses performed on count data, comparing gilts receiving lameness scores of zero with gilts assessed scores greater than zero.
NS: statistically not significant ($p < 0.05$, critical $\chi^2 = 5.99$; df = 2)
* The combined lameness score was assessed as 0-1.5 and >1.5 due to additive nature of CL score category.