Group housing of gestating sows: locomotion disorders and claw lesions

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<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>AI</td>
<td>Artificial Insemination</td>
</tr>
<tr>
<td>BCS</td>
<td>Body Condition Score</td>
</tr>
<tr>
<td>CY</td>
<td>Crossbred York</td>
</tr>
<tr>
<td>d</td>
<td>day</td>
</tr>
<tr>
<td>D</td>
<td>Dynamic group management</td>
</tr>
<tr>
<td>e.g.</td>
<td><em>exempli gratia</em>, for example</td>
</tr>
<tr>
<td>ESF</td>
<td>Electronic sow feeder</td>
</tr>
<tr>
<td>FAS</td>
<td>Free access stalls</td>
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<tr>
<td>Fig.</td>
<td>Figure</td>
</tr>
<tr>
<td>i.e.</td>
<td><em>id est</em>, that is</td>
</tr>
<tr>
<td>LS-means</td>
<td>Least Squares means</td>
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<tr>
<td>RA-SE</td>
<td>Rattlerow Seghers</td>
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<tr>
<td>S</td>
<td>Static group management</td>
</tr>
<tr>
<td>SD</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>SEM</td>
<td>Standard Error of the Mean</td>
</tr>
<tr>
<td>tVAS</td>
<td>tagged Visual Analogue Scale</td>
</tr>
<tr>
<td>VAS</td>
<td>Visual Analogue Scale</td>
</tr>
<tr>
<td>VM</td>
<td>Vario-Mix feeder</td>
</tr>
<tr>
<td>wk</td>
<td>Week</td>
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<tr>
<td>Zn</td>
<td>Zinc</td>
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CHAPTER 1 GENERAL INTRODUCTION

1.1 ANIMAL WELFARE

1.1.1 WELFARE

The term animal welfare is often used, by consumers, veterinarians, farmers, scientists and others. The term can, however, mean different things to all different users. There is no unanimity on a distinctive definition of animal welfare. Definitions vary depending on factors such as cultural, scientific, religious, and even political background (Swanson, 1995).

From a scientific point of view, the definition of animal welfare is dynamic and includes a combination of physical, psychological and behavioural aspects (Dawkins, 2006; Fraser et al., 1997; Fraser, 2003). First, research on aspects of animal welfare has focused on the body, using physiological measures, such as endorphins, plasma cortisol, and heart rate, to examine how the animal is coping with its environment (Broom, 1991). However, this does not give a clear overview of the overall welfare, as some physical parameters, e.g. heart rate and respiratory rate, are difficult to interpret, as they are influenced by both positive and negative experiences, as well as by breeding condition and time of the day (Dawkins, 2003). This would suggest not only looking at physiological measures but also to animals’ state of mind, or feelings (Swanson, 1995). The feeling based approach of animal welfare measures behavioural outcomes such as the willingness to work and behavioural signs of fear and frustration. Another important view of welfare is the possibility for animals to perform natural behaviours.

Animals housed in non-natural habitats, taken care of by humans, are challenged by a wide range of environmental challenges. The captivity status could result in an imbalance between the physical, psychological and behavioural characteristics of the animal. This imbalance could be caused by inappropriate housing, according to size and design, but also stressful stimuli like restricted movement, reduced feeding opportunities and other restrictions of behavioural opportunity are considered. In order to set minimum standards for keeping (farm) animals, legal definitions were set that regulate the welfare of farm animals.
Already in 1876, the Cruelty to Animals Act was adopted in the United Kingdom, to regulate animal experimentation. Since this first law according to animal welfare the regulations have been updated regularly, European Union (EU) wide.

### 1.1.2 Sow Welfare

Public concerns about the welfare of gestating sows resulted in the transition from individual housing towards obligatory group housing of gestating sows from 4 weeks after insemination until one week before the expected farrowing date in the whole EU from January 1st 2013 (Council Directive, 1998) onwards. Properly managed group housed sows can express more exploratory and social behaviour, which is considered beneficial for their welfare. Group housing improves the social contact and interactions between sows and the increased activity has a positive effect on their muscle and bone development (Gonyou, 2001; Marchant and Broom, 1996; Remience et al., 2008; Schenck et al., 2008). However, these positive characteristics of group housing may be accompanied by some aspects of diminished welfare. More feeding competition may occur and therefore the aggression towards other sows will increase, and there is an overall increase in activity, resulting in an increased risk for skin lesions, vulva biting, claw lesions and lameness (Anil et al., 2007; Chapinal et al., 2010). A characteristic of social group composition for pigs in wild populations is a relatively stable group of 2 to 4 related sows and their offspring (Gonyou, 2001). In commercial settings, however, sows experience different housing methods at different stages of gestation during one reproductive cycle: insemination crates, group pens and farrowing and lactation crates. Gestating sows are often housed in large groups with (somewhat to completely) unfamiliar animals and these group compositions are usually changed at least once per reproductive cycle. Several aspects need to be considered when housing sows in groups, including the total number of sows per group, stocking density, design of pens, type of flooring and bedding material, type of feeding system (ad libitum versus restricted), and group management (dynamic versus static) (Levis et al., 2013). All these factors may influence the levels of activity and aggression and the related risk for lameness and skin and claw lesions, which in turn affect sows’ welfare and performance. However, high levels of aggression are common in newly formed groups of sows (Velarde, 2007). This aggression may adversely affect sow welfare, particularly because of its effect on fear, injuries, pain, and stress (Chapinal et al., 2010; Harris et al., 2006).
There is a wide disparity in the design and management of group-housing systems for gestating sows, and all these features can affect sow welfare.

1.1.3 Locomotion Disorders and Claw Lesions

Locomotion disorders and claw lesions are frequently reported as problems in sow husbandry (Heinonen et al., 2013; Kronenberg et al., 1993ab; Nalon et al., 2013a). Lameness can be described as the clinical appearance of a series of locomotion disorders. They are characterised by movement with a deviation from a normal gait, and/or a reduced mobility. Many factors may influence the development of locomotion disorders in breeding sows. Locomotion problems are often associated with claw disorders (Anil et al., 2007), such as injuries to the sole, wall, white line and heel (Cador et al., 2014; Enokida et al., 2011). Although the link between claw lesions and lameness is not clear yet, however there is evidence that some types of claw lesions can cause lameness (Anil et al., 2007; Dewey et al., 1993; Gjein and Larssen, 1995; Kirk et al., 2005; Pluym et al., 2011). According to Nalon et al., 2013a the link between claw lesions and locomotion disorders is most likely related to pain. So, the overall claw condition, and therefore the combination of all claw lesions at variable severity levels, are important for sow welfare. Claw lesions, their causes and consequences have been studied extensively and the shift to group housing has resulted in more attention on this problem (Calderón Díaz et al., 2014; Grégoire et al., 2013; KilBride et al., 2009; Olsson et al., 2016; Sasaki et al., 2014). Very high prevalences of claw lesions have been reported, ranging between 60 to 99% of sows having at least one or more claw lesions (Gjein and Larssen, 1994; KilBride et al., 2010; Knauer et al., 2007; Pluym et al., 2011). The risk factors of claw lesions are complex and multifactorial, including genetics, housing, nutrition and management (Fan et al., 2009; Pluym et al., 2013c; van Riet et al., 2013). The primary cause of claw lesions is related to poor claw horn quality. Additional causes can be trauma and mechanical factors including excessive or inadequate wear. Inflammations, such as laminitis, abscesses, necrosis and ulcers can also cause claw lesions. These however will not be further discussed in this thesis. The strength of the claw varies between the soft and hard tissue of the claw. Besides, the junction between the soft and hard tissue is predominantly susceptible to injuries (Anil et al., 2007). Both types of tissues differ in mineral composition. Calcium, phosphorus, copper, and zinc levels are present in higher levels in the harder tissues of the claw,
such as the wall, while the softer tissue in the heel contains more water, natrium, kalium and iron (Anil et al., 2007; Van Amstel et al., 2009). Claw quality and consequently the susceptibility to claw lesions depends mostly on the quality of horn production (Torrison, 2010). This production is the end result of proliferation, keratinisation (cellular differentiation) and cornification (cell death) of keratinising epidermal cells in the claw epidermis (Tomlinson et al., 2004; Van Riet, 2015). The generic term “claw lesions” includes heel overgrowth and erosions, separations and cracks along the heel/sole junction, separations and cracks along the white line, horizontal and vertical wall cracks, skin lesions near the claw, and excessive (dew) claw length (Figure 1.1) (Anil et al., 2005), besides those different types of lesions also amputations of toes are causing pain and discomfort in sows. The presence of claw lesions, mainly white line and vertical wall cracks, causes lameness in 5 to 20% of all cases (Anil et al., 2007).

Figure 1.1 shows a number of different possible claw lesions which can be found in sows (van Riet et al., 2013).

Figure 1.1. A number of types of claw lesions in sows. (A) Haemorrhage; (B) heel erosion; (C) horizontal cracks in the horn wall; (D) overgrown dewclaw, heel erosion, and separation of the heel/sole junction. (Source: Van Riet et al., 2013).

1.2 IMPACT OF LOCOMOTION DISORDERS AND CLAW LESIONS

The importance of locomotion disorders, such as lameness as a welfare and economic problem is shown by its high prevalence: 8% to 15% of sows in group housing systems are estimated to be lame (Heinonen et al., 2006; KilBride et al., 2009). Claw lesions are very common, with a prevalence varying from 60 to 99 % (Anil et al., 2007; Enokida et al., 2011; Pluym et al., 2011).
1.2.1 Impact on Sow Health and Welfare

Locomotion disorders and claw lesions negatively affect sow health and welfare due to the associated discomfort and pain (Tapper et al., 2013). As a result, the general activity, and social and exploration behaviour might be reduced (Anil et al., 2002; Nalon et al., 2013a; Weary et al., 2009). Group housing of sows implies that all sows in the group have to cover distances to reach feeding and drinking areas and other specific sites where they can perform particular behaviours (Kroneman et al., 1993a). Lame sows may be less willing or capable of doing so, however it is unknown at what severity of locomotion disorders affects sows’ freedom of moving around. The stage of lameness at which sows start to become compromised in their mobility and behaviour is not known. By knowing this turning point, it is possible to better assess the impact on their health and productivity, and to be able to estimate if and when further actions, such as treatment or euthanasia are needed. Lame sows are reported to be less active, having shorter standing times and performing less social and explorative behaviour compared to sound sows (Madec et al., 1986; Valros et al., 2009; Weary et al., 2009). Cornou et al. (2008) showed that lameness affects the individual eating order of group housed sows whilst using an electronic sow feeder (ESF). Consequently, there is a risk that lame sows will suffer from hunger or thirst as they are unable to walk to the feeding and drinking locations in the pen. Besides being less able to reach the resources herself, lame sows are less fit than their sound pen mates, which affects her abilities to compete. The fact that severely lame sows were often in poor body condition supports the fact that lameness affects the drinking and eating behaviour of the sow (Bonde et al., 2004). Less exercise and an increase in time spent lying might as well predispose lame sows to urogenital infections (Heinonen et al., 2013).

Besides the pain caused by the claw lesions, the lesions may permit easy entry of infection, affecting joints with infections as well (Penny et al., 1965). These infected claw lesions can be even more a causative factor of lameness or impaired welfare due to pain and discomfort (Gjein and Larssen, 1994). Deen et al. (2007) described that although sows with mild claw lesions did not appear to be in pain, severe claw lesions may cause pain and lameness. Equally to the claw, overgrown (dew)claws may crack and get infected (Jackson and Cockcroft, 2007) or permit easy entry of infection as well. Additionally, overgrown dewclaws can get stuck in the slots of slatted
floor areas, with a high risk of amputation. Besides the increased risk of infection, the corium will be exposed which can be considered as painful for the sow (Pluym et al., 2011). In cattle and sheep, limb and joint disorders can lead to hyperalgesia (Laven et al., 2008; Ley et al., 1995; Ley et al., 1996; Whay et al., 1998), which can be defined as ‘increased pain derived from a stimulus that normally provokes pain’ (ISAP, 2012). The study of Nalon et al. (2013b), has demonstrated that lame sows also have an increased sensitivity to pain in the affected limb(s), which is an indication of hyperalgesia. This likely exacerbates the pain due to the original lesion(s), and therefore this compromises animal welfare even more.

1.2.2 IMPACT SOW PERFORMANCE AND LONGEVITY

Lameness has several negative consequences on performance such as a decrease in reproduction performance, longevity, and increased human workload and veterinary costs all impact profitability (Anil et al., 2005; Anil et al., 2009b; Ringgenberg et al., 2010). The most important effect of lameness and claw lesions on production is the effect on sow longevity. Sow longevity can be defined as the time interval between the first fertile mating and culling or death and sow longevity is important in pig production and animal welfare (Barnett et al., 2000; Engblom et al., 2007). Severely affected sows are removed from the herd immediately, and chronic, less severe lameness can affect the performance of sows and thus indirectly lead to sow removal (Anil et al., 2009b). A low culling rate is directly associated with an increase in number of piglets produced per sow. Lame animals are likely to be unable to attain optimal breeding efficiency and therefore culled before they reach their peak (parities 3-6) in production (Anil et al., 2009b; Stalder et al., 2004). According to different authors, lameness costs approximately €37 – 160 for each affected sow on farm (Deen et al., 2008; Dijkhuizen et al., 1989; Grandjot, 2007; Schuttert, 2008).

The effects on production can be manifested both pre- (e.g. mummified foetuses and a decreased litter weight) and postnatal (e.g. however weight at weaning and crushed piglets) (Kroneman et al., 1993b; Fitzgerald et al., 2012). Both Fitzgerald et al. (2012) and Kroneman et al. (1993b) found no associations between lameness and litter size, number of piglets born alive or stillborn or average birth weight of piglets born alive. In contrast, Anil et al. (2009a; 2009b) reported a lower
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number of piglets born alive for lame versus non-lame sows. This was supported by the research of Pluym et al. (2013b) who reported an increase in mummified foetuses as an effect of lameness. Anil et al. (2009b) found more crushed piglets when sows were lame during lactation, the authors stated that this was probably due to a diminished sow movement when lame. Pluym et al. (2013b) found an association between heel lesions and the presence of crushed piglets and both white line lesions and the presence of skin lesions above the coronary band were associated with stillborn piglets. In the research of Fitzgerald et al. (2012) the litter weight of the sows with overgrown claws was less than that of the control sows. The control sows spent more time standing after feeding and had probably a higher feed intake than the sows with overgrown claws. Additionally, an increased piglet mortality was found in sows with cracks in the wall horn and with difference toe length within a claw (lateral vs. medial) (Fitzgerald et al., 2012). However, Enokida et al. (2011) did not find any negative associations between claw lesions and the reproductive performance they monitored in their field study (adjusted 21-day litter weight, pre-weaning mortality, weaning-to-first-mating interval, farrowing percentage and overall culling risk at 1, 3 and 5 months after weaning), however there were only three sows (from the 308 monitored sows) with severe claw lesions (score 4, on a 5 point scale) in their study.

Financial losses can be attributed to increased work-load for the farmer, higher veterinary costs, lower carcass quality, secondary diseases, increased mortality and impact on reproduction (Deen et al., 2008; Schuttert, 2008). Culling decisions in sow breeding herds are usually based on economic considerations as most sows are culled when replacement gilts are expected to yield more (Dijkhuizen et al., 1986; Rodriguez-Zas et al., 2003). Nonetheless, replacing culled sows is costly; a sow needs to produce at least 3 litters before the producer gets a positive net value for the gilt investment (Stalder et al., 2003). As a high proportion of sows are already culled before they reach their maximum litter size, this hampers reaching maximal average herd litter size (D’Allaire et al., 1987). This means that early culling results in lower mean litter size, lower number of litters per sow per year, and consequently increasing costs per weaned piglet (D’Allaire et al., 1987). Pluym et al. (2013b) found that sows that were culled due to locomotion disorders were younger than the sows culled for another reason. Locomotion disorders are a major reason of early culling in pig production (Anil et al., 2009b; Engblom et al., 2007). A Danish study showed
that in 10 different herds on average 72% of the causes for culling were related to the locomotion system (Kirk et al., 2005).

1.3 DETECTING AND SCORING LOCOMOTION DISORDERS AND CLAW LESIONS

Detection locomotion disorders and claw lesions can be done using several subjective and objective methods. Visual assessment of the gait and claws is the most common method, and has been used in several animal species including sows.

1.3.1 LOCOMOTION DISORDERS

The occurrence and severity of lameness can be determined by several methods such as visual inspection of sow behaviour and the gait (Main et al., 2000; Nalon et al., 2014) and using mechanical techniques like pressure mats and accelerometers (Grégoire et al., 2013; Pluym et al., 2013b; Meijer et al., 2014). The common principle among all visual gait assessments is that the animals are allocated a score while walking, based on their gait, behaviour and posture. Several methods have been developed in order to visually score the gait of pigs (Table 1.1). These methods vary per type of pig, e.g. sow/piglet/finishing pig, type of scale (e.g. ordinal vs. continuous), the number of categories on the scale and the explanations of these categories.
Table 1.1 Commercially available visual locomotion scoring methods.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Type of scale</th>
<th>Scoring scale</th>
<th>Animal</th>
<th>Characteristics of scoring methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dewey et al. (1993)</td>
<td>Ordinal</td>
<td>0-9</td>
<td>Sows</td>
<td>Study on clinical lameness. (0: normal gait – 9: Cannot stand even with assistance)</td>
</tr>
<tr>
<td>Main et al. (2000)</td>
<td>Ordinal</td>
<td>0-5</td>
<td>Finishing pigs</td>
<td>Assessment of the repeatability of a scoring system integrating different parameters besides gait, such as the behaviour in the group, the response to human presence and the posture while standing. (0: bright, alert, easy accelerations – 5: Dull and unresponsive; will not stand unaided)</td>
</tr>
<tr>
<td>Geverink et al. (2006)</td>
<td>Ordinal</td>
<td>0-3</td>
<td>Finishing pigs, sows</td>
<td>Study on the repeatability of a scoring system for on-farm pig welfare monitoring. (0: normal gait – 3: unable to walk)</td>
</tr>
<tr>
<td>Karlen et al. (2007)</td>
<td>Ordinal</td>
<td>0-3</td>
<td>Sows</td>
<td>Lameness scoring system integrated with other measures to compare the welfare of sows housed in conventional stalls vs. in groups on deep litter. (0: normal – 3: severely lame)</td>
</tr>
<tr>
<td>Kilbride et al. (2009b)</td>
<td>Ordinal</td>
<td>0-5</td>
<td>Sows, gilts, finishing pigs</td>
<td>Cross-sectional study on the prevalence of lameness in association with limb lesions and floor types in commercial farms. (0: even strides – 5: does not move)</td>
</tr>
<tr>
<td>Deen et al. (2009)</td>
<td>Ordinal</td>
<td>0-3</td>
<td>Sows</td>
<td>Early detection tool for foot disorders and lesions, monitoring herd lameness prevalence, identifying individual sows for claw trimming. (0: easy movement – 3: reluctant to walk).</td>
</tr>
<tr>
<td>ZinPro Corp. Feet First ©</td>
<td>Ordinal</td>
<td>0-5</td>
<td>Sows</td>
<td>Study on the consistency over time, effect of sow characteristics and inter-observer reliability of repeated locomotion scoring at the herd level. (0: normal – 5: downer)</td>
</tr>
<tr>
<td>Mustonen et al. (2011)</td>
<td>Ordinal</td>
<td>0-4</td>
<td>Sows</td>
<td>Study on the validation of quantitative techniques for the assessment of lameness. (1: even strides, no problems – 5: unable to move) Tagged Visual Analogue Scale (tVAS). (0 mm normal gait, non-lame – 150 mm downer sow)</td>
</tr>
</tbody>
</table>
Ordinal scales use discrete ordered categories, where trained observers assign a score corresponding to the perceived severity of the condition (D'Eath, 2012; Main et al., 2000; Welfare Quality®, 2009). The number of categories or possible scores on a scale is very important because it determines the degree of discrimination possible. Scales with only two categories (e.g. non-lame vs. lame) are limited in giving information and entail loss of information about a condition compared to scales with five categories (e.g. non-lame, mild, lame, severe, extreme) (Hjermstad et al., 2011). Visual analogue scales (VAS) score a specific condition on a continuous scale. This type of scales use a straight line of normally 100 mm, but the length of the line varies, with two ends labelled, in case of locomotion scoring: ‘sound’ and ‘downer sow/could not be more lame’ (Hjermstad et al., 2011; Nalon et al., 2014). When the straight line of a VAS consist of extra labels we call it a tagged VAS (tVAS). The straight line is divided by tags identifying different degrees of severity of a disorder. There is a description per tag, that guides the users from one extreme of the tVAS (perfect) to the other (extremely bad) (Nalon et al., 2014). Observers give a mark on the line at that point that represents their perception of the extent of the assessed variable, such as gait or severity of claw lesions. In contrast with ordinal scales, visual analogue scales are able to detect change of any size and therefore can differentiate more specific between severities of lameness, where ordinal scales only can differentiate between categories. A VAS or tVAS does not limit the precision and sensitivity with which observers can differentiate between the different degrees of severity of the condition (Engel et al., 2003; Nalon et al., 2014; Quinn et al., 2007). A combination of the ordinal and continuous scale, a continuous scale including the thresholds of an ordinal scale, may reduce the risk of variation between observers, while the advantages of a continuous scale are maintained (Nalon et al., 2014). The potential of a tVAS was tested for lameness assessment in cattle (Tuyttens et al., 2009) and in sows (Nalon et al., 2014). Nalon et al. (2014) have compared the inter- and intra-observer repeatabilities of the tVAS with both a five point and a two point ordinal scale when scoring locomotion in sows. They found similarly high inter-and intra-observer repeatabilities as well as a high correlation with the experts’ scores for the tVAS and the five point scale. Additionally, they concluded that the tVAS was better than the two point scale on all fronts. In addition to the visual gait assessment several technological methods have been developed. Technological systems have the advantage that they measure
independent and can be automated. Both kinematic-based and kinetic based techniques have been developed and have been used in various animal species in order to evaluate gait and posture (Pluym, 2013; Van Nuffel, 2014). Kinematic techniques include video based motion analysis, footprint or trackway analysis and the use of accelerometers (Pluym, 2013). The use of kinetic-based techniques for lameness detection, are for example force plates and pressure-sensitive walkways/pressure mats; these methods focus on the forces exerted by the animals’ limbs (Pluym, 2013). De Carvalho et al. (2009) have used a pressure mat system in order to study the pressure distribution in relation to pig claw lesions. These automated methods will not be discussed further; within this thesis we will focus on visual gait scoring, for detailed information of these automated measures the dissertations of Pluym (2013) and Van Nuffel (2014) can be used. None of the above mentioned locomotion scoring methods directly evaluates the effects of lameness on the capability of locomotion. Severely lame sows are obviously expected to be restricted in their movement, but for mild and moderately lame sows the extent of restriction in movement is less predictable. In visual gait scoring methods ‘mildly lame’ is often used as borderline; however, it is not known if these animals are indeed restricted in mobility (e.g. the combination of a sow’s willingness and capability to move around).

1.3.2 Claw lesions

Just like gait scoring, several methods have been developed for scoring claw lesions. Only ordinal scales have been used in published studies, using roughly the same claw parameters to score for lesions (Table 1.2). Claw lesions include heel overgrowth and erosions, separations and cracks along the heel/sole junction, separations and cracks along the white line, horizontal and vertical cracks in the wall horn, skin lesions near the claw, dewclaw and claw length (Anil et al., 2007a).
Table 1.2. Publications about various claw lesion scoring methods in literature.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Scoring scale</th>
<th>Lesions scored</th>
<th>Description of the scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gjein and Larssen (1995)</td>
<td>1-5</td>
<td>Side wall cracks, heel lesions, overgrown heels, white line cracks, cracks in heel-toe junction, toe cracks.</td>
<td>1 (normal) – 5 (Very serious cracks)</td>
</tr>
<tr>
<td>Hoofs (2006) “Zeugenklauen Check”</td>
<td>1-4</td>
<td>Heel overgrowth and erosion, Dewclaws (length and integrity), claws (length), wall (vertical and horizontal cracks) skin lesions above coronary band.</td>
<td>1 (normal)- 4 (Severe)</td>
</tr>
<tr>
<td>Bradley et al. (2007)</td>
<td>1-3</td>
<td>Heel erosion Fischer's crack Heel overgrowth White line cracks, horizontal and vertical wall cracks, haemorrhage, abscess.</td>
<td>1 (Mild) – 3 (Severe)</td>
</tr>
<tr>
<td>Anil et al. (2007)</td>
<td>0-4</td>
<td>Wall, heel, sole, junction between heel and sole, white line, toe. Lesions per claw area included erosions, cracks, and overgrowths.</td>
<td>0 (No lesions) – 4 (Deep cracks)</td>
</tr>
<tr>
<td>Deen et al. (2009) FeetFirst® by ZinPro</td>
<td>1-3</td>
<td>Toes (length), dewclaws (length and integrity), heel overgrowth and erosion, heel-sole crack, white line, horizontal and vertical cracked wall.</td>
<td>1 (Mild) – 3 (Severe)</td>
</tr>
</tbody>
</table>

1.3.3 EXPRESSING GROUP-LEVEL OCCURRENCE OF LOCOMOTION DISORDERS AND CLAW LESIONS

Data on locomotion and claw scores at herd level can be presented in different ways, using for example percentages or mean locomotion or claw score at group level. Prevalence and incidence are the basic measures of disease frequency (Fletcher et al., 2012), both expressed in percentages. A prevalence gives an overview of the presence of the actual problem at a specific time point. The incidence is the number of newly diagnosed cases of a disease during a given period of time at risk. Mean scores, however, allow a more accurate representation of the severity
of a specific condition, e.g. lameness and claw lesions, compared to for example being lame or not. If a (t)VAS is used, mean scores can be given in mm. The incidence therefore allows for recognition of hazardous phases (new cases) within a specific timespan. Longitudinal, repeated measurements are needed when incidences are being calculated. Such studies are therefore ideal for analysing changes over time of health and welfare related issues such as locomotion and claw disorders. To calculate prevalence and incidence of a condition, a scoring system with a cut-off point is needed to assess whether an animal is suffering from the condition or not. In order to be able to express the occurrence of lameness or claw status at group level, assessing individuals is needed. According to locomotion disorders the question arises whether lameness varies on a continuum or that it is either present or absent. In the latter case, any cut-off is a bit arbitrary and based on consensus; as a result there will be a lack of information on the severity of the disease if it is expressed as an incidence or prevalence. In that case, locomotion scores from a VAS are more informative, describing lameness status in a more nuanced way than simply lame vs. non-lame. For lameness, no unequivocal cut-off between “lame” and “non-lame” can yet be determined, as some authors consider that some changes in the locomotion pattern (e.g., stiffness) might not result in discomfort or pain (Calderón Díaz et al., 2013; Fletcher et al., 2012). Research is needed to determine threshold values for the different changes in behaviour so it will be possible to detect deviations in the locomotion pattern, and ultimately determine the underlying cause of the deviations. Eventually this will allow to treat affected animals properly, to improve the welfare of the sows and to implement the necessary preventive measures.

1.4 Treatment and prevention of locomotion disorders and claw lesion

If prevention of lameness or injury is not possible, affected sows should be treated properly to avoid diminished sow welfare, production, and financial losses. After clinical examination and diagnosing the problem it should be decided if the animal warrants treatment (Rowles, 2001). Some cases of lameness or claw lesions are only discovered when it is chronic and recovery change is poor (Rowles, 2001). In the case where curing is not feasible, culling or euthanasia is the only option left. As lame sows may suffer from pain, they need to be treated with a non-steroidal anti-inflammatory drug (NSAID), or painkiller. Oral administration of ketoprofen or
injection with meloxicam has been proven to be efficacious and safe for treatment of non-infectious locomotion disorders in pigs, as it alleviated the signs of non-infectious locomotion disorders in pigs (Friton et al., 2002; Karriker et al., 2013; Mustonen et al., 2011). Treatment of claw lesions is more challenging because of the difficulty in making sure to treat exactly on the affected location. Ideally, the (infected) lesions should be cleaned and disinfected besides a suitable antibiotic and NSAID administration (Pluym et al., 2013b; Rowles, 2001). Claws that are at risk for lesions, such as overgrown claws, should be treated before they are amputated and further infection of the tissue can take place. So, overgrown claws should be trimmed of excess growth (Jørgensen, 2000). In an old study of Penny et al. (1965), the use of a foot bath containing five to ten percent formalin solution was effective against foot-rot.

As treatment is difficult, it seems more important to prevent the condition. Knowledge on possible strategies to prevent and control the development of locomotion disorders and claw lesions is of major importance. Factors affecting these disorders should be investigated as they are the key towards healthy sows.

1.5 Risk factors for locomotion disorders and claw lesions in group-housed sows

Locomotion disorders and claw lesions are multifactorial. Different risk factors related to both environment and the animal itself have been identified.

1.5.1 Environmental factors

Feeding system

The type of feeding system is essential in the case of group housing, because of its influence on aggression. Feeding systems can be classified in different ways and are described into detail by several authors (Den Hartog et al., 1993; Gonyou, 2003; Spoolder et al., 2009). Tuyttens et al. (2011) described seven options for group housing systems based on the feeding methods (Table 1.3): (1) Drop/trickle feeding; (2) Electronic sow feeder (ESF); (3) Free access stalls (FAS); (4) Ad libitum feeding; (5) Electronic feed dispensers; (6) Interval feed dispensers; (7) Feeding
stall/trough (manual). The classification of these seven categories is based on the following five criteria: (1) sows being completely physically separated from each other during feeding, (2) feed portion can be adjusted individually, (3) all sows can eat simultaneously; (4) ad libitum vs. restrictedly feeding; (5) automated vs. manual feeding.

Table 1.3. Classification of seven group housing systems based on feeding methods, used in Belgium sow husbandry (adapted from Tuyttens et al., 2011 and Van Gansbeke, 2006).

<table>
<thead>
<tr>
<th>Group housing system</th>
<th>Eating physically separated</th>
<th>Individually adjusted feed portion</th>
<th>Eating simultaneously</th>
<th>Restricted portions</th>
<th>Automated feed delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Drop/trickle feeding</td>
<td>Partial/no</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2. ESF</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3. FAS</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No/yes</td>
</tr>
<tr>
<td>4. <em>Ad libitum</em> feeding</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No/yes</td>
</tr>
<tr>
<td>5. Electronic feed dispensers</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6. Interval feed dispensers</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7. Feeding stall/trough (manual)</td>
<td>Partial/no</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Simultaneous feeding systems are feeding systems in which sows eat all at the same time, which prevents sows from fighting for food. However, an important criterion is whether or not during feeding the sows are completely or partially physically separated from each other. Being separated while eating provides protection from pen mates. Individual feeding stalls or troughs
in partial or short feeding stalls, with at least the head and shoulders protected, provides the best protection for aggression during feeding (Van Gansbeke, 2006). Floor feeding is another example of a feeding system that dispenses feed on the solid part of the floor whereby all sows in the pen have access to the same piles of feed (Marchant-Forde, 2009). Floor feeding allows dominant sows to eat more feed and gain more body weight than subordinate sows (Marchant-Forde, 2009). Sequential feeding systems, such as ESF, provide feed per animal and not all sows can eat at the same time. An ESF is often referred to as a non-competitive feeding system; sows eat individually and are protected from conspecifics whilst eating. However, if the ESF is not properly designed and managed, vulva biting and aggression can occur while sows are queuing to enter the ESF (Van Putten and Van de Burgwal, 1990). Sow feeders with individual recognition provide an easy control over individual feed intake of the sows as the feed portion can be adjusted individually, which is not possible with all feeding systems. Feed allowances are programmed into the ESF per individual and can be changed throughout the gestation period (Den Hartog et al., 1993; Gonyou, 2005). Additionally, free access (rear gate locking) stalls (FAS) are defined as a non-competitive feeding environment whereby a rear gate is either operated by the sow or a worker. Sow operated free-access stalls are designed to have the rear gate closed when the sow enters the stall and opened when the sow backs out. In that way sows can eat undisturbed and protected from others. Most designs of the sow operated free-access stalls allow the worker to lock the rear gates. Free-access stalls have also been designed whereby the rear gate is only locked by workers during feeding time or left open, if competition is not a problem (Den Hartog et al., 1993; Gonyou, 2005).

**Nutrition**

Gestating sows are usually fed restricted levels of feed, which may not provide sufficient satiety, and do not allow sows to fully fulfil their motivation to express foraging and feeding behaviours, especially when no bedding or roughage is used in the pens. Feeding sows restrictedly is needed to prevent the sows from excessive weight gain during gestation with ultimately a reduction in productivity. Feed restriction in group housed gestating sows is associated with stereotypic activity, increased aggression, restlessness and feeding competition. These are signs of non-stop feeding motivation and frustration (Bench et al., 2013; Marchant et al., 1995), which are risk
factors for locomotion disorders. High fibre diets successfully alleviate these hunger-motivated behaviours by increasing feeding time and gastrointestinal distension which consequently increase satiety and reduce feed motivation (Robert et al., 1997). However, the increased feeding time can cause crowding at sequential feeding systems, which initiates aggressive behaviour.

Nutrition is an important predisposing factor of sow lameness and claw lesions as it influences many processes, such as bone, articular cartilage and horn quality. Nutritional components often interact with each other, and therefore must be balanced since both deficiency and excessive intake may disturb these processes (Van Riet et al., 2013). The effect of nutrition on locomotion disorders and claw lesions was discussed by Van Riet (2015) and will not be discussed in this dissertation. The role of proteins, lipids, and carbohydrates in the feed is not completely clear, however, dietary mineral and vitamin deficiencies and toxicities may be detrimental to bone, articular cartilage, and horn quality, and thus important for a good claw quality (Van Riet, 2015).

Because hunger is likely to lead to competition for feed, strategies to reduce hunger between meals through higher feeding levels, dietary fibre, or foraging substrate should be examined into detail. The Council Directive (2001) obliges pregnant sows and gilts to be provided with sufficient amounts of high fibre diets, as well as high energy food, to satisfy hunger and the motivation to chew. Feeding a high fibre gestation diet is also positive as it prepares sows for the much higher feed intakes required in lactation (Guillemet et al., 2010). Straw bedding and forage based feeds can help fulfil satiety and the foraging needs of the sow, however bedding is not often present in sow housing systems. O’Connell (2007) showed that the provision of silage (1.9kg per day from a rack) reduced sham chewing and improved satiety, Stewart et al. (2008) concluded in contrary that small amounts of straw (0.3kg straw/sow/day) did not. High fibre diets (15.7% crude fibre) delivered through an ESF improved satiety and increased lying behaviour (Stewart et al., 2010), whereas diets with 9% crude fibre did increase resting behaviour but additional straw from racks was needed to reduce sham chewing (Stewart et al., 2011). It is likely that a combination of substrates and high fibre diets are needed to satisfy hunger in the sow and fulfil her foraging and exploratory and nutritional needs.
Chapter 1

Deriving conclusions on the topic of nutrition and feeding is difficult because research directly comparing same type of diets, using floor feeding, feeding stalls, and ESF systems has not been conducted.

**Floor type**

In a sow housing system there is the option to have either solid, partly slatted or fully slatted floors, additionally solid floors can be bedded. Floor type is one of the mean features of housing that may affect the welfare of the sows. Other important characteristics of the floor include material, quality, hygiene and the use of bedding. The floor in group pens of sows consists usually of solid or partly slatted concrete floors, as this is robust and relatively inexpensive and easy to clean and disinfect (Pavicic et al., 2014). However, it does not score well in terms of sow comfort (Tuyttens, 2005). As sows spend up to 80% of their time lying down in intensive systems, adequate flooring is essential to their welfare (Bergeron et al., 2000). Problems like lameness and claw and skin lesions are also linked to floor characteristics such as slip resistance, hardness and surface profile (Calderón Díaz et al., 2013). Although (straw) bedding may provide more comfort, it is incompatible with the manure disposal systems, holds increased risk for disease, often costs more and requires extra labour (Tuyttens, 2005). Rubber coverings may be a good alternative to exposed concrete: a softer rubber layer might increase lying comfort and the cushioning effect protects skin, claws and legs (Elmore et al., 2010; Tuyttens et al., 2008). In practice, mats, are mainly used during farrowing and lactation to increase sow (and piglet) comfort (Tuyttens et al., 2008). This short period, during which sows are usually kept in separate stalls, does not represent the highest risk for developing lameness and claw and skin lesions regardless of flooring type. A few short-term studies (Calderón Díaz and Boyle, 2014; Elmore et al., 2010; Tuyttens et al., 2008) and a single long-term study (Calderón Díaz et al., 2013) focused on the potential of rubber mats to improve the locomotory ability or sow welfare in group pens of gestating sows.

**Floor space allowance**

Insufficient floor space, both in quantity (amount) and quality (configuration, including physical and visual barriers), can lengthen or intensify aggression by affecting a sow’s ability to avoid or escape others and hence the formation of a stable hierarchy (Lindberg, 2001). This aggressive behaviour is an important risk factor for locomotion disorders and claw lesions. The minimal legal
requirements for floor space for group housed gilts is 1.64 m\(^2\) and for multiparous sows 2.25 m\(^2\) (European Commission, 2008). These recommendations apply to all type of group housing systems independent of feeding method or group management. Research of Barnett et al. (1992), Barnett et al. (2000) and Remience et al. (2008) showed in group housed gilts that at d 2 to d 54 after mixing, increasing space reduced aggressive behaviours, such as bites and head butts. Similarly for sows the number of threats, withdrawals and head interactions, such as bites, were reduced with increasing space at d 6 and 7 after mixing (Weng et al., 1998). Remience et al. (2008) found that in gestating sows the reciprocal aggressive behaviours, like bites of knocks did not differ, but the non-reciprocal aggressive behaviours at d 3 and 8 after mixing were greater at a smaller floor space. When sows are mixed directly after insemination an increasing space allowance reduces feeding aggression at d 2 after mixing, however there was no difference at d 8 after insemination (Hemsworth et al., 2013). Seemingly, the effect of floor space on aggression is particularly pronounced early after mixing. The studies of Barnett (1997) and Hemsworth et al. (2013) did not provide evidence that space affected skin injuries. However, Weng et al. (1998) and Salak-Johnson et al. (2007) found increased skin injuries as the floor space decreased. Also Remience et al. (2008) found that dynamic group housed sows had more skin lesions at smaller space allowance. It should be noted that space allowance probably interacts with other features of the pen like physical barriers, floor type and location of specific resources in the pen (for example feeding place and drinkers) and additionally with group size and total floor space (Remience et al., 2008). Animals allocated to a high floor space may have a greater opportunity for activity which may have increased the risk of injuries (Spoolder et al., 2009).

**GROUP SIZE**

As aggressive behaviour is an important risk factor for locomotion disorders and claw lesions, group size is important as well. Group size is known to affect aggressive behaviour, although results are inconclusive about ideal group sizes. Arey and Edwards (1998) concluded that more aggressive behaviour occurs in large groups. However, other research shows that there is no evidence that there is more aggression in large groups of up to 40 sows in experimental settings and up to 300 sows in commercial settings (Barnett et al., 2000; Spoolder et al., 2009). In small groups individual recognition is possible, however if group sizes are too large (>40), sows are
unable to recognize all pen mates. Other methods than individual recognition and aggression might be used by the sows to establish social dominance. For example, body size might be used to assess the fighting ability of others and thus influence whether or not an animal engages in aggression (D’Eath and Keeling, 2003; Rodenburg and Koene, 2007; Turner et al., 2001). Otherwise, in large groups there are more animals present and these animals can serve as refuge for targeted sows, allowing them to hide behind others or escape into the group (Anil et al., 2006; Spoolder et al., 2009; Turner and Edwards, 2004). Additionally sows may form subgroups within large groups, just as their wild conspecifics (Gabor et al., 1999). Forming subgroups avoid mixing and within the smaller subgroups social hierarchies may develop (Anil et al., 2006; Rodríguez-Estévez et al., 2010). Having smaller subgroups within a large group facilitates the formation of an efficient dominance hierarchy (Rodríguez-Estévez et al., 2010).

GROUP MANAGEMENT: STATIC VS. DYNAMIC GROUPS

Commercial sow groups can be held as either a static group, in which the group composition stays the same after formation, or as a dynamic group, in which sows are regularly removed from or introduced to the group. So, in dynamic groups animals are frequently introduced and removed from the group, which repeatedly creates unrest and agonistic behaviour, resulting in more skin lesions, as an indicator of aggression (Arey and Edwards, 1998). Several studies showed that there is more agonistic behaviour in dynamic groups, compared to static groups (Arey and Edwards, 1998; Barnett et al., 1992; Moore et al., 1994; Remience et al., 2008), due to the frequently introduced unfamiliar sows in dynamic systems. In dynamic groups introduction of new animals can be experienced between 3 and 12 times per gestation (Marchant-Forde, 2009). Research has put forward that the aggression related problems are higher in dynamic groups compared to static groups of sows (Arey and Edwards, 1998; Barnett et al., 2000; Durrell et al., 2003). A recent study showed an increase of skin injuries and lameness in a dynamic group where every 5 weeks 35-40 sows were replaced compared to a static group; although they found no effects on farrowing rate, weight gain, or litter size (Li and Gonyou, 2013). However, others found the opposite. Anil et al. (2006) found that even though the skin injury scores were highest in the dynamic group (group size 100 sows), both in general and 2 weeks after mixing, there were no effects of mixing on aggression, cortisol concentrations, farrowing performance, and longevity.
Also, Strawford et al. (2008) concluded that there were no differences in aggression, skin injuries, and cortisol concentrations between sows in static and dynamic (mixed at 5 week intervals) groups with an ESF. It should be noted that in the research of Strawford et al. (2008) the static groups consisted of 34 to 41 sows and the dynamic group of approximately 105 sows. It should be noted that the above mentioned studies differed in management procedures such as floor type and space allowance. Results of the research performed on type of group management seems contradictory. There seems no substantial evidence that sow welfare is unfavourably affected in dynamic groups in comparison to static groups.

1.5.2 Sow factors

Genetics

When looking at the heritability of aggression, D’Eath et al. (2009) found that the pen effect clarified a substantial part of the variation in the environmental component of aggression. This is associated with the role of group mates on an individual’s aggressive behaviour. Social interactions between pigs can originate from heritable traits. Genetic selection generally highlights physical traits of production, like growth and litter size, but the transition to group housing adds the requirement that sows can live peacefully in groups. Social behaviour should therefore be considered as an important and highly significant trait as well (Stricklin, 2001). Selection for reduced aggression in pigs is feasible and desirable, but as shown by D’Eath et al. (2009), other behaviours such as general activity and ease of handling may have a correlated response to some degree, with possible implications for animal production and welfare. Although research of Løvendahl et al. (2005) did not show a genetic relationship between sow aggressiveness and maternal behaviour, research in this area is lacking. The effects of genetic selection against aggression on other traits needs to be more clear. Stukenborg et al. (2012) indicate a moderate heritability for aggression received for gilts and sows ($h^2 = 0.42$) 48 h after mixing. For severe aggressiveness performed for 30 min after mixing a low heritability of 0.24 was found (Løvendahl et al., 2005). In growing pig, researchers described a low to moderate heritability ($h^2 = 0.26$ to 0.46) in the frequency and duration of engagement in reciprocal aggression (Turner et al., 2008; Turner et al., 2009).
Besides aggression, genetics is related to claw quality and leg conformation as well. Dissimilarity in the size of claws and varying tissue strength between medial and lateral claws contributes to difference invulnerability to lesions (Kornegay et al., 1990; Kroneman et al., 1993a; Webb, 1984). Claw size dissimilarity has been significantly associated with a higher culling risk (Tarrés et al., 2006). If the size difference between lateral and medial claws becomes larger, the prevalence of claw lesions increases (Kornegay et al., 1990). Dissimilarity in claw size is hereditary and depends on breed: a range of heritability values varying from 0.01 to 0.61 has been reported (Fan et al., 2009; Jørgensen, 2000; Pluym et al., 2013b; Steenbergen, 1990). In addition to dissimilarity in claw size, abnormal claw growth has been associated with claw lesions. This has also been reported to be heritable (Quintanilla et al., 2006). The heritability of claw quality suggests that genetic selection for claw characteristics could be beneficial for claw health. Besides claw quality also leg conformation/weakness are linked with locomotion disorders (van Grevenhof et al., 2012). Osteochondrosis is considered to be the underlying cause of leg weakness symptoms, and has a proven genetic component (de Koning et al., 2013; Jørgensen and Andersen, 2000; Jørgensen and Sørensen, 1998). Leg conformation is reported to be a risk factor for sow longevity. Reports suggest that heritable leg conformation traits could be indicators for longevity too (Anil et al., 2009b; de Sevilla et al., 2008; Hoge and Bates, 2011; Lopez-Serrano et al., 2000; Serenius and Stalder, 2004; 2006; 2007; Yazdi et al., 2000).

In a research with different breeds of fattening pigs Henryon et al., (2001) showed that there are some breed benefits according to the resistance to lameness. Pigs from the Duroc and Yorkshire breeds were generally more resistant than pigs from the Landrace and Hampshire breeds. In detail, the vulnerability of the Duroc and Yorkshire breeds for lameness was 1.4 to 3.0 times lower than the hazard of the Landrace and Hampshire breeds.

**Experience**

Familiarity may also affect aggression at mixing and therefore the risk of getting lame or claw lesions. The total time unacquainted pigs spend fighting after mixing is up to 97 times more than familiar pigs (Li and Johnston, 2009). So, mixing familiar sows that have been housed together before (i.e. in the previous gestation) may reduce aggression, as such sows still recognize each other (Li and Johnston, 2009). To maintain stable relationships (i.e., maintaining a dominance
hierarchy), animals must have the ability to recognize individual members of the group. It is thought that large group sizes hinder easy recognition and could disturb the development of hierarchies, which increases the duration and severity of aggressive behaviour (Turner et al., 2003). In addition to group size, the duration of having been separated is an important factor for sows to be able to recognize conspecifics although it is known that they are able to recognize each other several weeks after separation. Arey (1999) concluded that sows may be removed and returned after a 6-week period without any major disruption to social organization, but they used small groups of only six sows. Within large dynamic groups, Spoolder et al. (1996) found that gilts could remember former groupmates after 4 weeks of separation. Another option is to form sub-groups and pre-mix sows before introducing them into a larger group of sows. Subgroup behaviour during the first week in a large group appears to reduce aggression between subgroup members and between newly introduced and resident sows during the risky grouping period (Turner et al., 2003).

**Parity**
Social rank is directly linked to sow weight and parity, the heavier and often older sows are typically more dominant (Arey, 1999; Brouns and Edwards, 1994; D'Eath et al., 2009). Managing a group of sows in terms of parity distribution may affect aggressive behaviour and therefore locomotion disorders and claw lesions. Sorting by parity might be a valuable method to protect the most vulnerable young and small sows from severe injuries caused by aggression at grouping (Li et al., 2012). Literature suggests that in mixed parity groups, pen design can be improved, *e.g.*, by increasing the amount of space per sow and providing places or barriers where vulnerable or weaker animals can go to get away from other (aggressive) animals (Arey and Edwards, 1998; Li et al., 2012).

**Stage of Reproductive Cycle at Mixing**
Research shows that there are normally three stages during reproductive cycle at which sows can be mixed: directly after weaning, after insemination, or after pregnancy detection. Most studies have examined the effects of mixing once pregnancy has been confirmed at d 28 to 35 after insemination. There has been limited studies done examining mixing during earlier stages of pregnancy or even before insemination. The changing hormone levels during heat, insemination
and early pregnancy maybe partly the source for aggressive behaviour (Verdon et al., 2015). There is a progesterone peak at d 16 after insemination, this level remains elevated until just before parturition. For example, Stevensen (2015) found that sows mixed in the week after insemination were more aggressive compared to sows mixed 5 to 6 weeks after insemination. For both groups no difference in level of aggression was seen 7 days after the mixing. Strawford (2008) and Knox et al. (2014) however, found no difference in level of aggression between early mixing (day 2 to 9) or late mixing (day 35 to 46) after insemination. They both gave the sow intrinsic (genetics, size and experience) and management factors (feeding system and pen design) as possible explanations for this. In addition to (aggressive) behaviour, the stage of reproductive cycle at mixing might be related to reproductive characteristics as well. Spoolder et al. (2009) recommended that stress should be avoided to minimize reproductive failure, especially at week 2 to 4 of pregnancy, because at that time the attachment of embryos to the endometrium (11 to 16 d) occurs and shortly thereafter the maternal recognition of pregnancy happens, due to the hormonal changes. Knox et al (2014) approved this as with their findings of a lower conception rate for sows that were mixed early after insemination compared to late mixed and not-mixed sows. Both Knox et al (2014) and Li and Gonyou (2013) found that early mixed sows had a lower farrowing rate than late mixed sows. Housing sows individually during oestrus may cause stress and frustration because they cannot adequately express their natural behaviour. Nonetheless, risky situation will occur while group housed; for instance the dominant sows show more sexual behaviour than submissive sows, especially in terms of mounting (low-rank) sows, which may increase the risk on leg injuries to both (Pedersen et al., 1993).

1.6 References


General Introduction


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CHAPTER 2 RESEARCH OBJECTIVES

2.1 RESEARCH OBJECTIVES

Group housing, with emphasis on inadequate pen design and grouping methods, is one of the most important predisposing factors aggravating locomotion disorders and claw lesions in sows. Locomotion disorders and claw lesions are common and multi-factorial disorders, causing impaired animal welfare and economic losses (Chapter 1). The occurrence of locomotion and claw problems have increased with implementation of group housing for gestating sows, without knowing the risky stages in the reproductive cycle. In order to combine keeping sows in animal welfare friendly group housing, with good reproductive performance and productivity research and development is needed to optimize these systems. Research is needed to determine the relationship between lameness and mobility of sows. Various cross-sectional studies have been performed already focusing on sows’ locomotion and claw lesions, however insufficient longitudinal studies have been carried out, in order to detect the most harmful stages in the reproduction cycle as well as the long-term effect of specific management factors such as grouping method or pen design. Knowing this, will allow to treat affected animals properly, will improve the welfare of the sows and gives the opportunity to find and implement the necessary preventive measures.

The general aim of the thesis was to investigate locomotion disorders and claw lesions in sows in group housing systems, in order to improve the welfare, health and profitability of pig herds.

The specific research objectives were to investigate:

- the relationship between locomotion score and the mobility of the sows;
- the long-term effect of floor type in the group pens on gait and claw lesions of gestating sows;
- the long-term effect of group management on gait and claw lesions of gestating sows in commercial farms.
CHAPTER 3 – LOCOMOTION EFFECT ON A FEED REWARD COLLECTION TEST

Adapted from:

Effect of locomotion score on sows’ performances in a feed reward collection test.

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Chapter 3

ABSTRACT

Sows housed in groups have to move through their pen to fulfil their behavioural and physiological needs such as feeding and resting. In addition to causing pain and discomfort, lameness may restrict the ability of sows to fulfil such needs. The aim of our study was to investigate the extent to which the mobility of sows is affected by different degrees of lameness. Mobility was measured as the sow’s willingness or capability to cover distances. Feed-restricted hybrid sows with different gait scores were subjected to a feed reward collection test in which they had to walk distances to obtain subsequent rewards. In all, 29 group housed sows at similar gestation stage (day 96.6 ± 7 sd.) were visually recorded for gait and classified as non-lame, mildly lame, moderately lame or severely lame. All sows received 2.6 kg of standard commercial gestation feed per day. The test arena consisted of two feeding locations separated from each other by a Y-shaped middle barrier. Feed rewards were presented at the two feeders in turn, using both light and sound cues to signal the availability of a new feed reward. Sows were individually trained during 5 non-consecutive days for 10 min/day with increasing barrier length (range: 0 to 3.5 m) each day. After training, sows were individually tested once per day on 3 non-consecutive days with the maximum barrier length such that they had to cover 9.3 m to walk from one feeder to the other. The outcome variable was the number of rewards collected in a 15-min time span. Non-lame and mildly lame sows obtained more rewards than moderately lame and severely lame sows (P < 0.01). However, no significant difference was found between non-lame and mildly lame sows (P = 0.69), nor between moderately lame and severely lame sows (P = 1.00). This feed reward collection test indicates that both moderately lame and severely lame sows are limited in their combined ability and willingness to walk, but did not reveal an effect of mild lameness on mobility. These findings suggest that moderately and more severely lame sows, but not mildly lame sows, might suffer from reduced access to valuable resources in group housing systems.

Keywords: lameness, feed motivation, pig, gait, mobility
IMPLICATIONS

This study provides new insights on the effect of lameness on the mobility of sows. The results suggest that sow mobility is reduced only when the degree of lameness is rather severe, whereas mildly lame sows may not be as limited in their mobility as generally assumed. Sows with a stiff, uneven and non-fluid stride did not differ in their combined willingness and capability to walk for feed rewards, when compared with sound sows. This highlights the need for further research investigating the ability of (group housed) sows to access resources and express behavioural needs depending on their lameness status.

INTRODUCTION

Since January 2013, the EU requires group housing of gestating sows (Sus scrofa) from 4 weeks after insemination to 1 week before the expected farrowing date (EC Directive 2001/88/EC). Properly managed group housed sows can express more exploratory and social behaviour, which is considered beneficial for their welfare. Group housing, however, may also have negative consequences on sow welfare such as feeding competition and aggression, resulting in increased risk for skin lesions, vulva biting and lameness (Harris et al., 2006; Chapinal et al., 2010b). Lameness negatively affects sow welfare due to the associated discomfort and pain (Nalon et al., 2013; Tapper et al., 2013) and may reduce general activity, social behaviour and exploration (Weary et al., 2009). In addition, lameness has an economic impact as it decreases reproduction performance, longevity, human workload and veterinary costs (Anil et al., 2005; Ringgenberg et al., 2010; Pluym et al., 2013a). The importance of lameness as a welfare and economic problem is shown by its high prevalence: 8% to 15% of sows in group housing is estimated to be lame (Heinonen et al., 2006; Kilbride et al., 2009). Group housing of sows implies that individual sows have to cover (considerable) distances to reach feeding and drinking areas and other specific sites where they can perform particular behaviours (Kroneman et al., 1993). Lame sows might be less willing or capable of doing so. Considering the high prevalence and importance of lameness, it is necessary to know if lame sows are limited in their mobility and behaviour, and at which stage of lameness this occurs. The occurrence and severity of lameness can be determined by several methods such as visual inspection of the gait (Main et al., 2000; Nalon et al., 2014) and using
kinematic techniques like pressure mats and accelerometers (Grégoire et al., 2013; Pluym et al., 2013b; Meijer et al., 2014). However, none of these methods directly evaluates the effects of lameness on the capability of locomotion. Severely lame sows are obviously expected to be restricted in their movement, but for mild and moderately lame sows the extent of restriction in movement is less predictable. In visual gait scoring methods ‘mildly lame’ is often used as border line; however, it is not known if these animals are indeed restricted in mobility (by which we mean the combination of a sow’s willingness and capability to move around). The aim of this research was to evaluate the relationship between gait score and the mobility of sows. Mobility was assessed by using a feed reward collection test in which the sows had to walk a specific distance to and from two feeders in order to collect successive feed rewards. We hypothesized that sow mobility would be increasingly reduced with deteriorating gait score, and therefore that mildly lame, moderately lame and severely lame sows would collect fewer rewards than non-lame sows.

**MATERIAL AND METHODS**

**EXPERIMENTAL DESIGN**

We used an experimental setup in which sows had to walk back and forth between two locations where they received successive feed rewards. This setup resembles the methods of motivation testing (Kirkden and Pajor, 2006). In motivation tests, an animal’s willingness to work (e.g. walk, push, jump) for a certain reward (e.g. feed, extra space, social contact) is used to assess the reward’s importance to the animal while attempting to minimise the influence of other factors that may affect the amount of work performed (e.g. lameness, BW, age). We applied the opposite approach: in our tests, the differences in motivation were minimized and the influence of lameness was maximised. Feed-restricted sows were used, which allowed us to focus on the association between the degree of lameness and the number of rewards collected by the sows. The number of rewards obtained during a session was used as an indicator of the restriction in animals’ mobility, possibly due to lameness.
**Test arena**

The test arena consisted of a 25 m$^2$ square wooden pen with a solid concrete floor. The pen was divided into two connected areas using a Y-shaped metal barrier measuring 3.50 m in length (Figure 3.1). The maximum distance the sows had to walk between successive feed rewards was 9.30 m. In order to train the sows, the length of the barrier could be shortened (to 0 m) by sliding it through the pen wall, thus decreasing the distance that had to be covered between the two feeders to a minimum of 2.30 m. The sows were called to one of the two feeders by means of a sound (recorded rattle box) and a light cue just before delivery of a new feed reward (a combination of pieces of apple, raisins and 15 g feed pellets). As soon as a reward had been eaten, a new sound and light cue was provided and a new reward was presented in the opposite feeding trough, requiring the sow to walk around the barrier. The sows in the test arena were in auditory and olfactory contact with the other sows. To minimize distraction, any faeces and/or urine produced by one sow was removed before the entrance of the following sow.

![Figure 3.1. Feed reward collection test arena. (a) Feeding trough, (b) light, (c) slot for sliding the fence (d) through the pen wall to shorten the distance to be travelled.](image)
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ANIMALS AND HOUSING

A total of 29 gestating RA-SE sows from the herd of the Flemish Institute for Agricultural and Fisheries Research (ILVO) were selected based on their gait score (see below). The study included sows of parity two to eight with a median parity of four. All sows were approximately in the same gestation stage of 96.6 ± 7.0 days (mean ± s.d.) and had a mean weight of 267 ± 33 kg (mean ± s.d.). The experiment was conducted using three batches of 8, 9 and 12 animals, respectively. The sows had been housed individually from 1 week before parturition until 4 weeks after insemination. From then on, they were kept in static groups. The group pens (3.34 m²/sow) had a partly slatted concrete floor and solid concrete lying areas. The sows were fed a restricted diet as commonly used in practice, with 2.6 kg of a commercial gestation diet fed from an electronic sow feeder, which satisfies only about 40% to 60% of their ad libitum feed intake (Brouns et al., 1995; Meunier-Salaün et al., 2001). Water was available ad libitum.

GAIT SCORE

The feed reward collection test was preceded by gait scoring on all test days. To reach the test arena, sows had to walk a 60 m concrete run, at which time the locomotion scoring for the current experiment was performed (i.e. directly before each test session). To encourage the sows to move, a person walked beside them and used sound cues or waved as needed. Gait score was recorded by an experienced observer using the tagged visual analogue scale (tVAS) developed by Nalon et al. (2014). The sows were categorised into five gait score classes: non-lame (0 to 30 mm on tVAS); mildly lame (30 to 60 mm on tVAS); moderately lame (60 to 90 mm on tVAS), severely lame (90 to 120 mm on tVAS); or extremely lame (120 to 150 mm on tVAS) (Figure 3.2). By using a tVAS with descriptors and different colour shades on the scale, observers are helped to use the total length of the 150-mm bar (Nalon et al., 2014). No animals with a gait score >120 mm (extremely lame) participated in this experiment because they were not present in the herd (due to ethical considerations).
Feed Reward Collection Test

Figure 3.2. Lameness classes on the tVAS (adapted from Nalon et al., 2014). Explanation of scores.

1. ‘Good’: even stride, ease of movement. Little inducement needed, comfortable on all feet. 2. ‘Stiff, uneven’: movement is not fluid, uneven strides, stiffness. 3. ‘Limping’: lame in one leg, limping. Shortened stride. Compensatory behaviours (dipping of head, caudal swagger, arched back). 4. ‘Reluctant’: reluctant to place weight on affected limb(s). Reluctant to walk. Lame in more than one leg. Caudal swagger. 5. ‘Unable’: does not place affected limb on floor. Very unwilling to move, does not walk. A vertical mark along the tVAS can be placed to score a sow.

tVAS = tagged visual analogue scale.

Habituation and training for the feed reward collection test

Sows were habituated individually to the test arena for 5 non-consecutive training days before the start of the feed reward collection test. They received one individual 10-min training session per day. The purpose was threefold: to familiarise them with the test arena and procedure, to train them that a feed reward would be available after the sound/light cue and to train them that the reward could be obtained by walking around the barrier. The difficulty of the procedure was increased during training by increasing the barrier length (0, 88, 175, 350 and 350 cm on training days 1 to 5, respectively). Training was considered successful if at least three rewards (i.e. the sow walked around the barrier at least twice) were collected at training at day 5. All animals were successfully trained; no animals were excluded from the experiment. The sows were already used to being separated from the group because of prior locomotion testing carried out several weeks before this study.
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**Feed reward collection test**

After completion of the 5 training days, sows were tested individually once per day on 3 non-consecutive days. During the 3 test days the barrier length was at maximum length (350 cm), so the distance to cover from feeding trough to feeding trough was 9.30 m (Figure 1). During each 15 min test, we recorded how many times each sow walked around the barrier and collected a feed reward. All procedures were approved by the ILVO Ethics Committee (Reference 2011/146).

**Statistics**

The total number of rewards on each test day was analysed using a mixed Poisson regression model with test day and gait class as fixed effects. To correct for repeated measures and clustering within test batch, sow and batch were included in the model as random effects. Post-hoc pairwise testing was used to test the differences between different gait classes and the P-values were corrected with the Tukey–Kramer adjustment for multiple comparisons. All analyses were performed at a significance level of 5% using proc GLIMMIX in SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

**Results**

Based on visual gait scoring, sows were classified as shown in Table 3.1. As intended there was a reasonable variation in gait scores in all available classes (except for the extremely lame category).

**Table 3.1.** The total number of observations in each lameness category as determined by visual scoring

<table>
<thead>
<tr>
<th>Test day</th>
<th>Gait class*</th>
<th>Non-lame</th>
<th>Mildly lame</th>
<th>Moderately Lame</th>
<th>Severely lame</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>10</td>
<td>5</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>8</td>
<td>7</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>10</td>
<td>4</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>28</td>
<td>16</td>
<td>30</td>
<td>12</td>
</tr>
</tbody>
</table>

*No animals in gait class extremely lame participated due to ethical considerations.
The number of rewards obtained ranged from 0 to 23 per session (mean 8 ± 6 SD). No significant difference was found between test days ($F_{2,53} = 1.98$, $P = 0.15$). Non-lame and mildly lame sows obtained more rewards than moderately lame and severely lame sows ($P < 0.01$) (Figure 3.3). However, there was no difference between non-lame and mildly lame sows ($P = 0.69$), or between moderately lame and severely lame sows ($P = 1.00$).

![Boxplot of the number of rewards obtained by sows in five gait score classes. The box includes observations from the 25th to the 75th percentile; the horizontal line within the box represents the median value. Whiskers represent the 5% and 95% percentiles. Gait score classes with different letters differ significantly ($P < 0.05$). No animals in gait class extremely lame participated due to ethical considerations.](image)

**DISCUSSION**

The present study evaluated the relationship between gait score and the mobility (*i.e.* combined willingness and capability to walk) of sows using a feed reward collection test. Moderately lame and severely lame sows obtained fewer rewards than non-lame and mildly lame sows. However, no differences in obtaining feed rewards were observed between non-lame and mildly lame sows, or between moderately lame and severely lame sows. This suggests that sows with a gait score...
on the tVAS corresponding to moderately lame or severely lame (lame in at least one leg and showing compensatory behaviours) are limited in their locomotory behaviour. The results could be an indication that lameness is either absent or present, instead of present and evolving in different degrees of severity, as assumed in most gait scoring scales, including our tVAS (Main et al., 2000; Nalon et al., 2014). In literature, only minimal information is available about distances covered by pigs (Brendle and Hoy, 2011). The amount of work that animals are able and willing to do in order to obtain a reward depends on the trade-off between the incentive value of the reward and the amount of work needed to obtain it (Dawkins, 1990). In this study, we aimed for an equal level of feeding motivation in all sows. We were not so much interested in the sows’ motivation to feed, but rather in how lameness status affects the likelihood that a sow will fulfil this motivation. To achieve this goal, we used a reward that had great incentive value because it was highly palatable and because our sows were fed at commercial feed levels, which satisfy only about 40% to 60% of their ad libitum feed intake (Brouns et al., 1995; Meunier-Salaün et al., 2001). Such commercial feeding levels are known to leave sows hungry (Lawrence et al., 1988; Lawrence and Terlouw, 1993). Both feed deprivation (Robert et al., 1997; Patterson-Kane et al., 2011) and good palatability (Baldwin, 1976) are known to increase feeding motivation in sows. As a result, the mildly lame sows may have disregarded any discomfort they experienced during the test, leading to no observed differences in mobility in this test between sound and mildly lame sows. In addition, many farm animal species are known to be stoic, which masks their vulnerability to avoid becoming easy targets for predation or harassment by conspecifics (such as caused by impaired locomotion) (D’Eath et al., 2010). This aspect can be challenging when trying to recognize behavioural changes, thus sensitive detection methods are required that can notice the subtle changes in behaviour such as changes in locomotion pattern of sows. For example accelerometric devices could be used to detect changes in behaviour as is increasingly the case in cow husbandry (Chapinal et al., 2010a). It is possible that mildly lame sows do experience discomfort; however ignored their potential discomfort simply because of their high desire to reach the reward, the sensitivity of our test may be improved by either using sows that are less hungry or by using a less palatable reward. Alternatively, making sows walk further to obtain their reward or adding a stair, barricade or slope may also increase the feeding test’s sensitivity. An
increased workload is likely to have a stronger impact on animals that are more challenged by that particular type of work. In addition to changing the incentive value of the reward or the workload, assessing lameness at a different gestation state may also affect the test’s success. All tested sows were in the same gestation state (mean ± SD = 96.6 ± 7.0 days), but later in gestation sows become heavier and move less easily (Bos E-J., unpublished results). The possible changes in locomotion induced by gestational state may highlight the differences between non-lame and (mildly) lame sows. Mild lameness has recently attracted attention, either as a welfare problem in itself or as an indicator of an increased risk of developing into more severe lameness. It is also possible that the mildly lame sows did not behave differently from non-lame sows in the feed reward collection test because they actually experienced relatively little discomfort during walking. Possibly, the group we categorised as mildly lame on the basis of the visual gait scoring was just a group of sows with a rather stiff or less smooth gait, with a negligible impact on their ability or willingness to walk. If so the relevance of a mildly increased gait score for sow welfare is likely to be small. When using these indicators for animal welfare, it is important to determine a threshold to distinguish sows that are likely to experience discomfort and pain due to their condition from animals that have poor gait due to their conformation but are not in any pain. The EFSA Panel on Animal Health and Welfare (2012) reported that broilers with gait scores 4 and 5 on a five-point scale were unable to walk and therefore unable to feed properly. These animals are generally culled regardless of any consideration of the pain they experience. Both McGeown et al. (1999) and Paxton et al. (2013) showed that broilers can have an abnormal ‘awkward gait’ but these animals did not respond to analgesics; this may suggest they were not actually in pain. This shows that abnormal gait might be due to other causes than pain, even though these animals are often defined as lame when using visual gait scoring methods. Nonetheless, even if not due to pain, abnormal gait may still be an indicator of poor welfare as it may restrict the animal in its pursuit of important resources. In sow group housing systems, conspecifics compete for resources which may exacerbate the condition (Anil et al., 2009). Free-access stalls (with rear gates), where the resting areas are located directly at the individual feeding places, are the only type of sow housing where the sows do not have to traverse a significant distance in order to eat or drink (Levis et al., 2013). Severely lame sows did not perform worse in the feed reward collection test.
as compared with moderately lame sows. We categorised sows as moderately lame when they appeared lame in one leg and showed compensatory behaviours (Figure 2). The test results suggest that the mobility of these sows is reduced to a level comparable of sows we categorised as severely lame because they appeared reluctant to place weight on the affected limb(s). In other gait scoring scales these two categories are often taken together (D’Eath, 2012; Nalon et al., 2014). Perhaps we ought to downplay the weight allocated to the signs of mild lameness relative to the signs of more severe lameness when interpreting their consequences for sow welfare. In cows it is known that early detection and treatment decreases the prevalence of lameness (Leach et al., 2012). Whether this is also the case for pigs is not clear, because little is known about the transition of mild lameness to more severe lameness in this species. However, if mild lameness predicts future severe lameness, early detection may be beneficial for welfare and economics, as treating mild cases of lameness costs less per case than treating severely lame animals (Willgert, 2011).

**CONCLUSION**

In many group housing systems in the EU, gestating sows have to cover distances when moving between feeders, drinkers and lying areas, in contrast to previous housing in individual stalls in which locomotion was neither necessary nor possible for sows during gestation. Although the possibility for locomotion and social interaction are important advantages of group housing, our results suggest that moderately and more severely lame sows are restricted in covering distances. This puts them at risk of behavioural restrictions that may possibly result in reduced feed intake, limited engagement in social interactions and a higher risk of resting in inappropriate places, all of which are likely to reduce their welfare within the group. Our feed reward collection test revealed differences in mobility between non-lame and mildly lame sows v. moderately lame and severely lame sows, but no differences in total amount of rewards were found between non-lame and mildly lame sows. This may be because the sows that we classified as ‘mildly lame’ on the basis of visual gait scoring actually experience relatively little discomfort during walking, and/or because the test protocol needs improvement.
The sensitivity of the test may be improved by decreasing the attractiveness of the rewards or by increasing the workload for each reward.

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REFERENCES


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CHAPTER 4 – DYNAMIC VERSUS STATIC GROUP-HOUSED SOWS

Adapted from:

Locomotion disorders and skin and claw lesions in gestating sows housed in dynamic versus static groups

E-J. Bos¹,², D. Maes², M.M. J. van Riet¹,³, S. Millet¹,³, B. Ampe¹, G. P.J. Janssens³, F.A. M. Tuyttens¹,³

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Chapter 4

ABSTRACT

Lameness and lesions to the skin and claws of sows in group housing are commonly occurring indicators of reduced welfare. Typically, these problems are more common in group housing than in individual housing systems. Group management type (dynamic versus static) and stage of gestation influence the behavior of the animals, which in turn influences the occurrence of these problems. The present study compared prevalence, incidence and mean scores of lameness and skin and claw lesions in static versus dynamic group housed sows at different stages of gestation during three consecutive reproductive cycles. A total of 10 Belgian sow herds were monitored; 5 in which dynamic groups and 5 in which static groups were utilized. All sows were visually assessed for lameness and skin lesions three times per cycle and the claws of the hind limbs were assessed once per cycle. Lameness and claw lesions were assessed using visual analogue scales. Static groups, in comparison with dynamic groups, demonstrated lower lameness scores \( (P<0.05) \) and decreased skin lesion prevalence \( (24.9 \text{ vs. } 47.3\%, \ P<0.05) \) at the end of gestation. There was no difference between treatment group regarding claw lesion prevalence with 75.5\% of sows demonstrating claw lesions regardless of group management. Prevalences of lameness \( (22.4 \text{ vs. } 8.9\%, \ P<0.05) \) and skin lesions \( (46.6 \text{ vs. } 4.4\%, \ P<0.05) \) were highest during the group-housed phase compared to the individually housed phases. Although the prevalence of lameness and skin lesions did not differ three days after grouping versus at the end of the group-housing phase, their incidence peaked during the first three days after moving from the insemination stalls to the group. In conclusion, the first three days after grouping was the most risky period for lameness incidence, but there was no significant difference between static or dynamic group management.

Keywords: Lameness, pig, prevalence, incidence, gait (score)
INTRODUCTION

Since January 2013, all sows in the European Union must be group-housed from four weeks after service to one week before parturition (European Directive 2001/88/EC). Group housing allows for social contact and interactions between sows (Chapinal et al., 2010; Remience et al., 2008). Moreover increased activity of group housed sows as compared to individually housed sows, has a positive effect on muscle and bone development (Marchant and Broom, 1996; Schenck et al., 2008). However, the positive benefits to group housing of sows may also be accompanied by factors that negatively impact sow welfare. Depending on the feeding system, more feeding competition may occur, and aggression towards other sows increases, resulting in an increased risk for skin lesions, vulva biting, claw lesions and lameness (Chapinal et al., 2010; Anil and Deen, 2007; Harris et al., 2006). In commercial settings, sows will not only be housed in groups, but will also experience different types of housing through gestation including insemination and farrowing crates. Gestating sows are often housed in larger groups than feral pigs, with (somewhat to completely) unfamiliar animals and these group compositions are usually changed at least once per reproductive cycle (Gundlach, 1968). When housing sows in groups, many aspects need to be considered, including group size, group density, pen design, floor type, bedding material, feeding system and group management (dynamic versus static) (Levis et al., 2013). Commercial sow groups can be managed as either a static or a dynamic group. In static groups the group composition stays the same after formation, so only one breeding group is present per pen. sows experience one bout of mixing, and the associated aggression, at the beginning of gestation. If a sow recycles or is removed for some reason, no replacement sow is introduced. In dynamic groups, animals are introduced into and removed from the group throughout the gestating period, with the number of introductions and removals dependent upon individual farm Lameness is prevalent in group housed sows, as shown by Pluym et al. (2011) who found a lameness prevalence of 9.7 % in Belgian herds. Comparable findings for lameness prevalence are found in Finland (8.8 %), Norway (13.1 %) and the United Kingdom (14.4 % in gestating gilts and 16.9 % in gestating sows) (Gjein and Larsen, 1994; Heinonen et al., 2006; KilBride et al., 2009a). Dynamic groups have more than one breeding group housed in a pen together at the same time. This approach uses pen space more efficiently compared to static
groups. However, sows are exposed to multiple bouts of mixing and the associated aggression throughout gestation every time a new group of sows is introduced. Aggression is unavoidable when group housing pigs, because they will inevitably fight in order to establish a dominance hierarchy (Hoy and Bauer, 2005; Knox et al., 2013). Skin lesions are often a result of aggression (Turner et al., 2006). Due to the more frequent mixing bouts in dynamic sow groups, more aggressive behavior and therefore more skin lesions might be expected (Simmins, 1993; Moore et al., 1994; Arey and Edwards, 1998; Meunier-Salaün et al., 2002; Remience et al., 2008). As soon as the social hierarchy is established, the fighting decreases and aggressive behavior can be kept to a minimum in well managed and well-designed housing systems (Levis et al., 2013). The unrest and agonistic behavior associated with such changes result in more skin lesions and locomotion disorders, including claw lesions (Simmins, 1993; Arey and Edwards, 1998; Turner et al., 2006).

Locomotion disorders (deviations from a normal gait) are the second largest reason for early culling of sows (Pluym et al., 2011). Since the mandate for group housing of gestating sows in the EU the prevalence of these disorders has increased (Rodriguez-Zas et al., 2003; Engblom et al., 2007). Lameness can be described as the clinical appearance of locomotion disorders that might result in pain, discomfort and impaired mobility, depending on the severity and type of disorder (KilBride et al., 2009b). Lameness may also reduce general activity, social behavior and exploration, as reviewed by Weary et al. (2009). Many factors may influence the development of locomotion disorders in breeding sows. Lameness can have several non-infectious risk factors, such as osteochondrosis and limb malformation, and infectious risk factors such as joint arthritis or infected skin lesions (Jørgensen, 2000; Heinonen et al., 2006; Engblom et al., 2007; Weary et al., 2009; Nalon et al., 2013; Cador et al., 2014). Various studies have reported that management, breeding age, parity, claw lesions, feed, floor properties of the pen and rearing strategies are important risk factors (Kroneman et al., 1993a; KilBride et al., 2009a; Weary et al., 2009; Anil et al., 2009). Furthermore, sows housed in groups have a higher risk of lameness resulting from fighting due the aggression related to competition for feed or (re)grouping (Zurbrigg and Blackwell, 2006; Bos et al., 2016; Gjein and Larssen, 1995). Lameness has an economic impact, as it decreases reproduction performance and longevity and increases human workload and veterinary costs (Anil et al., 2005; Ringgenberg et al., 2005; Pluym et al., 2013).
Locomotion disorders can be associated with claw health, such as injuries to the sole, wall, white line and heel (Enokida et al., 2011; Cador et al., 2014). Claw lesions, their causes and consequences have been studied extensively and the shift to group housing has resulted in more attention for this problem (Anil et al., 2007; KilBride et al., 2010; Grégoire et al., 2013; Calderón Díaz et al., 2014; Sasaki et al., 2014; Olsson et al., 2016). Claw lesion prevalences of 60 to 95% have been reported (Pluym et al., 2009; KilBride et al., 2010). Claw lesion etiologies are complex and multifactorial but some studies suggest that genetics, housing, nutrition and facility management all play a role (Fan et al., 2009; Pluym et al., 2013; Van Riet et al., 2013).

Long-term sow observation and evaluation are needed to understand the impact of group management and associated housing methods on the evolution of leg and claw problems at different phases within the reproductive cycle. Prevalence measures give an overview of the occurrence of the actual problem and incidence measures (the number of newly diagnosed cases of a disease during a given period of time) allow for recognition of hazardous phases within the reproductive cycle of the sow. Mean locomotion scoring allows more accurate representation of the severity of the condition. Longitudinal studies allow to show the patterns of a variable over time, and to calculate incidences. The longitudinal, repeated measurements essential when incidences are being calculated. Although studies conducted by Pluym et al. (2009) have investigated the short term effects of group management on the prevalence of lameness and claw lesions in Belgian pig herds, to date, there are no longitudinal studies evaluating sow group management on lesion and lameness incidence.

The aims of the present study were to compare the prevalence, incidence and mean scores of lameness and skin and claw lesions in static versus dynamic group housed sows at different stages of gestation during three consecutive reproductive cycles.

**MATERIALS AND METHODS**

The study was approved by the ILVO Ethics Committee (Reference 2011/153). Participating farms were fully aware of the study’s aims and objectives and gave permission to collect and publish the data conditional upon our promise not to reveal their identity. All identifying information regarding the participating farms therefore remains unpublished.
Chapter 4

STUDY POPULATION

The present study was carried out on 10 commercial pig farms in Flanders, Belgium. Farms were selected based on their willingness to participate in this observational study. Farms were required to have a sow group housing system established for a minimum of 1 year, were not allowed to change group housing system during the study and were within 100 km from the ILVO institute, and there had to be an equal number of farms with dynamic and static group management. Farms’ individual characteristics are described in Table 4.1. The presence or absence of locomotion problems and skin or claw lesions was not taken into account when selecting the farms. Sows to be included in the study were randomly selected by age (using the randomization function in Excel) with a mean group size of 27 (group size range: 24 – 30) for a total of 138 and 132 sows in dynamic and static systems, respectively. At the onset of the study, the parity range was 1-6 (Table 1). Multiparous sows and gilts were combined and referred to as ‘sows’ for the remainder of the manuscript. Every sow of each of these groups was evaluated four times per cycle: locomotion and skin lesions were scored three times (sampling points 1, 2 and 3), whereas claw lesions were scored once per cycle (sampling point 4) (Figure 4.1.). As farms differed in time schedule according to moving animals, time spent in specific areas of the farms differed, see Table 1 for number of days spent in the insemination stalls per farm.

![Timeline of observations](image)

**Figure 4.1.** Timing of the various observations during each reproductive cycle of the sows. In addition to the first baseline measurement (0), locomotion and skin lesions were scored three times (1, 2, and 3) and claw lesions once (4) per cycle. Sampling point 1: prior to moving to the...
group. Sampling point 2: three days after moving to group. Sampling point 3: end of group housing phase, around d 108 of gestation. Sampling point 4: approximately 10 days after farrowing.

Table 4.1. General characteristics of the 10 studied herds.

<table>
<thead>
<tr>
<th>Farm</th>
<th>1</th>
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<tbody>
<tr>
<td>Group pen characteristics</td>
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<td>Group managementa</td>
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<td>D*</td>
<td>D*</td>
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<tr>
<td>Group size (number of sows)</td>
<td>70</td>
<td>80</td>
<td>170</td>
<td>48</td>
<td>56</td>
<td>80</td>
<td>46</td>
<td>20</td>
<td>58</td>
<td>72</td>
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<tr>
<td>Feeding system in group pen</td>
<td>VM</td>
<td>VM</td>
<td>VM</td>
<td>ESF</td>
<td>FAS</td>
<td>ESF</td>
<td>ESF</td>
<td>ESF</td>
<td>ESF</td>
<td>ESF</td>
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<tr>
<td>m²/sow in group pen</td>
<td>1.43</td>
<td>2.33</td>
<td>2.10</td>
<td>2.10</td>
<td>3.31</td>
<td>2.37</td>
<td>2.00</td>
<td>1.95</td>
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<td>2.61</td>
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<tr>
<td>Breed</td>
<td>RA-SE</td>
<td>Topigs</td>
<td>PIC</td>
<td>Crossbr York</td>
<td>Danbred</td>
<td>Topigs</td>
<td>Topigs</td>
<td>Crossbr York</td>
<td>Topigs</td>
<td>PIC</td>
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<tr>
<td>Number of days in insemination stallsb</td>
<td>30</td>
<td>28</td>
<td>28</td>
<td>25</td>
<td>35</td>
<td>3</td>
<td>28</td>
<td>5</td>
<td>4</td>
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<td>Batch production system (wk)c</td>
<td>11</td>
<td>5</td>
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<td>Number of studied sows at baseline per parityd</td>
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<tr>
<td>Parity 1</td>
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<td>14</td>
<td>12</td>
<td>9</td>
<td>9</td>
<td>25</td>
<td>8</td>
<td>5</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>Parity 2-4</td>
<td>27</td>
<td>11</td>
<td>15</td>
<td>16</td>
<td>16</td>
<td>0</td>
<td>21</td>
<td>13</td>
<td>12</td>
<td>20</td>
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<tr>
<td>Parity ≥4</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>

VM = Vario-Mix feeder, ESF = electronic sow feeder; FAS = free access stalls

* Farm 1, 9 and 10 used straw bedding in the gestation unit
a S = static groups; D= dynamic groups
b Farm used different number of days that sows spent in the insemination stalls
c Week batch production system for sows
d Parity range at onset of the study was 1-6

When sows were removed from the groups, no replacement sows were included in the study. Farmers remained in charge of making decisions about sow removals throughout the study. All observations were performed by two experienced assessors who had been trained to use the scoring systems. Training involved repeated scoring of locomotion, skin lesions and claw lesions of sows by all assessors until inter-observer repeatability exceeded 90%.
Chapter 4

**Locomotion**

A baseline locomotion score was recorded before the first service within the study (day 0) and further locomotion scoring took place at sampling points 1, 2 and 3 (Fig. 1). Locomotion was scored in the corridor behind the insemination crates or, during the group housed period of the reproduction cycle, locomotion was scored while a sow was walking in her home pen. If the sows needed to be encouraged to move, a person walked beside them and gave either vocal cues or waved his/her hands. Locomotion was scored using the 150 mm Visual Analogue Scale with labels (tVAS) developed by Nalon *et al.* (2014) (Figure 4.2). For the condition in question, the observers put a vertical mark across the tVAS in the position corresponding to their perception of the sows’ gait. Locomotion of sows was analysed as mean locomotion score, lameness prevalence and lameness incidence. For estimating lameness prevalence, sows were considered lame when their locomotion score was >60 mm on the tVAS (Bos *et al.*, 2016). For estimating lameness incidence, a new case of lameness was defined as a previously non-lame sow (<60mm on tVAS) that had become lame (>60mm) and for which the locomotion score had increased by >30 mm since the previous score. Incidence was calculated per day at risk.

![Figure 4.2. Lameness classes on the tVAS. Explanation of scores: 1. ‘Good’: even stride, ease of movement. Little inducement needed, comfortable on all feet. 2. ‘Stiff, uneven’: movement is not fluid, uneven strides, stiffness. 3. ‘Limping’: lame in one leg, limping. Shortened stride. Compensatory behaviours (dipping of head, caudal swagger, arched back). 4. ‘Reluctant’: reluctant to place weight on affected limb(s). Reluctant to walk. Lame in more than one leg. Caudal swagger. 5. ‘Unable’: does not place affected limb on floor. Very unwilling to move, does](image-url)
not walk. A vertical mark along the tVAS can be placed to score a sow. tVAS = tagged visual analogue scale.

**SKIN LESIONS**

Skin lesions were scored at the same time as locomotion scoring (Figure 4.1) by using a slightly adjusted scoring method from the Welfare Quality® protocol for pigs (Welfare Quality®, 2009). The left side of the sows’ body was visually divided into five regions: ears, front (head to back of shoulder), middle (back of shoulders to hindquarters), hindquarters and legs (from accessory digit and above). A 3-point ordinal scale was used to score skin lesions on each body region, with a score A indicating 0 to 4 visible skin lesions, score B indicating 5 to 10 lesions and score C indicating >10 lesions. These scores were summarized by assigning a binary total body score. If score A was recorded on all body regions, a total score of 0 was assigned. If at least one score B or C was recorded, a total score of 1 was assigned (e.g. positive score for the presence of skin lesions). Skin lesions of sows were analysed in terms of the prevalence and incidence of skin lesions.

**CLAW LESIONS**

Hind claws of the sows were visually assessed around 10 days after parturition (sampling point 4; Fig 1) while the sows were housed in the farrowing crates. During the time in the farrowing crates sows are individually housed, cannot walk away and lay down more calmly while suckling their piglets, which enables close inspection of the claws from all sides. When the sows were standing, not all parameters were immediately scored but as soon as the sows lay down, the remaining parameters were scored. Claws were scored using a recording system based on the “Zeugenklauen Check” by Wageningen University Livestock Research (Hoofs, 2006) and the ‘FeetFirst’ method by ZinPro (Deen et al., 2009), as described in Bos et al. (2016). Eight claw parameters: 1) heel horn, 2) heel/sole crack, 3) white line, 4) skin lesions between the coronary band and the origin of the dewclaw, 5) horizontal cracks in the wall horn, 6) vertical cracks in the wall horn, 7) claw length and 8) dewclaw length were evaluated using a visual guide to the type and severity of the lesions and erosion. Instead of the ordinal scale presented in literature, we used a 160 mm t VAS (Figure 4.3). The length of the dewclaw was determined by pushing the dewclaw against the claw to be able to compare dewclaw length and heel height. For each claw parameter a mean score per sow/parameter/inspection was calculated. Results of claw lesion
scores are presented as a mean score per sow per parameter and as claw lesion prevalence. A sow was defined as having a claw problem if the tVAS score was >80 mm for at least one parameter per sow.

Figure 4.3. Claw lesions classes on the tVAS. Eight claw parameters were used: 1) heel horn, 2) heel/sole crack, 3) white line, 4) skin lesions between the coronary band and the origin of the dewclaw, 4) horizontal cracks in the wall horn, 5) vertical cracks in the wall horn, 6) claw length and 7) dewclaw length. Explanation of scores depends on the claw parameter, but all scores vary between 0 mm (1) (a perfectly, healthy claw without any deviations, erosion, cracks or deviations in length and 160 mm (being a claw in terrible state, including for example severe erosion, cracks, inflammations and loo long or (partly) amputated (dew)claws). A vertical mark along the tVAS can be placed to score a claw parameter. tVAS = tagged visual analogue scale.

**Statistical analysis**

The mean locomotion and claw lesion scores were analysed using a linear mixed regression model with group management type (static or dynamic groups), phase of the reproductive cycle, their interactions and parity as fixed effects and farm and sow as random effects to correct for the repeated measurements. Non-significant interactions were excluded from the final models. The dichotomized skin lesion score and prevalence of locomotion and claw problems were analysed using similar logistic mixed regression models with the logit link. The analysed continuous data were considered to be sufficiently normally distributed, based on the graphical evaluation
Dynamic versus Static

(histogram and QQ-plot) of the residuals. In case of post hoc pairwise testing, p-values were corrected with the Tukey-Kramer adjustment for multiple comparisons. Incidence of lameness and skin lesions was calculated per day at risk. For the analysis of the incidence of lameness and skin lesions, only numerical results are provided. All analyses were performed using proc GLIMMIX in SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Results are given as LS-means ± SE.

RESULTS

STUDY POPULATION
For the total duration of the study 55.2% of the sows of the initial experimental groups were removed; 42% of removed animals came from static groups and 58% from dynamic groups. Reasons for removal were specified by the farmers as locomotion disorders (9%), reproductive failures (56%) and other or unknown reasons (35%).

MEAN LOCOMOTION SCORE
The interaction between phase in the cycle and group management had an effect (P<0.001) on mean locomotion score with greater locomotion scores at the end of the group housing period in dynamic vs. static groups (Figure 4.4.). There was a tendency for a parity effect on locomotion score (P = 0.068) with a decrease of 1.85 mm per parity level.
Figure 4.4. Effect group management of sows on mean locomotion score at different stages in the reproductive cycle. Results are given as LS-Means ± SE. * indicates significant differences between group management per phase in the cycle (P < 0.05).

LAMENESS PREVALENCE

The interaction between phase in the cycle and group management had no effect on lameness prevalence (P = 0.477), nor was there a parity effect (P = 0.527). Phase in cycle had an effect on lameness prevalence. There was a lower prevalence when sows were moved to the group pen (8.9%) compared to three days after grouping (23.0%, P = 0.040) and compared to the end of the group housing period (21.9%, P = 0.006) (Figure 4.5).
Figure 4.5. Percentage of lame sows per phase in the reproductive cycle. * indicates significant differences between phases in the cycle (P < 0.05).

**LAMENESS INCIDENCE**

Lameness incidence was the highest between move to group and three days after grouping regardless of management systems (Figure 4.6). The evolution of lameness incidence throughout the reproductive cycle is largely similar for both management systems.
PREVALENCE OF SKIN LESIONS

The interaction between phase in the cycle and group management had an effect on skin lesion prevalence (P<0.001). Skin lesion prevalence tended to be higher in dynamic groups (47.3%) as compared to static groups (24.9%, P=0.061) at the end of the group housing period, but did not differ during other phases of the reproductive cycle (Figure 4.7). Irrespective of type of group management, very few sows had skin lesions at move to group (Figure 4.7). Three days after grouping, however, more than half the sows had skin lesions. Parity significantly affected skin lesion prevalence (P<0.001); the lower the parity the higher the prevalence.
**Figure 4.7.** Prevalence of sows with skin lesions per phase in the reproductive cycle and for dynamic versus static group management separately. * indicates significant differences between phase in the cycle (P < 0.05). # indicates trend towards differences between group management systems (0.05 < P < 0.01)

**INCIDENCE OF SKIN LESIONS**

Incidence of skin lesions was the highest from grouping to three days after grouping for both group management systems (Figure 4.8).
Figure 4.8. Incidence of skin lesions per day-at-risk for dynamic versus static group management.

**MEAN CLAW LESION SCORE**

There were no differences in mean scores per claw parameter between the two group management systems ($P > 0.1$ for all 8 claw parameters). Mean scores per claw parameter per monitored cycle are shown in Figure 4.9. Parity affected the heel horn (increase of 2.89 mm on tVAS per increasing parity, $P < 0.001$) and claw length score (increase of 3.22 mm on tVAS per increasing parity, $P = 0.009$). There was a tendency for a parity effect for skin lesions around the claw (increase of 1.75 mm on tVAS per increasing parity, $P = 0.054$) and length of the dewclaw (increase of 2.50 mm on tVAS per increasing parity, $P = 0.073$). A significant effect of the monitored reproductive cycle for all claw parameters ($P < 0.050$) was observed, except for the heel sole crack; the higher the monitored cycle, the higher the mean claw score.
Figure 4.9. Mean claw scores in sows per claw parameter per cycle. Results are given as LS-Means ± SE

PREVALENCE OF CLAW LESIONS

The overall prevalence of claw lesions was 75.5%. No effect of group management (P = 0.613) or monitored cycle (P = 0.303) was observed. The prevalence of claw lesions increased with increasing parity (P = 0.004).

DISCUSSION

The present study showed that at the end of the group housing phase the mean locomotion score, lameness incidence and skin lesion prevalence were lower when sows were housed in static versus dynamic groups. We found no effect of group management on claw lesions nor on both lameness and skin lesion prevalence. According to the incidences, the first few days after grouping have a pronounced detrimental effect on the development of locomotion problems and skin lesions for both static and dynamic groups of sows.

LOCOMOTION

The mean locomotion score tended to be better for sows with a higher parity. This is consistent with results from other research (Heinonen et al., 2006; Fan et al., 2009; Li and Gonyou, 2013)
However, the decreased risk for a higher locomotion score by aging can be the results of the culling strategy, because all unhealthy or weak sows are culled, leaving only the more robust and healthy sows in the herd. This is an problem inherent to studies performed under commercial circumstances. During the present study, 55.2% of the sows were removed or euthanized over three reproductive cycles, typical for a commercial situation (Ringgenberg et al., 2010). Under commercial circumstances sows are often culled after farrowing or weaning but this depends on the reason of removal. This could possibly have influenced our study as well (Dijkhuizen et al., 1989; Stein et al., 1990).

The present study showed that around 22% of the sows were lame (at least 60 mm on the tVAS) while housed in the group pens. This means that they are lame in at least one leg, obviously limping and showing compensatory behavior. No difference between the two group management systems was found, and lameness prevalence varied widely between herds subjected to the same group management type. Lameness prevalence in the current study was higher than reported than prevalences reported for Finland (8.8% lame sows) and Norway, where 13.1% of the loose-housed dry sows showed lameness in a hind leg (Gjein and Larsen, 1994; Heinonen et al., 2010). The results of Pluym et al. (2009) confirm wide variation between herds in terms of lameness prevalence.

The peak in lameness incidence was found from immediately prior to move to group until three days after moving, irrespective of group management, this in agreement with the results of Bos et al. (2016). Numerically higher incidences were found in dynamic groups. Li and Gonyou (2013), reported increased cases of lameness in a dynamic group compared to a static group after the group housing period. This can be explained by the increased number of introductions of new sows into dynamic groups, which induces aggression and increases risk of injuries due to fighting (Anil et al., 2006; Stevens et al., 2015). In both types of group management systems, but in dynamic groups in particular, the first days after grouping are by far the most risky period for sows to develop lameness. This is to be expected, as aggression between sows is greatest when sows are first introduced to each other and they fight to form hierarchies, often resulting in locomotion problems (Stevens et al., 2015). The incidence during the other phases in the reproductive cycle was much lower, also in dynamic groups. This is unexpected, as we
hypothesized that in dynamic groups regular interactions between sows would occur throughout the entire group-housed period.

Interestingly, both the prevalence and mean score of lameness did not differ between the start and end of the group housing phase, while the incidence differed greatly. This shows the added value of using all three methods of measuring locomotion disorders. Prevalence of lameness was very low at the end of the time spent in the insemination crates. A reason for this can be that when sows are housed individually, no interactions can take place with other sows, and the sows do not have to cover distances in the pen in order to eat, sleep or defecate and urinate (Brendle and Hoy, 2011; Stevens et al., 2015). Diminished locomotion and interaction both decrease the risk of becoming lame or maintaining locomotion problems. In our study it appeared that sows recovered spontaneously from lameness during the time spent in individual housing. Research has shown that pigs with clinical signs of lameness can recover spontaneously when housed in pens where they can eat and drink without the need to compete with healthy sows, e.g. individual housing (Heinonen et al., 2013; Kroneman et al., 1993b).

**Skin lesions**

The first few days after moving to the group and the entire period of group housing appear to be critical for sow welfare given the high prevalence and incidence of skin lesions found in this study. The trend towards more lesions for sows in dynamic groups at the end of the group housing period is in agreement with our hypothesis. Total skin lesion scores were higher three days after move to group and at the end of the group phase compared to the moment before grouping; this is in agreement with other research (Arey and Edwards, 1998; Hoy and Bauer 2005; Sadler et al., 2011). Newly-grouped animals engage in aggressive behavior to form a social hierarchy, which is reflected in the number of skin lesions (Arey, 1999; Turner et al., 2006). Our study confirmed our hypothesis regarding aggressive behavior; at the end of the group-housed phase the prevalence of skin lesions was lower for static groups.

Numerically higher skin lesion incidences were found in dynamic groups in the first and second monitored reproductive cycle during the first three days of group housing compared to static groups. This is in accordance with the research of Li and Gonyou (2013), who reported an
increased number of skin injuries in sows observed before farrowing in a dynamic group compared to a static group. Strawford et al. (2008) found no differences in aggression, skin lesions and cortisol concentrations between sows in static and dynamic groups. In the third monitored cycle of the present study the incidence during the first three days of group housing was higher for static groups, which differs from the first and second cycle. Selective culling of sows might be a possible explanation for this shift in incidence, besides in the third monitored cycle the sample size was smaller compared to the first and second cycle.

Social interactions between pigs can originate from heritable traits; in our research we assessed sows with a different genetic background. Genetic selection generally highlights physical traits of production, like growth and litter size, but the transition to group housing adds the requirement that sows can live peacefully in groups. Social behavior should therefore be considered as an important and highly significant trait as well (Stricklin, 2001).

The time spent separated in the gestation stalls after artificial insemination varied among the 10 farms in this study. This may have influenced our results, as there is evidence that the stage of reproductive cycle at the moment of entering the group may affect aggression (Li and Gonyou 2013; Stevens et al., 2015). Besides, to maintain stable relationships (i.e., maintaining a dominance hierarchy), sows must have the ability to recognize individual members of the group. Research shows that large group sizes hinder easy recognition and could disturb the development of hierarchies (Turner et al., 2003; Li and Johnston, 2009). In addition to group size, the duration of having been separated is an important factor for sows to be able to recognize conspecifics although it is known that sows are able to recognize each other for several weeks after separation (Spoolder et al., 1996; Arey 1999).

The farms in our study used sows of different parities within a group, which also affects the aggressive behavior in a group. If no older sows are present, sorting by parity might be a valuable method to protect the most vulnerable young and small sows from severe injuries caused by aggression at grouping (Li and Johnston, 2009). Literature suggests that in mixed parity groups, pen design can be improved, e.g., by increasing the amount of space per sow and providing places or barriers where vulnerable or weaker animals can go to get away from other (aggressive) animals (Arey and Edwards, 1998; Li et al., 2012). Group housed sows would therefore benefit
from more research into the effect of parity division within the group, stage of reproductive cycle when grouping and genetics as a contributing factor to aggressive trait characteristics.

CLAW LESIONS
The prevalence of claw lesions (75.5%) corresponds to the reported prevalence of 60–90% in various other sow studies (Gjein and Larssen, 1994; Anil et al 2007; Pluym et al 2013). The causes of claw lesions are multifactorial, including genetics, nutrition, age, parity, earlier experience, and management and housing (Anil et al 2007; Calderón Díaz et al., 2013; Van Riet et al., 2013). We found that the prevalence of claw lesions increases with increasing parity. Several other studies confirm that the prevalence increases with the age of sows (Anil et al 2007; Pluym et al., 2011). A temporary decrease in prevalence during the lactation period has been reported as well (Pluym et al., 2011); we were unable to test this because we assessed the claws only once per cycle in this study.

STRENGTHS AND WEAKNESSES OF THE STUDY
Prevalence was calculated for all three output variables (locomotion, skin and claw lesions); for locomotion and skin lesions, incidence was also calculated. Prevalence and incidence are the basic measures of disease frequency (Fletcher et al., 2012). The prevalence is the total number of cases in the population at a specific moment in time. The incidence is the number of new cases in the population per day at risk. Incidence is thus a valuable measure to evaluate the risk of getting a specific disease, but it requires a longitudinal study and repeated monitoring. The present longitudinal study, in which we monitored specific parameters (locomotion and skin lesions) repeatedly over time in the sows, allowed us to study the process of change over time, and the effect of sow-specific factors (such as locomotion and skin lesions) as well as management-specific factors (such as group management). Because longitudinal data collection is time-consuming we had to limit the total number of farms that could be monitored.

To calculate prevalence and incidence of a condition, a cut-off point in the scoring systems is needed to assess whether an animal is affected with the condition or not. For lameness, no unequivocal cut-off between “lame” and “non-lame” can yet be determined, as some authors consider that some changes in the locomotion pattern (e.g., stiffness) might not result in
discomfort or pain (Weary et al., 2006; Calderón Díaz et al., 2013) and therefore should not be considered as lame. In the present study we used a cut-off based on the lameness score at which sows became less willing to walk to obtain a highly tempting reward (Bos et al., 2015). Using the mean locomotion score allowed us to describe the severity of lameness in a more nuanced way than classifying sows simply as lame vs. non-lame. However, VAS scores might lead to overestimation of the clinical importance of small differences, e.g. the tendency of a parity effect on locomotion score with a decrease of 1.85 mm per higher parity. A statistical significance does not necessarily mean that there is a biological relevance as well (Kelly, 2001). This biological impact on the sows is more important, and should be taken into account when assessing these statistical outcomes.

Field studies like this one provide valuable information about incidence, prevalence and severity of lameness and claw and skin lesions in practice, but the high variation among farms might limit the power to detect significant differences. A certain variation between farms is needed in order to identify risk factors for specific disorders. However, the observed farms differed so much for many factors that too few replications for each of these factors were available in order to test all their effects, besides this was not the aim of our study. Both dynamic and static group management systems are associated and therefore co-varying with their own, particular characteristics. The effect of each of these variables cannot be determined independently of group management system. For example, in dynamic groups more electronic feeding systems are being used compared to in static groups. This implies that we have to focus on the comparison between group management system as is used in practice, and that we cannot figure out exactly which aspects are responsible for the observed differences. All previous studies on the effect of group management differ in a number of other management procedures like the provision of bedding, type of flooring and space allowance (Strawford et al., 2008; Chapinal et al., 2010; Pluym et al., 2011). In our study there was no consistent, convincing evidence that sow welfare was adversely affected in dynamic groups in comparison to static groups, considering the high variation between herds.

Due to experimental restrictions (i.e., need to follow farm protocols) all observations were performed in the home pen of the sows. This may have influenced the locomotion, skin and claw
scores. Removing sows for ethical and economic reasons during the study period was inevitable and common practice under commercial settings. This longitudinal monitoring over three successive reproductive cycles under commercial circumstances resulted in a descriptive overview of the circumstances in the Flemish sow husbandry.

**CONCLUSIONS**

The first three days immediately after (re)grouping are a very risk full period for developing lameness or incurring skin lesions independent of group management system. Our results show better mean locomotion score and skin lesions prevalence in static versus dynamic group-housed sows, but we did not find a group management effect on claw lesions. All three output variables (locomotion, and skin and claw lesions) in group-housed sows would benefit from more research on time and method of grouping, effect of parity division within the group, and genetics as a contributing factor to aggressive trait characteristics. Future research should focus on optimizing the housing environment and management of group-housed sows to reduce the risk of developing lameness or being wounded.

**ACKNOWLEDGEMENTS**

The authors wish to thank Thomas Martens and Marleen van Yperen for their irreplaceable technical help during the study and Miriam Levenson for English-language editing. The authors also heartily thank the managers and workers at the 10 farms for their assistance with this study.

**REFERENCES**


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Chapter 4


Chapter 4


Chapter 4


CHAPTER 5 – EFFECT OF RUBBER FLOORING ON GAIT, CLAW LESIONS

Adapted from:

Effect of rubber flooring on group-housed sows' gait and claw and skin lesions

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ABSTRACT

This study evaluated the influence of floor type on sow welfare in terms of lameness, claw lesions, and skin lesions. In a 2 × 3 factorial design, we have investigated the effect of rubber coverings on concrete floors and the effect of 3 levels of dietary zinc supplementation on locomotion and claw and skin lesions in group-housed sows. Six groups of 21 ± 4 hybrid sows were monitored during 3 successive reproductive cycles. The sows were group housed from d 28 after insemination (d 0) until 1 wk before expected farrowing date (d 108) in pens with either exposed concrete floors or concrete floors covered with rubber in part of the lying area and the fully slatted area. During each reproductive cycle, locomotion and skin lesions were assessed 4 times (d 28, 50, 108, and 140) and claw lesions were assessed twice (d 50 and 140). Results are given as least squares means ± SE. Locomotion and claw scores were given in millimetres, on analogue scales of 150 and 160 mm, respectively. Here, we report on the effect of floor type, which did not interact with dietary zinc concentration (P > 0.10 for all variables). At move to group (d 28) and mid gestation (d 50), no differences between floor treatments were seen in locomotion (P > 0.10). At the end of gestation (d 108), sows housed on rubber flooring scored 9.9 ± 4.1 mm better on gait (P < 0.001). Regarding claw disorders, both parameters “heel overgrowth and erosion” (difference of 4.6 ± 1.8 mm; P = 0.01) and “heel-sole crack” (difference of 3.1 ± 1.5 mm; P = 0.04) scores were better for sows on rubber flooring at mid gestation (d 50). However, sows on rubber flooring scored worse for “vertical cracks in the wall horn” (difference of 3.4 ± 1.7 mm; P = 0.04). At the end of lactation (d 140), both “white line” (difference of 2.9 ± 1 mm; P = 0.02) and “claw length” (difference of 4.7 ± 1.4 mm; P < 0.001) had better scores on rubber flooring. No differences for skin lesions were observed between floor treatments. The improved scores for gait toward the end of gestation and some types of claw disorders at mid gestation suggest that rubber flooring in group housing has a beneficial effect on the overall leg health of sows. The documented increase in vertical cracks in the wall horn at d 50 requires further investigation.

Key words: floor type, locomotion, gestating sow, pig, rubber, skin and claw lesions
Effect of Rubber Flooring

INTRODUCTION

Since January 2013 pregnant sows in the EU must be group housed from 28 days after insemination until one week before farrowing (EU Council Directive 2008/120/EC). Flooring is usually solid or partly slatted exposed concrete floors. This type of flooring is robust and relatively inexpensive and easy to clean and disinfect (Pavicic et al., 2014), but it does not score well in terms of sow comfort (Tuyttens, 2005). As sows spend up to 80% of their time lying down in intensive systems, adequate flooring is essential to their welfare (Bergeron et al., 2000). Problems like lameness and claw and skin lesions are also linked to floor characteristics such as slip resistance, hardness and surface profile (Calderón Díaz et al., 2013). Although (straw) bedding may ensure more comfort, it is incompatible with the manure disposal systems, holds increased risk for disease, costs more and requires extra labour (Tuyttens, 2005). Rubber coverings may be a good alternative to exposed concrete: a softer rubber layer increases lying comfort and the cushioning effect protects skin, claws and legs (Tuyttens et al., 2008; Elmore et al., 2010). In practice, rubber mats are mainly used only during farrowing and lactation to increase sow (and piglet) comfort (Boyle et al., 2000). This short period, during which sows are usually kept in separate stalls, does not represent the highest risk for developing lameness and claw and skin lesions regardless of flooring type. A few short-term studies (Tuyttens et al., 2008; Elmore et al., 2010; Calderón Díaz and Boyle, 2014) and a single long-term study (Calderón Díaz et al, 2013) focussed on the effect of rubber flooring on the welfare of group-housed sows. The objective of the present longitudinal study over three successive reproductive cycles is to compare prevalence, incidence and mean scores of locomotion and claw and skin lesions between sows housed in gestation pens with fully concrete floors versus concrete floors partly covered with rubber mats.

MATERIALS AND METHODS

The study was conducted at the experimental farm of the Institute for Agricultural and Fisheries Research (ILVO). All procedures were approved by ILVO’s Ethics Committee (Reference 2013/196).


STUDY POPULATION AND DESIGN

The experiment started with 6 groups of 21 ± 4 non-lame RA-SE Genetics gilts. These groups were monitored during 3 successive parities.

When sows were removed from the experiment for ethical reasons, they were replaced by new non-lame gilts. During the experiment, 36 sows (27.5%) were removed from the experiment; 21 of them were replaced by gilts. Reasons for sow removal included; death (n = 10), euthanasia (n = 7) due to ethical considerations such as rectal or uterus prolapse or severe locomotion disorders, and reproductive failure (n = 19). Management and monitoring of the replacement animals was the same, however the experiment lasted in total three reproductive cycles, so the animals that entered the experiment during the second monitored cycle, were only monitored for two cycles in total. Due to replacing the removed sows, group composition changed over cycles. As the experiment started with only gilts, during the first monitored reproductive cycle only gilts were present, while during cycles two and three sows of different parities could be present. Twenty-six sows of the total study population were transferred to other groups (allocated to the same floor type) due to returns to service.

This longitudinal study was set up as a 2 x 3 factorial design, with the two floor types as first factor (concrete versus rubber-covered floors) and three dietary zinc (Zn) supplementation levels as second factor. This paper focusses on the effect of housing only; for a report on the effect of Zn, see van Riet et al. (2015).

Upon the gilts’ arrival at ILVO, the gilts were quarantined for 4 to 6 weeks until their first insemination at the age of on average 233 ± 12 days old. The quarantine unit had concrete flooring covered with straw bedding and was naturally ventilated without climate control. At the start of the experiment the original set of gilts was randomly assigned to a floor type and a feed treatment group. They were kept in the same treatment group throughout the total duration of the experiment (three reproductive cycles). Three randomly allocated groups of sows were housed during the gestation period (d28 until d108) in one of the pens with concrete floors, and three groups in one of the pens with rubber flooring. In addition, sows were randomly assigned to 1 of 3 feed treatments, either with 0 mg·kg⁻¹, 50 mg·kg⁻¹ or 100 mg·kg⁻¹ added Zn (50% organic and
50% inorganic Zn). Throughout the experimental period, sows were fed diets formulated according to NRC recommendations (NRC, 2012) and commercial standards except for Zn.

All sows were vaccinated against porcine reproductive and respiratory syndrome (Porcilis®, MSD Animal Health, d55 of gestation), neonatal diarrhea caused by E. coli (Neocolipor®, Merial, 7 and 4 weeks before parturition) and erysipelas and Parvovirus (Parvovax, Merial; one week postpartum). The sows were dewormed 17 days before parturition.

Housing and management conditions were identical for all 6 groups during the insemination period (from insemination, called day 0 of the reproductive cycle until d28 of gestation) as well as during the farrowing and lactation period (d108 until d140). During the insemination period, all sows were individually housed in commercial gestation stalls with partly slatted bare concrete floors (1.38 m² per sow, partly slatted (14.4%) with a slat width of 80 mm and slot width of 20 mm). In total, the sows were fed 2.3 kg per day, divided into two servings. Water was automatically provided via nipple drinkers for 15 min every hour and for 45 min while feeding to reduce water spillage.

When moved to the static gestation group pens (d28 after insemination), they were fed 2.6 kg feed per sow as provided by the electronic sow feeder (ESF) (Nedap N.V., Groenlo, Netherlands) with individual sow recognition via an electronic transponder attached to the sow’s ear. Experimental floor treatments were used during the group housed gestation period only (d28-108 of the cycle). In total 4 group pens were available: 2 identical pens with concrete floors and 2 identical pens with the entire slatted portion and half of the solid floors covered with a layer of rubber (Figure 5.1). The rubber mats placed on the solid floors were “PORCA relax U” mats (Gummiwerk KRAIBURG Elastik GmbH & Co KG., Tittmoning, Germany), 20 mm thick with edges reinforced against biting. The mats were attached to the concrete floor by using the KRAIBURG (Gummiwerk KRAIBURG Elastik) system (Figure 5.2, 1). The slatted floors were covered with rubber flooring (EasyFix Rubber Products Ltd., Galway, Ireland), 10 mm thick with a textured surface and wedge-shaped rubber protuberances on the underside used to firmly anchor the mat in the gaps of the slatted floor (Figure 5.2, 2a and b). Both the concrete and rubber-covered slatted floor area had a slat width of 91 mm and slot width of 20 mm.
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Figure 5.1. Layout (top view) of the four group pens and a close-up of one of the pens. Light grey indicates bare concrete (1,3); dark grey indicates rubber (1,4). ESF= Electronic Sow Feeder.

Figure 5.2. 1) Top view of textured KRAIBURG laying mat and system to attach rubber mats to the concrete solid floors. Picture courtesy of KRAIBURG Elastik GmbH & Co. KG. 2a) Side view of slat with rubber tabs inserted to attach rubber mat to cover the concrete slatted floors. 2b) top view of rubber-covered slat. 2a, b: pictures courtesy of EasyFix Rubber products.

The ventilation was set at 75m³·d⁻¹·sow⁻¹ and indoor temperature was maintained at 20°C. To facilitate easy access to the ESF, one light per pen located above the ESF was left illuminated during the night. Per group pen, 2 rubber balls and a fixed and automatic rotating fur brush were provided as enrichment. From one week before the expected farrowing date (d108) until weaning (d140), sows were housed in individual farrowing crates (crate size 1.33 m², pen size 3.60 m²) with slatted steel floors, which had a non-slip part and slat and slot widths of 10 mm. During farrowing
and lactation (d108 until d140 after insemination), sows were fed 3 kg·d$^{-1}$ + 0.25 kg per piglet in two servings per day. Water was available *ad libitum* in the group pens and farrowing crates.

**DATA COLLECTION**

The experimental period started 10 days before the first insemination (d0). Bodyweight, backfat thickness and body condition score (BCS) at the start of the study were 151 ± 16 kg, 15.5 ± 3.8 mm and 3.0 ± 0.5 for gilts assigned to concrete and 147 ± 24 kg, 15.4 ± 3.4 mm and 3.0 ± 0.5 for gilts assigned to rubber, respectively (mean ± SD).

All measurements were taken by four trained and experienced assessors. The intra- and inter-observer scores for repeatability were higher than 90%.

Figure 5.3 shows the timeline of the performed observations. The experimental period started 10 days before the first insemination (d0); baseline measurements were performed for locomotion and claw and skin lesion scoring. Locomotion scores at the baseline were 15.1 ± 14.0 mm for gilts assigned to concrete and 26.4 ± 14.2 mm for gilts assigned to rubber, respectively (mean ± SD). Mean baseline skin lesions score was 0 for both floor treatments and the mean baseline claw scores per parameter per floor type are shown in Table 5.1. Baseline measurements did not differ per floor type (P>0.1).

Table 5.1. Baseline claw scores (mm on tVAS) per floor type (mean ± SD, P > 0.1).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Rubber</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heel horn</td>
<td>34.15 ± 21.59</td>
<td>35.70 ± 22.29</td>
</tr>
<tr>
<td>Heel/sole crack</td>
<td>34.14 ± 21.46</td>
<td>42.95 ± 22.97</td>
</tr>
<tr>
<td>White line</td>
<td>40.18 ± 24.12</td>
<td>40.84 ± 22.98</td>
</tr>
<tr>
<td>Skin lesions</td>
<td>8.70 ± 14.74</td>
<td>11.01 ± 15.01</td>
</tr>
<tr>
<td>Horizontal cracks in wall horn</td>
<td>25.24 ± 20.56</td>
<td>31.17 ± 24.26</td>
</tr>
<tr>
<td>Vertical cracks in wall horn</td>
<td>19.31 ± 22.85</td>
<td>19.87 ± 24.24</td>
</tr>
<tr>
<td>Length of the claws</td>
<td>15.41 ± 15.60</td>
<td>12.30 ± 14.95</td>
</tr>
<tr>
<td>Length of dewclaws</td>
<td>17.73 ± 14.31</td>
<td>13.01 ± 16.03</td>
</tr>
</tbody>
</table>
Bodyweight, backfat thickness and BCS were determined to monitor sow’s health. Bodyweight was measured individually per sow. Backfat thickness was measured between the 3rd and 4th last rib, approximately 7 cm from of the spinal column. Backfat measurements were measured on the left and right side of the spinal column (Renco Lean Meater-12 60566, Renco Corporation, Minneapolis, MN, USA). If the difference between both sides was ≥ 2 mm, the measurements were repeated up to three times. The average backfat thickness was used for further calculations. Sows obtained a BCS on a scale from 1 (emaciated) to 5 (obese), with score 3 representing an ideal body condition (Evans, 1978).

Figure 5.3. Observations made at each moment in the reproductive cycle. dX = day in reproductive cycle; d-10= baseline, d0 = insemination, d28 = move to group, d50= mid group, d108 = end group, d140 = end lactation. After d140 sows were moved to the insemination crates to begin the next reproductive cycle.

LOCOMOTION

Following a baseline measurement performed 10 days before first service, locomotion was scored on d28 (move to group housing; “move to group”), d50 (middle of group housing; “mid group”), d108 (end of group housing; “end group”) and d140 (end of lactation; “end lactation”) (Fig. 3). Locomotion was observed while a sow was walking down a solid, concrete corridor (20 m wide). If the sows needed encouragement to move, a person walking beside them gave vocal cues or waved her hands. Locomotion was scored using the 150 mm tagged Visual Analogue Scale (tVAS) developed by Nalon et al. (2014). The tVAS is a straight line whose extremes correspond to the “perfect” and “worst” situation, respectively. For the condition in question, the observers put a
vertical mark across the tVAS in the position corresponding to their perception of the level of severity. Sows were considered lame when their locomotion score was > 60 mm on the tVAS (Bos et al., 2015). A new case of lameness was defined as a sow that received a locomotion score > 60 mm on the tVAS and if the increase since the previous observation was > 30 mm when the previous score was < 60 mm.

**CLAW LESIONS**

Following to a baseline measurement the claw lesions were scored on d50 and d140 (Figure 5.3). For simultaneous scoring of all 4 claws, sows were placed in a hydraulic chute (FeetFirst Sow Chute; Zinpro Performance Minerals, Eden Prairie, MN, USA) and hoisted into the air. Ethical considerations prevented observation of the claws at either move to group or end group. All four claws were cleaned (with water, a brush and a hoof knife) and dried (with a paper towel), after which all eight toes (lateral and medial toe of all four claws) were inspected. Claws were scored using a recording system based on the “Zeugenklauwen Check” (Wageningen University Livestock Research) and the FeetFirst method by ZinPro (Deen et al., 2009). Eight claw parameters (Table 2) were evaluated using a visual key to the type and severity of the lesions. Instead of the ordinal scale presented in literature, we used a 160 mm tVAS tagged at 40, 80 and 120 mm (Table 5.2). For each claw parameter a mean score per sow/parameter/inspection was calculated. The sow was defined as having a claw problem if the tVAS score was > 80 mm for at least one toe.
Table 5.2. Tagged visual analogue scale (tVAS) for claw lesion scoring in sows. To score each parameter, a vertical mark was drawn on the tVAS line and the distance from 0 mm was measured. For skin lesion scoring, only skin lesions above the coronary band to the coronary band of the dewclaw were included. The length of the dewclaw was determined by pushing the dewclaw against the claw to be able to compare dewclaw length and heel height.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>0-40 mm</th>
<th>40-80 mm</th>
<th>80-120 mm</th>
<th>120-160 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heel horn</td>
<td>Healthy</td>
<td>Slight overgrowth and/or erosion</td>
<td>Moderate overgrowth and/or erosion with moderate cracks</td>
<td>Severe overgrowth and/or erosion with cracks</td>
</tr>
<tr>
<td>Heel/sole crack</td>
<td>Healthy</td>
<td>Slight detachment of heel-sole crack</td>
<td>Extensive detachment of heel-sole crack</td>
<td>Long, deep detachment of heel and sole</td>
</tr>
<tr>
<td>White line</td>
<td>Healthy</td>
<td>Shallow and/or short detachment along white line</td>
<td>Clear and/or long detachment along white line</td>
<td>Long, deep detachment along white line</td>
</tr>
<tr>
<td>Skin lesions</td>
<td>None</td>
<td>Mild injury</td>
<td>Moderate/substantial injury</td>
<td>Severe, inflammation, infection of coronary band</td>
</tr>
<tr>
<td>Horizontal cracks in wall horn</td>
<td>None</td>
<td>Small, superficial cracks</td>
<td>Several cracks</td>
<td>Multiple severe, deep cracks</td>
</tr>
<tr>
<td>Vertical cracks in wall horn</td>
<td>None</td>
<td>Small, superficial cracks</td>
<td>Several superficial cracks</td>
<td>Multiple, severe, deep cracks</td>
</tr>
<tr>
<td>Length of the claws</td>
<td>Normal</td>
<td>One or both toes slightly longer</td>
<td>One or both toes significantly longer</td>
<td>Long toes that complicate locomotion</td>
</tr>
<tr>
<td>Length of dewclaws</td>
<td>Normal</td>
<td>Dewclaw slightly longer</td>
<td>Dewclaw touches floor when standing</td>
<td>Dewclaw is cracked or (partly) missing</td>
</tr>
</tbody>
</table>
SKIN LESIONS
Following a baseline measurement performed 10 days before the first service, skin lesions were scored on d28, d50, d108 and d140 (Fig. 3). Skin lesions were scored on the left side of the sow’s body using the methods of Welfare Quality® (2009). The side was visually divided into five sections: ears, front (head to back of shoulder), middle (back of shoulders to hindquarters), hindquarters and legs (from accessory digit and above). A 3-point ordinal scale was used to score skin wounds on each body region, with a score 0 indicating 0 to 4 visible skin lesions, score 1 indicating 5 to 10 lesions, and score 2 indicating > 10 lesions. Scores were dichomatized for analysis, where all scores ≥ 1 were converted to 1 because score 2 was rarely assigned. Only the lesions on the front and on the middle quarters were used for data analysis as lesions on the other body regions were only rarely observed.

STATISTICS
The locomotion, mean claw lesions and skin lesions scores were analysed using a linear mixed regression model with floor type, dietary Zn supplementation, phase of the reproductive cycle, their interactions and parity as fixed effects and reproductive cycle, with sow and group as random effects to correct for the repeated measurements. Non-significant interactions were excluded from the final models. The corresponding prevalences were analysed using similar logistic mixed regression models with the logit link.

For the analysis of the incidence of lameness only numerical results are provided; statistical analyses of these data is difficult because incidence needs to be calculated at group level but in this study there were only three groups per floor type.

The analysed continuous data were considered to be sufficiently normally distributed based on the graphical evaluation (histogram and QQ-plot) of the residuals. In case of post hoc pairwise testing, p-values were corrected with the Tukey-Kramer adjustment for multiple comparisons.

The threshold for significance was set at P < 0.05. All analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA).
RESULTS

All results are given as LS-means ± SE. Results are shown as average over the three monitored cycles, as there was no interaction between cycle and phase in the cycle, nor an effect of cycle (P > 0.1).

LOCOMOTION SCORE

The concrete floor and rubber flooring groups both had the worst lameness scores at d108 (Figure 5.4). At that point, locomotion scores in groups housed on rubber flooring were significantly lower than the groups housed on concrete (P < 0.001). Lameness scores of sows housed on rubber flooring at d108 were 43 mm ± 3.5 and scores for sows with concrete floors were 53 mm ± 3.5 (Fig. 4). For sows housed on rubber flooring, no differences in locomotion scores were seen within the group housing period (P > 0.1).

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**Figure 5.4.** Locomotion scores on tVAS per phase in the reproductive cycle for groups housed on concrete versus rubber floors during gestation. *Difference in scores between floor type (P < 0.001). A-B-C-D: phases in cycle without a common letter differ significantly on concrete floors (P < 0.050). X-Y-Z: phases in cycle without a common letter differ significantly on rubber floors (P < 0.050).**
**Prevalence of Lameness**

The prevalence of lameness was not significantly affected by the interaction between phase in the reproductive cycle and floor type \((P = 0.481)\). No significant differences in the prevalence of lameness between floor types were found, irrespective of the phase in the reproductive cycle \((P = 0.341)\). Lameness prevalence was significantly higher \((P < 0.050)\) during the group-housing phase as compared to individual-housing phases of the reproductive cycle \(i.e.\) farrowing until lactation and insemination \(\text{(Figure 5.5)}\).

![Figure 5.5. Mean prevalence of lameness over 3 reproductive cycles per floor type per phase in the cycle. Lame: locomotion score $>60$ mm on tVAS. A-B: phases in cycle without a common letter differ significantly \((P < 0.050)\) \(\text{(concrete)}\). X-Y: phases in cycle without a common letter differ significantly \((P < 0.050)\) \(\text{(rubber)}\).]

**Incidence of Lameness**

Incidence of lameness was calculated per day at risk. Incidence of lameness was the highest on d50 for sows housed on concrete floors \(\text{(Figure 5.6)}\).
**SEVERITY OF CLAW LESIONS**

Phase of reproductive cycle had a significant effect on all claw parameters ($P < 0.001$) except for ‘horizontal cracks in the wall horn’ ($P > 0.100$) (Figure 5.7). Floor type affected the mean severity of various claw parameters during mid group and at the end of lactation. At d50 both ‘heel overgrowth and erosion’ ($P = 0.010$) and ‘heel–sole crack’ ($P = 0.041$) scores were lower (*i.e.* less severe) for sows on floors with a rubber covering. However, ‘vertical cracks in wall horn’ ($P = 0.048$) indicated higher severity on floors with a rubber covering at d50. At d50 sows housed on rubber flooring showed a tendency for higher (more severe) ‘white line’ scores ($P = 0.057$) and ‘claw length’ scores ($P = 0.081$). At d140, sows on rubber flooring had lower (less severe) scores for both ‘white line’ ($P = 0.024$) and ‘claw length’ ($P < 0.001$), additionally there was a tendency for better scores for “vertical cracks in the wall horn” for sows housed on rubber ($P = 0.081$).

Figure 5.6. Incidence of lameness per day at risk per floor type. Lame: locomotion score $>60$mm on tVAS.
Figure 5.7. Mean claw score (±SD) for the different parameters at d50 (mid gestation) and d140 (end lactation) of the reproductive cycle in the two groups (concrete vs. rubber) floor treatment. * denotes significant differences in mean claw score between floor type and between phase in the reproductive cycle (P < 0.050). † denotes a tendency to a difference between floor type (0.05 < P < 0.100)

**PREVALENCE OF CLAW LESIONS**

The prevalence of sows with at least one claw lesion was higher at d140 than at d50 (94.8% vs. 84.6%; P < 0.001) (Figure 5.8). Claw lesion prevalence was not related to floor type (P = 0.707).
Figure 5.8. Prevalence of claw problems per floor type and at 2 moments in the reproductive cycle. Claw problem = sow has at least one toe with a score > 80mm on the tVAS. *denotes a difference in prevalence of claw lesions between these 2 sampling moments during the reproductive cycle (P < 0.001).

**SKIN LESIONS**

Skin lesions occurred on both floor treatments. Floor type did not affect skin lesion scores for the front (P = 0.568) and middle (P = 0.848). Overall 82.4% of all sows had score 0 and 17.6% had score 1 for the front quarter and 87.9% score 0 and 12.1% score 1 for the middle. Differences between the phases in the reproductive cycle were observed for both front and middle (P < 0.001) (Figure 5.9).
Figure 5.9. Mean percentage of sows with skin lesions present on the front and middle parts of their left side. A-B-C: phases in cycle with a different superscript differ significantly in the front (P < 0.001). X-Y: phases in cycle with a different superscript differ significantly in the middle (P < 0.001).

INTERACTIONS WITH ZINC SUPPLEMENTATION

The interaction between Zn supplementation and floor type was not significant for any of the outcome variables (all P > 0.100). Zn supplementation was retained in the model only to correct for the infrequent small effects of Zn supplementation within the statistical models. Due to the insignificant effects, this paper focuses only on the effect of floor type on locomotion, claw and body lesions. For results of Zn supplementation we refer to van Riet (2015). No effect of Zn supplementation was found for locomotion scores (P > 0.050), claw health scores (P > 0.050), or skin lesions (P > 0.050). An effect of Zn supplementation was observed for incidence of lameness (P = 0.037) and on mean claw score for the heel horn on d50 (P = 0.01; for all other claw parameters, P > 0.100).
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DISCUSSION

LOCOMOTION

Flooring is a main contributor to locomotion problems in pigs (Heinonen et al., 2006; Zurbrigg and Blackwell, 2006). For sows housed on concrete flooring as well as on rubber flooring, locomotion scores showed increasing problems during the group-housed gestation period. The difference between floor treatments increased as gestation progressed, with lower (more positive) scores for sows housed on rubber flooring. This beneficial effect of rubber flooring on lameness is in contrast with Elmore et al. (2010). In Elmore’s study, however, only the floor in the feeding stalls was covered with rubber mats and the sows were observed for 10 days instead of several months. It therefore seems likely that before positive effects on gait will be observed, either a sufficiently large floor area must be covered with rubber, sows need to be housed on rubber for a longer period of time, or both. The prevalence of lameness was high during the group-housed period, especially for the sows housed on concrete (i.e. at d50, concrete = 30.5% and rubber = 16.8%) and at d108 (concrete = 35.6% and rubber = 22.7%). This is mostly in accordance with other studies (Heinonen et al., 2006; Kilbride et al., 2009; Calderón Díaz et al., 2013). Calderón Díaz et al. (2013) reported a high prevalence of lameness (34% sows on concrete and 30% of the sows on rubber) already at the start of their experiment, one week after artificial insemination (AI). In contrast, in our study mean prevalence of lameness was only 4.9% on the day the sows entered the group pens (28 days after AI). The low prevalence of lameness during the time spent while housed individually in insemination crates and farrowing crates is in accordance with several other studies reporting a high prevalence and incidence of lameness in group-housed sows (Gjein and Larssen, 1994; Anil et al., 2007; Kilbride et al., 2009).

It seems that the time spent in both farrowing and insemination crates results in an improvement of the gait (spontaneous recovery). Besides the selective culling of lame sows, a possible explanation for the decrease in prevalence is that while individually housed, there is virtually no risk of intense (negative) social interaction resulting in physical damage. In addition, individually housed sows do not have to locomote in order to get to the feeder or drinker, thus resting their limbs and enabling a spontaneous healing process. In future research, the gait of individual sows
should be monitored frequently for a prolonged period of time. Knowledge of measures that can be taken to promote spontaneous recovery or conversely, whether certain conditions aggravate lameness is important for determining the optimal timing of either treating or removing the animal from the group.

The present study showed that the incidence of lameness also differed between the groups housed in pens with partially rubber-covered floors versus bare concrete only. Incidence of lameness is a relevant measure for identifying risk factors because severe lameness is reason for culling and because incidence only shows new cases of a specific disease. Incidence does require frequent monitoring, however, which increases workload. Measures of prevalence, expressed as a percentage of the total population, can describe how many sows in a population were lame at a specific sampling moment. In the present study, incidence peaked during the first half of the gestation period, but the peak was considerably less pronounced for the sows housed on the rubber instead of concrete floors. Rubber flooring did not eliminate the risk of sows developing lameness, but it did decrease the chance of becoming lame, particularly during the first half of the gestation period. In studies on cows, softer flooring also reduced the likelihood of becoming lame compared with concrete flooring (Hernandez-Mendo et al., 2007; Vanegas et al., 2006). A classification system according to lameness is needed to calculate prevalence and incidence of this condition. No unequivocal cut-off between lame and non-lame can yet be determined; as some authors consider that some changes in gait (e.g., stiffness) might not result in discomfort or pain (Weary et al., 2006; Calderón Díaz et al., 2013). The cut-off used in the present study is based on the lameness score at which sows became less willing to walk to obtain a highly tempting reward (Bos et al., 2015). Some effects could be supported by statistical significance when the actual locomotion scores (tVAS data) were used but not when the dichotomized version (i.e. the incidence or prevalence) was used as response variable in the models (Nalon et al., 2014). Besides the need for a partly arbitrary cut-off, the use of a prevalence or incidence also entails an increasing loss of information compared to the resolution with which the lameness severity has been scored originally. The continuous scale used in the present study yielded a very high level of resolution, which was limited only by the discriminatory capabilities of the observers.
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CLAW LESIONS

Although the overall prevalence of claw lesions found in our study for claw lesions appears high (94.8% at end group) it is similar to the prevalences reported by Anil et al., 2007; Enokida et al., 2010; Pluym et al., 2011; and Sasaki et al., 2014. The effect of flooring differed according to lesion type. Some lesion types were less severe when sows were housed on rubber flooring, but at d50 of gestation vertical cracks in the wall horn were more severe, though at d140 there was a tendency towards better scores for this claw parameter in sows housed on rubber. Furthermore, at d50 both the white line and the vertical cracks in the wall horn showed tendencies towards worse scores for sows housed on rubber; this changed at d140, where both parameters showed significant better scores for sows on rubber. There might be an association between the rubber and the worse scores, but the study might have insufficient statistical power to detect it. However, these findings may be clinically important and warrant further consideration. Nonetheless, these tendencies towards worse scores on rubber at d50 disappeared towards the end of the cycle; at the end of the reproduction cycle, both white line and claw length scores indicated less severity for sows housed on rubber floors. This is mostly in contrast with Calderón Díaz et al. (2013) who reported a more pronounced increased risk for toe overgrowth, dewclaw overgrowth and injuries, heel sole cracks, white line, and horn wall cracks in their first parity sows housed on rubber slat mats compared to sows housed on a bare concrete slatted floor. However, in our study the group pen consisted of a solid floor area as well, whereas in Calderón Díaz et al. (2013) a fully slatted floor was used in the group pen. Furthermore, the characteristics of the slats themselves also significantly affect claw health (Webb, 1984; Anil et al., 2007; Pluym et al., 2013). One possible advantage of the rubber flooring may be that the claws were protected from the rough concrete slats which could damage the claws (Boon and Wray, 1989). As a side effect, Calderón Díaz et al. (2013) found that the manure could not easily pass through the slats, creating a possible negative effect on claw hygiene. Pluym et al. (2013) reported that poor hygiene (especially wet, dirty floors covered with liquid and manure) softens and irritates the claw, consequently reducing claw strength. This did not seem to be the case in the present study in which the moisture content of the horn wall and horn wall strength were not affected by the type of flooring (van Riet, 2015). Telezhenko et al. (2008) reported that claws of cows housed on
rubber-coated slats could grow too long as rubber is less abrasive than the concrete slats. This was not observed in the sows in the present experiment.

To remedy the high prevalence of claw lesions and better understand the variability of the effect of a softer floor, more knowledge of the aetiology and the development of claw lesions is warranted. Dissimilarity in the size of claws and varying tissue strength between medial and lateral claws contributes to difference in vulnerability to lesions (Webb, 1984; Kornegay et al., 1990; Kroneman et al., 1993). Claw size dissimilarity has been significantly associated with a higher culling risk (Tarrés et al., 2006). If the size difference between lateral and medial claws becomes larger, the prevalence of claw lesions increases (Kornegay et al., 1990). Dissimilarity in claw size is hereditary and depends on breed and statistical method: a range of heritability values varying from 0.01 to 0.61 has been reported (Steenbergen, 1990; Jørgensen, 2000; Fan et al., 2009; Pluym et al., 2013). In addition to dissimilarity in claw size, abnormal claw growth has been associated with claw lesions. This has also been reported to be heritable (Quintanilla et al., 2006). The heritability of claw quality suggests that genetic selection for claw characteristics could be beneficial for claw health.

**SKIN LESIONS**

The first few days after entering a group housing pen appear to be critical for sow welfare, due to the formation of a hierarchy structure within a group (Arey, 1999). The number of skin lesions is often used as an indicator of grouping aggression (Turner et al., 2006). We have monitored the number of skin lesions to eliminate the possibility that the measured differences per floor type in locomotion and claw lesions could be the result of differences in aggression within the groups. We hypothesized that floor type would not be associated with aggression and that this would therefore not be reflected in the skin lesion scores. We found indeed that skin lesion scores were higher after the sows had moved into the group pens, which was expected because sows unfamiliar with each other generally fight to establish a social hierarchy (Arey and Edwards, 1998; Hoy and Bauer, 2005; Sadler et al., 2011). We found no differences in skin lesions between groups housed on concrete versus on rubber flooring. This suggests that the amount or severity of aggression at grouping was not affected by floor type. According to McGlone (1985), the lesion
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score clearly showed higher risk for the front body part in contrast to the middle and particularly the posterior part of the animal. In the present study, lesions were nearly exclusively observed on the front and middle sections. Skin lesions on the legs, ears and rear seemed to be less relevant in relation to agonistic behaviour. Studies on growing pigs suggest that if weight differences between the pigs of 5-6 weeks of age are large (> 3 kg), then the frequency of fighting may be reduced at mixing (Rushen, 1987; Mount and Seabrook, 1993). During our experiment only gilts (of approximately same size and age) were present during the first reproductive cycle, whereas during cycles 2 and 3, replacement gilts were present in each group.

This study was carried out under experimental circumstances that mimicked the commercial situation as much as possible. We only tested the effect of the rubber floor covering on one sow breed in group pens equipped with an ESF. Results might vary among breeds or management and feeding strategies. Due to the longitudinal monitoring a clear impression over time was obtained. Removing sows for ethical reasons could have slightly influenced the results, but it was inevitable and only the sows with highest degree of apparent suffering were removed. With the current experimental setup we could not differentiate between the effects of the rubber lying mats and the rubber coating on the slatted floors.

CONCLUSION

Sows housed in pens with rubber flooring had a reduced prevalence and incidence of lameness, a better average locomotion score, and somewhat less severe claw lesions, possibly because of the cushioning effect of the rubber. Covering concrete slats and lying areas with rubber mats can be accomplished easily in practice and might be a powerful adaptation to improve sow welfare and reduce culling in group housing systems. Further testing of rubber flooring under different (group housing) management systems is required to fully explore all the benefits and possible limitations. In addition, separate testing of both the rubber lying mats and the rubber covering for slatted floors is needed before conclusions can be drawn about the specific effects of both types of rubber flooring.
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REFERENCES


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CHAPTER 6 GENERAL DISCUSSION

This dissertation investigated locomotion disorders and claw lesions in sows in group housing systems, in order to improve the welfare, health and profitability of pig herds. Detailed discussion of the separate papers can be found in the corresponding papers shown in Chapter 3, 4 and 5 in this thesis. Across the experiments conducted in this thesis, lameness prevalence and incidence and claw lesions prevalence were measured at different stages of the reproductive cycle. This general discussion focuses on cross-paper comparisons and on future research that can be recommended based on the findings of this doctoral study.

Since January 2013, at all farms in the European Union with at least 10 sows present, all sows must be group-housed from four weeks after service to one week before parturition (European Directive 2001/88/EC). Group housing allows for social contact and interactions between sows (Remience et al., 2008; Chapinal et al., 2010) and for increased activity as compared to individually housed sows. Group housing also has a positive effect on muscle and bone development (Marchant and Broom, 1996; Schenck et al., 2008). However, these benefits of group housing of sows may be accompanied by factors that negatively impact sow welfare. Important negative impact on sow welfare is due to the higher prevalences of locomotion disorders and claw lesions, that have been reported in group housing compared to sows housed in stalls throughout the gestation phase (Anil et al., 2003; Harris et al., 2006). Inadequate pen design such as improper floor condition is considered to be one of the most important risk factors for locomotion disorders and claw lesions (Bergeron et al., 2000). Locomotion disorders and claw lesions are multifactorial and negatively influence animal welfare and farm profitability.

LAME VS. NON-LAME: A CUT-OFF VALUE

Group housing of sows implies that individual sows have to cover (considerable) distances to reach feeding and drinking areas and other specific sites where they can perform particular behaviours (Kroneman et al., 1993). Being restricted in covering distance puts them at risk of behavioural restrictions that may possibly result in reduced feed intake; limited engagement in
social interactions; and resting in inappropriate places, all of which are likely to reduce their welfare.

A classification system according to lameness is needed to calculate prevalence and incidence of lameness, meaning there needs to be a cut-off point between lame and non-lame. No unequivocal cut-off can yet be determined, because some authors consider some changes in locomotion (e.g., stiffness) might not result in discomfort or pain (Weary et al., 2006; Calderón Díaz et al., 2013).

We wanted to evaluate the relationship between gait score and the mobility of sows, as this could give valuable information about if and when sows are restricted in covering distances. Mobility was assessed by using a feed reward collection test in which the sows had to walk a specific distance to and from two feeders in order to collect successive feed rewards. Locomotion was scored (in mm) on a 150 mm tagged Visual Analogue Scale (tVAS) with five lameness classes (adapted from Nalon et al., 2014): non-lame (0 to 30 mm on tVAS); mildly lame (30 to 60 mm on tVAS); moderately lame (60 to 90 mm on tVAS); severely lame (90 to 120 mm on tVAS); or extremely lame (120 to 150 mm on tVAS) (Figure 6.1).
Figure 6.1. The relation between locomotion status and distance covered, expressed as number of collected rewards. The figure represents data of the feed reward collection test (Chapter 3). Categories on the tVAS can be described as followed: “Non lame”: Even stride, ease of movement. Little inducement needed, comfortable on all feet. “Mildly lame”: Stiff, movement is not fluid, uneven strides. “Moderately lame”: Lame in one leg, limping. Shortened stride. Compensatory behaviours (dipping of head, caudal swagger, arched back). “Severely lame”: reluctant to place eight on affected limb(s). Reluctant to walk. Lame in more than one leg. Caudal swagger. “Extremely lame”: Sow does not place affected limb on floor. Very unwilling to move, does not walk.

Our results (Chapter 3) suggest that moderately and severely lame sows are restricted in covering distances: there was a clear cut-off point at ca. 60 mm on the tVAS scale (Fig 6.1), meaning that moderately lame and severely lame sows obtained fewer rewards than non-lame and mildly lame sows. The feed reward collection test (Chapter 3) revealed differences in mobility between non-lame and mildly lame sows vs. moderately lame and severely lame sows, but no differences in total number of rewards were found between non-lame and mildly lame sows. This may indicate that lameness is either absent or present, instead of, as assumed in most gait scoring scales, including the used tVAS, that lameness is expressed in different degrees of severity (Main et al., 2000; Nalon et al., 2014). Where a lame sow might not be able to move about and meet its feed and water requirement for example, a stiff sow will still be able to move, nonetheless it might be extra challenging (Anil et al., 2009). It is important to understand the relation between the restriction in movement and behaviour and the severity of the lameness. However, it is also possible that mildly lame sows did not behave differently from non-lame sows in the feed reward collection test because they actually experienced relatively little discomfort during walking. The group we categorised as mildly lame on the basis of the visual gait scoring could have been a group of sows with a rather stiff or less smooth gait, with a negligible impact on locomotory ability. If so, the relevance of a mildly increased gait score for sow welfare is likely to be small. It is possible that mildly lame sows do experience discomfort but ignore it simply because of their high motivation to obtain the reward. In addition, pigs are known to be stoic animals, that mask their vulnerability to avoid becoming easy targets for predation or harassment by conspecifics.
(such as caused by impaired locomotion) (D’Eath et al., 2010). The sensitivity of the test may be improved by decreasing the attractiveness of the rewards or by increasing the workload for each reward.

The cut-off point discovered in the experiment described in Chapter 3 was used in the incidence and prevalence calculations in the other two experiments (Chapter 4 and 5).

**GROUP HOUSING AND LOCOMOTION AND CLAW DISORDERS**

Aggression is unavoidable when housing pigs in groups, especially when animals are regrouped, because they will inevitably fight to establish a dominance hierarchy (Hoy and Bauer, 2005; Knox et al., 2013). In dynamic group housing systems, where pregnant sows are introduced into and removed from the group, more aggressive behaviour might be expected than in static groups (Simmins, 1993). The unrest and agonistic behaviour associated with such changes in group composition result in more skin lesions and locomotion disorders (Arey and Edwards, 1998). Some reports indicate more agonistic behaviour, and therefore more locomotion disorders and claw lesions in dynamic compared to static groups (Meunier-Salaün et al., 2002; Moore et al., 1994).

The aims of the longitudinal study on commercial farms were to compare locomotion disorders and claw lesions in sows housed in either dynamic or static groups and to identify the periods of the reproductive cycle during which sows are at an increased risk of becoming lame (Chapter 4). Results showed that at the end of the group housing phase the mean locomotion score and skin lesion prevalence were lower when sows were housed in static groups. During all assessed phases in the reproductive cycle the lameness incidence was lower in static groups compared to dynamic groups (Chapter 4). We found no effect of group management on claw lesions nor on the lameness prevalence and skin lesion prevalence. For both group management systems the first three days immediately after (re)grouping were a very risky period for developing lameness; lameness incidence was on average 3.0% during that phase. This is to be expected, as the aggression between sows is greatest when sows are being mixed and they fight to form hierarchies, often resulting in locomotion problems (Stevens et al., 2015).

With the current study setup, we were not able to distinguish if in dynamic groups the newly introduced animals or the resident sows were the ones to get injured, as we have only observed
the sows in our study and not the whole group. Besides, we are unknown about the sows being a winner or loser of a fight. Nonetheless, it would have been of great added value if we were able to define those sows and also the hierarchy in the group. Our study setup was not designed like that. Krauss and Hoy (2011) reported that most agonistic interactions occurred between resident and new sows in their experiment so they conclude that the main function of the agonistic interactions was to establish a new social hierarchy. In static groups no sows are present in the pens when a new group enters the group housing facility, so this might decrease the level of aggression. Nonetheless, even in those static groups aggressive behaviour is inevitable as a hierarchy needs to be formed as well.

The first three days immediately after (re)grouping are a very risk full period for developing lameness or incurring skin lesions independent of group management system. By law sows need to be group housed from d28 of gestation, however much discussion is aimed at the corrected stage to group sows. These discussions are based on the assumption that stress negatively affects embryo survival during early pregnancy, which is before d21 of pregnancy. It is believed that mixing after completion of placentation (28 days after insemination) will minimize effects of stress on the maintenance of pregnancy (Arey and Edwards 1998). Literature shows that repeated relatively mild, acute stress and elevations of cortisol during the period prior to oestrus and ovulation do not impact sow fertility (Soede et al., 2006; 2007) but that fertility may be adversely affected if the stress is relatively severe and prolonged (Turner et al., 2002; 2005). Bokma (1990) reported indeed that grouping of sows during the first week of pregnancy resulted in 20% return rate and grouping during the fourth week of pregnancy in a significantly lower return rate of 10%. However, in his study, the sows were kept in dynamic groups of 40 sows, where weekly, 5 to 6 new sows were introduced in the group. It is possible that the repeated introduction of new sows in the group caused the higher return rate instead of the stage of grouping. However, results in literature are contradicting as Kirkwood and Zanella (2005) found that regrouping at d2 after insemination gave the highest farrowing rate and regrouping around d14 gave the lowest farrowing rate. They found no effect of time of grouping on litter size. Also van Wettere et al. (2008) found no indications that individually housing of gilts immediately after their first insemination did improve embryo survival. Besides, they found no differences in pregnancy rate.
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or embryo survival rate between gilts that were either not mixed (but remained in their pre-mating group), or were mixed at d3-4 of pregnancy or d8-9 of pregnancy. In their study, 24 gilts were used per treatment, with a group size of 6. Also Cassar et al. (2008) found no effect of day of gestation at grouping on farrowing rate, total born litter size of liveborn litter size. These variable results most likely mean that other factors related with for example the group housing system or the genetics of sows, influence the effects of timing of grouping on reproductive performance.

Problems like lameness and claw and skin lesions are also linked to floor characteristics such as slip resistance, hardness and surface profile (Calderón Díaz et al., 2013; Platz et al., 2008). Karlen et al. (2007) reported that when sows are group-housed on deep rice hull bedding, the severity of feet and leg disorders can be lower or similar to the levels seen in stall systems. Although (straw) bedding may ensure more comfort, it is often incompatible with the manure disposal systems, it holds increased risks for disease, it costs more bare concrete floors and requires extra labour (Tuyttens, 2005). Rubber coverings, as investigated in our research, may be a good alternative to exposed concrete: a softer rubber layer increases lying comfort and the cushioning effect protects skin, claws and legs (Elmore et al., 2010; Tuyttens et al., 2008). In practice, softer flooring is often used during farrowing and lactation to increase sow (and piglet) comfort (Boyle et al., 2000). This short period, during which sows are usually kept in separate stalls, does not represent the highest risk for developing locomotion disorders and claw lesions while being housed in groups, regardless of flooring type. In our longitudinal experiment (Chapter 5) the sows housed in pens with rubber flooring had a reduced prevalence and incidence of lameness, a better average locomotion score, and somewhat less severe claw lesions, possibly because of the cushioning effect of the rubber. Covering concrete slats and lying areas with rubber mats can be accomplished easily in practice and might be a powerful adaptation to improve sow welfare and reduce culling in group housing systems. Rubber mats can protect against lameness in a number of ways. Rubber is a more soft and elastic surface and therefore provides more secure footing compared with concrete floors (Flower et al., 2007). As a results there is a greater area of the claw in contact with the floor, this divides the pressure on the claw and reduces the impact on both joints and claws (Rushen and de Passillé, 2006; Carvalho et al., 2009). In addition, the more
cushioning effect of rubber compared to concrete might improve blood circulation in the foot (Singh et al., 1993; Galindo and Broom, 2000). Lying comfort increases as well, while laying on rubber compared to concrete flooring (Tuyttens et al., 2008). The softer flooring reduces the impact load on the joints and full body of the sow, which can prevent from stiffness for example.

Our results described in Chapter 5 are in agreement with a few studies (Elmore et al., 2010; Tuyttens et al., 2008) which report that rubber flooring increases the welfare of group-housed sows.

Combining all the measurements of the study described in Chapter 4 and the experiment described in Chapter 5, similar findings are found as reported in literature (Calderón Díaz et al., 2013; Heinonen et al., 2006; Kilbride et al., 2009; Pluym et al., 2011; Sarjokari et al., 2013). We found that on average 7% of the sows were lame just before being moved to the group pens (d28), 23% were lame three days after grouping, and 26% of the sows were lame at the moment of being moved to the farrowing pens (d108 of the cycle). Regarding lameness incidence, there were on average 4% new cases of lameness per day at risk from “move to group” to “three days in the group”, and hardly any new cases of lameness from “three days in the group” towards d108 of gestation. This implies that hardly any new cases developed a few days after regrouping, but the lameness persisted until the end of the gestation period. Apparently, not much healing takes place during the group housing phase, probably due to the ongoing competition for food and water with healthy sows. This is acknowledged by Heinonen et al. (2013) who stated that lame sows should be given the possibility to recover from the condition in proper sick pens, where they can eat and drink without the need to compete with healthy sows. Besides, it is shown that lame sows show increased lying time, so it is important to take care of their lying comfort to ensure freedom of discomfort (Valros et al., 2009). In cows it is known that early detection and treatment decreases the prevalence of lameness (Leach et al., 2012). Whether this is also the case for pigs is not clear, because little is known about the transition of mild lameness to more severe lameness and the spontaneous recovery of locomotion disorders in this species.

According to the overall claw lesion prevalence, assessed while sows were housed in the farrowing crates, 85% of the sows had at least one claw lesion. This is in agreement with reported claw lesions prevalence in literature (Anil et al., 2007; Enokida et al., 2011; Pluym et al., 2011).
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Type and severity of claw lesions might be influenced by the type and the number of activities performed by the sows, and these two factors vary substantially between pen designs and between groups (Anil et al., 2007). Flooring influences the development of claw lesions as well as shown in Chapter 5, however no consistent results in favour or against rubber top layers with regard to claw lesions were found. Regarding claw disorders, more specific foot-rot in fattening pigs, Osborne and Ensor (1955) reported a floor type effect as well. They have reported that despite floor type (wood, concrete and dirt) the same percentage of pigs developed the disease on wood as on concrete, though those sows on wood developed the disease later than those on concrete, and in a milder form. All pigs on wood recovered spontaneously, whilst those on concrete developed severe progressive lesions.

LIMITATIONS OF THE STUDIES

The longitudinal monitoring over three successive reproductive cycles under commercial circumstances resulted in a descriptive overview of the circumstances in the Flemish sow husbandry (Chapter 4). Field studies like these provide valuable information about incidence, prevalence and severity of lameness and claw and skin lesions in practice. As this study was carried out at commercial farms we were limited while assessing the animals, besides, we had to follow farmers opinion according to removing animals. As, we had to follow farm protocols, all observations were performed in the home pen of the sows. This may have influenced the locomotion, skin and claw lesions scores. The high variation among the 10 participating farms might have limited the power to detect significant differences. Though, a certain variation between farms is needed in order to be able to identify risk factors for specific disorders. As the observed farms in our study differed for many factors which had too few replications we were unable to test all their effects. Besides, both dynamic and static group management systems were associated and therefore co-varying with their own, particular characteristics. The effect of each of the variables cannot be determined independently of group management system. For example, in dynamic groups more ESF are being used compared to in static groups. We focussed on the comparison between group management system as is used in practice, and not all separate
aspects. In experimental studies a better control of confounding factors is possible compared to observational, field studies (Chapter 4).

The second longitudinal study was carried out under experimental circumstances that mimicked the commercial situation as much as possible (Chapter 5). We only tested the effect of the rubber floor covering on one sow breed in group pens equipped with an ESF, in groups with a low stocking density. Results might vary among breeds or management, feeding strategies and stocking densities. Removing sows for ethical reasons could have slightly influenced the results, but it was inevitable and only the sows with highest degree of apparent suffering were removed. Besides, a limitation is that with the current experimental setup we were not able to differentiate between the effects of the rubber lying mats and the rubber coating on the slatted floors.

To calculate the prevalence and incidence of a condition, binary data are needed, e.g. an animal is affected with a disease or not. This means that when using scoring scales with more than two categories or using VAS scales a cut-off point needs to be decided. In the two longitudinal studies (Chapter 4 and 5) we used a cut-off based on the lameness score at which sows became less willing to walk to obtain a highly tempting reward (Chapter 3).

Using a VAS while assessing locomotion of claw lesions allowed us to describe the disorder in a more nuanced way than classifying sows simply as affected with the disorder vs. not-affected (healthy). However, a VAS scores might lead to overestimation of the clinical importance of small differences because statistical significance is reached more easily, e.g. the tendency of a parity effect on the locomotion score with a decrease of 1.85 mm per higher parity. A statistical significance does not necessarily mean that there is a biological relevance as well. This biological impact on the sows is more important, and should be taken into account when assessing these statistical outcomes. Furthermore, all claw lesions assessment described in this dissertation we performed using a scoring system adapted from the claw lesion scoring guide of Zinpro Corporation and the scoring guide “Zeugenklaufencheck” of Wageningen University. Our scoring guide used a tVAS, instead of an ordinal scale, as used in both previous mentioned guides. This could have limited to possibility to compare our results with other reports. However, the tVAS can be used as ordinal scale as well, but it also allows to distinguish in the severity of the disorder.
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Regarding claw lesion assessment, there might be some limitation in comparing the results found in Chapter 4 and 5. In our experimental study (Chapter 5) we have scored all four claws of the sows, using a sow chute (©Zinpro Corporation, Eden Prairie, MN, USA), allowing us to score all four claws and to clean the claws before scoring. In the field study we scored only the hind claws without cleaning as this was practically impossible. We have only assessed the sows when they were lying down in the farrowing crates, this might have limited the detection of lesions.

**Perspective for Future Research**

Future research should focus on the effect of lameness and claw lesions on the behavioural restrictions of the sows. The development of these disorders and more specific the aetiology needs a better understanding in order to draw conclusions *e.g.* about the effect of mild lameness and early treatment of locomotion disorders and claw lesions. Automated measures might be helpful to assess the effect of locomotion disorders and claw lesions on welfare and health status of sows. Beside, being able to recognise small changes in sows ‘behaviour, which could be the precursor of problems regarding locomotion disorders and claw lesions.

Further testing of different floor types and more specific rubber flooring under different (group housing) management systems is required to fully explore the benefits and possible limitations. Separate testing of both the rubber lying mats and the rubber covering for slatted floors is needed before conclusions can be drawn about the specific effects of both types of rubber flooring. Also the comparison between (softer, more cushioning) rubber top layers and softer bedding like straw should be looked into.

Regardless of floor type or group management system, more research is needed on time and method of grouping. Both pen design and several management factors may be associated with the aggressive encounters among newly mixed sows, and thus with lameness and claw lesions. It would be beneficial for sow welfare to avoid the peaks in lameness incidence during the first days after grouping.
**Main Findings of the Thesis**

- Moderately and more severely lame sows are restricted in covering distances;
- High lameness and claw lesions prevalences and incidences were found in group-housed gestating sows;
- The restriction in movement in moderately and more severely lame sows, together with the high lameness and claw lesion prevalences and incidences implicate an impaired sow welfare whilst being group-housed;
- The first three days immediately after (re)grouping are very risk full for an increased level of aggressive behaviour, based on the skin lesions and lameness development independent of group management system;
- Sows housed in pens with rubber flooring from d28 until d108 of gestation had a reduced prevalence and incidence of lameness, a better average locomotion score, and some of the 8 claw parameters scored less severe;
- Covering concrete slats and lying areas with rubber mats can be accomplished easily in practice and might be a powerful adaptation to improve sow welfare.

In conclusion, optimizing the housing environment and management of group-housed gestating sows is needed in order to reduce the risk of developing locomotion disorders and claw lesions and improving overall welfare.

**References**


Chapter 6


SUMMARY

Public concerns about the welfare of gestating sows resulted in the transition from individual housing towards obligatory group housing of gestating sows from 4 weeks after insemination until one week before the expected farrowing date in the whole EU from January 1st 2013 onwards. Properly managed group-housed sows can express more exploratory and social behaviour, which is considered beneficial for their welfare. Group housing improves the social contact and interactions between sows and the increased activity has a positive effect on sows’ muscle and bone development. These positive characteristics of group housing may be accompanied by some aspects of diminished welfare, however. There is a wide disparity in the design and therefore also management of group-housing systems for gestating sows, and all these features can affect sow welfare. Group housing, with emphasis on inadequate pen design and grouping methods, is one of the most important predisposing factors aggravating locomotion disorders and claw lesions. Locomotion disorders and claw lesions are common and multi-factorial disorders, causing impaired animal welfare and economic losses. The occurrence of locomotion and claw problems have increased with implementation of group housing for gestating sows, without knowing the risky phases in the reproductive cycle. In order to combine keeping sows in animal welfare friendly group housing, with good reproductive performance and productivity research and development is needed to optimize these systems. Research is needed to determine threshold values for the different lameness indicators so it will be possible to detect lame sows at every severity level of lameness. Various cross-sectional studies have been performed already focusing on sows’ locomotion and claws, however insufficient longitudinal studies have been carried out, in order to detect the most harmful moments in the reproduction cycle as well as the long-term effect of specific management factors such as grouping method or pen design. Knowing this, will allow to treat affected animals properly, will improve the welfare of the sows and gives the opportunity to find and implement the necessary preventive measures (Chapter 1).

The general aim of this thesis was to investigate locomotion disorders and claw lesions in sows in group housing systems, in order to improve the welfare, health and profitability of pig herds. The specific research objectives were to investigate the relationship between locomotion score and
sow mobility (Chapter 3); the long-term effect of group management on gait and claws of gestating sows in commercial farms (Chapter 4); and the long-term effect of floor type in the group pens on gait and claws of gestating sows (Chapter 5).

In a feed reward collection test (Chapter 3), we have investigated the extent to which the mobility of sows is affected by different degrees of lameness. Mobility was measured as the sow’s willingness or capability to cover distances. Feed-restricted hybrid sows (n=29) with different locomotion scores were subjected to a feed reward collection test in which they had to walk distances to obtain subsequent rewards. All group-housed sows (gestation stage d96.6 ± 7 SD) were visually recorded for gait and classified as non-lame, mildly lame, moderately lame or severely lame. Test arena consisted of two feeding locations separated from each other by a Y-shaped middle barrier; feed rewards were presented at the two feeders in turn. After training, sows were individually tested once per day on 3 non-consecutive days with the maximum barrier length such that they had to cover 9.3 m to walk from one feeder to the other. Non-lame and mildly lame sows obtained more rewards than moderately lame and severely lame sows (P < 0.01). However, no significant difference was found between non-lame and mildly lame sows (P = 0.69), nor between moderately lame and severely lame sows (P = 1.00). The results suggest that sow mobility is reduced only when the degree of lameness is rather severe, whereas mildly lame sows may not be as limited in their mobility as generally assumed. Sows with a stiff, uneven and non-fluid stride did not differ in their combined willingness and capability to walk for feed rewards, when compared with sound sows. This highlights the need for further research investigating the ability of (group-housed) sows to access resources and express behavioural needs depending on their lameness status. The found cut-off point in the experiment described in Chapter 3 was used in the lameness incidence and prevalence calculations in the other experiments (Chapter 4 and 5).

The first longitudinal field study was carried out at 10 commercial sow farms aiming to compare the prevalence, incidence and mean scores of lameness and skin and claw lesions in static versus dynamic group housed sows at different stages of gestation during three consecutive reproductive cycles and to identify the risky phases in the reproductive cycle (Chapter 4). In total 10 Belgian sow herds were monitored: five with dynamic and five with static group management.
All sows were visually assessed for lameness and skin lesions three times per cycle (before moving to group, three days in group, and end of group housing) and the claws of the hind limbs were assessed once per cycle (10 days after farrowing). Results show that static groups scored better at the end of gestation for mean locomotion score ($P < 0.05$) and skin lesion prevalence (24.9 vs. 47.3%, $P<0.05$). On average 75.5% of the sows had a claw lesion regardless of group management. Prevalences of lameness (22.4 vs. 8.9%, $P < 0.05$) and skin lesions (46.6 vs. 4.4%, $P < 0.05$) were highest during the group-housed phase compared to the individually housed phases. Although the prevalence of lameness and skin lesions did not differ three days after grouping versus at the end of the group-housing phase, their incidence showed a pronounced peak during the first three days after moving from the insemination stalls to the group. Hence, the first three days immediately after (re)grouping are a very risk full period for developing lameness or incurring skin lesions independent of group management system. Based on the limited number of monitored farms, it does not seem that using static group management can reduce the incidence of such problems during this critical period. All three output variables (locomotion, and skin and claw lesions) in group-housed sows would benefit from more research on time of grouping. Future research should focus on optimizing the housing environment and management of group-housed sows to reduce the risk of developing lameness or being wounded.

The second longitudinal experiment was carried out at the research facilities of ILVO, aiming to compare prevalence, incidence and mean scores of locomotion and claw and skin lesions between sows housed in gestation pens with fully concrete floors versus concrete floors partly covered with rubber mats (Chapter 5). Six groups of 21 ± 4 hybrid sows were monitored during 3 successive reproductive cycles. The sows were group housed from d28 after insemination (d0) until 1 wk before expected farrowing date (d108) in pens with either exposed concrete floors or concrete floors covered with rubber in part of the lying area and the fully slatted area. During each reproductive cycle, locomotion and skin lesions were assessed 4 times (d28, 50, 108, and 140) and claw lesions were assessed twice (d50 and 140). Results show that at the end of gestation (d 108), sows housed on rubber flooring had a better mean locomotion score ($P < 0.001$). At move to group (d28) and mid gestation (d50), no differences between floor treatments were seen in locomotion ($P > 0.10$). Lameness prevalence was higher for sows housed on concrete
flooring (30% vs. 15% on d50 and 33% vs. 20% in d108, respectively). Incidence of lameness was the highest on d50 for sows housed on concrete floors (3.3% vs 1.8% of new cases of lameness per day at risk, respectively). Regarding claw disorders, both parameters “heel overgrowth and erosion” and “heel-sole crack” scores were better for sows on rubber flooring at d50 (P < 0.05). However, sows on rubber flooring scored worse for “vertical cracks in the wall horn” (P < 0.05). At d140, both “white line” and “claw length” (difference of 4.7 ± 1.4 mm; P < 0.001) had better scores on rubber flooring (P < 0.02). No differences for skin lesions were observed between floor treatments. Covering concrete slats and lying areas with rubber mats can be accomplished easily in practice and might be a powerful adaptation to improve sow welfare. Further testing of rubber flooring under different (group housing) management systems is required to fully explore all the benefits and possible limitations. In addition, separate testing of both the rubber lying mats and the rubber covering for slatted floors is needed before conclusions can be drawn about the specific effects of both types of rubber flooring. The improved scores for gait toward the end of gestation and some types of claw disorders at mid gestation suggest that rubber flooring in group housing has a beneficial effect on the overall leg health of sows.

Summarizing, optimizing the housing environment and management of group-housed gestating sows is needed in order to reduce the risk of developing locomotion disorders and claw lesions and thus improving overall welfare.
SAMENVATTING

Recente veranderingen in de Europese wetgeving hebben er toe geleid dat per 1 januari 2013 drachtige zeugen verplicht in groepen gehuisvest moeten worden vanaf 28 dagen na inseminatie tot een week voor de verwachte werpdatum. Groepshuisvesting verbetert de mogelijkheden tot sociaal contact tussen zeugen, daarnaast kunnen de zeugen vrij rond bewegen wat een positief effect heeft op de spier- en botontwikkeling. De positieve eigenschappen van groepshuisvesting kunnen echter ook gepaard gaan met factoren die het welzijn negatief beïnvloeden.

Er zijn verschillende mogelijkheden wat betreft groepshuisvesting van drachtige zeugen, zowel qua ontwerp van de stal als qua management van de dieren. Deze verschillende eigenschappen van het groepshuisvestingssysteem kunnen het welzijn van de zeug, zowel positief als negatief, beïnvloeden. Groepshuisvesting kan een van de belangrijkste predisponente factoren van locomotieproblemen en klauwletsels zijn, wanneer huisvesting en management niet toereikend zijn. Locomotieproblemen en klauwletsels zijn beide multifactoriële aandoeningen en komen veel voor in de zeugenhouderij. Deze problemen hebben negatieve gevolgen voor zowel het dierenwelzijn als voor de rendabiliteit van het bedrijf. Het aantal dieren met locomotieproblemen en klauwletsels is gestegen sinds de invoer van groepshuisvesting voor drachtige zeugen, mede door de risicovolle momenten tijdens de groepshuisvestingsperiode. Dus, om een goed welzijn, gezondheid en reproductieresultaat bij drachtige zeugen te waarborgen, is het zeer belangrijk om deze groepshuisvestingsperiode te optimaliseren qua leefomgeving en management.

Onderzoek is nodig om vast te stellen of en wanneer zeugen in groepshuisvesting beperkt worden in hun mogelijkheid zich voort te bewegen. Dit is belangrijk omdat zeugen in groepen afstanden moeten afleggen om naar de voeder- en drinkplaats te komen. Daarnaast is het belangrijk om te kijken naar de evolutie van locomotieproblemen en klauwletsels bij zeugen op lange termijn, en of deze afhankelijk zijn van manier van groeperen (stabil vs. dynamisch) of stalinrichting. Verschillende cross-sectionele studies zijn al uitgevoerd, echter onvoldoende longitudinale studies zijn uitgevoerd op dat vlak. Dit terwijl deze juist nodig zijn om de risicovolle periodes in de reproductiecycli te detecteren en het effect van verschillende managementfactoren te testen.
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en evalueren. Indien deze risicovolle periodes en management factoren bekend zijn, kunnen preventieve maatregelen toegepast worden om het dierenwelzijn van zeugen in groepshuisvesting te verbeteren.

Het algemene doel van dit proefschrift was om de locomotieproblemen en klauwletsels bij drachtige zeugen in groepshuisvesting te onderzoeken om dierwelzijn en gezondheid en dus ook de productie te verbeteren. De specifieke doelstellingen waren het onderzoeken van: de relatie tussen locomotiescore en mobiliteit (Chapter 3); het langetermijneffect van groepsmanagement op locomotieproblemen en klauwletsels van drachtige zeugen in commerciële landbouwbedrijven (Chapter 4); en het langetermijneffect van vloertype in de groepshuisvesting op locomotieproblemen en klauwletsels van drachtige zeugen (Chapter 5).

Als eerst hebben we de “Feed reward collection test” (Chapter 3) uitgevoerd waarin we hebben onderzocht in welke mate verschillende levels van kreupeleheid invloed hebben op de mobiliteit van drachtige zeugen. Mobiliteit werd gemeten als de bereidheid en het vermogen van de zeug om afstanden af te leggen. Hiervoor hebben we bij beperkt gevoederde zeugen (n=29) met verschillende locomotiescores getest hoeveel afstand zij aflegden om een voedselbeloning op te halen. Alle zeugen (drachtstadium d96,6 ± 7 SD) werden eerst visueel beoordeeld op locomotie en daarna geclassificeerd als niet, mild, matig, ernstig of zeer ernstig kreupe. De testarena bestond uit twee voederlocaties die van elkaar gescheiden waren door een Y-vormige barrière waardoor de afstand tussen de twee voederlocaties 9,3 m bedroeg. De voedselbeloningen werden om en om gepresenteerd op een van beide locaties. Na voldoende en succesvolle training werden de zeugen eenmaal per dag getest op drie opeenvolgende dagen. De niet kreupele en mild kreupele dieren haalden meer voedselbeloningen op dan zowel de matig als ernstig kreupe dieren (P < 0,01). Er werd echter geen significant verschil gevonden tussen niet-kupele en mild kreupele zeugen (P = 0,69), noch tussen matig en ernstig kreupele zeugen (P = 1,00). Deze resultaten suggereren dat de mobiliteit van een zeug wordt verminderd wanneer de mate van kreupeleheid minstens matig of ernstig is, maar dat mild kreupele dieren niet zo beperkt worden als algemeen verondersteld wordt. Zeugen met een stijve, ongelijke en niet-vloeiende gang verschilden niet in hun gezamenlijke bereidheid en vermogen om voort te bewegen om voedselbeloningen op te halen in vergelijking met perfect stappende, niet-kupele, zeugen. Dit
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benadrukt de noodzaak voor het verder onderzoeken van de daadwerkelijke beperking die in groep gehuisveste zeugen ervaren door hun locomotiestatus en dus de mogelijkheid om de belangrijke plaatsen, zoals de voeder- en drinkplaats, in het hok te bereiken. Het gevonden verschil tussen enerzijds geen en milde kreupelheid en anderzijds matig en ernstige kreupelheid is verder gebruikt voor incidentie en prevalentie berekeningen in de andere experimenten (Chapter 4 and 5).

De eerste longitudinale studie werd uitgevoerd op 10 commerciële zeugen bedrijven. Het doel van deze veldstudie was de incidentie, prevalentie en gemiddelde scores van locomotie en klauwletsels te vergelijken tussen bedrijven met stabiele en dynamische zeggengroepen gedurende 3 opeenvolgende reproductiecycli. Daarnaast wilden we de risicovolle periodes in de reproductiecyclus van een zeg identificeren (Chapter 4). In totaal zijn er 5 Vlaamse zeugehouderijen met stabiele en 5 Vlaamse zeugehouderijen met dynamische groepen opgevolgd. Driemaal per cyclus (Vlak voor verplaatsen naar groep; drie dagen na het in de groep gaan; Einde groepshuisvesting (d108)) werden de zeugen visueel beoordeeld op locomotie en huidletsels. Eenmaal per cyclus (10 dagen na werpen) werden de klauwen ook visueel beoordeeld. De resultaten tonen aan dat aan het einde van de groepshuisvestingsperiode zeugen in stabiele groepen beter scoorden dan zeugen in dynamische groepen wat betreft gemiddelde locomotiescore (P < 0,05) en huidletselprevalentie (24,9 vs. 47,3%; P < 0,05). Gemiddeld had 75,5% van de zeugen een klauwletsel, ongeacht het groepsmanagement. De prevalenties van kreupelheid (22,4 versus 8,9%, P < 0,05) en huidletsels (46,6 versus 4,4%, P < 0,05) waren het hoogst tijdens de groepshuisvestingsperiode in vergelijking met de individueel gehuisveste periode. Hoewel de prevalentie van kreupelheid en huidletsels niet verschilden tussen “drie dagen in het in groep gaan” en “eind groepshuisvesting”, was dit wel het geval voor de incidentie, die piekte tijdens de periode van het in de groep zetten tot drie dagen daarna. Hieruit concluderen we dat de eerste drie dagen direct na het in groep gaan, een zeer risicovolle periode is voor het ontwikkelen van kreupelheid of het krijgen van huidletsels, onafhankelijk van het groep managementsysteem. Op basis van de resultaten op de opgevolgd bedrijven, kunnen we niet concluderen dat een bepaald groepsmanagement het voorkomen deze problemen kan beïnvloeden. Om deze reden zou toekomstig onderzoek zich moeten richten op het optimaliseren
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van de leefomgeving en het totale management van zeugen in groep, om de kans op het ontwikkelen van kreупelheid of verwondingen te beperken.

De tweede longitudinale studie is uitgevoerd op het proefbedrijf van ILVO. Dit experiment had als doel de prevalentie, incidentie en gemiddelde scores van locomotie en klauw- en huidletsels te vergelijken tussen groepen drachtige zeugen gehuisvest in groepshokken bestaande uit volledig betonnen vloeren versus betonnen vloeren deels bedekt met een rubberen toplaag (Chapter 5).

Zes groepen van gemiddeld 21 ± 4 hybride zeugen werden opgevolgd gedurende 3 opeenvolgende reproductiecycli. De zeugen waren in groep gehuisvest van d28 na inseminatie (d0) tot 1 week voor de verwachte werpdatum (d108), de groepshokken bestonden ofwel volledig uit betonnen vloeren, ofwel uit betonnen roostervloeren volledig bedekt met rubberen matten en 50% van de ligruimte bedekt met rubberen ligmatten. Tijdens elke reproductiecyclus, werden locomotie en huidletsels 4 keer (d28, 50, 108 en 140) beoordeeld en klauwletsels werden tweemaal (d50 en 140) beoordeeld. De resultaten laten zien dat op d108, zeugen gehuisvest op rubber een betere gemiddelde locomotiescore hadden dan zeugen gehuisvest op beton (P < 0,001). Op de andere meetpunten zijn geen verschillen in gemiddelde locomotiescore tussen de twee vloerbehandelingen gevonden (P > 0,10). De prevalentie van kreупelheid was hoger bij zeugen gehuisvest op betonnen vloer (30% vs. 15% voor d50 en 33% vs. 20% op d108, respectievelijk). Incidentie van kreупelheid was het hoogst van d28- d50 voor zeugen gehuisvest op betonvloer (3,3% versus 1,8%, respectievelijk). De scores voor het balhoorn en de overgang van het balhoorn naar de zool waren beter voor zeugen op rubber vloeren op d50 (P < 0,05). Echter, zeugen op rubber vloeren scoorden slechter voor "verticale scheuren in het wandhoorn" (P < 0,05) op d50. Op d140, scoorden zowel de "witte lijn" en "klauwlengte" parameters beter op rubber vloeren (P < 0,02). Voor huidletselscores zijn geen verschillen gevonden tussen de vloerbehandelingen. De verbeterde locomotiescores op d108 en verbetering van sommige klauwaandoeningen halverwege de dracht suggereren dat de rubberen toplagen in de groepshuisvesting een gunstige invloed hebben op de algemene pootgezondheid van drachtige zeugen. We concluderen dat het bedekken van betonnen vloeren met een rubberen toplaag is gemakkelijk toepasbaar en kan bijdragen aan het verbeteren van zeugenwelzijn. Verder onderzoek met betrekking tot het testen van rubberen vloeren in verschillende 150
groepshuisvestingen en managementsystemen is nodig om alle voordelen en mogelijke beperkingen in kaart te brengen. Met dit experiment konden we geen onderscheid maken tussen het effect van de rubberen toplaag op de roostervloer en op de ligplaatsen. Om onderscheid te kunnen maken tussen de effecten van de rubberen matten op de ligplaatsen vs. de matten op de roostervloer is extra onderzoek nodig.

Samenvattend, het optimaliseren van de leefomgeving en het management van drachtige zeugen in groepshuisvesting is nodig om het risico op locomotieproblemen en klauwletsels te verlagen en dus het algemene welzijn te verhogen.
CURRICULUM VITAE

Emilie-Julie Bos was born on November 17, 1985 in Les Lilas, France. After obtaining her pre-university degree at “Coornhert Gymnasium” in Gouda, Netherlands, she started studying Animal Sciences at Wageningen University. Both a BSc and a MSc degree in Animal Sciences were obtained. The topics she studied in her MSc were diverse, and focused on keel bone fractures in laying hens and developing a zoo animal welfare monitoring system. For her research internship Emilie-Julie went to Paignton Zoo in the United Kingdom, where she investigated the possibilities to reduce energy consumption by studying the effect of seasonal temperature on the behaviour of zoo housed giant Aldabran tortoises, howler monkeys, pudús, and several bird species.

In December 2012, Emilie-Julie started her PhD research at the Department of Reproduction, Obstetrics and Herd Health, at the Faculty of Veterinary Medicine of Ghent University in cooperation with the Institute for Agricultural and Fisheries Research (ILVO). The PhD project was funded by the Agency for Innovation by Science and Technology in Flanders and focused on locomotion problems and claw lesions in gestating sows housed in groups.

Emilie-Julie is author and co-author of several publications in peer-reviewed international journals and she has actively participated in numerous international conferences. While being a PhD student Emilie-Julie followed several courses such as Analysis of Variance; Applied Longitudinal Data Analysis; Introduction, Analysis and Graphs in R; Introduction to SAS; Advanced Academic Conference Skills; Sustainable Food Production Through Livestock Health Management. Therefore, she obtained the certificate of the Doctoral Training Programme of Life Sciences and Medicine. Additionally, she was a lecturer and supervisor for many bachelor and master students and she has taught an international course in Sow Welfare.

Since September 2016 she works for the Agrifirm Innovation Centre, part of the Royal Agrifirm Group, as Researcher Sows and Piglets.
Curriculum Vitae

AWARDS AND TRAVEL GRANTS

FWO Travel Grant 2016: to attend the 50th Congress of the International Society for Applied Ethology. Edinburgh, United Kingdom

ISAE Congress attendance fund 2015: to attend the 49th Congress of the International Society for Applied Ethology. Sapporo, Japan

University of Ghent, Mobility Fund 2015: to attend the 49th Congress of the International Society for Applied Ethology. Sapporo, Japan
LIST OF PUBLICATIONS

PAPERS IN SCIENTIFIC JOURNALS


CONFERENCE PROCEEDINGS


List of Publications


**OTHER PUBLICATIONS**


DANKWOORD


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Dankwoord

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