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SOW LAMENESS AND CLAW LESIONS EVALUATION

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Dedication

This thesis is dedicated to my family.

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Introduction

The objective of this chapter is to describe lameness in breeding female pigs and its economic implications on swine production. This chapter also explains the assessment of lameness and various risk factors associated with lameness in pigs.

Definition of Lameness

Beusker (2007) defines lameness as "a deviation from the normal gait caused by lesions, defects, injuries, diseases and/or other factors located somewhere in the limb or the rest of the body, and is accompanied by pain or at least some kind of discomfort. It serves as a kind of being bothered- signal given by the animal (deliberately or not) to its observer and as a strategy used by the animal in order to maintain a certain state of comfort or even welfare". The Medical dictionary defines "lameness" as "a condition of diminished function, particularly because of a foot or leg injury". Lameness is also defined as a term that is commonly used to designate animals showing a wide range of locomotor problems judged on the ability to bear weight (Channon *et al.* 2009). Locomotor problems are also considered as indicators of animal well-being (Whay *et al.* 2003). In pigs, lameness may be manifested due to the pain associated with claw lesions.

Hoof Anatomy

Bovine and porcine feet have similar anatomical features. Figure 1 shows the anatomy of the pig foot. The foot is below the fetlock joint and the most distal part of the limb. The foot is comprised of two digits (third and fourth) that are responsible for weight-bearing. The distal part of the digits is named claws, which are surrounded by horny capsules. Four bones are part of each digit of the foot: the proximal, middle and distal phalanges, and the navicular bone. The proximal and middle phalanges are situated proximal to the claw and the distal phalanx and navicular bones are within the claw. Two joints are presented in the pig foot: the proximal interphalangeal and distal interphalangeal. Other anatomic structures of the foot include: the extensor and flexor tendons, and navicular bursa. The interdigital space is between the two claws and it connects them with a smooth hairless skin. The first digit is completely absent in pig feet, and the second and fifth digits are reduced, nonfunctional digits referred to as dew claws.

Each claw consists of a horny keratinized hoof, which is modified epidermis. Each hoof is integrated by the wall, sole, heel and white line. The wall is considered the hardest horn. The two surfaces that meet the ground are the sole and heel, with the heel being more prominent than the sole. The white line is the softest horn at the sole-wall junction on the ventral aspect. The dermis or corium contains the nerve and blood supply and is responsible for the horny claw production.

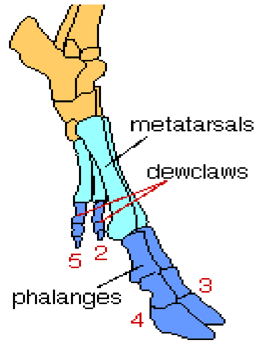


Figure 1.1: Anatomy of the porcine foot (2= second digit; 3= third digit; 4; fourth digit; 5= fifth digit).

Lameness and its impact on swine production

Lameness in pigs is an important economic issue for swine breeding herds. Locomotor problems are one of the most common reasons for involuntary sow culling in swine breeding herds (Dagorn and Aumaitre, 1979; Kirk *et al.* 2005; Anil *et al.* 2005; Engblom *et al.* 2008). The most recent National Animal Health Monitoring Study by the USDA reports 15.2 percent of culling is due to lameness.

Lame sows will not reach their potential reproductive efficiency and may be culled before they reach their expected productive life in the herd (Jorgensen, 2000), suggesting the adverse economic effect of the condition (D'Allaire *et al.* 1987). Indeed, lame sows are reported to produce 1.5 litters less than healthy sows (Grandjot, 2007). Mote *et al.* (2008) identified in commercial farms a 7% failure to produce a single litter in gilts; 13%

of the young sows where removed before their second litter; and only 57% of sows reached their fourth parity. Thus the adverse economic cost of lameness may be linked as well to the costs of additional acquisition of gilts as replacements for lame sows.

Although a sow may become lame at any time during its reproductive cycle, the impact of lameness will be the greatest if the sow is lame when she enters the farrowing crate. Lameness could result in more severe economic losses by affecting the behavior of the sow during the lactation period through limitation of physical movements. Moreover, Bonde *et al.* (2004) reported that lameness in sows may result in uncontrolled lying down behavior, increasing the risk of piglet death due to crushing. Severely lame sows often are in poor body condition, and can have wounds on the hind feet and hock that may lead to increased time in recumbency (Bonde *et al.* 2004). Bonde *et al.* (2004) reported an association between poor body condition and lameness with shoulder lesions. Likewise, Davies *et al.* (1997) reported a higher prevalence of shoulder lesions among sows with low body condition, and other factors, including floor type and activity level during parturition were suggested as potential risk factors. Thin sows have less sub-cutaneous tissue that protects against decubital ulcers of the shoulder and other areas and this may be compounded by increased recumbency in cases of severe lameness. Indeed, one study confirmed that sows with lameness were 17 times more likely to develop shoulder lesions compared to sound sows (Rosendahl *et al.* 2004).

Lameness may affect sow longevity in more than one way. The pain associated with lameness can inhibit lactation feed intake (Oldham, 1985). Cytokines (interleukin-1, interleukin-6 and tumor necrosis factor-alpha) released by inflammatory processes induce anorexia and lethargy (Johnson, 1997). Reduced feed intake during lactation can affect subsequent reproductive performance and can adversely affect sow longevity (Kirkwood, 1987; Baidoo *et al.* 1992).

Moreover, water intake and motor activity are also affected by lameness. A study that included 125 pregnant sows from eight different swine herds, reported a mean water intake of 17 liter/day/pregnant sow (sigma~7). Body condition, lameness, parity, and stage of pregnancy affected the water intake of these sows. Moreover, time sows spent standing was affected by parity, body condition and lameness (Madec *et al.* 1986).

Lameness may also affect the reproductive performance of the sow (Heinonen *et al.* 2006), and retention of sows with health problems in the herd may have an effect on the herd performance in the long term. Anil *et al.* (2007) found that more sows without any health problems including lameness farrowed and had higher numbers of piglets born alive than sows with reported health problems. Anil, S.S. *et al.* (2008) determined the impact of the implementation of a sow removal decision-support system (DSS) based on analgesic intervention (Flunixin meglumine, 2.2 mg/kg i/m, on 3 alternate days) and sow removal options for lameness. Two different groups (DSS implemented group and DSS implemented/analgesic treated group) of lame sows were compared based on their production performance. The DSS implemented group showed a higher litter birth and wean weights; lower pre-weaning mortality; and less number of piglets born alive. Also, the proportion of removed sows was lower in the DSS implemented/analgesic treated group. The beneficial effect of analgesic treatment suggests that pain has a detrimental effect on reproductive and lactation performance in lame sows.

Another study showed a tendency for locomotor disorders to be associated with sows failing to return to estrous (Andersen and Boe, 1999). Likewise, a study performed in cows reported that the proportion of cows that ovulated was reduced by being lame and the proportion was further lowered when the lameness was combined with high somatic cell counts (Morris *et al.* 2009).

Lameness in sows: assessment and scoring systems

Assessing the locomotion of sows to identify lameness in large confinement herds is a practical challenge. However, the relocation of sows to farrowing crates offers an opportunity to observe the gait of sows. The diagnosis of lameness in a sow breeding herd can start with the general herd evaluation followed by clinical evaluation of individual animals (Straw, 2006). Despite the high prevalence of lameness in swine herds, its diagnosis can be subjective due to the lack of a 'gold standard'.

Most of the methods developed so far for lameness assessment are based on uneven bearing of weight; however, the methods are mostly limited to observational deviations in the normal gait which are difficult to judge. For example, Whay *et al.* (2003) found that producers were able to identify one out of four cases of dairy cows with leg disorders. Similarly, Espejo *et al.* (2006) reported that only one out of three lame cows was correctly detected.

Anil *et al.* (2008) assessed the sensitivity and specificity of the lameness scoring system (0=non-lame to 3=severe lame) in 78 sows (non-lame and sows with different scoring levels of lameness). The sows were evaluated by inexperienced clinicians that were video trained for five minutes. The study reported a higher sensitivity and specificity for lameness scores of level 3. The lower sensitivity for non-lame and lower specificity for score 1 indicated a less precise process for grading sows with less severe or non lameness. The latter distinction is critical for the application of preventive therapeutic measures in order to prevent aggravation of the lameness in sows. In contrast, Manson and Leaver, (1988) developed a 5-point scoring system based on the evaluation of the cows while walking away from the observer on concrete flooring. The scoring system bases its grading on a five point scale, allowing for half scoring; the authors consider this is useful by the early identification of alterations in comfort and gait.

There are several factors that might be assessed in order to detect abnormality in the locomotion of an animal (Whay, 1999) including: the head movement while walking (hanging or nodding), spine (straightening or arching), and stride length (tracking or shortening), hind limbs (degree of abduction or adduction), walk (willingness), feet contact to the floor, lameness (apparent). For example, Main *et al.* (2000) developed a six point scale that ranged from 0 (no abnormality in posture, gait, or behaviour) to 5 (severely lame pig, incapable of standing unaided) in order to assess lameness in finishing pigs. This scoring system was repeatable between two trained observers; however, it was not repeatable between untrained observers.

Other scoring systems have been described in the literature. A visual analogue scale (VAS) developed by Welsh *et al.* (1993); which is based on drawing a line somewhere over a 100mm-line by the observer, the ends of the 100mm-line represent the scoring grading of lameness (left=completely sound, right=could not be more lame). The repeatability of this scoring system relies on the fact that it must be performed always by the same person.

Whay (1999) compared the methods developed by Manson and Leaver (1988), Whay *et al.* (1997) and by Welsh *et al.* (1993). The study revealed that neither of these methods met the criteria of "accuracy", repeatability" and "sensitivity" previously set by Welsh *et al.* (1993). The Manson and Leaver method may be useful for early detection of locomotion changes rather than specific lameness score. The Whay method had the lowest sensitivity when compared to the others methods, however it had a better criteria for scoring clinically lame animals. The VAS method had the highest sensitivity. Additionally, other approaches have been recently developed for lameness scoring in cattle addressing the understanding of behaviors related to pain, which may assist the development of welfare assessment systems. Obel (1948) developed a system on the basis of scoring the behavior of a standing horse, the willingness to move and pain. Indeed, O'Callaghan *et al.* (2003) designed a study in order to assess pain subjectively (posture scoring) and objectively (daily activity levels <steps/hour>). The authors reported that the presence of foot lesions and the reduced daily activity levels were associated with an increased posture score; the presence of claw lesions was more likely to reduce the daily activity levels and to develop obvious lameness among a total of 345 lactation dairy cows evaluated during winter.

More recently, Dyer *et al.* (2007) used a new technique (using an algometer) for pain magnitude and frequency detection. This technique aims to objectively quantify pain in the claw of the bovine foot by the calculation of pain indices (PICLAW). The study reported an ipsilateral effect of pain and also an effect on the lateral claw, being lower for the medial claw. These findings are in agreement with the higher incidence of claw lesions on the lateral claw of the foot (Murray *et al.* 1996). If the pain was present, the magnitude of pain was not different between the medial and lateral claws. Moreover, the study showed for the first time that animals with limbs with a normal locomotion score had a high frequency of pain detection on their lateral claws (37.2%). Therefore, subclinical claw lesions are important issues for dairy farmers and clinicians because pain is present in the absence of lameness. These findings support previous descriptions of subclinical claw lesions (Manske, 2002; Somers *et al.* 2003), where lesions were detected in the absence of locomotion disorders.

Joint lesions are one of the most common reasons for euthanasia in Danish sow herds and they are readily diagnosed by specified gait and posture variables affected by certain joint lesions. Kirk *et al.* (2008) examined the relation of abnormal gait and posture in 60 sows with specific joint lesions in a Danish herd. The randomly selected sows were scored clinically and pathologically. This study found an association between different variables and clinical conditions of the animals, for example: variables ‘fore-and hind legs turned out' and 'stiff in front and rear' were positively associated with lesions in the elbow joint, while variables ’hind legs turned out' and 'stiff in rear' were associated with lesions in the knee joint. Although strong correlations were found, further research is needed to optimize the diagnosis of sow lameness both for researchers and clinicians.

Pathological and clinical evaluation of lameness in sows

Lameness in sows can be evaluated by clinical examination of the musculoskeletal system. However, the examination of the limbs and joints at necropsy may be useful and necessary to differentiate the causes of lameness in pigs. Differential diagnoses include: footrot, leg injuries, osteochondrosis, leg weakness, osteomalacia, fractures, and arthritis. Footrot has been described in up to 100% of adult pigs (Penny *et al.* 1980); which is mainly defined as a condition of infection of soft tissues of the pig’s foot after an injury. Although there are etiological agents associated with footrot in sheep and cattle; there is no particular organism associated with the infection of the foot in pigs. However, osteochondrosis is reported as the most common cause of lameness in growing pigs and breeding pigs (Grondalen, 1974; Reiland, 1975a). Also, Dewey *et al.* (1993) reported that 45 out of 48 sows evaluated postmortem had microscopic lesions consistent with osteochondrosis. These lesions were bilateral and symmetrical and also were present in several joints of the same affected animal. Dewey also reported that the average parity of the sows culled with osteochondrosis (1.3) was less than the average parity of the sows culled due to other lameness disorders (3.4). These results were supported by previous reports that most often osteochondrosis presented clinically in pigs between 6 and 15 months of age (Grondalen, 1974; Reiland 1975a).

Other causes of lameness such as: infectious arthritis and foot lesions (footrot, overgrown claws, and torn dewclaws) have been pointed by Dewey et al. (1993). The most salient finding in that study was that older parity sows 4.4 (±2.5) were more frequently diagnosed with foot disorders than younger parity sows 2.4 (±2.5) (Dewey *et al.* 1993).

Kirk *et al.* (2005) reported locomotor disorders (72%), arthritis (24%) and fractures (16%) as the most prevalent reasons for euthanasia of sows (n=172), after performing necropsy of 265 culled sows from 10 different Danish sow herds. By comparison, spontaneous death (n=65) was predominantly associated with gastrointestinal problems and splenic (45%) and reproductive disorders (24%). Arthrosis was diagnosed as a secondary disorder in 88% of the sows euthanized and 92.5% of the sudden deaths. Also, claw lesions were frequently observed in both groups of sows, with overgrown heels the most frequent lesions.

Sanz *et al.* (2007) reported that sow euthanasia was performed more commonly during gestation and lactation than in breeding phase of production, and accounted for almost 40% of sow mortalities in a swine herd located in North Carolina. Also, arthritis was the most common finding among the sows (average parity <3) that were required to be euthanized, in agreement with previous studies ((Irwin *et al.* 2000; Christensen *et al.*1995; Svedsen *et al.* 1975). However, one of these reports showed that sows older than parity 3 were more likely to die as a result of arthritis than younger sows (parity ≤3) (Svenenden *et al.* 1975).

Jorgensen (2000) investigated the association between different leg weakness symptoms and osteochondrosis/osteoarthrosis and claw disorders in sows together with the influence of age on these findings. Sows (n=117) from one herd were followed from six months of age until culling. Leg weakness was evaluated once every gestation following a scale from 1 (normal) to 4 (severe changes). At slaughter, lesions in joints, growth plates and claws were scored on a scale from 1 (normal) to 5 (very severe changes). Some of the clinical signs of osteochondrosis and osteoarthrosis were: buck-kneed foreleg, turn out of fore and hind legs, upright pasterns and hind legs, stiff locomotion, lameness and tendency to slip. Clinical signs for claw lesions were: buck-kneed forelegs, upright pasterns, steep hook joints, turn out of hind legs, standing under position on hind legs, stiff movements, swaying hindquarters, goose-stepping hind legs, tendency to slip and lameness. Overgrown claws were strongly associated with leg weakness and appeared to be secondary to leg weakness.

Anil *et al.* (2008) aimed to analyze the association between claw lesions and lameness by evaluating 771 pregnant sows (110 days of gestation). The sows were scored for claw lesions (erosions, cracks, and overgrowths) with the scoring scale of 0 (no lesions) to 4 (severe lesions) points. This study reported that not all type of claw lesions were associated with lameness. Heel lesions (OR=0.656, CI=0.458, 0.94) and white line lesions (OR=0.689, CI=0.480, 0.990) were associated with lameness whereas overgrown heel (1.186, CI=0.830, 1.693), heel-sole lesions (0.837, CI=0.587, 1.193), sole lesions (0.860, CI=0.603, 1.227) and side wall lesions (OR=0.686, CI=0.462, 1.016) were not associated with lameness. Several other studies have also reported the association between claw lesions and lameness. Anil *et al.* (2007) reported an association between white line lesions and lameness in sows in the USA. Others (Dewey *et al*.1993; Penny *et al.* 1963) have suggested claw lesions as the major reason for lameness development.

Lameness – risk factors – claw lesions and environment

Claw lesions have been suggested to be an important cause for lameness in sows (Dewey *et al.* 1993; Anil *et al.* 2007). Severe claw lesions are putatively painful and may permit entry of upward infection, leading to lameness. Claw lesions in pigs are the result of interactions between claw and the floor surface. It is important to understand the mechanisms of the interaction between the foot and the floor in order to identify the causes of foot injuries. Webb and Nilsson (1983) reviewed the association between injuries in pigs and the physical characteristics of the floor such as friction, abrasiveness, hardness, surface profile and thermal properties. Webb (1984) described that pigs tend to walk mainly on their outer digits, even though the inner toe is still used. This is consistent with the higher incidence of injuries in the outer digit compared to the inner digit. However, when comparisons were made between the back and the front feet, the study did not report any statistical difference in the weight bearing. This lack of difference does not appear to concur with the reported differences in the incidence of injuries between the front and back feet. Therefore, the difference of the incidence of injuries presented in the front and back feet might be explained by environmental factors rather than differential weight bearing. Another hypothesis explored by Webb (1984), was that perforated floors will limit the contact area between the soft heel bulb, and therefore the animals may experience discomfort or might be injured more easily than on solid floors.

Studies on the effect of floor type on lameness are scanty; most of the studies are based cattle and these results are not directly transferable to swine. Bergsten (2001) studied environmental factors associated with the development of lameness in cattle. One of these factors was the housing system, which has been associated with lameness in dairy cows. Free-stall barns are often designed with concrete floors, which provides a cleaner environment and it is more durable. A disadvantage attributed to this type of housing floor is the harsh and abrasive surface.

Frankena *et al.* (2009) reported that the gait disturbance was reduced in cows kept on straw when compared to cubicle houses with concrete hallways. Moreover, Gait can be improved when animals are walked on rubber surfaces vs. concrete floors; specifically although it is suggested that cows tend to adjust their gait in response to surface softness and friction. Phillips and Morris (2000) reported that cows showed longer strides and more joint angulations on high vs. low-friction concrete surface. Moreover, Flower *et al.* (2007) reported that cows with and without sole ulcers that walked on rubber surface had longer strides, higher stride heights, more stride overlap, shorter periods of triple support, walked faster, and had lower overall gait scores, better tracking-up, better joint flexion, more symmetric steps, and less reluctance to bear weight on their legs compared to the cows that walked on concrete surface.

Boyle *et al.* (2000) reported that sows provided with mats tended to slip less on their hind and front limb when compared to sows with metal slatted floors in the farrowing crates. Therefore, mats provided a comfortable condition and also reduced the slipping. Although there was no significance difference in the presence of foot lesions, piglets on mats did have slightly lower incidence of wounds in the heel and dew claws. In addition, there was a significant reduction of bruised soles among litters on mats.

Telezhenko (2007) studied the preferences of dairy cows for rubber compared with concrete flooring surface under a free-stall housing system. The proportion of cows standing on softer or harder rubber flooring was higher when compared to the control group, where solid concrete flooring surface was offered. Also, the proportion of non-lame cows walking on the slatted side or solid rubber mats was higher when compared to the control group. On the other hand, lame cows did not show any preference for softer flooring surfaces as non-lame cows did. This lack of preference may presumably be explained by the higher competition with the higher ranked cows. However, the majority of the cows showed a higher preference of walking and standing over soft rubber flooring rather than concrete flooring surfaces.

Vanegas *et al.* (2006) reported that cows housed on concrete had higher likelihood of becoming lame compared with cows housed on rubber floors after 130 days in milk (DIM). An Irish study performed by Leonard *et al.* (1994), reported that claw lesions occurred less in heifers housed with a rubber bedding floor than the control group without rubber. In addition, Bergsten and Frank (1996) reported that cows had higher scores for sole hemorrhages on concrete floor when compared to rubber floors; there was also an association between high concentrate diets and lesions. Moreover, the study determined a seasonal effect, with higher sole hemorrhage scores for heifers calving in the fall compared to those calving in the spring. Rushen *et al.* (2007) reported that the incidence of swelling of joints (carpus) was higher in cows on concrete than in cows on rubber mats, which may have a negative effect on the welfare of the cows. Because cows place more weight on their front knees to stand up (Lidfors, 1989); the increased swelling could make the lying down a painful condition, and explain the longer time the cows spent standing on the concrete floor surfaces. Moreover, the authors suggested that hardest flooring surfaces lead to increase swelling, which leads to reduced willingness of cows to lie down and stand up.

Tuyttens *et al.* (2008) reported that sows had a preference for lying areas covered with mats when compared to concrete flooring surfaces. However, the preference was affected by the time the sows had been previously exposed to the experimental set-up. Similar findings were previously reported by Phillips *et al.* (1996) where sows' preferences for floor surfaces depended on the time animals were exposed to unfamiliar situations. This study also reported that the likelihood of sternal recumbency was higher on concrete than on mats, providing evidence that mats can improve the comfort especially on cold environments. However, this study did not evaluate the effects of the mats on leg health, pressure sores and skin lesions. However, Boyle *et al.* (2000) reported that the provision of mats may be associated with more frequent skin lesions in pigs and more severe skin lesions were also reported by Gravas (1979).

Heinonen *et al.* (2006) evaluated 646 sows from 21 herds and reported an 8.8% prevalence of lameness. Animals housed on slatted floors had twice the odds of being lame, and 3.7 times the odds of being severely lame, than animals housed on solid floors. Zurbrigg and Blackwell (2006) reported that there were differences in the development of lameness between different housing systems; groups housed on solid floors had fewer lame sows when compared to groups of sows housed on slatted floors.

Norring *et al.* (2006) reported a significant difference in characteristics of the flooring surfaces, with a polyurethane coated flooring being rougher than concrete flooring. Also, piglets housed on polyurethane coated flooring had a higher frequency of claw lesions.

Gjein and Larssen (1995) evaluated lame pregnant sows for 12 months. The study was performed in 15 different herds that housed the animals on partly slatted concrete floors (12 farms) or plastic slats (3 farms). The overall prevalence of lameness identified among the herds was 13.1% and the claw lesion prevalence was 3.8%. Regarding the type of floor the authors reported that sows housed on concrete slats had a relative risk of lameness 2.4 times higher than sow in herds that housed sows on plastic slats. On the other hand, farms with low status of hygiene had a relative risk of lameness 2.8 times higher than farms with better hygiene. In addition, claw infections were mainly observed on farms with dirtier floors and on farms with less than 2 m^2 of space per animal. Also, concrete slatted floors increased the risk of claw infections compared with plastic slats.

Anil *et al.* (2007) characterized claw lesions and identified the factors associated with types of claw lesions in 184 pregnant sows (110 days of gestation) in a herd located in Minnesota. The authors reported that only 7 out of 184 evaluated sows did not have any foot lesion, and all of these sows were housed in stalls during gestation. The wall (88.6% of claws evaluated) and heels (85.4% of claws evaluated) were the areas with the most severe lesions on forelimbs. Body weight increased the likelihood of wall lesions on day

109 of gestation. As back fat increased, the likelihood of heel lesions increased, however the likelihood of overgrown heels decreased. Lame sows were more likely to have white line lesions on any claw than sound sows. Also, parity was associated with white line lesions, and sows of parity ≤5 were more prone to develop white line lesions than sows with parity >5. However, it is important to mention that for this study older parity sows have been selected for soundness. The study also reported that sows housed in groups with electronic sow feeders (ESF) had a higher likelihood to develop all types of lesions in any claw than sows housed in stalls.

Kroneman *et al.* (1993) reported that claw lesions were mostly developed in the hind legs and being most common on first parity sows. Also, claw lesions occurred at higher incidence among sows housed in the group housing system compared to sows housed in crates. However, there was no association between claw lesions and lameness.

Lameness – Risk Factors - Nutrition

Nutrition may play an important role in the development of claw lesions, since the quality of the claw depends on its physical structure and this is controlled by cellular processes affected by nutrition (Ossent *et al.* 1998). The importance of trace minerals in the keratinization process has been reported previously (Tomilson *et al.* (2004). However, the effect of these trace minerals in ameliorating claw lesions in pigs has not been well demonstrated. Anil *et al.* (2009) showed that sows consuming inorganic trace minerals had more lesions on the sole than sows fed with complexed trace minerals.

Penny *et al.* (1980) reported that after 12 months of biotin supplementation (1160 micrograms/day of biotin), lame sows had fewer lesions of heel erosion, white-line, heel bruising and "corn", and lesions present in the lateral claw were also less severe.

Moreover, Webb *et al.* (1984) reported significant increments in the compressive strength of the mid-abaxial sidewall region of pig's hoof after supplementation with biotin (1mg d-biotin/kg feed). Also, the hardness was increased. On the other hand, biotin supplementation was associated with reduced hardness of the heel bulb on the shore A and D hardness scale; which measures the degree of resistance of claw horn against the penetration of a spring-loaded probe. Simmins and Brooks (1988) reported that early dietary supplementation of sows with biotin induced a significant improvement in the maintenance of horn integrity. Although, the incidence of claw lesions was increased between 170 days and first gestation, a reduced incidence in claw lesions was observed at weaning in the biotin supplemented group compared to the control group ($p<0.05$); The most prevalent lesions were cracks located in the heel/toe junction and the heel, and the side wall and adjacent white-line region of the toe. Calabotta *et al.* (1982) determined the effects of restricted growth rate and elevated levels of Ca and P on feedlot performance and foot and leg scores and measurements of 96 gilts during growth and development. The study concluded that energy intake and elevated Ca P levels had little effect on the incidence and severity of foot lesions. Reiland (1975b) showed an association between fast growth rate and increased incidence and severity of osteochondrosis. Moreover, soundness was not affected by increased Ca and P levels or restricted energy intake, supporting data from previous studies (Reiland, 1975b; Grondalen, 1974).

Lameness – Risk Factors – Genetics

The association of genetics with lameness has been reported with varying results. Heinonen *et al.* (2006) reported that Yorkshire pigs had 2.7 times the odds of being lame than Landrace or crossbreed animals. Similarly, Oravainen (2008) reported that Yorkshire sows had higher likelihood of being lame when housed in loose-housed systems. However, according to Peltoniemi *et al.* (1992) Landrace boars were more likely to become lame. Also, Landrace were more severely affected by osteochondrosis (Jorgensen, 2000). The reported differences may be influenced by environmental, management factors or influenced by the genome of the animals. There are few studies that performed any genomic analysis to determine genes associated with lameness or any other particular gait abnormalities. Onteru *et al.* (2008) examined 134 porcine genes that affected skeletal development, mineral metabolism and other genes for single polymorphism (SNP) discovery. The study identified a total of 370 SNPs, but only 22 genes were evaluated for their association with gait and locomotion disorders in 2000 pigs. Of these 22 genes only eight genes (CALCR, HDBP CALCA, MTHFR, OXTR, IHH, ANKH, LRCH1 and OPN) have shown a significant association with leg and body conformation traits.

Lameness – Other Risk Factors

Schenck *et al.* (2008) evaluated the effect of exercise during gestation on the musculo-skeletal system, production variables, and behavior. They reported no effect of exercise on lameness. However, there were differences in bone density, density and quality, lying behavior, and piglet survival.

Tiranti and Morrison (2006) determined the association between limb conformation scores in 961 gilts and retention through the second parity. Thirty one percent of gilts were removed before the second parity, and survival time in females with poor conformation scores for the hind limbs was lower than for females with better conformation scores. Therefore, gilt selection based on conformation may have positive results by reducing sow attrition and improving performance traits in the long term.

Chapter II

Effect of rubber mats in farrowing crates on the expression of lameness and subsequent sow performance

Chapter Summary

The aim of this study was to explore the effect of providing rubber mats in farrowing crates on the impact of lameness on sow welfare and performance. The study was conducted at Southern Research and Outreach Center, Waseca and involved 70 lame and 70 non-lame sows. An equal number of lame and non-lame sows were randomly allocated to farrowing crates with bare cast iron floors or to identical crates provided with rubber mats of 3 cm thickness placed over those floors. The frequency of getting up and dog sitting was affected by lameness on day 9 post-farrowing (P=0.029) but was not affected on days 3 or 15 post-farrowing (P>0.05). The frequency of drinking water was affected by lameness on days 3 and 9 post-farrowing (P<0.05) but not on day 15 (P>0.05). Lameness did not affect the frequency of eating on days 3, 9 or 15 post-farrowing (P>0.05). The presence of rubber mats did not affect the frequency of getting up and eating of the sows (P>0.05), but it did affect the frequency of dog sitting and drinking water on day 9 post-farrowing (P=0.02). There was no significant difference in farrowing performance, body condition, low feed intake, total feed intake, feed intake on week -1 and week-2 post-farrowing between the groups. Back fat measurement at 109 d

of gestation (odds ratio 0.832; 95% CI: 0.741-0.933) was negatively associated with the likelihood of having shoulder ulcers at weaning (P=0.0019). The likelihood of shoulder ulcers was 3.0 (95% CI: 1.410-6.346) times higher on cast iron when compared to rubber mats on hind limbs (P=0.0043). Parity, housing system and lameness were not associated with shoulder ulcers in this study. The survival of sows at 200 days post-weaning did not differ among groups (P>0.05). In general, the results indicate adverse effects of lameness on postural behavior and feed and water consumption during lactation. However, post-partum behavior of the sow and familiarity of stall-housed sows to postural changes in restricted space could have influenced the results. Also, the protective effect of rubber mats on the likelihood of shoulder ulcers and the improvement on the behavior of the sows may improve the welfare of animals.

Introduction

Lameness in sows is an important economic issue in breeding herds. Locomotor problems are a major reason for sow culling in swine breeding herds (JØrgensen, 2000; Anil *et al.* 2005). Culled sows are removed due to locomotor problems in up to 14% of the cases in North American breeding herds (Stone, 1981; Friendship *et al.* 1986). The likelihood of sow removal because of locomotor problems decreases as parity number increases (Dagorn and Aumaitre, 1979; D'Allaire *et al.* 1987; Paterson *et al.* 1997), suggesting the adverse economic effect of the condition (D'Allaire *et al.* 1987).

The economic implications of lameness can be linked to decreased production, higher replacement costs and lower salvage values. Lame sows are reported to produce 1.5 litters less than the healthy sows (Grandjot, 2007). Lack of approved analgesics and practical difficulty in offering individual medications in large herds make prevention of lameness a better option than treatment.

A sow may express lameness at any time during its reproductive life; however, the adverse effect of lameness will be the highest if the sow is lame when she goes to the farrowing crate. Lameness may be associated with pain; and therefore can inhibit lactation feed intake (Oldham, 1985). Cytokines (interleukin-1, interleukin-6 and tumor necrosis factor-alpha) released by the inflammatory process can induce anorexia and lethargy (Johnson, 1997). A negative association between dry matter intake and locomotion scores in dairy cattle has been suggested by Bach *et al.* (2007). Reproductive performance and sow longevity can adversely be affected by reduced feed intake throughout the lactation period. Inadequate lactation feed intake has been associated to poorer subsequent reproductive performance of a sow (Kirkwood *et al.* 1987; Baidoo *et al.* 1992) leading to a removal from the herd. Lameness may also affect sow's ability to make postural changes within the farrowing crate, leading to less time spent standing. Moreover, lame sows may spend more in lateral recumbency which may lead to a higher incidence of shoulder lesions (Anil *et al.* 2006).

Although a sow may become lame on any limb, the hocks in the hind limbs are more prone to injuries due to poor flooring (Weary and Taszkun, 2000). Rushen *et al.* (2007), in a study in dairy cattle, reported that the incidence of swollen knees and hocks tended ($p=0.06$) to be lower on rubber mats than on concrete.

An important cause of lameness has been suggested to be claw lesions (Dewey *et al.* 1993; Anil *et al.* 2007). Severe claw lesions are putatively painful and may permit entry of ascending infections, leading to lameness. Claw lesions in pigs are the result of the interactions between claws and the floor surface. Webb and Nilsson (1983) have reviewed the association between injuries and the physical characteristics of the floor such as friction, abrasiveness, hardness, surface profile and thermal properties. Leonard *et al.* (1997) reported that floor type might also affect the sows' standing and lying-down behavior. However, studies on the effect of floor type on lameness and its effects in sows are scanty; most of the studies are of cattle and these results are not directly transferable to swine.

The adverse effect of lameness on welfare and performance is expected to be reduced by providing rubber mats during the lactation period. Sows with rubber mats are expected to be more able to make postural changes and therefore more likely to consume more feed and water because of the relative ease of getting up. The present study aims to explore the effect of providing rubber mats in farrowing crates in reducing the presumed adverse effects of lameness on welfare and performance of sows.

Materials and Methods

Animals, housing and feeding – The study was performed at the University of Minnesota, Southern Research and Outreach Center, Waseca, Minnesota. All protocols were approved by the Institutional Animal Care and Use Committee of the University of Minnesota. This study involved 70 lame and 70 non-lame gestating sows (Genetically Advanced Pigs, GAP Genetics, Winnipeg, Manitoba, Canada) of parities 0 to 8 and weighing 402 to 738 lb at 109 days of gestation. Gestating sows were housed either in pens (12.75 m x 6.75 m) with one electronic sow feeder (ESF) per pen (TEAM electronic sow feeder; Osborne Industries, Osborne, Kansas) (n=77) or in stalls (Crystal Spring Hog Equipment Ltd, St Agathe, Manitoba, Canada; length 200 cm, width 60 cm wide, height 97 cm) (n=63). Pens and stalls had fully slatted flooring (solid portion 12.7 cm wide and

12.7 cm deep; slots 2.54 cm wide). Thirty nine parity one or two sows, 19 sows of parities three to five, and 10 sows of parities > five were housed in pens. Twenty one parity one or two sows, 32 sows of parities three to five, and 10 sows of parities > five were housed in stalls. The distributions of parities in pens and stall-housed sows did not differ (chi-square test; $P>0.05$). During gestation (until day 109) sows were fed 2.5 to 3 kg of feed daily. Sows while in the farrowing crates were offered 3 kg of feed per day until farrowing, and ad libitum feed during lactation. Equal numbers of sows were randomly allocated to farrowing crates (214 cm x 66 cm, excluding a creep area for the piglets) with cast iron floor or to crates with the cast iron floor covered with rubber mats (2cm thickness) on the posterior half. Sows were weaned at an average of 18.4 days of lactation (SD, 1.4 day).

Data collection

Lameness scores – The sows were observed by a single observer while moving them from their gestation housing to the farrowing crates. Lame sows were identified based on unequal weight bearing on all limbs. Sows were categorized for lameness as lame or non-lame. A subjective lameness score of severity of lameness from 0 (non-lame) to 3 (severely lame) was also recorded for data description.

Claw lesions scores – Claw lesions were assessed prior to farrowing (day 110 of gestation) after the sows were moved into farrowing crates. Lesions included erosions, cracks, and overgrowths. The lesions were examined on a severity scale of 0 (no lesions noted) to 3 (severe). Claw lesion locations were classified as side wall, heel, sole, junction between heel and sole, white line, dew claws or toe. A total claw lesion score was calculated as the sum of all individual lesion scores for the claw.

Behavior variables - The behaviors of the sows were recorded and scored using cameras and a time-lapse video recording for 24 h on days 3, 9 and 15 post-farrowing. Events and postures evaluated included frequency of getting up, drinking water, dog sitting, and eating. A sow was considered to be eating or drinking from the time her head was observed in the feeder or at the nipples, respectively. A subsample of sows (n=108) was randomly selected to calculate the time that the sows were in lateral recumbency on day 9 post farrowing. The longest uninterrupted lying period observed during day 9 post-farrowing (T-max) was also determined for each sow (Rolandsdotter *et al.* 2009).

Performance variables – Data were obtained from the PigCHAMP database (PigCHAMP, Ames, Iowa) of the research unit to evaluate the farrowing performance of sows. Variables evaluated were numbers of born alive piglets, mummies, and stillborn; need for farrowing assistance; preweaning piglet mortality and recorded reasons; litter birth weight and litter weaning weight; parity; lactation length; disease and treatment events in the farrowing crates; and sow removal events. The litter from each sow was weighed at birth and at weaning using a weighing cart (Ag Alliance) with an electronic scale (Model TI500; Transcell Technology, Inc, Wheeling, Illinois; accurate to 1 lb).

Body weight and condition - At 109 days of gestation and on the day of weaning (15 to 24 days post farrowing), all sows were weighed on an electronic scale (Ag Alliance, Altoona, Iowa), and backfat was measured at the last rib (5 cm from the midline of the back on both left and right sides) with a Lean-Meater ultrasound unit (Renco, Minneapolis, Minnesota). Body condition was also evaluated following the 5 point scale (1=thin, 5=fat) described by Straw and Meuten (1992).

Feed intake - Sows in farrowing crates were hand-fed twice daily weighed amount of feed which was recorded on the sow cards. Feed consumed was assumed to be equal to that fed if the feeder was empty. The average lactation feed intake (LFI) for each sow was calculated by dividing the total quantity of feed consumed from day 2 of lactation until weaning by the number of lactation days for that sow. The average feed intake for week-1 and week-2 post-farrowing were also calculated. The frequency of the number of lactation days that the sows were consuming ≤ 5 lbs (2.27 kg) was also calculated for all sows using daily feed intake (day 2 to 14 of lactation) .

Shoulder ulcers – Shoulders of sows were examined for shoulder ulcers on day109 of gestation and at weaning. Lesions were scored following a 4 point grade scale according to severity and size (Zubrigg, 2006).

Other variables - Longevity of sows in terms of culling, euthanasia and death with reason thereof prior to subsequent farrowing was recorded (up to 200 days). Wean to estrus interval, number of services to conception, pregnancy status 45 d-post-breeding and subsequent farrowing rate were also obtained from the PigCHAMP database.

Statistical analysis

Behavior, performance productivity, body condition and feed intake variables – Two way ANOVA was employed to determine the effects of lameness and floor type (rubber mat vs. cast iron) on the behavior, performance, average feed intake and body condition variables of the sows. In all the analyses, the interactions between lameness and floor type were included. Means were compared with the use of Tukey's pairwise comparison with the SAS probability-difference option (SAS-PDIFF). The feed intake (category of 0 to 5 lbs or 2.27 kg) of lame and non-lame sows and flooring type (rubber mat vs. cast iron) on days 2 to 14 of lactation were compared, controlling for the effect of housing system (Proc Genmod, SAS v 9.2).

Shoulder ulcers – A logistic regression model was used to analyze the associations of the floor type (rubber mat vs. cast iron) and the presence of lameness and other covariates (parity, weight and back fat at 109 days of gestation) with the presence of shoulder ulcers.

Survival analysis – Univariate analyses were performed for treatment groups (Kaplan-Meier curves and a log-rank test of equality) to identify associations with sow longevity during the period ≤ 200 days after weaning. Kaplan-Meier curves were used (along with the log-rank test) to verify whether survival functions were approximately parallel among strata.

A *P* value of 0.05 or less was considered significant in all comparisons. All statistical analyses were performed with SAS System for Windows, version 9.2 (SAS Institute, Cary, North Carolina, USA).

Results

Animals and baseline information – Mean backfat thickness for sows housed in pens (18.13 mm; SD, 4.44) and sows housed in stalls (17.08 mm; SD, 4.50) did not differ (two-sample T-test; P=0.06). Mean weight for sows housed in pens (545.38 lb; SD, 68.65) and sows housed in stalls (550.30 lb; SD, 70.73) did not differ (two-sample T-test; P=0.10). A total of 108 sows (score 1=89 sows; score 2=15sows; score 3=4 sows) out of 240 sows evaluated were identified as lame animals. The lameness scores of the sows are presented on table 2.1. The proportions of sows that were identified as lame did not differ significantly between sows housed in stalls (41.4%) compared to sows housed in pens (48.4%) during gestation (two sample proportion test; P>0.05).

The mean total claw lesion scores of sows housed in pens (53.8; range, 20 to 126) was higher than in sows housed in stalls (32.2; range, 6 to 63) (two-sample T-test; P<0.05).

Behavior, performance, body condition and feed intake –The frequency of getting up and dog sitting on days 3, and 15 post-farrowing was not affected by lameness (*P*>0.05), but it was affected on day 9 post-farrowing (*P*= 0.029). The frequency of drinking water on day 15 was not affected by lameness (*P*>0.05), but it was affected on days 3 and 9 post-farrowing (*P*<0.05). Lameness did not affect the frequency of eating on days 3, 9 and 15 post-farrowing (*P*>0.05). The presence of rubber mats did not affect the frequency of getting up and eating of the sows (*P*>0.05), but it did affect the frequency of dog sitting and drinking water on day 9 post-farrowing (*P*=0.02). The effect of lameness and rubber mats allocated on the posterior half of the sows on the behavior are shown in table 2.2. The frequency of getting up was significantly higher in the non-lame group with rubber mats than the lame group with rubber mats on days 3 and 9 post-farrowing (*P* <0.05). It was also significantly higher than the lame group without mats on day 15 post-farrowing (*P* <0.05). The frequency of dog sitting and drinking water were significantly higher in the non-lame group with rubber mats than the lame group with rubber mats on days 9 and 15 post-farrowing (*P* <0.05). There were no statistical differences in the frequency of dog sitting, drinking water and eating between all groups on day 3 post-farrowing. The frequency of eating was significantly higher in the non-lame group with rubber mats than the lame group without mats on day 9 post-farrowing (*P* <0.05). There were no statistical differences in the frequency of eating among all groups on day 15 post-farrowing. Table 2.3 presents the behavior of the four groups of sows. The proportion of time that the sows were in lateral recumbency on day 9 post farrowing (mean for all sows= 0.92 hours, SD=0.04) did not differ among groups (P>0.05). The T-max observed during day 9 post-farrowing (mean for all sows= 4.6 hours, SD=1.4) was also not different among groups (P>0.05).

There was no significant difference in farrowing performance and body condition among groups. There was no significant difference in LFI, total feed intake, feed intake on week -1 or week-2 post-farrowing. The number of days sows consumed less than 5 lbs (2.27 kg) was 42% higher in lame sows and 30% lower in stall housed sows (P<0.05 for both). Use of rubber mats was not associated with feed intake in this study. Table 2.4 presents the productivity performance, body condition and feed intake variables of the four groups of sows.

Shoulder ulcers – A total of 52 sows developed shoulder lesions in this study. Table 2.5 presents the shoulder ulcer prevalence at weaning among all sows evaluated. Logistic regression analysis showed that backfat thickness at 109 d of gestation (odds ratio 0.832) was negatively associated with the likelihood of having shoulder ulcers at weaning (P=0.0019). The odds of shoulder ulcers was also 3.0 (1.410-6.346) times higher in sows without mats than sows with rubber mats on hind limbs (P=0.0043). Parity, housing system and lameness were not associated with the occurrence of shoulder ulcers. Table 2.6 shows the odds ratio and confidence intervals of the factors associated with shoulder ulcers at weaning.

Survival analysis – The reduction in survival function was proportional between lame and non-lame sows, and the Kaplan-Meier survival curves were approximately parallel (Figure 2.1). The 200 days survival rate for lame sows without rubber mats was 79 percent, which was not different from the survival rate for lame sows with rubber mat (73 percent) ($P > 0.05$). The 200 day survival rate for non-lame sows without mats was 75 percent, which was not different ($P > 0.05$) from the survival rate for non-lame sows with rubber mat (78%). Mean survival time for lame sows with rubber mats was 169 days after weaning, whereas mean survival time for lame sows without rubber mats was 174 days ($P>0.05$). Mean survival time for non-lame sows with rubber mats was 177 days after weaning, whereas mean survival time for non-lame without rubber mats was 171days ($P>0.05$). The test of equality indicated that the survival time did not differ significantly among groups of sows ($P>0.05$) (Figure 2.2 and 2.3).

Discussion

The effect of lameness on the behavior of the sows on this study is indicative of the adverse effect of lameness on postural behaviors. This supports a previous study that found that lameness was related to alter lying down behaviors (Bonde *et al.* 1987). If sows are lame they are more likely to spend more time lying down and also have more difficulty rising, leading to an altered frequency of those behaviors. In our study, 90% of the lame animals displayed only mild manifestations of lameness, which may explain the small differences observed overall in the frequencies of the behaviors among the groups of sows. Moreover, post-partum behavior of the sow and familiarity of stall-housed sows to postural changes in restricted space could have influenced the results of our study.

The high prevalence of shoulder lesion at weaning in this study (33%) was in accordance with previous research that had reported a high prevalence of shoulder lesions of up to 48% at 12 days post-farrowing (Davies *et al.* 1997). Our data showed that shoulder lesions were negatively associated with backfat thickness at 109 d of gestation. For every unit (mm) that the backfat was increased at 109 days of gestation the likelihood of developing shoulder lesions was reduced by 17%. Christensen *et al.* (2002) also found an association with backfat depth. That study reported that for each mm extra backfat depth, the risk of pressure ulcers was decreased by 16%. Davies *et al.* (1997) also reported that body condition score, back fat depth and tuber depth were risk factors for shoulder lesions. Their study considered that soft tissue overlying the tuber is a direct determinant for the risk of developing shoulder lesions in lactating sows. These findings may support the hypothesis that the shoulders of sows with good body condition have less pressure sores from the environment.

We found no association of lameness, parity or housing system with the risk of shoulder lesions. Among these, the lack of association between parity and shoulder lesions was supported by Davies *et al.* (1996). In contrast, others studies have reported an association between parity (Davies *et al.* 1997; Christensen *et al.* 2002; Zurbrigg, 2006) and lameness (Bonde *et al.* 1987) with shoulder lesions.

Additional contributing factors may be associated with the development of shoulder lesions including floor type and activity level during parturition and lactation (Davies *et al.* 1997). Rolandsdotter *et al.* (2009) showed an association between prolonged lateral recumbency and shoulder lesions in lactating sows. In contrast, our study did not show any significant difference between the time that sows that developed shoulder lesions spent in lateral recumbency compared with sows that did not develop shoulder lesions.

The presence of rubber mats under the hind limbs during lactation was associated with lower proportion of sows with shoulder lesions under the conditions of this study. Zubrigg (2006) reported that the presence of rubber mats during the lactation period reduced the time of the healing process of shoulder lesions by 7 days.

The overall performance of the sows in terms of productivity performance during the period of this study was not affected by lameness or the presence of the rubber mats on the posterior half. Although the rubber mats did not affect feed consumption, the number of day that lame sows consumed ≤ 5 lbs (2.27 kg) was 42 % higher when compared to non-lame sows under the conditions of this study. Previous studies have reported the adverse effect of consuming less than 3.5 kg of feed during the first two weeks of lactation, which leads to higher likelihood of being removed before a subsequent farrowing (Anil *et al.* 2006). However, our study found no difference in the survival of lame and non-lame sows for up to 200 days after weaning.

Woven wire, cast iron and, triangular bar (*tri-bar*) are common flooring materials used for farrowing crates. It is logical that if a sow with a markedly altered gait on a slatted or wire floor walks with more or less normal gait on a soft floor, there are problems. A significant difference in the frequency of weight shifting when lame sows walked on concrete floor and on rubber mats has been reported (Anil *et al.* 2007). Higher odds of lameness (Heinonen *et al.* 2006) and a higher prevalence of claw lesions were found in sows housed on slatted floors than on concrete floors (Ehlorsson *et al.* 2002).

Rushen *et al.* (2004) suggested, based on studies in cattle, that the type of floor can influence the manifestation of lameness. The prevalence of footpad lesions in cows has been reported to be greater on rough concrete than on smooth concrete (Wood, 2001). Other bovine studies have also indicated the advantages of rubber flooring for lame animals compared to concrete surface in terms of gait (Flower *et al.* 2007), stride length (Telezhenko and Bergsten, 2005), postural changes and duration (Rushen *et al.* 2007), and heel lesions (Vanegas *et al.* 2006). Brennan and Aherne (1987) observed a higher severity of foot lesions in starter pigs penned on woven wire flooring than in those penned on plastic coated expanded metal floors.

Table 2.1: Distribution of lameness severity scores in sows from stall or pen gestation

	Housing system		
Lameness Score*	**Pen (n=124)**	**STALL(n=116)**	**Total**
0	64	68	132
1	54	35	89
2	9	6	15
3	1	3	4

* Lameness score 0 (non-lame) to 3 (severe lame)

Table 2.2: Mean frequency of observed behaviors among lactating sows at different days post-farrowing

Behavior	Day	Lame: Lame (n=70) Mean (SE)	Lame: Non-Lame (n=70) Mean (SE)	Mat: No (n=70) Mean (SE)	Mat: Yes (n=70) Mean (SE)
Getting up	3	6.64 (0.39)	7.83 (0.55)	6.89 (0.41)	7.59 (0.54)
	9	8.26 (0.39)[a]	9.47 (0.38)[b]	8.69 (0.41)	9.06 (0.38)
	15	9.99 (0.49)	11.33 (0.59)	10.19 (0.51)	11.13 (0.58)
Dog sitting	3	9.89 (0.69)	11.83 (0.72)	10.60 (0.73)	11.11 (0.69)
	9	12.03 (0.61)[a]	13.91 (0.61)[b]	12.09 (0.59)[a]	13.88 (0.63)[b]
	15	18.71 (0.92)	20.77 (0.92)	18.81 (0.97)	20.67 (0.99)
Drinking water	3	9.26 (0.52)[a]	10.94 (0.61)[b]	9.87 (0.60)	10.33 (0.55)
	9	11.86 (0.57)[a]	13.60 (0.59)[b]	11.77 (0.55)[a]	13.71 (0.60)[b]
	15	17.16 (0.77)	19.10 (0.88)	17.30 (0.84)	18.96 (0.81)
Eating	3	6.20 (0.35)	6.91 (0.36)	6.41 (0.34)	6.70 (0.38)
	9	7.67 (0.36)	8.60 (0.32)	8.04 (0.34)	8.23 (0.34)
	15	9.00 (0.40)	10.03 (0.47)	9.27 (0.40)	9.76 (0.48)

[a,b] Within each row, within each category of lame or mat, the means with different superscripts differ significantly (P<0.05)

Table 2.3: Mean frequency of observed behaviors among lactating sows on days 3, 9 and 15 post-farrowing

Behavior	Day	Lame No Mat (n=35)	Lame Mat (n=35)	Non-Lame No Mat (n=35)	Non-Lame Mat (n=35)
		Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Getting up	3	6.66 (0.49)[a]	6.63 (0.63)[a]	7.11 (0.66)[ab]	8.54 (0.86)[b]
	9	8.43 (0.63)[a]	8.09 (0.49)[a]	8.94 (0.53)[ab]	10.00 (0.53)[b]
	15	9.86 (0.68)[a]	10.11 (0.71)[ab]	10.51 (0.78)[ab]	12.14 (0.89)[b]
Dog sitting	3	9.57 (0.91)[a]	10.20 (6.23)[a]	11.62 (1.13)[a]	12.03 (0.89)[a]
	9	11.20 (0.79)[a]	12.88 (0.91)[ab]	12.97 (0.87)[ab]	14.86 (0.85)[b]
	15	17.66 (1.20)[a]	19.78 (1.39)[ab]	19.97 (1.51)[ab]	21.57 (1.41)[b]
Drinking water	3	9.06 (0.69)[a]	9.46 (0.79)[a]	10.69 (0.98)[a]	11.20 (0.73)[a]
	9	10.91 (0.73)[a]	12.82 (0.85)[ab]	12.63 (0.81)[ab]	14.57 (0.84)[b]
	15	16.00 (1.07)[a]	18.31 (1.08)[ab]	18.60 (1.28)[ab]	19.60 (1.22)[b]
Eating	3	6.37 (0.46)[a]	6.03 (0.54)[a]	6.46 (0.49)[a]	7.37 (0.51)[a]
	9	7.83 (0.55)[ab]	7.50 (0.45)[a]	8.26 (0.42)[ab]	8.94 (0.48)[b]
	15	9.00 (0.57)[a]	9.00 (0.58)[a]	9.54 (0.57)[a]	10.51 (0.75)[a]

[a,b] Within each row, the means with different superscripts differ significantly ($P<0.05$)

Table 2.4: Reproductive and litter performance, body condition and feed intakes of sows by lameness status and floor treatment (mat or no mat)

Productivity measure	Lame		Non-Lame		
	No Mat (n=35)	Mat (n=35)	No Mat (n=35)	Mat (n=35)	
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	*P*
Total born	12.00 (0.57)	11.97 (0.52)	11.77 (0.55)	11.86 (0.60)	NS
Born alive	10.94 (0.55)	10.97 (0.52)	10.74 (0.49)	10.63 (0.56)	NS
Stillborn	0.89 (1.05)	0.83 (1.12)	0.77 (1.09)	0.97 (1.34)	NS
Mummies/litter	0.17 (0.08)	0.17 (0.08)	0.26 (0.11)	0.56 (0.09)	NS
Litter birth weight (lb)	37.89 (1.61)	37.78 (1.51)	37.6 (1.64)	37.04 (1.64)	NS
Piglet birth weight (lb)	3.61 (0.11)	3.55 (0.10)	3.54 (0.08)	3.59 (0.09)	NS
Piglets weaned	9.29 (0.33)	9.46 (0.29)	9.66 (0.19)	9.66 (0.20)	NS
Litter wean weight (lb)	134.88 (5.62)	130.19 (4.76)	136.18 (3.96)	136.13 (4.03)	NS
Piglet wean weight (lb)	14.46 (0.32)	13.76 (0.28)	14.09 (0.29)	13.97 (0.29)	NS
Sow weight at 109d (lb)	545.57 (10.56)	557.29 (12.09)	534.06 (11.99)	553.46 (12.31)	NS
Sow weight At weaning (lb)	500.86 (11.42)	508.26 (11.93)	492.91 (12.63)	509.60 (13.32)	NS
Weight difference (109d–weaning) (lb)	-44.71 (6.22)	-49.03 (4.44)	-41.14 (5.77)	-43.86 (4.13)	NS
Sow back fat at 109d (mm)	17.31 (0.65)	16.91 (0.81)	18.09 (0.84)	18.31 (0.73)	NS
Sow back fat At weaning (mm)	14.54 (0.55)	14.60 (0.64)	15.57 (0.69)	15.29 (0.59)	NS
Back fat difference (109d-weaning) (mm)	-2.77 (0.32)	-2.31 (0.33)	-2.51 (0.33)	-3.03 (0.33)	NS
Total feed intake (lb)	224.14 (9.84)	218.51 (9.79)	234.74 (11.19)	220.26 (9.46)	NS
Daily feed intake (lb)	11.99 (0.52)	11.71 (0.53)	12.45 (0.52)	11.81 (0.48)	NS
Daily feed intake (week-1) (lb)	9.64 (0.53)	9.06 (0.54)	10.11 (0.51)	9.73 (0.52)	NS
Daily feed intake (week-2) (lb)	13.43 (0.59)	13.43 (0.59)	13.99 (0.61)	13.38 (0.53)	NS

Table 2.5: Shoulder ulcer at weaning among all sows evaluated

	Flooring system		
Shoulder ulcer	**No mat (n=79)**	**Mat (n=78)**	**Total**
No ulcer	44	61	105
Ulcer	35	17	52
Shoulder ulcer (%)	44.3[a]	21.8[b]	33.12

[a,b] Within shoulder ulcer incidence row, the means with different superscripts differ significantly (P<0.05)

Table 2.6 Factors associated with shoulder ulcers at weaning

Explanatory variables	Odds ratio (CI)	*P**
Sow back fat at 109 d (mm)	0.832 (0.741-0.933)	0.0019
Sow weight at 109 d (lb)	1.004 (0.996-1.013)	0.3227
Parity (1 vs. 3 to 9)	0.879 (0.201-3.843)	0.6481
Parity (2 vs. 3 to 9)	1.380 (0.429-4.433)	0.4340
Housing system (stall vs. ESF)	1.393 (0.596-3.254)	0.4442
Flooring system (cast iron vs. rubber mat)	2.991 (1.410-6.346)	0.0043
Lameness (non-lame vs. lame)	1.225 (0.563-2.667)	0.6090

* Based on multivariate logistic regression analysis

Figure 2.1: Kaplan-Meier graph of the time to removal from the herd for lame (doted line) and non-lame (solid line) sows after lameness assessment. Day 0 is the day of weaning following treatment.

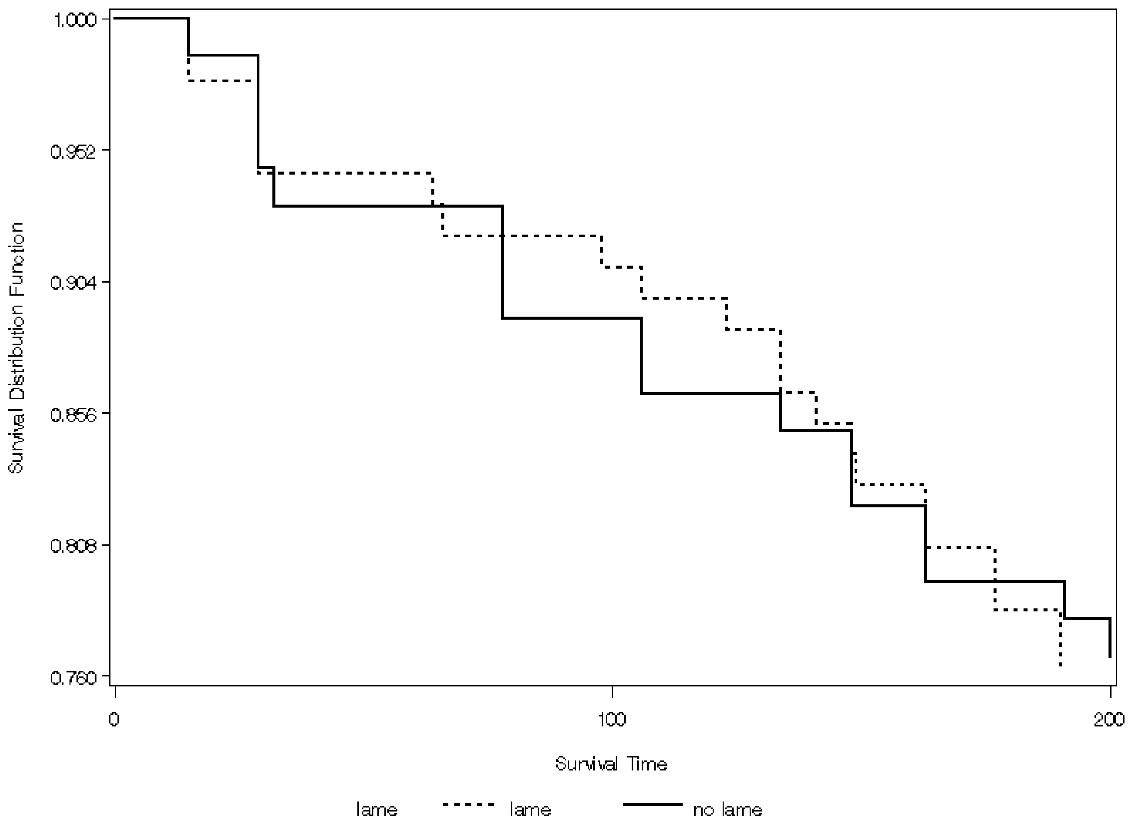


Figure 2.2: Kaplan-Meier graph of the time to removal from the herd for lame sows with no mats (solid line) and lame sows with rubber mat (doted line) after lameness assessment.

Day 0 is the day of weaning following treatment.

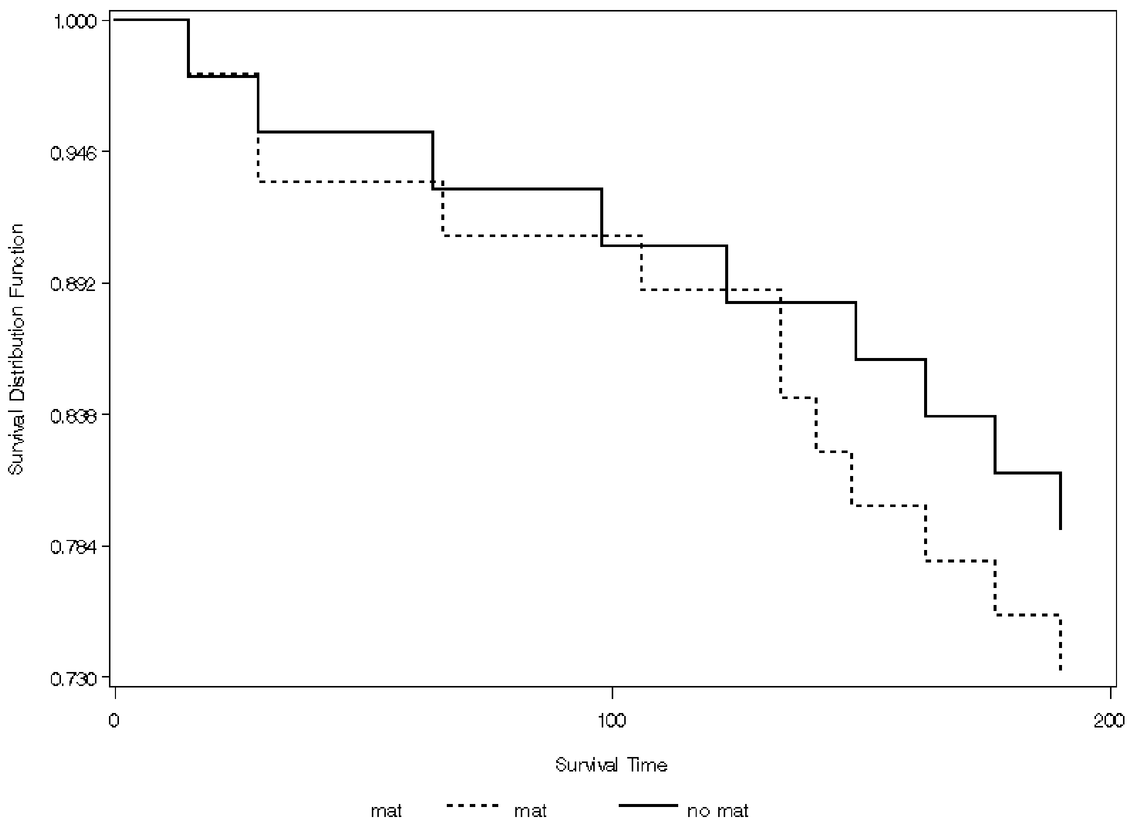
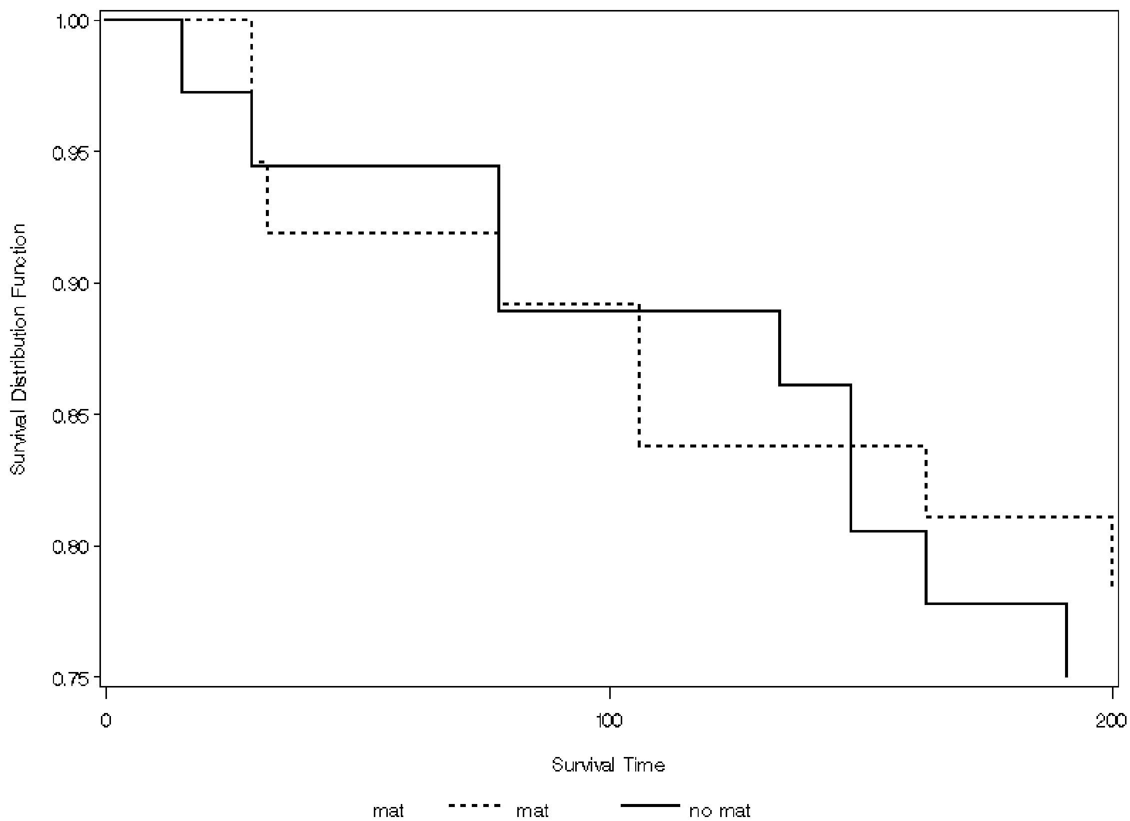


Figure 2.3: Kaplan-Meier graph of the time to removal from the herd for non-lame sows with no mats (solid line) and non-lame sows with rubber mat (doted line) after lameness assessment.

Day 0 is the day of weaning following treatment.



Chapter III

Claw lesions and their relationship with the performance and longevity of stall-housed sows in two sow herds

Chapter Summary

The aim of this study was to determine the relationship of claw lesions with the performance and longevity of breeding sows. The study was conducted in two commercial breeding herds located in the US Midwest and involved 343 sows. White line lesions (odds ratio 1.151, CI, 1.101-1.331) and overgrown toes (odds ratio 1.154, CI, 1.101-1.331) were positively associated ($P<0.05$ for both) with the likelihood of having ≤10 piglets born alive. The numbers of stillborn piglets were positively associated with the likelihood of having ≤10 piglets born alive (odds ratio 1.298, CI, 1.138-1.481) ($P<0.01$). Herd A was more likely to remove sows prior subsequent farrowing (3.570, CI, 1.848-6.896) than Herd B ($P=0.0002$). Non significant likelihoods of removal from the herd prior subsequent farrowing increased with an increase in the numbers of stillborn (OR: 1.132, CI: 0.953-1.345) and mummies (OR: 1.228, CI: 0.770-1.959). Sows of parity 1 and 2, were less likely than sows of parity >5 ($P<.0001$) to be removed from the herd prior to subsequent farrowing. The likelihood of removal from the herd prior to subsequent farrowing decreased by approximately 8% with every additional piglet born alive and 25% with every additional piglet weaned ($P<0.05$ for both). The likelihood of

removal from the herd prior to subsequent farrowing increased by approximately 16% and decreased by 18% for every additional unit in severity of elongated dew claws and white line lesions, respectively ($P<0.05$). The results of this study indicate potential adverse effects of claw lesions on the productivity of sows.

Introduction

Reduced sow longevity is an economic and welfare issue in swine breeding herds for several reasons. First, there is a direct relationship between the length of productive life of sows (number of days between selection dates until removal from the breeding herd) and the numbers of piglets produced by the sow. Second, higher replacement rates potentially increase the risk of introducing diseases into herds. Third, from an animal welfare perspective it is unacceptable to retain sows over numerous parities that are not able to adapt to the physiologic demands of producing pigs.

Sows are removed from herds for various reasons including reproductive failure and health problems. The risk for removal may vary over the life of a sow, and the periparturient period is one time of elevated risk of removal due to productivity and welfare issues. An estimated 1.6 to 7.2% of culling was associated with parturition problems (Stalder *et al.* 2004). Chagnon *et al.* (1991) reported that 42% of mortalities of sows occurred during the peripartum period, and lactation feed intake is one of the most important factors affecting sow survival and retention. Sows with reduced feed intake (≤3.5 kg per day) during the first two weeks of lactation had a higher risk of being removed from the herd before achieving the subsequent parity (Anil *et al.* 2006). Lameness is considered one of the most common reasons for sow removal, and Friendship *et al.* (1986) summarized that locomotor problems accounted for 14% of sow removals.

Although there are multiple factors and lesions contributing to lameness in sows, claw lesions appear to be crucial (Penny *et al.* 1963). Gjein and Larsesen (1995) reported that around 96% of loose-housed sows and 80% of stalled sows had at least one lesion on lateral claws of hind legs. Several risk factors have been associated with the development of claw lesions including: interaction between the floor surface and the horn of the claw (Simmins and Brooks, 1988); floor design (Jensen, 1979); and biotin deficiency (Simmins and Brooks, 1988). However, not all claw lesions result in clinical lameness. Anil *et al.* (2007) reported that white lesions were associated with lameness in breeding sows. Other claw lesions may allow the entry of bacteria leading to infections and more severe pain and clinical lameness.. Pain associated with lameness may reduce feed intake (Johnson, 1997), and reduced lactation feed intake is linked to poorer reproductive performance and reduced longevity of breeding sows (Baidoo, 1992).

Knowledge of the factors resulting in early removal of sows is needed in order to improve herd productivity and sow longevity. Understanding the etiology of claw lesions and their association with sow performance and longevity would help swine farmer to take decisions that improve sow wellbeing and longevity. The objectives of this study were: 1. To evaluate the association of claw lesions scores with productivity measures of stall-housed sows 2. To identify the risk factors associated with sow removal from the herd within 220 days after farrowing.

Material and methods

Animals and housing – Data for this study were collected from two sow herds located in the US Midwest between the first week of May-2009 and the first week of August-2009. This study involved 343 sows of parities 1 to 13. Sows were housed in stalls during gestation. Stalls had fully slatted flooring. Seventy five sows of parities 1 and 2, 60 sows of parities 3 to 5, and 10 sows of parities > 5 were from Herd A, and 79 sows of parities 1 and 2, 96 sows of parities 3 to 5, and 23 sows of parities > 5 were from Herd B. Distribution of parities in sows from herd A and herd B are represented in figures 3.1 and 3.2.

Data collection

Claw lesion scores –A convenience sample of 343 sows (Herd A, n=145, Herd B, n=198; of 1500 sows each herd) was examined for claw lesions. The claws were examined while the sows were in a recumbent position as there was no mechanical restraint to facilitate lesion scoring. The sites of claw lesions were recorded (side wall, heel, including overgrown heels, white line, heel-sole junction, and overgrown toes and dew claws). The scoring system was simplified to be more applicable in the field by using a single score of 0 (no lesion in both claws of the foot) to 3 (at least one lesion is severe in both claws of the foot). A total claw lesion score was calculated as the sum of all individual lesion scores for the foot.

Performance variables – Data were obtained from the PigCHAMP Care 3000 database (PigCHAMP Care 3000, Ames, Iowa) of the swine herds to evaluate the farrowing performance of sows in terms of piglets born alive, mummies, stillborns, preweaning mortality (and reasons), parity, lactation length, incidence of disease and treatments; and sow removal events prior to subsequent farrowing (up to 220 days).

Statistical analysis

Claw lesions and performance – A multivariate logistic regression analysis was performed to assess the association of lesion scores of different claw areas, stillborn, mummies, parity and sow herd with number of piglets born alive (≤10 vs. >10) (Proc Logistic, SAS v 9.2).

Longevity analysis – Kaplan-Meier curves were used to verify whether survival functions were approximately parallel among Herd A and Herd B. Multivariate logistic regression models (Proc logistic) were performed to identify the association of the longevity of these sows prior subsequent farrowing (up to 220 days) with the data collected (total lesion scores for each claw area and performance variables).

For analysis, parity was categorized into parities 1 and 2, 3 to 5 and >5. *P* values of 0.05 or less were considered significant in all comparisons. All statistical analyses were performed with SAS System for Windows, version 9.2 (SAS Institute, Cary, North Carolina, USA).

Results

Claw lesions – Median and range of lesion scores on different areas of affected claws are presented in table 3.1. The total lesion score for all claw areas ranged from 0 to 27 and only two sows had no lesions. Among the 343 sows evaluated and considering claws from all limbs, 78.7% had at least one lesion in the toe, and 94.4% had at least one elongated dew claw (Figure 3.3). Other common areas affected were heel and overgrowth and erosion (HOE) (50.4% of sows with lesions), white line (51.3% of sows with lesions). Lesions in the heel-sole crack (HSC) (14% of sows with lesions) and wall (16.9% of sows with lesions) were less common. The proportions of sows with lesions were greater than the proportions of sows without lesions in all claw areas, except the white line (51.3% of sows with lesions) ($P < 0.05$; one-sample proportion test).

Performance - There was no difference in born alive, stillborn, mummies, calculated pig deaths, lactation length and piglets weaned between Herd A and Her B (Two sample T-test; P>0.05). Table 3.2 presents the reproductive and litter performance, by Herd A and Herd B for more details.

Claw lesions and performance – A total of 105 sows (30.6%, mean=6.9, standard deviation=2.8) had ≤10 piglets born alive. The number of sows that had >10 piglets born alive was 238 (69.4%, mean=13.2, standard deviation=2.16). White line lesions (odds ratio 1.151, CI, 1.108-1.314) and overgrown toes (odds ratio 1.154, CI, 1.101-1.331) were positively associated (P<0.05 for both) with the likelihood of having ≤10 piglets born alive. The likelihood of having ≤10 piglets born alive tended to increased with the severity of lesions in other claw areas as well; heel-sole crack (odd ratio 1.216, CI, 0.963-1.535) and side wall (odds ratio 1.075, CI, 0.875-1.321); though the associations were not significant. The numbers of stillborn piglets were positively associated with the likelihood of having ≤10 piglets born alive (odds ratio 1.298, CI, 1.138-1.481) (P<0.01). The number of mummies (odds ratio 0.911, CI, 0.602-1.379), sows of parities 1 and 2 (odds ratio 0.469, CI, 0.199-1.105) and sows of parities 3 to 5 (odds ratio 0.525, CI, 0.234-1.179) compared to sows of parity >5 had lower likelihood of having ≤10 piglets born alive, though these associations were not significant. There was no difference between herds in the likelihood of sows having litters of ≤ 10 piglets born alive. Table 3.3 presents the odds ratio and confidence interval of the factors associated with number of piglets born alive (≤10 vs. >10).

Longevity analysis – The survival functions were proportional between Herd A and Herd B, and the Kaplan-Meier survival curves were approximately parallel (Figure 3.4). The 220 day survival rate for Herd A was 55.9 percent, which was not different from that Herd B (65 percent). Mean survival time for sows from Herd A was 162 days after farrowing, whereas mean survival time for sows from Herd B was 169 days (P>0.05). However, it is noted that these values are underestimated because the largest observed time is censored and the estimation is restricted to the largest event time. The results (Table 3.4) indicated that the likelihood of removal from the herd prior to subsequent farrowing were associated with the number of piglets born alive, piglets weaned, overgrown dew claws and white line lesions (P<0.05 for all). Herd A was more likely to remove sows (3.570, CI, 1.848-6.896) when compared to Herd B (P=0.0002) prior to subsequent farrowing. The number of stillborn and mummies were not associated with the persistence in the herd prior to subsequent farrowing based on the multivariate analysis (P >0.05). Sows of parity 1 and 2 were less likely to be removed from the herd than sows of parity >5 (P<.0001). Sows parity 3 to 5 were not associated with removal of sows from the herd prior subsequent farrowing when compared to sows of parity >5 (P=0.3746). The likelihood of removal from the herd prior to subsequent farrowing decreased by approximately 8% with every additional piglet born alive and 25% with every additional piglet weaned (P<0.05 for both). The likelihood of removal from the herd prior subsequent farrowing increased by approximately 16% and decreased by 18% for every additional unit in severity of elongated dew claws and white line lesions, respectively (P<0.05). The likelihood of removal from the herd prior to subsequent farrowing tended to increase with the severity of lesions in other claw areas as well; toe (odds ratio, 1.049, CI, 0.888-1.239), heel and overgrowth and erosion (odds ratio, 1.081, CI, 0.918-1.272), heel-sole crack (odd ratio 1.151, CI, 0.869-1.523) and side wall (odds ratio 1.005, CI, 0.797-1.257) but the associations were not statistically significant.

Discussion

The small proportion of sows with no claw lesions is consistent with a previous study that reported that 80% of stalled housed sows had at least one claw lesion (Gjein and Larssen, *et al.* 1995). Lesions observed in the wall, heel, and white line were the most prevalent in that study. For the present study, elongated dew claws were evident in 94.2% of the sows, followed by elongated toes in 78.7% of the sows. The high prevalence in elongated toes and dew claws may be explained by the weight distribution of the sows on the claws and limbs (Webb, 1984). Our method of lesions scoring did not differentiate between lateral and medial claws. However, previous studies have shown more lesions in the lateral claw (which bears a greater weight load) than in medial claws.

The flooring in our study farms was fully slatted, which has been associated with higher prevalence of claw lesions than other floor types such as solid concrete floors or straw bedding (Holmgren *et al.* 2000). The space between the slats, surface abrasiveness, and edge design (Boon *et al.* 1989) might influence the risk of lesions occurring. Claw lesions have been recognized as an important cause of lameness (Penny *et al*. 1963). In this study the evaluation of lameness was not performed.

White line lesions and overgrown toes were positively associated with the likelihood of having ≤10 piglets born alive; suggesting that productivity of sows can be negatively influenced by the development of severe claw lesions in sows. The white line is the cemented junction between the wall and the sole and is a natural weak point (Budras *et al.* 1996). Injuries in the white lines may facilitate ascending infections (Kempson and Logue, 1993). Other claw areas were also associated with the likelihood of having ≤10 piglets born alive; though the associations were not significant ($P<0.05$).

Previous studies have reported a high risk of stillborns for sows having litters with more than 12 piglets (Dial *et al.* 2002). The risk of stillborns may be increased due to prolonged farrowing. The associations between larger litters and lower birth weights and longer farrowing duration have been reported in previous studies (Dial *et al.* 1992). In the present study, there was a positive association between reduced number of live born piglets and stillbirths. Moreover, Cutler *et al.* (1992) reported that the size of a litter is increased with parity then it reaches to plateau between the fourth and sixth farrowing. For this study we didn't analyze the previous litter size. However, the litter size is positively associated with the previous litter size (Heyde, 1992). The number of mummies, parity and herd were not associated with having ≤10 piglets born alive.

There are several performance measures that are used for culling decisions in swine herds. The number of piglets born alive and piglets weaned are very influential and we found a negative association between the number of live born piglets and weaned piglets with sow persistence (prior next farrowing). Therefore, sows that have higher numbers of live born piglets and weaning more piglets are less likely to be removed from the herd.

The application of nutritional and management measures may improve the adverse effects of claw lesions on the performance of swine herds. Some nutritional measures have been documented as factors that reduce the incidence of claw lesions. One of these nutritional measures is diets supplemented with biotin (Simmins and Brooks, 1988). Moreover, the importance of trace minerals in the keratinization process has been reported previously (Tomlinson *et al.* 2004). A study also showed that sows consuming inorganic trace minerals had more lesions on the sole than sows fed with complexed trace minerals (Anil *et al.* 2009). It is also important to minimize the development of open wounds that will increase the risk of ascending infections. The results of this study indicate potential adverse effects of claw lesions on the productivity of sows. Therefore, it is important to identify factors affecting sow productivity and to reduce early removal of sows due to low productivity.

Table 3.1: Median and range of lesion scores on different areas of claws across all limbs in 343 lactating sows

	Lesion score	
Area affected (n=343)	**Median**	**Range**
Toes	2	0 - 10
Dew Claws	4	0 - 12
Heel overgrowth and erosion (HOE)	1	0 - 8
Heel-sole crack (HSC)	0	0 - 4
Wall	0	0 - 7
White line	1	0 - 10
Front limbs	1	0 - 7
Hind limbs	4	0 - 12
Total claw lesions	11	0 - 27

Table 3.2: Reproductive and litter performance, by Herd A and Herd B

Productivity measure	**Herd A** (n=145)	**Herd B** (n=198)	
	Mean (SD)		***P****
Total born	13.30 (3.64)	12.58 (3.77)	0.08
Born alive	11.70 (3.45)	11.00 (3.90)	0.08
Stillborn	1.28 (2.05)	1.35 (2.26)	0.74
Mummies/litter	0.32 (0.69)	0.23 (0.53)	0.14
Calculated pig deaths	1.14 (1.46)	0.97 (1.16)	0.23
Lactation length	19.75 (10.50)	19.98 (6.94)	0.80
Piglets weaned	10.42 (2.38)	9.92 (3.21)	0.12

* Based on Two sample T-test analysis

Table 3.3: Variables associated with number of piglets born alive (≤10 vs. >10)

Explanatory variable	**Odds ratio (CI)**	***P****
Performance		
Stillborn	1.298 (1.138-1.481)	0.0001
Mummies	0.911 (0.602-1.379)	0.6591
Parity		
Parity (1 and 2 vs. >5)	0.469 (0.199-1.105)	0.1583
Parity (3 to 5 vs. >5)	0.525 (0.234-1.179)	0.3454
Herd		
Herd (Herd A vs. Herd B)	1.079 (0.632-1.842)	0.7811
Claw area		
Toes	1.154 (1.101-1.331)	0.0488
Dew Claws	0.925 (0.817-1.048)	0.2217
Heel overgrowth and erosion (HOE)	0.930 (0.807-1.073)	0.3223
Heel-sole crack (HSC)	1.216 (0.963-1.535)	0.1001
White Line	1.151 (1.108-1.314)	0.0372
Wall	1.075 (0.875-1.321)	0.4902

* Based on multivariate logistic regression analysis

Table 3.4: Factors associated with sow removal at 220 days post-farrowing

Explanatory variable	**Odds ratio (CI)**	***P****
Performance		
Piglets born alive	0.913 (0.836-0.997)	0.0452
Stillborn	1.132 (0.953-1.345)	0.1722
Mummies	1.228 (0.770-1.959)	0.4095
Piglets weaned	0.755 (0.655-0.870)	<.0001
Parity		
Parity (1 and 2 vs. >5)	0.045 (0.014-0.140)	<.0001
Parity (3 to 5 vs. >5)	0.155 (0.053-0.456)	0.3746
Herd		
Herd (Herd A vs. Herd B)	3.570 (1.848-6.896)	0.0002
Claw area		
Toes	1.049 (0.888-1.239)	0.5729
Dew Claws	1.161 (1.030-1.358)	0.0174
Heel overgrowth and erosion (HOE)	1.081 (0.918-1.272)	0.3505
Heel-sole crack (HSC)	1.151 (0.869-1.523)	0.3268
White Line	0.822 (0.697-0.969)	0.0197
Wall	1.005 (0.797-1.257)	0.9926

* Based on multivariate logistic regression analysis

Figure 3.1: Frequency distribution of parity on Herd A

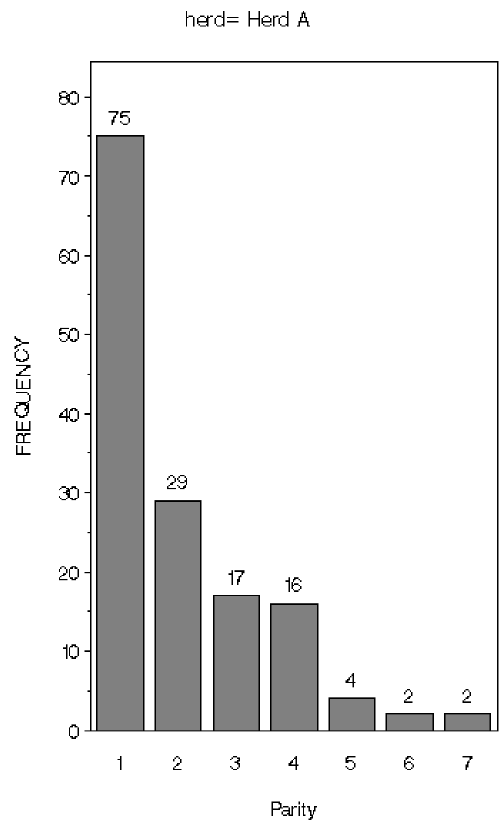


Figure 3.2: Frequency distribution of parity on Herd B

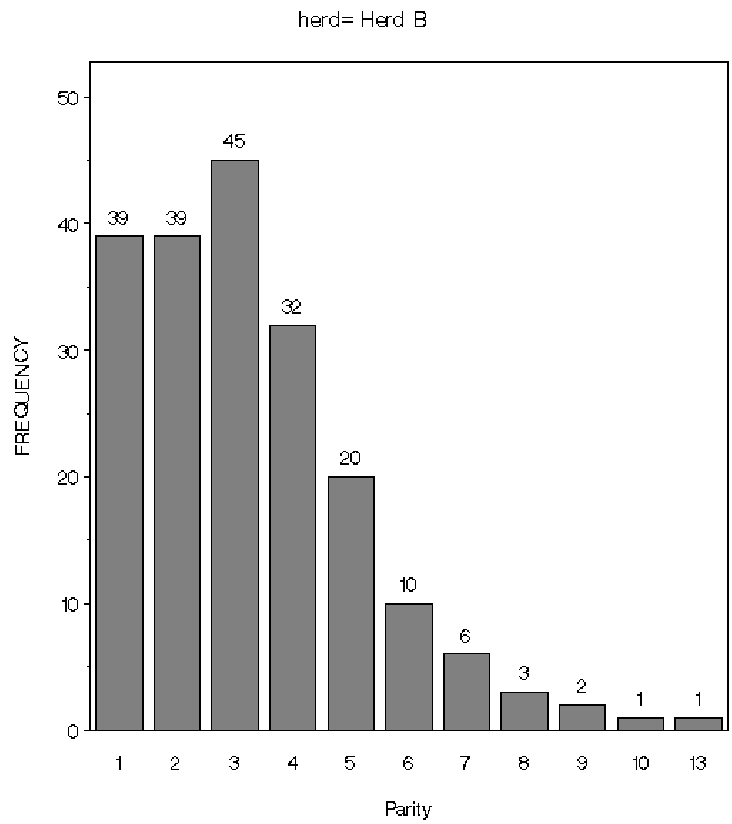
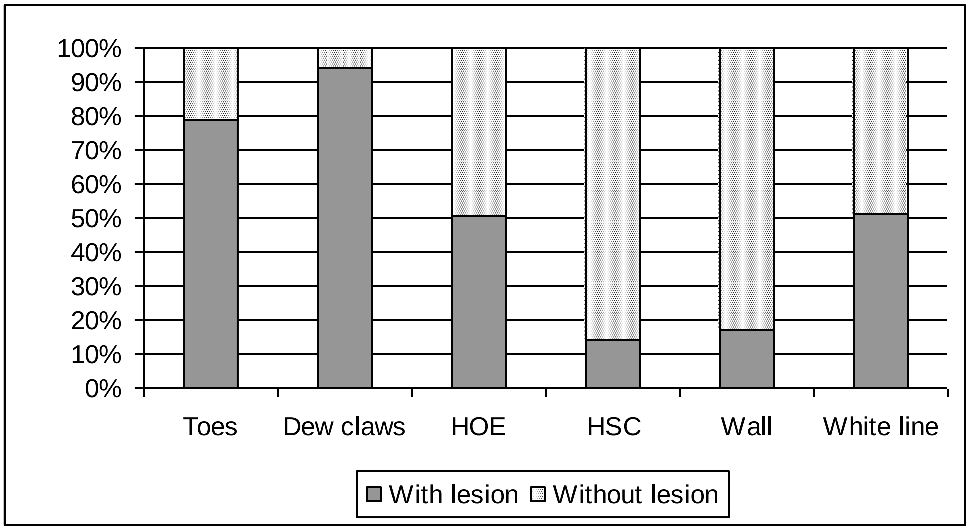
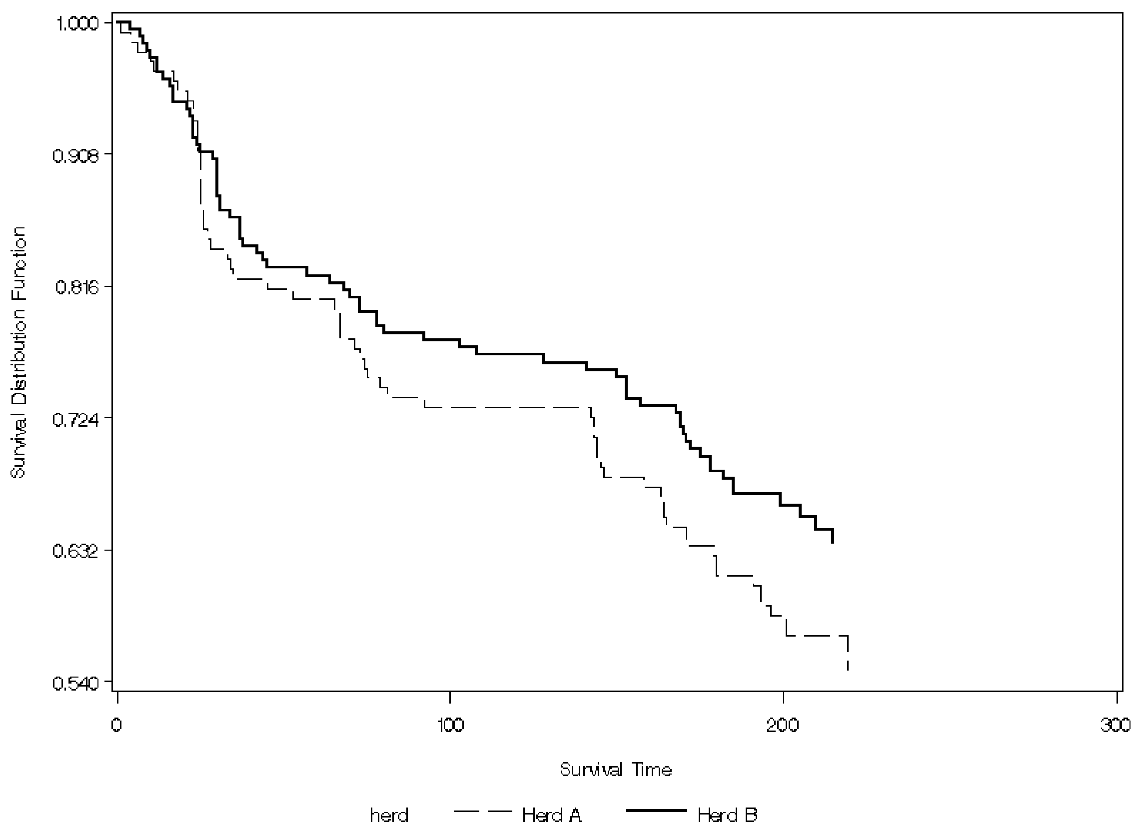


Figure 3.3: Proportions of 343 sows with and without lesions on different claw areas



The proportions of sows with lesions were greater than the proportions without lesions for all claw areas, except the white line ($P < .05$; one-sample proportion test).

Figure 3.4: Kaplan-Meier graph of the time to removal for herd A (blue line) and Herd B (red line) after farrowing. Day 0 is the day of farrowing.



Chapter IV

Discussion and Conclusions

Lameness in sows is well known as a common factor compromising animal well-being and profitability for the swine industry. Although risks factors of lameness are well documented, minimizing lameness in sows is difficult. Because treatment of lame sows is often unsuccessful, there should be more effort towards prevention and management.

We must understand more about improving the environmental conditions including flooring conditions in swine breeding herds. The second chapter of this thesis explored the effect of rubber mats in farrowing crates on the expression of lameness and subsequent sow performance. Although no significant results were obtained for reproductive performance, there was an improvement in the behavior of animals manifested as more events of sitting and drinking water when sows had rubber mats in the posterior half of the farrowing crates when compared to sows without mats. These behaviors may be fundamental for maintaining the needs for activity of a sow throughout the lactation period. One of the strengths of this study is the availability of data and possibility of measuring back fat, body weight before and at weaning, daily feed intake (feed disappearance), birth and weaning litter weights; which are variables not commonly measured and recorded in commercial breeding farms. However, some limitations may be mentioned; such as: the sample size of this study was originally calculated for an estimated effect of the treatment of 0.5; which was not the case for most of the results obtained for the performance variables; meaning that the sample size was underestimated for this study. The distribution of locomotion scores observed among lame animals may be accounted as a limitation for this study; where 63 out of 70 lame sows where scored with a locomotion score 1, 6 out of 70 where scored with a locomotion score 2 and only one sow had a locomotion score 3. The higher proportion of sows with locomotion score 1 may explain the inconsistent difference of productivity traits among the groups. No data regarding locomotion scores and productivity among breeding sows was found in the literature. Further research may be focused on estimating the effect of different locomotion scores on productivity and behavior or sows and also monitoring animals housed on different flooring systems throughout multiple lactations; which may lead to more strong evidence to support the hypothesis that softer surfaces will improve the welfare and performance of sows. Indeed, towards the direction of prevention of the aggravation of locomotion scores and incidence and healing of claw lesions and other lesions.

Lameness and its adverse effects on productivity and longevity of sows have been reported in the literature and discussed throughout the literature review of this thesis. However, the adverse effects of claw lesions on sow behavior and performance remain poorly understood. In chapter 3 we conducted an observational study to understand the nature of claw lesions and their relationship with sow performance and longevity. Under the conditions of this study, white line lesions and overgrown toes were positively associated with the likelihood of having $\leq$10 piglets born alive; suggesting that productivity of sows can be negatively influenced by the development of severe claw lesions in sows. Moreover, the likelihood of removal from the herd within a period of 220 days after farrowing increased by approximately 16% and decreased by 18% for every additional unit in severity of elongated dew claws and white line lesions. The higher likelihood of removal due to higher scores of elongated dew claws may be explained by the visibility of the dew claws while sows are standing when compare to the white line lesions; which remain less visible. The results of this study suggest potential adverse effects of claw lesions on the productivity of sows. More extensive studies are needed in order to determine the effect of painful claw lesions on the reproductive performance of sows. One of the limitations that can be mentioned for this study is that no physical restraint was available for claw lesion scoring. The time programmed to score the sows during the visits to the farm was stipulated by the observer; which was around one hour. During this time some sows were lying down and a randomization of the selection of animals was not possible leading to a convenience sample. Therefore, the sows that were lying down at the moment of scoring were the sows evaluated for this study. The limitation of not having physical restraint also made the process of scoring each animal longer due to the fact that animals that noticed that the observer was close to the crate were more likely to get up and the observer had to come back several times in order to obtain a completed claw lesion score for each evaluated. Further research could also attempt to identify the advantages and disadvantages of different floor types during the different stages of sows' productive life in order to prevent the incidence of claw lesions. Moreover, evaluate different strategies to reduce the high prevalence of claw lesions in female breeding sows; combining different nutritional programs and flooring characteristics may be a more ideal strategy in order to prevent claw lesions and therefore the high prevalence of lameness in sows.

Although claw lesions appear to be a crucial cause of lameness (Penny et al. 1963), not all claw lesions are associated with clinical lameness. Although the association of claw lesions and lameness is well documented; the effects of the claw lesions on the pressure distribution when the animal is moving remains unknown. A recent study reported a system for measuring the force and pressure distributions in movement analysis of pigs (Carvalho *et al.* 2009). This technology may be useful to describe the development of claw lesions of animals housed on different flooring systems over their productive life and its effect on claw integrity and pressure distribution. Other possible studies using this new technology could be focus on developing and validating a more objective method for locomotion scores for the research community.

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