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Genetic study on Health and Robustness in Norwegian Landrace;

A study based on phenotypic records made in a commercial pig farm in the US

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ACKNOWLEDGMENTS

In the beginning of my animal science studies, I discovered that I really had an extra curiosity in breeding and genetics, in addition to all of the biology behind it. I have always had an interest in agriculture, food production and animals, and to combine all this to my education has been both an ideal opportunity, and an incredible educational journey.

I wanted to be a part of a project that was working with breeding and genetics, to help enrich the animals' welfare and increase production profits.

I want to thank Topigs Norsvin and the positivity of the Project Leader, Eli Grindflek, for assigning me to this project, and trusting me with the amount of work, as well for sending me all the way to the United States alone. A huge thanks goes to Bjørn Olav Vennatrø, with his knowledge, outgoing enthusiasm and passion for pigs and the farmers, and for always welcoming me to join his working days. I also want to thank Lars Terje Bogevik and his family for greeting me in the US and making sure I got everything right before exploring the next months on my own, and for also making sure I got home safely.

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Ås, August 2015

Åse Marte Langrud

SUMMARY

For swine production to be as efficient as possible and to value animal welfare, it is important to have robust and healthy pigs. A breeding sow that can thrive and nurture healthy piglets in different environments is a robust sow. There are very different ways to produce pork meat around the world, and to provide a healthy and hearty pig is essential to Topigs Norsvin to succeed in the world market. It is important to find traits that have an influence on production and are vital for economics, breeding and animal welfare, and to acquire an overview of the animals' strengths and weaknesses. Records were used to estimate correlation and genetic parameters to find out whether the new traits in this project might be suitable to use in the breeding selection or not.

Over a four-month-period, 1,243 Norsvin Landrace breeding sows were recorded in this project in the US. The phenotypes used in this study are partly from my own data collection during my stay and partly from the InGris registration done at the same farm. The recording was divided in two phases; in the first phase, 34 traits were recorded, and after an evaluation, 23 traits were recorded in the second phase. In this MSc. Thesis, 19 traits were analyzed with a focus on leg and hoof traits.

A medium heritability was estimated for the traits of dewclaw and toe length, at 0.26 and 0.49 respectively. Other leg traits, including assessment and swellings (bursitis tenosynovitis) was estimated to a low to medium (0.17 and 0.22) heritability. Traits indicating pain, as well as sow performance traits, gestation length and number of born piglets, was low h^2 (0.16 and 0.12).

The traits may be genetically related to each other, so correlations were estimated. The genetic correlation between toe length and dewclaw length was highly positive (0.95). The leg assessments were negatively correlated to hoof length (-0.09 and -0.44), while the front and hind assessment were highly correlated with each other (0.74), and also correlated to bursitis/tenosynovitis. The arching of the back was correlated to hoof length and dew claw length (0.35 and 0.61), whereas the gestation length and number of piglets born were negatively correlated (-0.49).

Of the 19 traits investigated, the front and hind leg assessment had a low heritability, and majority of the pigs were too soft in the joints at full growth, and negatively correlated to hoof soundness. Looking at the results from the breeding values in this study, we can conclude that it is possible to include hoof length traits in the breeding goal.

NORSK SAMMENDRAG

For at svineproduksjonen skal være så effektiv som mulig, og ivareta god dyrevelferd, er det viktig å ha en sterk og robust gris. En gris som trives, vokser og produserer mange, store og friske grisunger uavhengig av miljøet som den er i. Det er svært ulike driftsmåter rundt i verden, og det er viktig for Topigs Norsvin å kunne tilby en sunn og robust gris til verdensmarkedet. I prosjektet "Health and robustness" i Norsvin, er hensikten å finne egenskaper som har betydning på produksjon, påvirker økonomi, avl og dyrevelferd. Fokuset i denne mastergradsoppgaven er flere ulike egenskaper, med hovedvekt på bein og klauver. Dataen ble brukt for å estimere arvegrad på nye egenskaper som muligens kan anvendes i seleksjon av ungpurker.

De fenotypiske registeringene ble samlet inn fra en kommersiell svineprodusent i USA. I en fire måneders periode, ble 1.234, Norsvin Landsvin, avlspurker observert. De fenotypiske registreringene i denne studien, ble delvis samlet på gården av meg og resten av dataen ble hentet ut fra Ingris registrering av de ansatte. Registeringene ble utført i to ulike faser. Første fase var det 34 egenskaper, og etter en gjennomgang ble det kuttet ned til 23 egenskaper i andre fase. I denne mastergradsoppgaven, ble 19 egenskaper valgt ut og analysert med hovedfokus på bein og klauv.

Arvegraden estimert på tålengde, bakklauv lengde var på medium nivå (0,26 og 0,49). Beineksteriør vurdering og hevelser (bursitt/tenosynovitt) var estimert lav til medium nivå (0,17 og 0,22). Egenskaper som hentyder til smerte og ubehag, og purkas produksjonsegenskaper som drektighetslengde og antall fødte grisunger var lav til middel arvelig (0,12 – 016).

Egenskapene er genetisk tilknyttet til hverandre, og det ble estimert korrelasjoner mellom egenskapene. I den genetisk korrelasjonen ble tålengde og bakklauv svært positiv (0,95). Bein eksteriør ble negativ korrelert til tålengde (-0,09 og -0,44). Frem og bak vurdering av eksteriør er sterkt korrelert med hverandre (0,74), og også positivt korrelert til hevelser. Krum rygg var korrelert med tålengde (0,35 og 0,61). Antall fødte smågris og drektighets lengde er negativt korrelert (-0,49).

Frem og bak eksteriørvurdering av bein har lav arvegrad, og flertallet av purkene var for myke i leddene, som er negativ korrelert med klauv helse. Ved å se på resultatene om arvegrader i dette studiet, er det mulig å bruke egenskapene om klauver, som tålengde, i avlsmålet.

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1. INTRODUCTION

The consumers of animal products are starting to become more aware of where their food comes from, and how it is made, both ethically and for food safety reasons. With robust pigs, the amount of medication and other illness treatments will decrease, thereby leading to less or no danger of medical residue in the finished product and less risk of antibiotic resistance. There is a great focus for all concerned on durability and robustness in pigs. Efficiency and economic beneficiation are both affected by the pigs' durability, and many litters, including a high litter size, a high milking ability (more piglet survival), fertility, and a willingness to eat, drink and "survive," are some of the key points. By increasing the robustness of the pig, the profitability rises, as a result of a reduction in gilt recruiting costs. The cost for raising a fully-grown sow, which dies or has to be euthanized without making any or little profit, is undesirable. Both increased profits to the pig producer and a competitive international edge will be gained by developing a functionally robust pig. Producing swine products at a lower cost and an increased profit is an environmental gain. Increasing the health of the pigs decreases the amount of antibiotics (The Pig Site, 2014), as a high use of antibiotics poses a risk for developing antibiotic-resistant bacteria, which can affect human health through later aspects. Robustness and disease tolerance are important topics that researchers are investigating, so knowing the heritability of new traits affecting robustness can be included to improve the breeding goal. The main hypothesis in this study is that bad feet and legs will lead to a low efficiency. Animals with poor feet and leg conditions will eat and drink less (Diaza et al., 2015; Fitzgerald et al., 2012; Heinionen et al., 2013; Kongsted, 2006; Le et al., 2015; Leonard et al., 1997), which affects their milk and overall condition, which again affects the growth and survival of the piglets. Undiscovered unsoundness will result in more removals, though some removals are possible to avoid if discovered and treated early, with many small types of unsoundness together leading to a low durability (Gjein, 1997). The goals in this thesis are to help increase the robustness of the breeding sow, and by accomplishing this, new traits were recorded. These traits were then used to estimate heritability, in addition to which trait could possibly be used in a breeding goal. A breeding goal that includes traits affecting the health, and not only production traits, makes it possible to select for robust pigs, thus increasing the durability in commercial pig farms. Animals that are robust, healthy and have a high vitality make them long-lasting, well-functioning production animals.

2. BACKGROUND

The collection of data from the United States of America, and not Norway, was decided on because we wanted to optimize the traits in the environment that the animals were raised in, e.g. different housing, feeding, management, etc. There is also currently much more Norsvin Landrace produced in the US than in Norway. For the project, it was easier to collect a lot of information in a short amount of time from one large farm.

2.1. Norwegian Landrace (Norsvin Landrace)

The Norwegian Landrace, internationally called Norsvin Landrace, is a breed that has been developed from the "old" Norwegian pig and from the other Scandinavian countries (https://snl.no/norsk_landsvin). Landrace is a breed with a long body, hanging front ears, a white body and occasionally a small black spot. The breed is an effective and productive pig that keeps improving through the breeding program led by Norsvin.

The Norsvin Landrace is a dam line in the hybrid breeding system, and is therefore primarily selected for their maternal traits (20%), such as high fertility, milking ability, udder, reproduction (2%) and litter size (28 %), but it also has other production traits: feeding efficiency and growth (12%), slaughter and meat quality (8%) and health (30%). The Landrace is a lean pig, and the semen from Norsvin Landrace is exported across the world for its beneficial feed efficiency and growth. In order to make faster progress, some animal breeding strategies choose to use only a few traits in their breeding programs. Norsvin in Norway has been focusing on many traits in their breeding goals, and has been adding more and more traits over the years. In that way, the genetic progress per trait may go more slowly than a more intense selection, although in the long run the result creates a more robust, healthy and beneficial pig. Approximately 2,000 purebred sows in Norway are the foundation for the breeding progress in the Norwegian Landrace.

2.2. Breeding System in Norway and Internationally – Topigs Norsvin

The Norwegian company Norsvin owns the Norsvin Landrace and its breeding program and development, but the genetics and international sales go through Topigs Norsvin. At the boar test station in Hamar, Norway, they perform an advanced CT scanning of 3,000 boars a year, and have full control over the feed efficiency, growth and testing of the boars selected for breeding. Over 280 boars are based at a semen station in Hamar, including approximately 50 elite boars each year for each breed. At Norsvin, 425,000 doses of boar semen are produced every year. Nucleus farms are pig producers/farmers who breed and sell purebred pigs and have a very extended protocol compared to a normal pig farm; some of these engage in the individual weighing of piglets at three weeks of age and the on-farm testing of gilts at 100 kg, as well as selecting young boars to go for testing in Hamar.

Topigs Norsvin is a relatively new company. In 2014, Norsvin International AS and Topigs International merged, and became the second largest swine genetic company in the world. Topigs Norsvin is a company with phenotypic scoring, CT-scanning, a test station, major production data, genomic selection and a global breeding program and they have made solid progress in pig genetics.

Norwegian Pig Breeding

The breeding program in Norway is built as a pyramid, where the purebred nucleus is at the top, and keeps the best sows. They sell the next best ones to multipliers, where they breed hybrid dams for sale to piglet producers, who then use a third breed as a sire (Figure 1). The 2015 swine population in Norway has 34 Landrace nucleus herds, eight Duroc nucleus herds and only one Hampshire. The multipliers breed the dam hybrid to be used in piglet production, with an imported Yorkshire/Z-line from the Netherlands. Because of market rights, only Nortura costumers have access to use

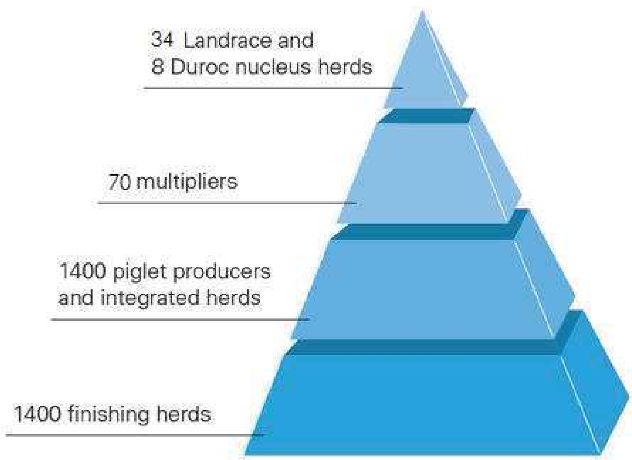

Figure 1: The breeding pyramid in the Norsvin breeding program

Duroc as a sire. The swine producers not in cooperations with Nortura use Hampshire semen imported from Sweden. Norsvin use approximately 30% of its annual turnover to research and development in breeding and feeding. The Norwegian breeding system is illustrated in the section 9.3 of the Appendix.

In the 1950s, technology such as ultrasound was already used on live pigs for selection benefits. During the breeding in the 50s, the focus was on growth, feeding efficiency and slaughter quality, in which feed efficiency comprised 50% of the breeding goal. In 1959, the boar testing station was established, while in the 1960s and 70s the focus on meat percentage and fat thickness started through gilt scoring, and it was here that the genetic gain was sped up. In the late 70s and early 80s, meat quality was in focus, as well as halothane gene testing at farms and boars at the boar station test. There was also a development in hybrid breeding, testing the third breed as a sire, and in Hampshire and Duroc. In the late 80s and early 90s, they started the selection on exterior and sperm quality. Offspring testing started in 1968, and in 1997 offspring were changed to using full-sibs test for tested boars. In 1994, the crossbred slaughter pig was presented with a better meat quality, named "Edel gris." At this time, they also started using Computed Tomography (CT). In 1999, the Norsvin Landrace was an official pure dam line breed, with a focus on maternal traits, e.g. litter size, shoulder score, teat numbers and reproduction. In 2008, Norsvin opened the new test station with a modern CT scanner, scanning 3,500 Landrace and Duroc boars every year. The breeding goals were getting more advanced, with added traits such as health/strength (exterior and osteochondrosis). Lastly, breeding goals alternated from quantity to quality during this time (Gj.-Enger, 2011, Norsvin historical retrospective poster).

2.3. TOPIGS NORSVIN in the US

The main markets for Topigs Norsvin are in North America, and the northern and eastern parts of Europe, but it is present in 54 countries. In the US, the swine production is approximately 5.8 million breeding sows, and 116 million slaughter pigs every year. By comparison, Norway had 49,000 breeding sows and 272,000 thousand slaughter pigs in 2014 (InGris, 2014). Norsvin USA LLC (NUSA) is a subsidiary of Topigs Norsvin, which is in charge of the North American market. There are currently about 400,000 sows with Norsvin genes in the US, with a goal of reaching one million sows in 2018. The Norwegian multiplier farm in the US was established in 2002 when Norsvin flew 600 pigs from Norway to Cheyenne, South Dakota. The goal was to have a robust production that could provide Norsvin sows to more pig farmers, and then to the consumers. The Norsvin Landrace slogan is *“Healthy, efficient, productive and lean.”*

Breeding Setup – Multiplier Farms in the US

As with everything else, it is risky to have all your eggs in one basket. That is why the risk assessment must concern the purebred pigs when building multipliers in the US. In Norway, we have a strict policy on how large pig farms can be, so naturally there will be more of a small nucleus spread around Norway. In North America, they do not have the same restrictions. This means that it is easier to have a big farm with a more efficient production, but that the challenge or risk is that if something happens to that farm, the result would be devastating as a nucleus herd. So in order to prevent being too vulnerable, they started new multiplier herds and another big combination multiplier herd. In 2013, there were Norsvin genes in 350,000-400,000 sows in the US, either purebred or hybrids. LZ a hybrid between Norsvin Landrace and the Z-line (TN70), which is used with dams in bigger productions in multiplying production, and are called Power Houses if they have more than 20,000 breeding sows.

Christensen Farms – One of the Biggest Family Farms
(http://www.christensenfarms.com/)

Cheyenne is the original nucleus farm Norsvin established in South Dakota in 2002. Cheyenne is owned by Norsvin USA, with Christensen Farms being a customer. In 1974, the two Christensen brothers started with pig production which became the fourth biggest pork production company in the US. With over 1,000 employees and 54 sow farms, they have five feed mills and over 400 nurseries and grow-finish sites (Figure 2). Their locations are in South Dakota, Colorado, Illinois, Nebraska, Iowa and Minnesota (where the headquarters are located). In addition to permanent employees, CF also offers student programs in Swine Production Internship in Animal Science or related fields.

O = Office and lunch room

B = Breeding

F = Farrowing

N = Nursery

Figure 2: Overview of the size of farm, where the records were collected; Photo: Google Maps

2.4. International Commercial Pig Farming, CF vs. Norwegian Farming

There are vast differences between Norwegian pork production and commercial production to CF. Norwegian pig farmers have to follow many political regulations when it comes to the number of animals at one farm, animal density at the farm, individual roaming space, feeding, medication and traditions (Lovdata, 2003). A Norwegian pig farm must not exceed 105 breeding sows, as decided by government regulations. These inequalities make it is important to have a robust pig that can function in various environments.

Housing

<u>Christensen Farms M1</u>

Christensen Farms (CF) M1 has crated the sows in individual pens at all times during the breeding and farrowing. In breeding, the sows are standing on a partially slatted concrete floor. The slats are about 5 cm wide, which can make it a challenge for the sow to place her feet while standing or moving back and forth (Figure 3). The sow does not have the opportunity to move around, but can lie down, sit or stand.

Figure 3: Concrete floors with wide openings; Photo: Å.M. Langrud

In the farrowing rooms, the sows are standing on fully slatted metal floors, while the piglets have a bigger space compared with the space dedicated to the sow. Rubber mats for piglet bedding are placed on one side with a heating lamp overhead. This is to protect and heat the piglets, as well to make them seek the warmth of a safe place safe rather than under a stepping mom.

Norway

The housing differs in Norway when it comes to flooring. Some have full straw bedding, and some have solid floors with sawdust. By law, a farmer must supply the pigs with some sort of bedding. The housing is strictly regulated by legislation, in which the sows are required to have space to move around, a solid floor to lie down on, and the concrete slats are not allowed to be wider than 2.5 cm to prevent unnatural movement or pigs not willing to walk in the "manure area" for fear of taking a misstep. It is also encouraged to have the sows in small groups to be social, but still have enough space to avoid bullying and fighting. At the farrowing pens in Norway, the sows are still required by law to have enough space to move around during the birth and nursing of her piglets. The piglets are protected with a "piglet corner" that often has a heated floor, solid walls and a roof with a heating lamp on top. The pen is normally appointed with bars along the walls, thereby preventing piglet deaths from the sow lying down on a piglet along the wall.

Feeding and Medication

Christensen Farms M1

Homemade feed is used from their own fields at local mills, which is mostly corn based and has the necessary vitamins, minerals, etc. added. In that way, the farms keep total control of what is made and what enters the barns. By doing this, they decrease the risk of diseases that may come from other places. In the farrowing, laxatives are added to the feed to help prevent constipation, hence inducing hybrid sows on expecting- and/or fallowing days. At this point, purebred Norsvin Landrace only receive oxytocin before and at farrowing. Other assistance medication or vitamins are given at the first sign of illness, and medications are given both individually and for entire groups according to the situation. When castrating and tail docking young piglets, no anesthesia is provided.

Norway

In Norway, the government has decided that all fabricated feeding should be priced the same all over Norway. It is regulated to be low-cost, so that the farmers will buy feed instead of making it for themselves, and there are strict rules for the composition of the feed. No antibiotics, laxatives or medicine are allowed within the feed, and can only be given as an addition if needed for a specific individual. It is illegal to treat animals with "group medication," and is only allowed when given for deworming. Tail docking is illegal in Norway, and castration is only to be performed by a licensed veterinarian with the use of anesthesia and analgesics.

Medicine Used at the Farm in the US

Table 2: Medicine overview

Drug	Medical description	Reason for use
Lutalyse **(luta)**	**Hormone**	Induces and opens cervical during farrowing
Acepromazine **(Ace)**	**Phenothiazine derivative antipsychotic drug**	Sleep, calming down
Tylan 200 **(Ty)**	**Antibiotics**	Illness, used with Banamine
Banamine **(Ban)*** **(**Flunixin**)**	**Non-steroidal anti-inflammatory drug**	Pain killers, used with Ty
Lincomycin, LincoMed and LincoBac **(Linco)**	**Antibiotics**	Swollen joints, infectious forms of arthritis, mycoplasma pneumonia
Oxytocin	**Hormone**	Start contracting during farrowing and/or help milk flow
Vitamin K**	**Vitamin**	Clotting mechanisms and hemorrhages, especially piglet navel bleeding
Cal-Phos*	**Mineral**	Farrow
Dexamethasone***	**Steroid**	For swollen joints, mastitis, flu or edema

* Flunixin should not be combined with other NSAIDs or corticosteroids, as this increases the risk of gastric ulcers, right dorsal colitis, and kidney disease.

** Not drugs, vitamin or minerals

*** Unspecific treatment with high doses, brain edema (Norsk legemiddelhåndbok)

Management

Christensen Farms M1

Here, there are between 15 to 20 employees during a working day, in which each of them has their own special location and responsibility in their field, whether that is in the nursery, breeding or farrowing. In the different sections, they still have people in charge of different areas and tasks, and they all have to follow industry-leading guidelines and work together as a team. They follow a special program that includes and highlights animal care and handling. CF also has annual training and internal on-farm assessments to continuously improve animal care and welfare.

Norway

In Norway, the farms are much smaller than the farm used in this project, as a farmer often works and manages the whole system from breeding to slaughter alone. Both full- and part-time employees are used throughout the entire system, and often assist at all parts of the production process. Due to this, the farmer has the total overview of the production and animals, which can be a more committed job, 24/7, because most swine producers live at their farm. The Norwegian farmer needs to be good on every point in the swine production system, but may not have the opportunity to specialize and focus in different areas as the ones working in one field only. The Norwegian farmer often has multiple work areas at the farm, both out in the field and maybe with a part-time job in addition to the farm, which might cause some to be not so committed.

2.5. Literature Review

Animal welfare and challenges in having long-lasting sows, and producing and taking care of high number of piglets, is a subject that has been more relevant over the last few years, as the swine industry is becoming bigger and more efficient (Wachenfelt, 2009). The chosen traits in this master thesis were used in terms of a discussion of scientists, experiences, reviews from farmers, as well as international challenges, literature and employees at both Norsvin and CF. In Norway, leg and exterior is the third highest removal reason, only 1.2% first reason, which was return to estrus (InGris, 2014).

Conformation

Elderly sows had bigger litters; therefore, keeping older healthy sows at a parity of 3 – 6 can be beneficial for the ones that can endure the life in the environment we put them in, and not culled just because of old age. In Norway in 2014, 8.2% were culled due to old age, which was ranked in 6th place (Engblom, 2006; InGris, 2014). For the first parity, the sows have 12.2 live-born, and are at their highest at a parity of 4 with 14.1 live-born (Ingris, 2014). Abell et al.

(2010) found that replacing sows to keep up genetic improvement as the only purpose was not profitable. The recommendation was culling when the average value of the genetic loss is acceptable at the price of growth or purchase of a new gilt. In PigChamp™2007, 20-25% of the culled sows was caused by locomotion problems. To make the conformation recording less subjective and to save on labor work, a high technology methodology has been attempted, but has proven to be expensive. A combination of measurements may be the most effective, e.g. with traits such as locomotion, lameness, stepping, weight pressure on claws, claw lesion, heel overgrowth, wall cracks, white line cracks, etc. (Nalon, 2013). Video system detection has also been tried to record leg or claw problems causing lameness, which was successfully utilized. Video solutions are a potential tool for other factors as well, such as various factors at farrowing or gilt assessment, locomotion, weight and structure used in animal scoring (Kongsro, 2013).

Conformation, exterior traits and osteochondrosis (OCT) have an estimated heritability from low to medium. (Aasmundstad, 2014). In this PhD thesis, the conformation traits were discussed and heritability was estimated, mainly focusing on OCT. A selection to decrease cases of OCT would be effective because of the heritability (0.31) and being low to moderate when correlated with other exterior traits. OCT and early growth are highly genetically correlated, which might come from young pigs putting too much weight on an immature structure.

If a sow develop or injures her feet, it can affect her performance, and therefore also her production value. Fitzgerald (2012) has shown that an injury or negative development in the hoof wall and over grown toes has an effect on the sow's lactation and behavior. Other researchers have also confirmed that the sow's eating and standing time decreases if she has overgrown toes (Kongsted, 2006; Leonard et al., 1997). The sows that had claw and leg disorders weaned fewer piglets per litter, and that piglet mortality during lactation was associated with crack and toe size (Fitzgerald, 2012).

Faster growing pigs kept in conditions with little or no movement is a restraint on the pigs' claws, legs and joints. Flooring made to keep clean and sufficient for production may not be in the best interest for the pig. Animals on inadequate flooring can cause animals to develop hoof defects (Carvalho et al., 2009), whereas a more natural straw bedding has been shown to have a positive effect on the prevalence of injuries to sows (Olssen et al., 2004). In previous studies, the heritability on feet and leg has shown to range between low to moderate (0.01-0.40) (Fan, 2009). One study, however, does not support that conclusion, in which they found no relationship between negative production performance and culling risk with a claw lesion (Enokida, 2010).

Studies have shown that feeding and nutrients are important in the development and structure of foot quality. Factors to avoid lameness, influence bone and articular cartilage and horn quality have been confirmed, though not fully understood (Riet et al., 2013). Biotin deficiency can be a nutritional disease caused by a lack of biotin in the feed, which further causes lesion of the hoof wall and sole (Kornegay, 1985). Feeding with non-supplement maize flour that has less biotin than wheat flour resulted in foot lesions and other associated illnesses. With wheat flour-based feed, the excretion of biotin is 10 times higher than that of a maize flour diet (Kopinski et al., 1989).

The locomotion and comfort of the sow's feet do impact on her economic value, but it may be possible to alternate and breed for more successful and valuable sows. A genetic association study done in a Swedish Yorkshire nucleus showed that heritability on leg conformations was low to moderate (0.02 to 0.20), and had significant correlations of leg confirmations to toe quality and litter size, in addition to a shorter heat interval after weaning (-0.35 and -0.31) (Lea et al., 2015).

Claw and Injuries

A pig's claw is made out of the hoof wall, dermis and inner structure, although the hoof wall of a pig is not as strong as that of cattle hoof (Fjeldaas, year unknown). The white line is the velcro connecting the hoof wall to the pedal bone (Figure 4). Underneath, the front part is a sole and a heel at the back. The pig has much of the weight on the heel, which can be compared to the cushion of a dog's paw (Figure 5). Poor claw and leg soundness can cause a serious compromise in animal welfare and a sows' performance, and therefore a financial impact on production. Both leg weakness and claw injuries are leg problems that have generated a significant amount of studies (Diaza et al., 2015; Fitzgerald, 2012; Lea et al., 2015). There are a multitude of reasons on why leg and claw weakness is a known challenge in almost all large commercial pig farms, with the main reason being floor quality (Wachenfelt, 2009). The flooring effect and movement together have a strong influence on a sow's feet.

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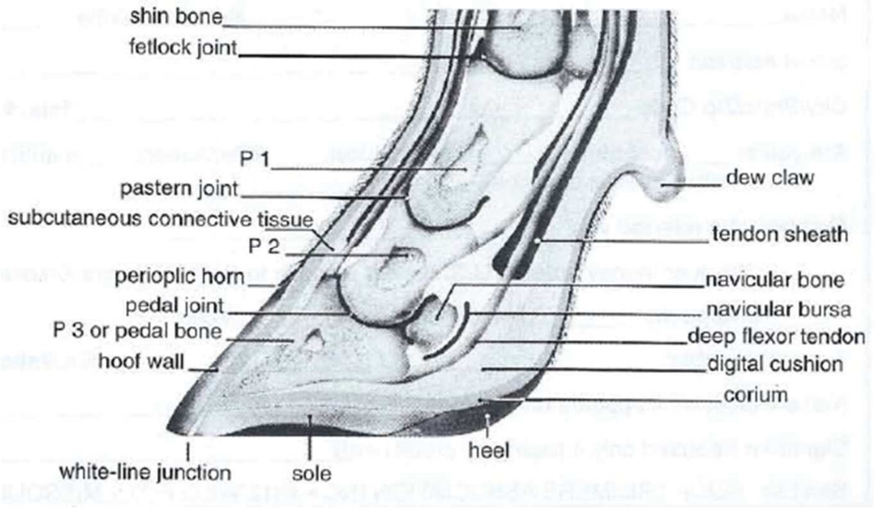

Figure 4: Anatomy of the claw hoof; www.hooftrimmingtools.com

Preventative measures for claw lesions such as claw trimming and foot bath antibiotics will have some effect, but often the problem is not discovered before it is severe, so then the prognosis of the treatment is not so rewarding. The claw size and hoof growth can be used as criteria for selection to improve the sow's longevity. Earlier studies show the heritability of the hoof size to differ from 0.01 to 0.61 depending on breed and statistical methods. (Plyum, 2013).

Claw infections can develop from claw lesions and become a cyst in the transition between claw and skin. Crates with bad hygiene and little or no bedding increase the risk of claw infection (Gjein, 1997).

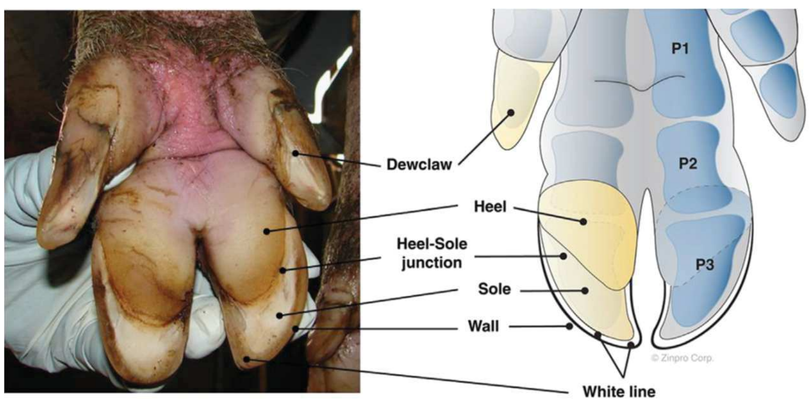

Figure 5: Underneath the claw, white line, sole and heel (Nalon et al., 2013 and ZinPro Corp.)

The behavior and visual signs of discomfort with overgrown claws have been discussed in numerous studies (Heinionen et al., 2013; Plyum et al., 2013; Wachenfelt, 2009). Due to uncomfortable feet, the sow spends less time standing, slipping and shifting her weight more when she stands, which requires more attempts at standing up. By constantly shifting her weight, she is stepping around or stomping on the same spot, and not standing still. Overgrown dewclaws are associated with other hoof problems, and unbalanced movements affect the mortality of the piglets, as well as the sow's well-being (Diaza et al., 2015).

Bursitis, Swelling and Tenosynovitis

A constant pressure and trauma to the skin overlying any bony prominence can develop into bursitis. The bone's outer layer (periosteum) reacts, making the skin thicker, and swells to a soft bump. The legs of a pig have little muscles or fat, and are mainly bone and tendons (Figure 6). A pig in growth puts more weight on the leg bones, and on a hard surface or slatted floors with large gaps can be postponed. Sows housed in a way that makes them passive and encourages little movement are at a higher risk for bursitis. It is normal for the bursitis to develop over the lateral side of the hocks and elbows and around the hocks. Inflammation caused by secondary infection can also be mistaken as bursitis, but is not something that should occur under normal circumstances (The Pig Site*).

Tenosynovitis is an inflammation in the tendon that can be painful and influence lameness. There are various types, with acute and chronic both being due to trauma. Infected tenosynovitis is combined with wounds and requires antibiotics. Most of the infections in

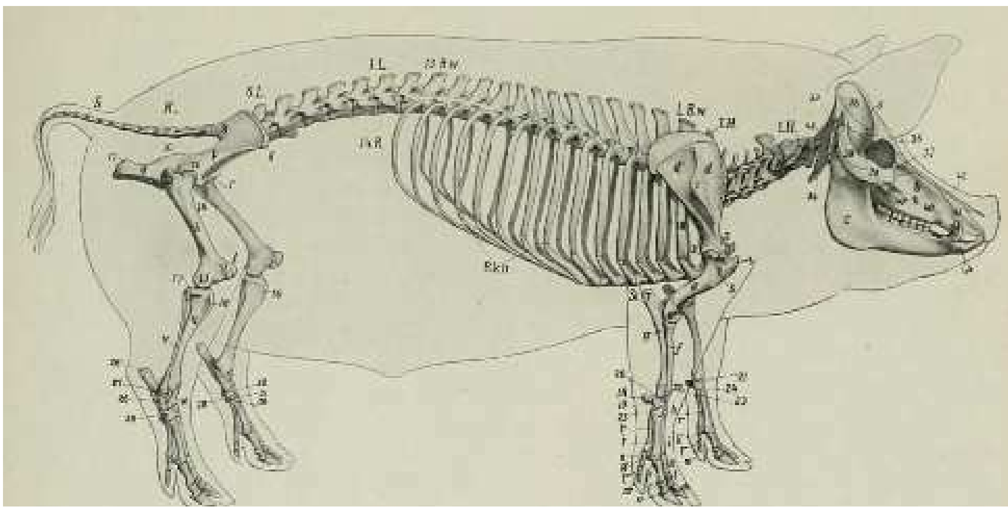

Figure 6: The skeleton of the pig. The anatomy of the domestic animals, by Septimus Sisson. Page 161

joints in slaughter animals are due to bacterial infections from the skin, which are spread to joints through the blood. This can be wounds from mouth, tail or other open lesions the animal have been inflicted. It is therefore important to avoid and treat every damage and trauma the pig encounters (Gjein, 1997). Infection in connection with Mycoplasma hyosynoviae in joints and tendons will cause swelling on the hocks and over the front knees, and without laboratory tests or an autopsy, it is indistinguishable from osteochondrosis (Tokach, 2011).

Lameness was not registered in this project, but is very relevant to feet and claw problems, and stepping is the trait recorded that is associated with lameness. Straw et al. (1999) define lameness as: "The inability to use one or more limbs in a normal fashion while generally displaying a normal degree of alertness and coordination in the other unaffected limbs." Lameness is a term that covers many different illness and injuries from the joints, legs and claw that is often categorized as one disease. The result of serious lameness is mortality and culling, which is connected with fertility because of general discomfort and sickness behavior (Heinionen et al., 2013). Genes associated with exterior traits have been identified in pigs, and can also be used in biological analyses ([1]Fan et al., [2]Fan et al.) and possibly genomic selection.

Dehydration and Temperature

Dehydration and a high temperature (fever) are normally a sign of illness. These factors are often the result of other origins, such as diseases, diarrhea, a lack of water access or other inflammation and ailments.

Severe dehydration lowers the heartbeat or can even raise the heartbeat; it causes lower blood pressure, which will result in weakness, tiredness or apathy, low respiration, cold body parts and less flexible skin (Figure 7). Dehydration and fever are serious problems that can be lethal. The most accurate way to define dehydration is through a blood sample, but in normal practice early discovery is vital. Signs to check are skin flexibility, sunken eyeballs, dry gums, weakness, the color of the urine or no urine. During the gestation period, the sow drinks normally and more towards the end. The variation of water consumption can be used a warning of, e.g. lameness or sickness. Increased water consumption can also come from the pigs trying to satisfy their hunger (Kruse et al., 2010), with another serious condition in dehydration being "salt poisoning" (Amdal et al., year unknown)

For one liter of milk production, the sow needs to drink four liters of water. Therefore, if the sow is dehydrated, she will have problems producing milk for her piglets. Dehydration during farrowing is also a bad sign for the sow. If she is tired because of dehydration, the farrowing will go slow or even stop, which may result in the death of piglets before they are born (stillborn).

The normal temperature for pigs range between 38.3 – 39.5^{o} C, but during farrowing the temperature will rise, and a fever rising to 41^{o} C can be lethal. A chronic fever for more than three weeks is connected with chronic disease, and should be inspected and dealt with. Before treating for fever, one should always find the reason for the symptom. Fixing the symptom does not fix the cause, as fever will again lead to dehydration, especially if combined with diarrhea (Sjaastad et al., 2010).

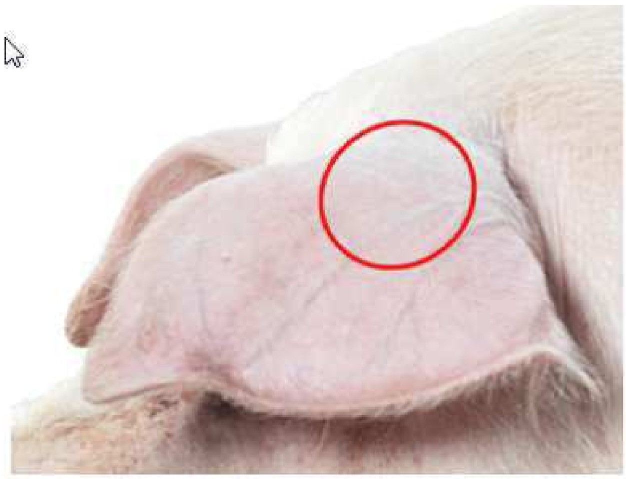

Figure 7: The soft thin skin of the back side of the ear, imakes t is possible to do the dehydration evaluation by testing the flexibility of the skin.   Photo: T.Aasmundstad, Norsvin.

Sows' Performance Traits

In this study, some performance traits are recorded because of their link to robustness, and also used as effects in the statistical model. These production traits are gestation length, breed of litter, weaning weight and age and number of weaned. To help enrich production, the production traits are the primary goal in animal breeding, but it has been shown that the exterior in connection to health is also associated with production (Diaza et al., 2015; Heinionen et al., 2013). Gestation length is anticipated to be approximately 115 days, but it is possible for the sow to farrow between days 111 and 120. The average gestation length is 115 days, but it is normal to farrow between 113 to 117 days (Gjein, 1997). The gestation length may also be affected by the litter size. In this thesis the number of total born is the number of live-born plus stillborn, and mummies are not included. Mummies are piglet fetuses that die after day 35 of gestation and do not become completely absorbed, instead drying inside the womb. The number of weaned piglets is the amount of piglets that a specific sow has managed to maintain and feed during her time with the piglets. Weaning weight is the weight of the piglets in the entire litter, which is corrected by the number of piglets weaned. The weaning age is the age that the piglets are weaned from their mom. In Norway, it is not allowed to wean before four weeks (28 days), with the average being 32.3 days (InGris, 2014). At CF, the piglets are systematically weaned at three week of age, but the weaning age recorded differs due to the sow's weaning. A well-functioning sow may be used as a nurse mom. Weaker sows with either too little milk, a bad condition, illness or other reasons are a "Kick Out," and therefore have a shorter weaning age than the scheduled three weeks. Removal refers to the sows that have been sent to slaughter, died or been euthanized, and are not going to get another litter. The reason can be sickness, age or traits that are not wanted in production.

3. MATERIAL AND METHOD

The results are phenotypical registrations of Norsvin Landrace from one commercial farm in South Dakota, as well as the InGris input data from the staff at the North American commercial farm, also located in South Dakota. All the data in this thesis was collected from the same farm over a short period of four months. The environmental differences between the sows were minimal when collected at the same place. All the sows were purebred Norsvin Landrace, regardless of whether her litter was purebred or hybrid, and the traits were focused on the sow, and not the piglets.

3.1. THE FARM - Commercial “Family” Farm in South Dakota

M1 is one of 50 sow farms that belong to Christensen Farms, which is a Topigs Norsvin customer. There were 4,000 breeding sows in the barn at registration time, with about half of them being purebred Norsvin Landrace (Norwegian Landrace). The farm was under the process of making the entire production at this specific farm a purebred Norsvin Landrace, which means they keep many purebred Norsvin Landrace sows during re-breeding selection. The farm buildings were comprised of three connected breeding barns, and one barn with 12 farrowing rooms 60 pens in each room, thus totaling 720 farrowing pens. The sows are individually crated at all times, with the water supply being surface water in the breeding rooms and drinking nipples in the farrowing rooms. There were some challenges with the gilts coming in the farrowing, which had a difficult time finding or using the drinking nipples, probably because of the location of the nipple compared to the water surface. It was located high up, and they were looking for water down at their front feet. The piglets were kept in eight different nursery rooms after weaning, with approximately 300 piglets in each nursery room and piglets from three farrowing rooms in one nursery room. The normal routine was weaning three farrowing rooms a week, with piglets weaned at the age of three weeks. The procedure was often to use oxytocin during farrowing, and lutalyse on or past the due date.

3.2. Relevant Background Information on Selected Traits

There were 1,234 purebred Norsvin Landrace sows registered in farrowing and weaning in the period from September 17, 2014 to January 2, 2015. In addition to the registration of the 1,234 sows, an investigation about the reasons for removal was also performed. The main goal of this investigation was to obtain a better understanding of why the animals were removed and acquire more of a focus on uncovering the numbers of "unknown" deaths in the barn.

The registration was then merged with data from InGris (http://www.animalia.no/in-gris/). In the records, 21 animals with a phenotypic registration could not be found in InGris. This is probably due to a wrong punching of ID numbers, typos on the sow cards or some other registration errors.

In the first phase of this project, I recorded 36 different traits to explore whether they had any variation, and whether they could be used in an estimation of heritability and maybe used later in breeding value estimation (section 9.5 of the Appendix). After six weeks of registrations, traits were checked by Drs. Aasmundstad and Thingnes on whether they had any variations or not. Additionally, some of the traits were skipped since they were so complicated or difficult to record, with the reason being to focus more on the traits with variations and validation. The traits that did not make it to the second round were: appetite, dehydration at weaning, blood circulation, respiration panting, respiration coughing, indication of pain in relation to a willingness to rise, indicators of pain vocalization, number of piglets at the sow, feces consistency, blood in feces, blood in urine, the color of urine, observation during suckling period, aggressiveness towards management, presenting udder for piglets and delayed milking.

Due to a lack of variation of the traits mentioned above, different leg and hoof traits then became the main focus of analyses in this assignment, while leg weakness and lameness is the third runner-up to the main culling reasons in Norway (InGris, 2014).

3.3. Phenotypes Registered During the US Stay

The time used for the recording of one animal differed between three-eight minutes. Nevertheless, at the beginning of the study when more traits were recorded, it was estimated to take twice as long or more due to multiple rounds and techniques to do the assessments.

Note: The registration was done in a two-step recording process half-way during the stay, with a visit from Dr. Aasmundstad and Dr. Thingnes, who went through and discussed the provisional results at that time. The registration protocol was therefore reformed, due to difficult registration and/or a low variation on some traits. The traits that were skipped are listed in Appendix 2.

Phenotypes Recorded in Phase 2

Most of the traits with variations and a sufficient amount of recordings were taken into phase 2, and included in this MSc thesis. The traits included are all described in this chapter.

1. Farrowing Time (Day, Night or overlapping)*
   This indicates at what time the farrowing took place. The staff was at work only during the "Day," which was between 6 am and 3pm. After working hours, the farrowing was registered as "Night." The cases that were farrowing starting before or continued after working hours were registered as Day/Night or Night/Day. The last two groups have now been combined in one group.

2. Farrowing - Medical Lutalyse and/or oxytocin or natural; also registered if the sow got sleeved*
   The medically induced farrowing or normal farrowing was divided into two groups: normal farrowing and induced farrowing. Both were included if the sow was sleeved or retained.

3. Dehydration during farrowing
   The following is used to test dehydration during farrowing: Ear pinch test and timing the seconds to measure hydration; pulling the skin of the backside of the ear back and clocking the seconds it took to snap back. If dehydrated, it would be slow to snap

back or the skin staying up. In an individual assessment according to the amount of skin of the sow, some of them had some extra skinfolds.

4. Temperature

The rectal temperature of the sows at weaning is an indicator on health and illness.

5. Hoofs, only back legs

From scoring the toes, the scale was made from Zinpro (Appendix 1) as a starting point, but alternating it after the situation at the farm. The toes were scored using a scale from 0 to 3, where 0 = normal and 3 = Severe. Score 3 was more severe at the test-farm in fallowing traits: toes, heel overgrowth and heel sole crack.

- Toes: The length of the front toes (Figure 8)
- Dew claws, the length or broken: The length or broken dewclaws

Figure 8: Severe toe length (scored 3);

Photo Å.M.Langrud

- Heel overgrowth: The roughness, overgrowth, erosion and/or severe damage on the heel cushion (Figures 9, 10, 11 and 12)

Figure 9: Severe heel overgrowth and erosion – picture from underneath (scored 3)

Photo: Å.M. Langrud

Figure 10: Severe heel overgrowth and erosion – cross-section on deceased sow (scored 3). Notice the deep bleeding erosion.

Photo Å.M. Langrud

Figure 11: Normal heel – picture from underneath at sow parity 3 (scored 0)

Photo: S.I. Ånestad

Figure 12: Normal heel – cross-section on deceased sow (scored 0)

Photo Å.M. Langrud

- Heel and sole crack; The line between the heel cushion and the sole beneath the hoof

- White line: The line between fixing the hoof wall and sole.

- Horizontal crack in the hoof wall
- Vertical crack in the hoof wall: Vertical and horizontal crack in the hoof wall was merged into one trait, called the "hoof wall crack"

6. Indicators of pain (scored 1-4, with 1 being none)

The pain and discomfort trait were scored using a scale from 1 to 4, where 1 = normal, and 4 = severe.

- Arching of back: The size of the curve in the sow's back, thus indicating discomfort. This can all be from foot problems, digestion, airways or general ailments.
- Stepping: Not standing comfortably on hind legs, keep stepping, continuing shifting the weight when standing, also often leaning on the interior.

7. Visual inspections of legs

The visual inspection of bursitis, swelling and tenosynovitis was scored using a scale from 1 to 4, where 1 = normal and 4 = severe.

- Front legs
- Hind leg Left
- Hind leg Right

Hind legs merged into one group after registration (Figure 13)

Figure 13: Bursitis and tenosynovitis seen on hind legs from behind (scored 4)

Photo Å.M. Langrud

8. Front leg exterior judgment

   (Figures 14 and 15)

9. Hind leg exterior judgment (scored 1-7, where 1 is soft, 4 normal and 7 stiff)

   The same scale used in gilt field scoring, with the scale from 1 to 7, where 4 is normal, 1 = soft and 7 = stiff, as well as an assessment of the angle (flexibility) of the joints in the sows. An error may be from the sow not being able to move or stand correctly in the small crate during judgment (Figures 16 and 17).

Figure 14: Front legs "lion feet" (scored 1)

Photo: Å.M. Langrud

Figure 15: Front legs (scored 6)

Photo Å.M. Langrud

Figure 16: Hind legs, soft (scored 1)

Photo Å.M. Langrud

Figure 17: Hind legs, stiff (scored 7)
Photo: Å.M. Langrud

10. Udder*

- Number of teats in function: Teats that are fully swelled and obviously in use for the piglets.
- Number of non-functional behind navel: Where on the udder the piglets are favoring: empty, flat or never used teats. May be error – flat teats, but with a couple of drops counted as non-functional?
- Number of chewed teats: Obviously chewed or damaged teats that may result in little milk or sow not willing to expose its udder (Figure 18)

Figure 18: Chewed teats - some more severe than others, but all chewed were recorded. This is at a medium stage.

Photo: Å.M. Langrud

11. Injury (scored 1-2)*: Injuries inflected by the crates or other harm.

12. Eligible for re-breeding/Removal (scored 1-2): Registered after the manager marked which sow was to be culled or euthanized. Not very confident source when the manager did not always get around before weaning day.

13. Comment*: Anything special, positive or negative about the sows that would be useful or good to record to confirm the other registration on that specific individual.

*Traits with variation and recorded up until the end, not analyzed in this thesis.

Registration InGris database made by farm employees:

1. Live-born: Number of piglets born alive and survived
2. Week of farrowing: The location on the sows, where she is located and who is managing/taking care of her and her group; also has the same condition as the sows close to her, such as ventilation, lighting, etc.
3. Stillborn: Number of piglets born dead or so weak they died immediately after birth
4. Parity/Litter number: The number of the litter on the sow, indicating her age and the use of her. Effective?
5. Removal date: If she was slaughtered or sold out of the farm
6. Removal code: The reason for her removal – decoded to removed or not in removal
7. Sire ID (male parent)
8. Dam ID (male parent)
9. Litter ID
10. Weaning age. Number of days the piglets were when weaned (or number of days the sow has been with the piglets. A Kick Out or nurse mom will have different days than the scheduled 21 days.
11. Weaning weight: The total weight of her litter
12. Number of weaned piglets: The number of piglets at the sow when weaned – error when pulldown?
13. Gestation length: The number of days from insemination to farrowing

Some of the sows expecting a hybrid litter could receive lutalyse to artificially help start the farrowing. The practice of the medical help differed between the personal staff working and their routine; some gave before the due date and others were more reluctantly on medical assistance until after their due day.

3.4. Animal Structure

All the animals with phenotypes were purebred Landrace sows, born and raised at the M1 farm. The sows originated from 45 sires and 597 dams. The pedigree utilized in the analysis included all animals with phenotypes and their ancestors > seven generations back.

3.5. Statistical Models

The programs used in this assignment are InGris, Microsoft Office EXCEL and Word, SAS 9.4 (Statistical Analysis System) and DMU (Analyzing multivariate mixed models). All traits were treated as normal distributed, regardless of their distribution.

The traits of: Toe length overall (TLO), Toe length (TL), Dew claw length (DCL), Heel overgrowth and erosion (HO), Hoof crack hind claw (HC), Hind assessment (HA), Front assessment (FA), Bursitis and swelling front leg (BF), Bursitis and swelling hind leg (BH), Stepping (ST), Arching of back (AB), Temperature (TE), Dehydration (DH), Number of weaned piglets (NW), Removed or not (RE) (RE is a Binary variable) were all analyzed in Model 1. Gestation length and weaning age was treated as covariate

Model 1 - Main model:

$$Y_{ijklmopqr} = AnimalID_i + Farrowing\ week_j + Litter\ number_k + Litter\ breed_l + Dam\_litterno_m + Judge\ 2_n + Weaning\ age_o + Weaning\ age^2{}_p + Gestation\ length_q + Gestation\ length^2{}_r + \varepsilon_{ijklmnopqr}$$

Y is the individual phenotypic observation value of the traits.

Fixed effects:

$AnimalID_i$ individ

Farrowing week$_j$ is the environment of the sow at her place in the barn. The sows that were farrowing at the same place would be stalled at same location being exposed for the same management, feeding, ventilation, water supply, light condition, etc. (j = 34,...51).

Litter number$_k$ indicated the age of the sow, or whether she was a new gilt or an experienced sow. The effect was that the gilts also had problems with the drinking nipples when moved to the farrowing barn (k = 1,…9).

Litter breed$_l$ is the breed of the litter that the sow is pregnant with, and if it is a purebred Norsvin Landrace litter or a hybrid of Yorkshire, PIC or TN70 (l = 1,...4).

Dam_litterno$_m$ is which litter the sow is born in (m = 1,…7).

Judge 2$_n$ is the scoring of the different judges. One is from the Å.M.L assessments and the other from the CF staff (n = 1,2).

Random effects:

Weaning age$_o$ is the age of the weaning of the piglets from the sow. The routine is to wean at three weeks. But if the sow is ill, she will be weaned before three weeks, or she can be used as a nurse mom to feed other piglets younger piglets, making her go overtime; therefore, this is the number of days the sow spent with the piglets, and not the age of the piglets (o= 0,…33).

Weaning age^2 $_p$

Gestation length$_q$ is the number of days the sows have been pregnant with piglets from insemination to farrowing (q=111,…120).

Gestation length^2 $_r$

$\mathcal{E}_{ijklmnopqr}$ is the random residual belonging to observation.

Model 2 - *Total born (TB) and Weaning age (WA):*

Y is the trait Total born and Weaning age.

$$Y_{ijklmnop} = AnimalID_i + Farrowing\ week_j + Litter\ number_k + Litter\ breed_l + Dam\_litterno_m + Judge\ 2_n + Gestation\ length_o + Gestation\ lenght^2{}_p + \mathcal{E}_{ijklmnop}$$

Model 3 - *Weaning weight (WW):*

Y is weaning weight

$$Y_{ijklmnopqrst} = AnimalID_i + Farrowing\ week_j + Litter\ number_k + Litter\ breed_l + Dam\_litterno_m + Judge\ 2_n + Number\ weaned_o + Number\ weaned^2{}_p + weaning\ age_q + Weaning\ age^2{}_r + Gestation\ length_s + Gestation\ length^2{}_t + \varepsilon_{ijklmnopqrst}$$

$Number\ weaned_o$ is the number of piglets weaned from the sow at approximately three weeks (o = 0,…15).

Model 4 - *Gestation length (GE):*

$$Y_{ijklmno} = AnimalID_i + Farrowing\ week_j + Litter\ number_k + Litter\ breed_l + Dam\_litterno_m + Judge\ 2_n + \varepsilon_{ijklmno}$$

Y is gestation length

Correlations

Both genetic and phenotypic correlations were estimated in DMU using bivariate analyses, with the same fixed effect for each trait as with the univariate analyses. There was a multi-dimensional correlation attempted, but was not completely effective with the limited amount of data in this project.

4. RESULTS

4.1. Description of observed values for the traits analyzed

A total of 19 traits were analyzed in this thesis, with the main focus being on the leg and hoof exterior and some performance traits.

Table 4: Number of observations per trait; minimum and maximum values of the mean number and standard deviation of the 19 traits studied

Trait	N	Min	Max	Mean	SD
HLO	1,227	0	3	0.94	0.74
TL	1,227	0	3	0.93	0.82
DCL	1,227	0	3	0.96	0.86
HO	1,225	0	3	2.56	0.61
HC	1,227	0	2	0.33	0.40
FA	1,225	1	7	2.17	0.79
HA	1,224	1	7	3.47	1.07
BF	1,224	1	4	2.20	0.84
BH	1,222	1	4	2.58	0.80
ST	1,223	1	4	1.47	0.81
AB	1,222	1	4	1.63	0.77
TE	1,226	36	41	38.85	1.36
DH	781	0.5	10	2.45	1.10
GE	1,234	111	120	116.86	1.57
TB	1,243	2	24	14.29	3.45
NW	1,243	0	15	10.40	2.52
WW	1,186	33	120	67.05	11.44
WA	1,243	0	33	20.05	3.89
RE	1,205	1	2	1.13	0.33

HLO = Hoof length overall, TL= Toe length, DCL = Dew claw length, HO = Heel overgrowth, HC = Hoof crack, FA = Front assessment, HA= Hind assessment, BF = Bursitis/tenosynovitis front legs, BH = Bursitis/tenosynovitis hind legs, ST = Stepping, AB = Arching of back, TE = Temperature, DH = Dehydration, GE = Gestation length, TB = Total born, NW = Number weaned, NWE = Number weaned weight, WA = Weaning age, RE = Removal

The Norsvin Landrace sows were recorded as farrowing from weeks 34 to 51 (N =1,234). Even if the phenotypical recording was only conducted during a very short period, there is a variation in which weeks the sows farrowed. The reason to record this was to have the information as a fixed effect as a possible environmental influence on the sow at their placement in the barn. The routine was to have the sows on the breeding schedule stalled at the same place. The weaning age (N = 1,243) differed from >14 to 28< because it is registered on the sow. The curve has a normal distribution with a 20 as a vertex (15.5%), but also a small hump at >14 (3.7%). Just over half the sows weaned between 19 and 22 days, while one-fourth (24.7%) of the sows weaned before 19 days, and 19.9% weaned after 22 days. The early sows were "kick outs" (KO) because of different physical errors, such as sickness or a lack of milk production. Others may go longer than three weeks because they are used as "pulled down"/"nurse mom" for piglets with a KO mother. The normal practice is to wean the piglets from their mom at 21 days old, and it is clear that most are in the range of approximately 20 days.

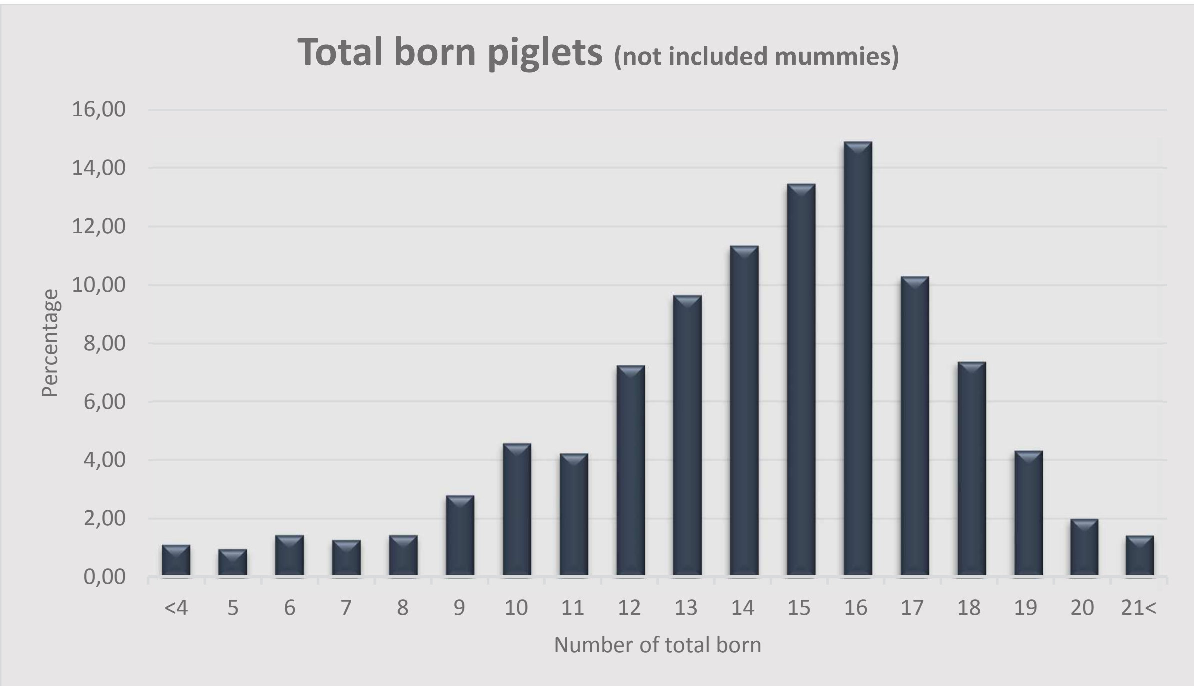

Figure 19: Total born; N = 1,243

The total born piglets are the numbers of fully developed piglets at farrowing. Another possibility is that these numbers are wrongly recorded, because of death directly after farrowing from environmental factors such as suffocation or being trapped between the sow and the crate.

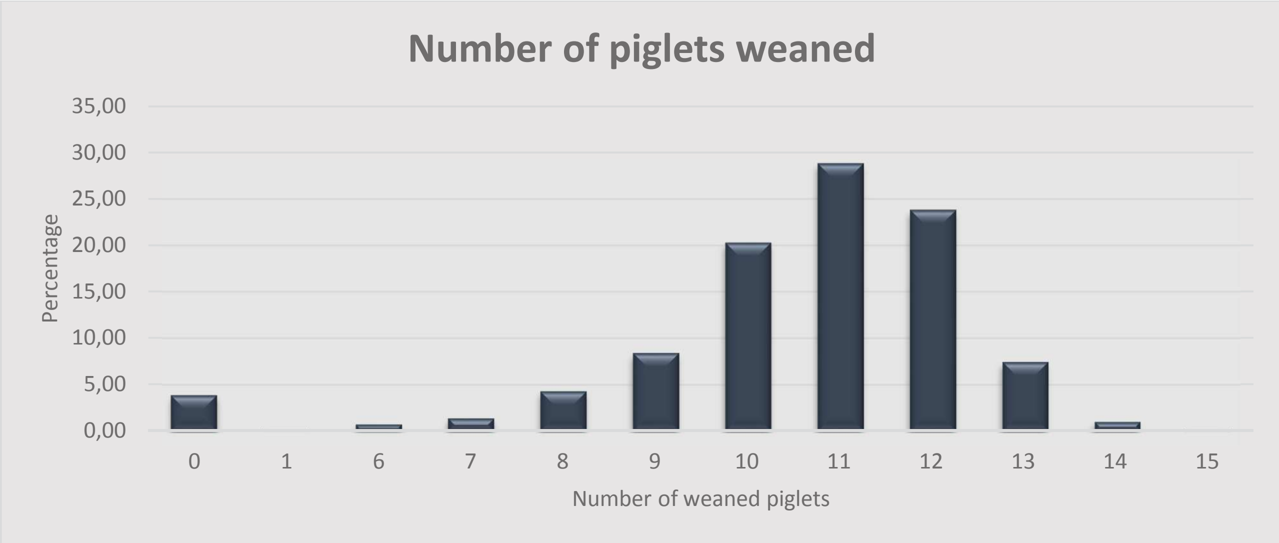

Figure 20: Number of weaned piglets: N = 1,243

The amount of piglets the sow weans differs quite a bit from what they farrow. This is due to both piglet death during the time spent with their mother and cross-fostering.

The weight at weaning (N = 1,186) is the weight of the total litter at three weeks of age. The majority (83.4%) of the litter weight was between 51-80 kg. Only 7% of the litters were 50 kg and lighter, and just 3.6% of the litters were heavier than 80 kg. The numbers of piglets per litter differed, thereby affecting their weight.

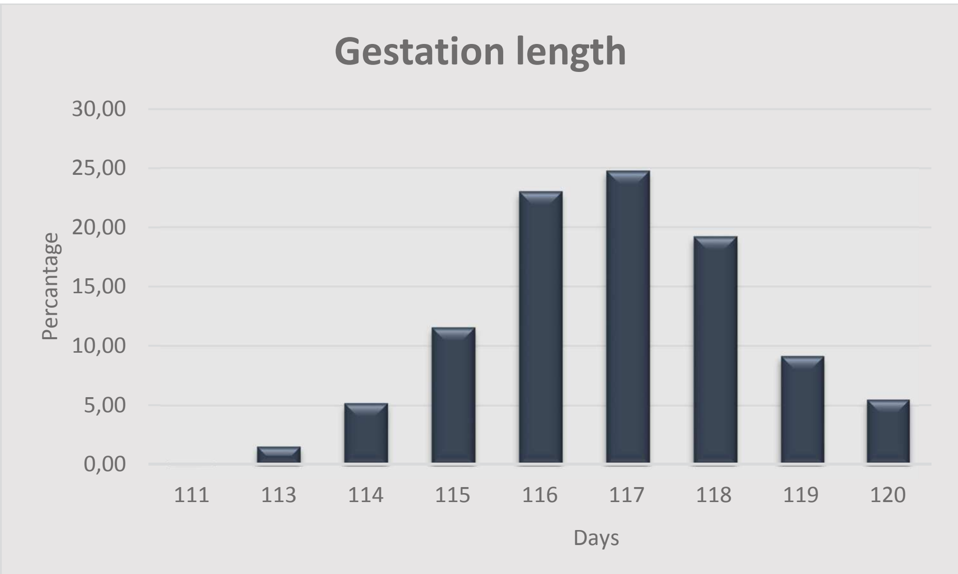

Figure 21: Gestation length; N= 1,234

Gestation length is close to a normal distribution, between 111 – 120 days. Only 0.08% at 111 days and 18.4% from days 111 to 116 farrowed. A total of 66.9% of the sows farrowed between 116 and 118 days, and 14.7% of the sows farrowed on days 119 and 120.

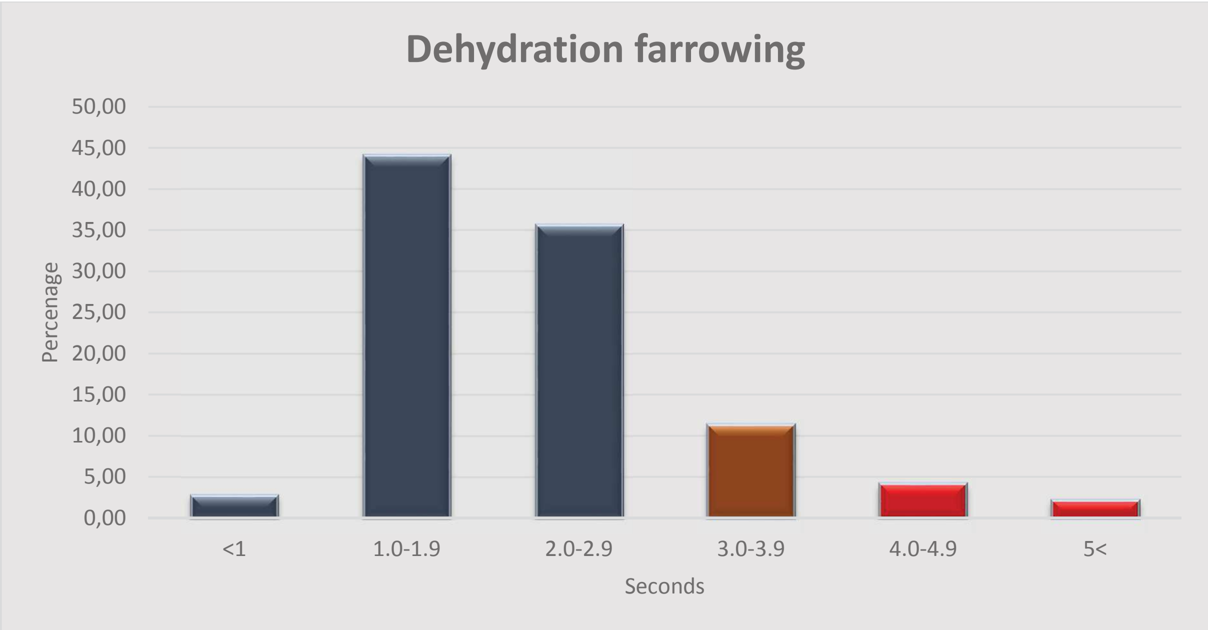

Figure 22: Dehydration during farrowing; N = 781

The dehydration test during farrowing showed that most of the sows were well hydrated at farrowing. The brown and red columns show the sows that were in the dehydrated zone. Unfortunately, not all the sows were tested for dehydration because at the start of the project the dehydration test was done on sows for weaning, but half-way through we saw that it was more interesting to see the hydration situation at farrowing.

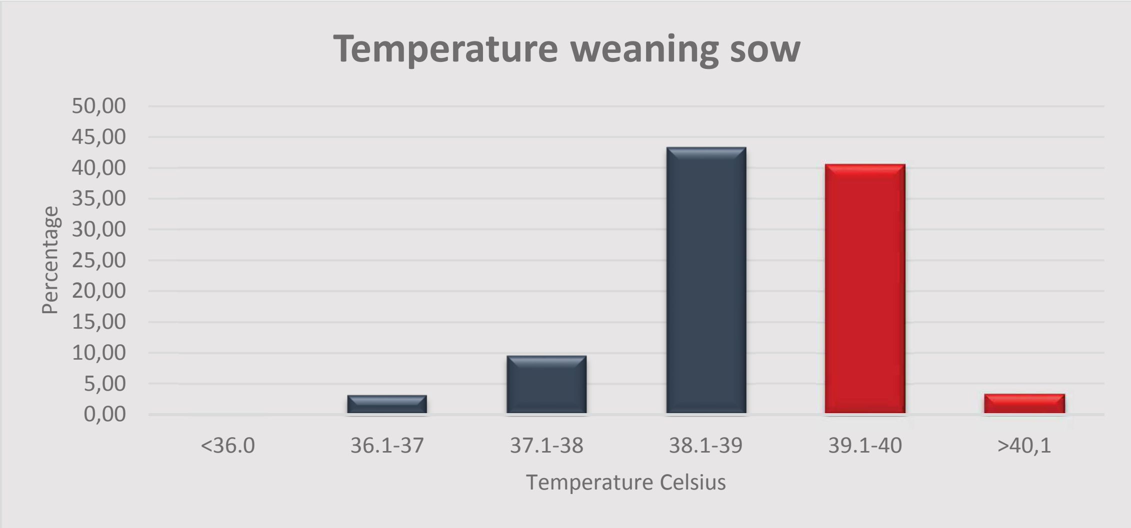

Figure 23: Temperature N = 1,226

When sows' temperature was taken at weaning to check their condition, more than 3% had a fever of over 40ºC. When sows are moved from "Farrowing rooms" to "Breeding" a new staff takes over, and judges the sows' condition only by how they look as they walk in. This shows that there might be something going on with many of the sows, and that they need extra attention when returning to breeding.

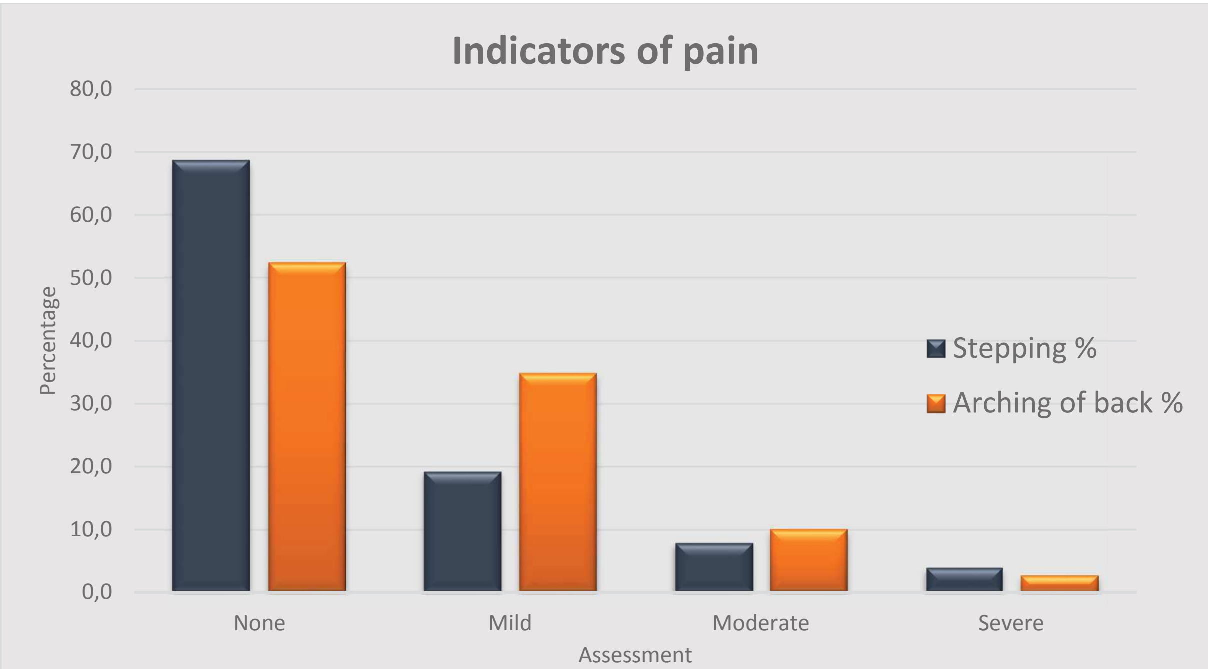

Figure 24: Indicators of pain: Stepping, N = 1,223; Arching of back, N = 1222

The majority of sows (68.7% ST, 53.4% AB) show no sign of pain in these traits. There are more signs of an arching of the back through the group, which among others can be caused by different reasons, such as leg problems, discomfort in digestion or reproductive organs.

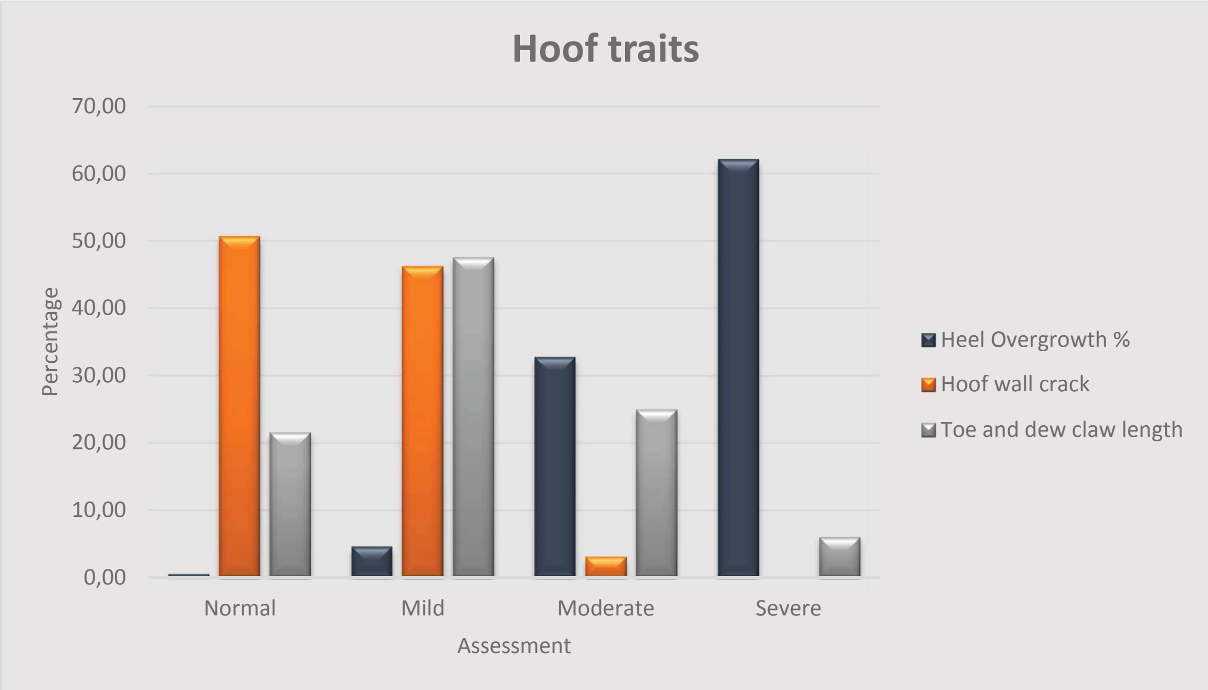

Figure 25: Heel overgrowth, N = 1,225

Hoof wall crack, N = 1,227

Toe overall length, N = 1,227

The records of hoof traits are on the hind legs only. The heel overgrowth is highly represented, with 62% of the registered sows having severe heel complications and 37.7% having moderate overgrowth and erosion. Half of the registered group does not have any hoof wall crack, and 46% have only mild signs. The length of toes and dew claws have a more normal distribution, in which 21.6% are a normal length, 47.5% are mildly overgrown, 25% have a moderate length and 6% are severe.

Figure 26: Front leg, N = 1,225

Hind leg, N = 1,224

The leg assessment evaluation is based on the principle of the gilt assessment at 100 kg. A score of 4 is normal, 1 is soft and 7 stiff. The front legs are very soft, where more than half of the sows scored 2, which means their pastern almost touched the ground, while 16.6% was scored a 1. The hind legs that scored 4 were 23.8 %, but most (44.6%) of them showed a softness at 3. Very few of the sows had stiff front legs, with more than the optimal 4.

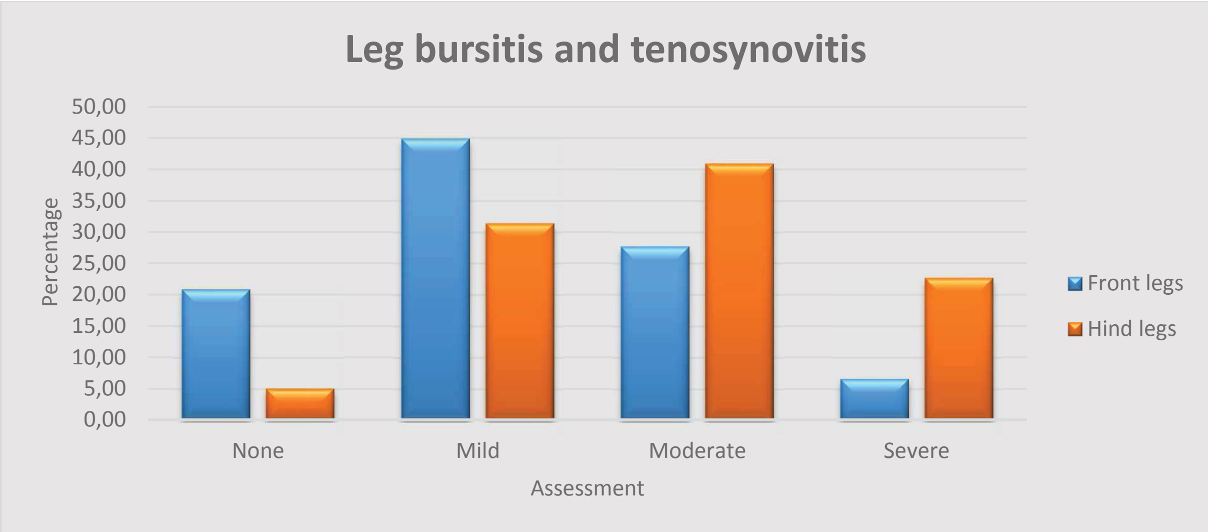

Figure 27: Bursitits, swelling and tenosynovitis

Front leg, N = 1,224

Hind legs, N = 1,222

Only 5% had no remarks on the hind leg. A total of 20.8% of the front legs had no remarks, but the majority had mild to moderate while 22.6 % of the hind legs had severe remarks.

Figure 28: Litter breeds

LY: N = 156. Norsvin Landrace: N = 525. LxP: N = 422 TN70: N = 140. Total born N = 1,243

The purebred sows were used to breed new Norsvin Landrace, but were also bred hybrid with three other breeds. These hybrid breeds (LY, LxP, TN70) were made with sires of Yorkshire, American Landrace and Z-line.

The removal was based on the manager's selection of sows at weaning. The recording was made from notes from management, and if they wanted a specific sow culled or re-bred, 82.3% went to re-breeding.

5.1. Estimation of Genetic Parameters

The estimation of heritabilities, as well as phenotypic and genetic correlation, was performed on all traits with BLUP, DMU and SAS 9.4. The genetic correlation on eight traits was not successful.Table 6 has the exterior traits, in addition to a couple of traits influenced by their health status and environment, temperature (TE) and dehydration (DH). In Table 7, traits affecting the production and mother ability were assembled. Only gestation length (GE) and total born (TB) were significant, and were therefore the only with genetic correlations. The heritability on the traits in this study ranged from 0 - 0.49 h^2. The heritability and genetic correlations of the 19 traits are presented in Tables 6 and 7.

Table 6: Estimated heritabilities are shown on the diagonal (blue boxes). Phenotypic correlations are shown above the diagonal and genetic correlations below the diagonal. Standard errors are in brackets. HLO = Hoof length overall, TL= Toe length, DCL = Dew claw length, HO = Heel overgrowth, HC = Hoof crack, FA = Front assessment, HA= Hind assessment, BF = Bursitis/tenosynovitis front legs, BH = Bursitis/tenosynovitis hind legs, ST = Stepping, AB = Arching of back, TE = Temperature, DH = Dehydration, NE = Not estimated

	HLO	TL	DCL	HO	HC	FA	HA	BF	BH	ST	AB	TE	DH
HLO	**.47** (.08)	.86	.84	.05*	.11*	-.01	-.22	.07	.04	.10	.05	-.00*	-.03*
TL	.97 (.02)	**.49** (.08)	.45	.01*	-.09*	-.07	-.29	.07	.03	.13	.02	-.04*	.09*
DCL	.95 (.03)	.84 (.08)	**.26** (.07)	.31*	.02*	.04	-.08	.05	.02	.03	.05	.07*	-.01*
HO	ne	ne	ne	**.01*** (.02)	.05*	-.01*	-.06*	.30*	-.15*	.06*	.09*	.07*	-.05*
HC	ne	ne	ne	ne	**.00*** (.02)	-.04*	.10*	.05*	-.01*	.06*	.24*	.07*	.06*
FA	-.09 (.21)	-.28 (.19)	.12 (.24)	ne	ne	**.17** (.06)	.24	-.13	-.03	-.03	.11	-.05*	-.02*
HA	-.44 (.15)	-.62 (.13)	-.14 (.22)	ne	ne	.74 (.12)	**.26** (.08)	.00	.01	.03	.00	-.13*	.06*
BF	.39 (.25)	.35 (.24)	.51 (.27)	ne	ne	.10 (.30)	.10 (.28)	**.09** (.04)	.24	.05	.08	.07*	-.01*
BH	.37 (.17)	.24 (.18)	.48 (.18)	ne	ne	-.06 (.25)	.28 (.22)	.16 (.27)	**.22** (.06)	.10	.06	.00*	.02*
ST	.24 (.21)	.21 (.21)	.24 (.25)	ne	ne	.08 (.28)	.07 (.25)	-.12 (.30)	-.09 (.26)	**.14** (.06)	.24	.24*	.04*
AB	.49 (.21)	.35 (.22)	.61 (.20)	ne	ne	.10 (.27)	-.25 (.25)	.58 (.26)	.0 (.26)	.89 (.18)	**.14** (.05)	.05*	.01*
TE	ne	ne	ne	ne	ne	ne	ne	ne	ne	ne	ne	**.08*** (.05)	.01*
DH	ne)	ne	ne	ne	ne	ne	ne	ne	ne	ne	ne	ne	**.00*** (.03)

Table 7: Estimated heritabilities are shown on the diagonal (blue boxes). Phenotypic correlations are shown above the diagonal and genetic correlations below the diagonal. Standard errors in brackets
GE = Gestation length, TB = Total born, NW = Number weaned, NWE = Number weaned weight, WA = Weaning age, RE = Removal. ne = Not estimated

	GE	TB	NW	WW	WA	RE
GE	**.16** (.08)	-.25	-.15*	-.19*	-.21*	.04*
TB	-.29 (.32)	**.12** (.05)	.65*	.46*	.18*	.08*
NW	ne	ne	**.06** *(.05)	.76*	.21*	.09*
WW	ne	ne	ne	**.06** *(,04)	.24*	-.15*
WA	ne	ne	ne	ne	**.06** *(.04)	-.02*
RE	ne	ne	ne	ne	ne	**.08** * (,05)

5.1.1. Heritability

From an estimation of the heritabilities of the 19 traits, the overall growth of the hoof length, both toe length and dew claw length, was the considerably highest heritability from the others (h^2: 0.26 – 0.49). The four traits in Table 6, Heel overgrowth (HO), Heel crack (HC), Temperature at weaning (TE) and Dehydration (DH) are all traits that were not significant and had a very low/no heritability (h^2: 0-0.08). The front leg assessment (FA) had an estimated lower heritability, 0.17, than the hind leg (HA) at 0.26. The same was true on bursitis/tenosynovitis, in which the heritability on the front legs was estimated to be low at 0.09 and the hind leg to 0.22. The heritability of Stepping (ST) and the Arching of the back (AB) were both estimated at 0.14.

In Table 7, the performance/production traits on the sow and her fertility have been estimated. Gestation length (GE) was estimated to 0.16 h^2 and Total born (TB) were also estimated to a low heritability at 0.12 h^2. The rest of the traits were low and not significant; the Number weaned (NW), Weaning weight (WW), Weaning age (WA) and Removal (RE) at heritability were 0.06-0.08 h^2.

5.1.2. Phenotypic Correlations

To estimation of phenotypical correlation was calculated by the formel; $\frac{(\mathrm{COV\ A12+\ COV\ E12})}{(\sqrt{\sigma \mathrm{A1}+\sigma E1*})\ (\sqrt{\sigma \mathrm{A2}+\sigma \mathrm{E2}})}$ given by Gjerlaud-Enger.

From Table 6, the hoof traits between Toe Length (TL) and Dew Claw Length (DCL) and Hoofs Overall Length (HLO) is highly correlated (0.86 – 0.84) because the HLO is made from the mean of TL and DCL. The correlation between TL and DCL are medium (0.45). Heel Overgrowth and Erosion (HO) are medium correlated with DCL (0.31) and Bursitis Front leg (0.30). Bursitis Hind leg (BH) and HO are low negatively correlated (-0.15), whereas the other correlations between the other traits and HO are very low positive (HC, ST, AB, TE) and negative (FA, HA, DH). Heel Crack (HC) is medium to low positively correlated (0.24) to the Arching of the Back (AB). The HC correlation to the other traits is very low positive (HA, BF, ST, TE, DH) and negative (FA, BH). The Front leg assessment (FA) is medium to low positively correlated (0.24) with HA and low with AB (0.11). The FA is low negatively correlated to BF (-0.13). The rest of the traits are low to almost not negatively correlated (BH, ST, TE, DH). The Hind Assessment (HA) is low negatively correlated with TE (-0.13), and low to nothing with the rest (BF, BH, ST, AB, DH). Bursitis front legs (BF) is medium to low positively correlated to BH (0.24) and low positive to not correlated with the rest (ST, AB, TE, DH). Bursitis in the hind legs (BH) is low positively correlated to St (0.10) and very low to not correlated to AB, TE and DH. Stepping (ST) is medium to low positively correlated (0.24) with AB and TE, and almost not correlated to DH (0.04). Arching of the back (AB) is low to not correlated with TE and DH (0.05 – 0.01), and Temperature (TE) is not correlated to DH (0.01).

In Table 7, Gestation Length (GE) is medium to low correlated to TB (-0.25) and WA (-0.21), low correlated to NW (-0.15), WW (-0.19) and not correlated to RE (0.04). As expected, Total Born (TB) is medium to high positively correlated to NW (0.65) and medium positively correlated to WW (0.46). TB is low positively correlated to WA (0.18) and RE (0.08). The Number of Weaned (NW) is highly positively correlated to WW (0.76), low positively correlated to WA (0.21) and RE (0.09). The Weaning Weight (WW) is medium low positively correlated to WA (0.24) and low negatively correlated to RE (-0.15). Lastly, Weaning Age (WA) is not correlated to Removal (-0.02).

5.1.1. Genetic Correlations

The variation between genetic correlations differs from 0.0 to 0.84. The highest correlations between two traits are TL and DCL. Surprisingly, there were no genetic correlations (0.0) between BH and AB. HLO and the two traits of TL and DCL were very highly correlated

($0.97_{0.02}$ and $0.95_{0.03}$) since HLO is a combination of TL and DCL. The correlation of TL and DCL also has a very high correlation of $0.84_{0.08}$. The leg assessment traits FA and HA are medium and highly correlated to the hoof length ($-0.09_{0.21}$ to $-0.62_{0.13}$, respectively). The correlation between FA and HA is highly positive ($0.74_{0.12}$). However, FA is minor negatively correlated to BH ($-0.06_{0.25}$). Bursitis/tenosynovitis in the front and hind legs (BF and BH) shows a low correlation to each other ($0.16_{0.27}$), and are both positively correlated to hoof length traits ($0.24_{0.18}$ – $0.51_{0.27}$); both BF and BH are positively correlated to FA and HA ($0.10_{0.30}$ – $0.28_{0.28}$). ST is positively correlated to hoof length traits ($0.21_{0.21}$ – $0.24_{0.24}$). ST is weakly positively correlated with front and hind leg assessment ($0.07_{0.25}$- $0.08_{0.28}$), and negatively correlated to BF and BH ($-0.12_{0.30}$ and - $0.09_{0.26}$, respectively). Arching of the back is medium positively correlated to hoof length traits (HLO, TL, DCL), ($0.35_{0.22}$ – $0.61_{0.20}$). Arching of the back has a low correlation to FA ($0.10_{0.27}$), and a medium correlation to HA ($-0.25_{0.25}$). There is a medium/high positive correlation between AB and BF ($0.58_{0.26}$), and no correlation between AB and BH ($0.0_{0.26}$). There is a high correlation between AB and ST ($0.89_{0.18}$).

Gestation length (GE) and Total born (TB) are medium negatively correlated ($-0.29_{0.32}$) in Table 7. This means that many piglets in the litter cause the sow to have a shorter gestation length.

6. DISCUSSION

6.1. Traits

Hoof Traits

Hoof problems are a serious matter shown in this study to be medium heritable. The length of the hoof has a heritability at 0.49, and only 21.55% of the sows have a normal hoof length. The heritability on hoofs is estimated in recent studies, in which toe heritability was estimated at 0.40 (Le et al., 2015), supporting this project's findings on a medium to high heritability. However, much lower heritabilities have also been reported in other studies (Fan et al., 2009; Luther et al., 2009; Jørgensen and Andersen, 2000; Jørgensen and Vestergaard, 1990). The sows do not move much in their crates, so there is little or no natural wear of their hoofs. The effect of having bad feet has shown that it can affect the production by causing the sow pain and discomfort, thus making her eat and drink less (Fitzgerald et al., 2012; Le et al., 2015). By not producing enough milk, it will make her less suitable for raising all of her piglets, or only to be able to provide a small-sized litter. It weakens the immune system, which effects ovulation/fertility. To avoid hoof problems, it is possible to perform hoof trimming, but that costs the farm in terms of both money and labor. In large swine production herds, this is not always done routinely at every farm. To prevent such an issue it is possible to breed for more normal hoof qualities, since it shows that the heritability is at a level that is possible to modify in a breeding plan. Due to the typical US housing facilities, the need to breed for hoof traits could be beneficial. It might be possible to select gilts that have good hoofs at the 100 kg gilt selection test. The challenge is that there is most likely very little variation at that early stage, and in this project the correlation between gilt test and this recording was not done. At the young gilt testing, all the upcoming sows have small, light and normal hoofs, but there might be a potential to have some relative information if the recording of the sows is done at gilt and then later in farrowing.

Heel overgrowth and erosion, and hoof cracks, did not show any heritability. So making breeding plans to alter them would not be possible. Unfortunately, 62% of the sows had severe heel erosions, which makes it uncomfortable to stand for a longer period of time (Fitzgerald et al., 2012). Since no heritability was shown (0.01), one can say that it was mainly caused by the environment, but it may also be because of too little variation in this study or limited amount of observations. Some of the older sows that had good claws might manage the environment better, or had better physical advantages in terms of the way they stand, the technique used when they lie down, the amount of time on their feet or just the heritable benefit.

The overgrown heels are very hard, and often become weakened with erosion going deep up the heel. By dissecting the heel of a deceased sow, it is possible to see how far down the erosion goes in, hence confirming the suspicion that severe heel overgrowth and erosion is a painful condition (Figure 9, page 28).
For the trait "hoof wall cracks", 50.6% had normal hoofs and 46.2% had mild or hint, and therefore not a problem in this farm. No sows had severe-, and only 3.1% had moderate remarks. This trait did not show any heritability (0.00) in this study. Leg Traits

Only 5.5% of the sows had normal front legs, and only 0.5% had front legs that were stiffer than desired. The majority of the sows had a front leg score of 2, which means that they are too soft. This is often considered as a problem since as a sow grows and stays longer in production, her joints become too weak for her increasing weight. In this study, the front leg was estimated to have a rather low heritability of 0.17. The front leg was estimated to be 0.19 by Le et al. (2015) , in line with the current study. The hind leg score was estimated to have a higher heritability (h^2=0.26), and this was also close to the estimates obtained by Le et al. (2015) on the rear and side views on hind legs (h^2=0.20). The heritability was as expected due to previous studies on this breed, in which the heritable estimation of leg exterior assessments was low to medium (0.05 – 0.36) (Aasmundstad, 2014). However, the correlation between front and hind legs was found to be 0.26. The front and hind leg assessment is medium genetically negatively correlated to hoof traits, as the angle of the hoof may be affecting how the hoof is worn. The softer the joints, the longer the toe will grow because of less wear. A sow in discomfort, e.g. heel overgrowth, may adjust her weight to relieve the pressure, thereby making the toe angle grow without wear and making the angles of the legs look soft.

Bursitits and tenosynovitis are an obvious problem, especially on the hind legs.

Bursitis and tenosynovitis have some of the same estimation when it comes to heritability, in which the front legs have a very low heritability (0.09), while the hind legs are medium to low (0.22). The genetic correlations between Bursitis front legs (BF) and Bursitis hind legs (BH), and hoof traits, are medium positive ($0.24_{0.21}$-$0.51_{0.27}$). Consequently, it is possible that the more sore the hoofs and heels are, the more time the sows will spend lying down. As a result, pressure and friction on the legs over time, to avoid any painful pressure on the feet, will then lead to aching leg conditions such as bursitis or tenosynovitis.

Indicators of Pain and Discomfort

The two traits “stepping” and “arching of the back” were selected to be used as indicators of pain and discomfort. The reason why these two were used was the possibility to use them in crated sows at any time during the recording, and that they were fairly easy to observe. The challenge of observing the arching of the back was that some sows put all their weight on the entrance gate or did not want to stand for a longer amount of time. Stepping had to be evaluated over a small amount of time to confirm whether the sow was just moving or continuously stepping. Arching of the back and stepping had a high genetic correlation to each other, but the reason for the animal showing discomfort may be caused, for several reasons, by other than just feet or hoof problems. Although the overall genetic correlation to hoof length was medium high, there could be something that is linked but not certain. The heritability of both traits is low (0.14). In one study, the heritability of the arching of the back may also be the same as the standing under position study, in which the result was 0.02 h^2 (Lea et al., 2015) but it was estimated close 0.13 h^2 (Aasmundstad, 2014). The expectation was that arching of the back would be more correlated to heel overgrowth, due to the discomfort standing on cracked and sore feet. However, the phenotypic correlation between heel overgrowth and arching of the back was 0.24, and only 0.06 for heel overgrowth and stepping.

Both temperature and dehydration were estimated to not be heritable in this project (0.08 and 0.00, respectively). They were, however, used as covariations in the model. Dehydration seemed to be the result of young gilts not being able to get sufficient water supply when moved to the farrowing rooms and presented to new drinking systems. The older sows were familiar with the water supply system in the farrowing, whereas the new gilts were both smaller and unfamiliar with the nipples. Other small sows might also have trouble not reaching the drinking nipple, as some small gilts were observed standing on their toe on one front leg to reach the drinking nipple. So in the best case, dehydration would be an indication of the height of the sow to access the drinking nipple. Sickness and dehydration affect the sow’s attempt to be active in feeding and drinking, which again can lead to fever and high temperatures. As mentioned previously, fever is stated in the literature as being part of a symptom, and not a sickness, so feverish sows might be affected because of different sicknesses, dehydration or local inflammations. It is normal for sows to have a temperature around 38^{o} C, though when it rises over 39^{o} C it is a sign that something is wrong. Surprisingly, many of the sows had a very high temperature. In conclusion, both temperature and dehydration are based on environmental factors.

Performance Traits

Some of the sows received medical assistance when they arrived on their due date, but only oxytocin was given to the purebred sows. The gestation length was estimated to have a low heritability (0.16). Earlier estimation of gestation length was on average 0.24 h^2. (Hanenberg., 2001). A long gestation length is phenotypically negatively correlated to the total born (-0.25), and may also have an effect on the number of stillborn. Earlier study have estimated the genetic correlation of number of piglets born alive and growth rate to be 0.08 (Rydhmer, 2000). The length of gestation is highly affected by the environment, because of medications used to start farrowing at a certain day. The drawback of this is that if the sow is induced, the piglets and her body might not be as ready as if she was to start farrowing naturally. Movement and nest-building are behaviors the sow normally performs before farrowing, which helps her in preparing. This has been found to lead to shortened farrowing time and less stillborn (Fredriksen, 2014). The results in this project show that the more piglets in the litter, the shorter the gestation time (-0.29).

The number of total piglets born includes both the live-born and the stillborn, but does not include mummies. A low heritability has been shown in total born (0.12), although the successful fertilization of all eggs, is very much affected by the time of insemination. The recording of mummies may show that the sows are actually fertile, based on how many eggs have been successfully conceived. If the sow has a litter in which half or more are mummies, it would appear that she was not very fertile, with a small amount of eggs ovulating. Other studies have estimated a similar heritability (0.09) of total born (Rydhmer, 2000).

The number of weaned piglets is supposed to show a sow’s ability to the caring and feeding of her litter. At the farm, they practice a distribution of the litter according to the size of the litter and/or the condition of the sow, so therefore there may be a lack of variation, thus making the heritability low (0.06). It is common to use pull-down sows (nurse mom), which are sows newly weaned from their original litter and moved to a new litter. The number of weaned are highly positively correlated to the number of born (0.65), which can be explained based on the number of developed teats and milking ability. Higher correlations were expected, but the results in this project were affected by sow moving, nurse moms and the switching of piglets between litters. Some piglets never make it to weaning age due to severe injuries or sickness, and it is a well-known problem that sows can lie on, step or squeeze the piglet to death. During the observation, the farm installed new heating lamps, which gave much more controlled warmth than the previous situation. Hopefully, this will have a positive effect on piglet loss when the piglets do not walk or sleep more than necessary around their mom to seek warmth and comfort.

The weaning weight is based on the entire litter, and as expected are highly positively correlated to the number of weaned and total born, as the bigger the litter, the higher the weight. It was not estimated to be very heritable (0.06), and is affected by many different environmental impacts and little variation. In one study birth weight was estimated to have a heritability of 0.4 (Rydhmer, 2000).

The weaning age of the piglets is decided by the farm staff, and is a low heritable trait (0.06) in this study. All piglets are weaned at 21 days, but the sows are sometimes kicked out earlier depending on their body condition, milking ability or general shape. Some other sows stay in the farrowing for several days as a nurse mom for another litter after weaning her original litter. The results indicate that the longer the weaning age, the better fit a sow is.

Litter breeds: The spread looks quite similar, but the LxP hybrid shows to be more to the right, and has a higher number of total born per litter. This might be because of the vitality of the piglets, due to the heterosis effect, more than the genetic variation of purebreds.

The removal in this registration is based on the sow card remarks. If she was going out because of parity (age), unwanted exterior, traits or illness was decided by the farm management. Sows are normally sent to slaughter when they reach a parity of 6, but some were much older. The removal had little variation, and removal was a management decision, so the heritability was also expected to be very low (h^2=0.08).

From the literature, one can conclude that unsound hoofs, claws and legs have a lower efficiency. Moreover, there is an undiscovered unsoundness when it comes to hoof and leg problems in the swine industry.

In this project, the source of potential errors may be from misinterpretations, mistyping, collaboration difficulties, misreading, moved sows with missing data, "KickOuts" before weaning date not being registered and being lost in the breeding system, as the judges might have different personal assessments of the sows. The Norsvin Landrace is a large and long pig, so some of the assessments done could be inflicted by the way the sow was standing or leaning in the crate, thereby making it difficult to have identical assessments when the sows had different postures. The negative effect on adding more traits in a breeding goal, such as claw length, is that the production traits will progress less efficiently than if the focus is on fewer traits. However, with more traits, and particularly in managing the balance of the combination of health and production traits together, one will increasingly breed for a production animal that is more robust.

A further project might be the observation of sows at different stages during the production, which would help in acquiring an overview on the development on a sow's hoof and leg during her growth and performance. Using the gilt test scores to compare assessments later may show how some leg traits develop as a sow grows. One big error is that even if the sow was retained, she was also sleeved. This means that many of the sows that are registered as sleeved could also be retained without showing that in this registration. Some traits may be affected by a hybrids vitality in the litter, such as litter weight and number of weaned.

This study consists of a relatively small amount of records collected over only a four-month period. Ideally in these kind of studies, it is desired to have thousands of sows from various farms, and preferably over several generations.

7. CONCLUSIONS

- This study included 19 health traits based on records on 1,243 sows.
- Hoof traits have a medium heritability, and are possible traits to be included in the breeding goal
- Heel overgrowth and hoof cracks are environmental damage, but did not show any heritability different from zero
- Front and hind leg assessments have a low heritability, and the majority of the pigs had too much softness in the joints at a fully-grown size. This is negatively correlated to hoof soundness, and not a desirable correlation. Softer joints may lead to longer hoofs.
- Bursitis and tenosynovitis have a low heritability, and are correlated to the soundness of the hoof. Worse bursitis and bad hoof soundness.
- Stepping as a pain indicator has a low heritability, a medium to low correlation to foot hoof soundness, and a high positive correlation with arching of the back. This means that bad hoof soundness will also increase stepping.
- Arching of the back has a low heritability and is medium correlated to hoof soundness and bursitis in the front legs.
- Gestation length and total born have a low heritability and have a medium to low negative correlation to each other, meaning that more piglets have a slightly shorter gestation length.
- The number of weaned, weaning weight and weaning age did not show any heritability from zero. They only have a positive medium to low correlation.

- The results in this study can be an important contribution to understand the genetics of different health and robustness traits in pigs, and for possible use in a breeding program.

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9. ATTACHMENTS – APPENDIX

9.1. Hoof scoring from Zinpro.com

9.2. Phenotypes from the first half of recordings

Phenotypes registered during half the stay, and not recorded because of a lack of variation or too time consuming:

1. Appetite

    This was measured in the amount of food left, though this was not a good indicator because of management giving different amounts. Not always proceeding according to fallowing guidelines (mostly giving more after talking with several employees) and registration was done at different parts of the day.

2. Dehydration weaning

    Dehydration moved from weaning to farrowing. Wanted to know how their hydration was after one short week after being moved from breeding barn with water surface to farrowing pen with drinking nipple at weaning, especially in relation to the gilts showing trouble finding or using the drinking nipple.

3. Circulation

    This is in relation to the color of the ear, thus indicating the blood circulation throughout the body. There are almost never any "blue" ears; one indicator that would be interesting would be the ear temperature, which was too difficult to measure accurately during this stay.

4. Respiration
    a. Panting

        Heavy breathing

    b. Coughing

        Airway problems, dry or productive coughs

5. Indicators of pain
    a. Willingness to rise

        The sow's ability to stand up, with speed, technique and eagerness evaluated. One big error was the "laziness" of the sows. Some sows did not show any pain on rising when fed, but did not stand up during evaluation. Some sows also jumped up because they were startled, even if they showed pain later.

    b. Vocalization

Very individual as to whether they screamed or not during rising; same error here as a willingness to rise.

6. Number of piglets at the sow

   It was decided not to include because the amount of piglets at each sow was recorded by the staff, and could be retrieved from InGris.

7. Feces

   a. Consistency

      Even if the sows were fed laxatives, they had a very different consistency. But because of the use of laxatives, it was decided that it affected the results too much to be reliable.

   b. Blood in feces

      Mostly very dark feces made the judgment very uncertainty, and in addition, and because of the consistency, the entire feces registration was removed.

8. Urine

   a. Blood in urine

   b. Color of urine

It was very challenging to register urination for 60 sows in one room, and also very time consuming. They did not always urinate when standing up, sometimes urinating while lying down.

9. Observation during suckling period

   a. Aggressive towards management

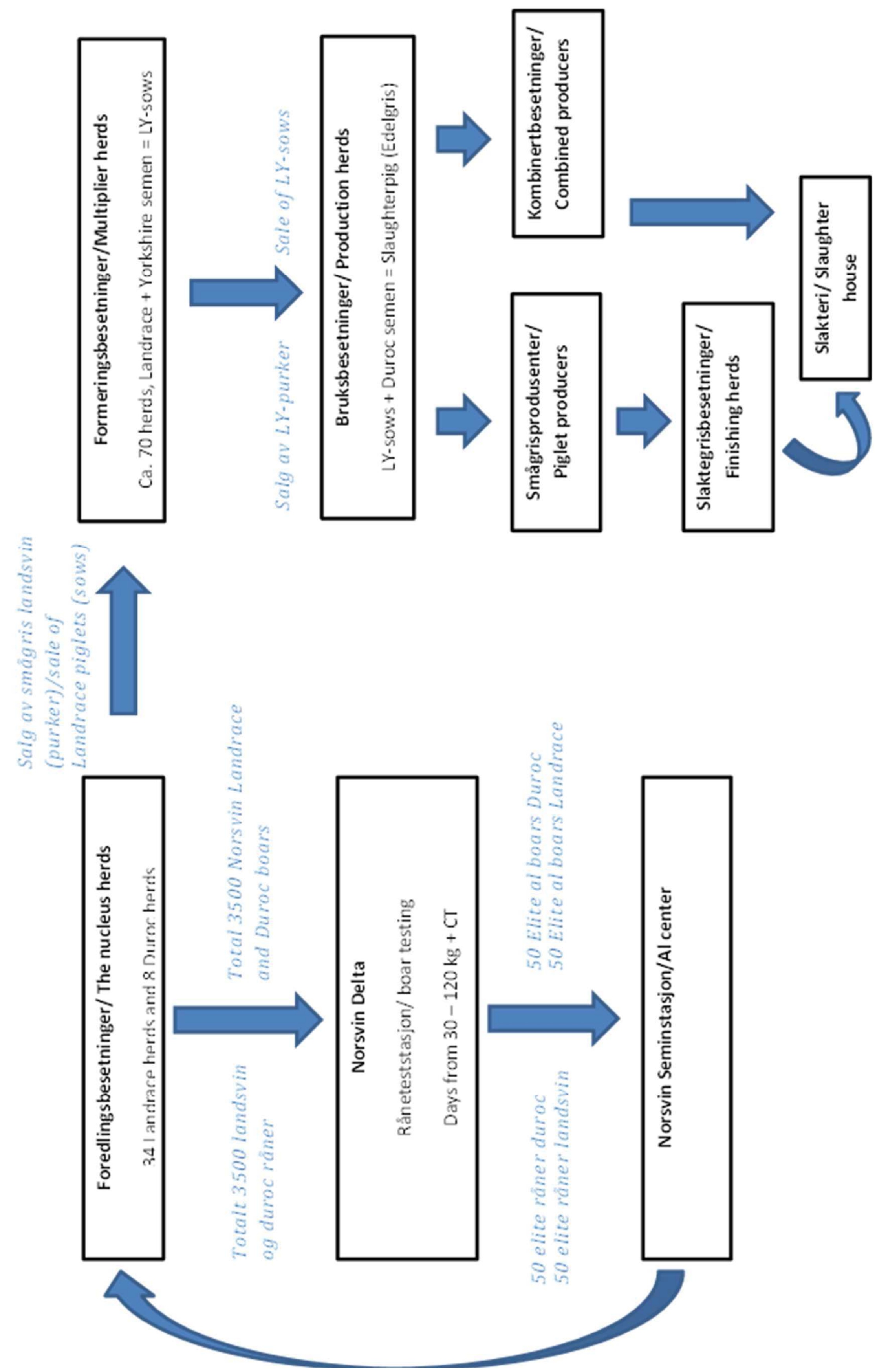
   b. Aggressive towards piglets

   c. Presenting udder for piglets

   d. Delayed milk

These traits would be more accurate if registered by the staff in that specific room, as it is not reliable to have small moment judgements by one person at the end close to weaning.

9.3. Norwegian Breeding System



9.4. Protocol for recording:

TOPIGS NORSVIN

Topigs Norsvin USA – Data protocol for recordings related to «Robust pig project», weaning of sows

For use in Christensen Farms only

Torunn Aasmundstad

June 16, 2014

Topigs Norsvin USA Research and Development protocols

The purpose of this manual is to provide instructions for recording and the computer entry of data into the Topigs Norsvin Information System for the Research and Development Project: "Robust pig."

This protocol is only concerning additional registrations regarding the condition of the sow one day (Monday evening) prior to weaning. All recordings except those under point 14 should be recorded by a Topigs Norsvin master student during the first two months until the protocol is settled.

Where to record:

1) The recordings should be written on a recording scheme supplied by Topigs Norsvin (Lars Terje Bogevik).

2) Registration tools: Thermometer for rectal usage and stopwatch.

How and what to record: Alternative A: Sow is able to stand up. Alternative B: Sow is not able to stand up.

A) Alternative A: The sow's condition should be assessed in the farrowing crate when the sow is standing up. If the sow is unable to stand, see alternative B. Most recording should be performed by visual inspection.

1) Record sow ID, operator ID, date of registration, room number and pen number. Record water flow in crate as liters/minutes.

2) Rectal temperature of sow.

3) Circulation. Color of ears (Normal (N), blue (B)).

4) Respiration:

I) Panting: Non-visible breathing (normal (N)) or labored breathes with abdomen (A); II) Coughing (no/yes), if yes: non-productive cough (YNP) or productive cough (YP).

5) Dehydration. Pull ear fold and record number of seconds until normalization.

6) Feces – if not present record N.P, else:

I) Consistency (not present (N.P.), normal (N), soft (S), diarrhea (D), separate hard lumps (H).

II) Blood in feces yes/no (N), if yes: coagulated blood (black (B)), fresh blood (Red (R)).

7) Urine – if not seen record N.P., else:

I) Blood in urine (Y/N).

II) Color of urine: normal (N), dark (D), clouded whitish/flocky (C)

8) Indicators of PAIN:

I) Willingness to rise up (normal (N), slightly unwilling (H), not willing (go to alternative b).

II) Arching of back (normal, slight, medium, pronounced).

III) Sow is “stepping,” e.g. avoid putting weight on one or several feet (no stepping (N), slight (H), medium (M), pronounced (P).

IV) Vocalization (no vocal (N), grunt (G), shout (S)).

9) Front leg assessment – according to Appendix B, Off test exterior scoring.

10) Hind leg assessment – according to Appendix B, Off test exterior scoring.

11) Hoofs: Score hoofs according to Lesion scoring guide for the following: toes, dew claws, cracked wall horizontal, cracked wall vertical (normal, mild, moderate, severe). All four legs are to be assessed and the worst hoof is to be recorded (i.e. if front left leg has severe toes, this is to be a yes. If same sow’s right hind hoof dew claws are overgrown, this is a yes as well).

12) Udder:

I) Number of piglets at the sow.

II) Number of teats in function.

III) Number of non-functional glands behind navel.

13) Injury: Injury that is inflicted the sow (e.g. eaten on by piglets, cut by fixture) is the reason for culling (Y/N).

14) Observation during suckling period:

I) Aggressive towards management (Y/N).

II) Aggressive towards piglets (Y/N).

III) Presenting udder for piglets (normal (N), slightly sub-optimal (H), medium sub-optimal (M), pronounced sub-optimal (P)).

IV) Farrowing:

i) Medically induced labor: farrowed without interventions (IN), piglets pulled (IP), retained pig (IR) where “I” denotes “induced” and N, P and R denotes “normal”, “pulled” and “retained,” respectively.

ii) Non-induced labor: farrowed without interventions (NN), piglet pulled (NP), retained pig (NR)) where “N” denotes “normal” and N, P and R denotes “normal”, “pulled” and “retained” respectively.

V) Delayed milk, record number of days before normal lactation.

15) Appetite: normal (N), reduced (R) or no intake (NI)

16) Visual inspection of legs: Look for deviations from normal appearance (swollen, bursitis, calluses and abrasions). Record each leg individually. Scale: Normal (N), slightly swollen/bursitis/callus/abrasions (H), moderate swollen/bursitis/callus/abrasions (M), pronounced swollen/bursitis/callus/abrasions (P). Record leg and severity, e.g. front right medium as: FRM. Front left (FL), hind right (HR) and hind left (HL). Two first letters denote which leg, last letter the severity of the deviation. If all four legs are normal, score a sole N, as this covers all four legs.

17) Overall conformation of sow – eligible for re-breeding or not. (Y/N)

B) Alternative B: If show is unable/unwilling to stand:

1) Record sow ID, operator ID, date of registration, room number and pen number. Record water flow in crate as liter/minutes; also, if wet feed is given yes(y)/no (N).

2) Rectal temperature of sow.

3) Circulation. Color of ears (Normal (N), blue (B)).

4) Respiration:

I) Panting: Non-visible breathing (normal (N)) or labored breathes with abdomen (A); II) Coughing (Y/N), if yes: non-productive cough (YNP) or productive cough (YP).

5) Dehydration. Pull ear fold and record number of seconds until normalization.

6) Feces – if not present record N.P, else:

I) Consistency (not present (N.P.), normal (N), soft (S), diarrheic (D), separate hard lumps (H)

II) Blood in feces yes/no (N), if yes: coagulated blood (black (B)), fresh blood (red (R)).

7) Urine – if not seen record N.P., else:

I) Blood in urine (Y/N).

II) Color of urine: normal (N), dark (D), clouded whitish/flocky (C).

8) Indicators of PAIN:

I) Willingness to rise up (not willing (NW)).

IV) Vocalization (no vocal (N), grunt (G), shout (S)).

12) Udder:

I) Number of piglets at the sow.

II) Number of teats in function.

III) Number of non-functional glands behind navel.

13) Injury: Injury that is inflicted to the sow (e.g. eaten on by piglets, cut by fixture) is reason for culling (Y/N).

14) Observation during suckling period:

I) Aggressive towards management (Y/N).

II) Aggressive towards piglets (Y/N).

III) Presenting udder for piglets (normal (N), hint of sub-optimal (H), medium sub-optimal (M), pronounced sub-optimal (P)

IV) Farrowing:

i) Medically induced labor: farrowed without interventions (IN), piglets pulled (IP), retained pig (IR), where "I" denotes "induced" and N, P and R denotes "normal", "pulled" and "retained," respectively.

ii) Non-induced labor: farrowed without interventions (NN), piglet pulled (NP), retained pig (NR)), where "N" denotes "normal" and N, P and R denotes "normal", "pulled" and "retained" respectively.

V) Delayed milk, record number of days before normal lactation.

15) Appetite: normal (N), reduced (R) or no intake (NI).

16) Visual inspection of legs: Look for deviations from normal appearance (swollen, bursitis, calluses and abrasions). Record each leg individually. Scale: Normal (N), slightly swollen/bursitis/callus/abrasions (H), moderate swollen/bursitis/callus/abrasions (M), pronounced swollen/bursitis/callus/abrasions (P). Record leg and severity, e.g. front right medium as: FRM. Front left (FL), hind right (HR) and hind left (HL). Two first letters denotes which leg, last letter the severity of the deviation. If all four legs are normal, score a sole N as this covers all four legs.

17) Overall conformation of sow – eligible for re-breeding or not. (Y/N)

9.5. FORM USED DURING ASSESSMENT

Phases 1 – 36 records

Sow_id		
Room/Pen		
Operator_id		
		Recording
Appetite	(**N**ormal, **R**educed, **N**o **I**ntake (**NI**)	
De-hydration	Sekunder	
Circulation - colour of ear	(**N**ormal, **B**lue)	
Temperature	Farenheit	
Hoofs (0 -3)	Toes	
	Dew claws	
	Heel overgrowth and erosion	
	Heel-sole crack	
	White line	
	Cracked wall horizontal	
	Cracked wall vertical	
Respiration	Panting (**N**ormal, **A**bdomen)	
	Coughing (**N**o, **Y**es,**N**o**P**rod(ynp), **Y**es,**P**rod(yp))	
Indicators of pain	Willing to rise (**N**ormal, **S**ligthly, **M**edium**,** **P**ronounced)	
	Arching of back (**N**o, **S**light, **M**edium, **P**ronounced)	
	Stepping (**N**o, **S**light, **M**edium, **P**ronounced)	
	Vocalisation (**N**o, **G**runt, **S**hout)	
Visual inspection of legs	**FL** **HL** **HR**	(**N,H,M,P**)
Front leg assessment	(unggrismaling 1 - 7)	
Hind leg assessment	(unggrismaling 1-7)	
Udder	Number of piglets at the sow	
	Number of tats in function	
	Number of non-functional glands behind navel	
	Number of chewed tits	
Faeces	Consistence (**N**ot **P**resent, **N**ormal, **S**oft, **D**iarre, **H**ard)	
	Blood in faeces (**Y**es, **N**o)	
Urine	Blood in urine (**Y**es, **N**o)	
	Color of urine (**N**ormal, **D**ark, **C**louded)	
Injury	(**Y**es, **N**o)	
Eligble for re-breeding	(**Y**es, **N**o)	
Observation during suckling period	Agressive towards management (**Y**es, **N**o)	
	Agressive towards piglets (**Y**es, **N**o)	
	Presenting udder for piglets (**N**ormal, **H**int, **M**edium, **P**ronounced)	
	Farrowing (Medical Incuced "**i**", without "**N**" + **N**ormal, **P**ulled, **R**etained. (Ex: **NN** = **N**on-induced **N**ormal))	
	Delayed milk (number of days)	

Phase 2 –

23 records

Date of registration		
Sow_id		
Room / Pen		
Operator_id		
Farrowing time	Day/Night	
Medical Induced	Induced/Normal-Normal/Retain/Sleeved	
De-hydration Farrowing	Seconds	
Temperature (farenheit)		
Hoofs (0 - 3)	Toes	
	Dew claws	
	Heel overgrowth and erosion	
	Heel-sole crack	
	White line	
	Horizontal	
	Vertical	
Indicators of pain	Arching of back	
	Stepping	
Visual inspection of legs	Front Legs	
	Hind leg Left	
	Hind leg Right	
Front leg assessment	1-7	
Hind leg assessment	1-7	
Udder	Number of tats in function	
	Number of non-functional glands behind navel	
	Number of chewed tit	
Injury	Y/N	
Eligble for re-breeding	Y/N	
Comment		

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