Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Landscape Architecture,
Horticulture and Crop Production

Effects of grooving slippery concrete floors on dairy cows´ claw health, behavior, fertility and survival
- farmers experience and herd data

Effekten av att rilla hala betonggolv på mjölkkors klövhälsa, beteende, fertilitet och överlevnad – lantbrukarnas erfarenheter och besättningsdata

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ABBREVIATIONS

AI = Artificial insemination

CFI = Calving to first insemination

CI = Calving interval

CLI = Calving to last insemination

COF = Coefficient of friction

DD = Digital dermatitis

DO = Days open

ECM = Energy corrected milk

$H_{Control}$ = Herds with un-grooved concrete floors

$H_{Grooved}$ = Herds with grooved concrete floors

HHE = Heel horn erosion

IH = Interdigital hyperplasia

LPL = Length of production life

NR = Non-returns at 56 days after AI

PDD = Papillomatous digital dermatitis

$Period_1$ = The 6-month period prior start of grooving

$Period_2$ = The 6-month period after grooving was finished

RCOF = Required coefficient of friction

SH = Sole haemorrhage

SOMHRS = Swedish official milk and health recording scheme

SPC = Services per conception

SU = Sole ulcer

WLA = White-line abscesses

WLD = White-line disease

WLH = White-line haemorrhage

WLU = White-line ulcer

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ABSTRACT

The most common floor type in dairy barns is concrete. Concrete does unfortunately get slippery over time due to mechanical and chemical degradation. Slippery floors increase the risk of slipping and falling and influence cows' behavior, which can affect claw health, fertility and survival. One common solution to provide more friction and reduce slipperiness is to groove the floor. In this thesis, the effect of grooving on claw health, fertility, and survival are examined by a questionnaire and an epidemiological study. The questionnaire included 53 of about 300 farmers who contracted Växa Sverige to groove their floors, during recent years. The 34 questions included specific information about the grooving, animal health, behavior, and housing. Farmers replied that grooving improved *oestrus* expression (31 %), increased activity (22 %), gave higher claw wear (10 %) and decreased muscle strain injuries (81 %). Other farmers did not see any differences in these traits before and after grooving. The epidemiological study included 118 herds who grooved their concrete floors ($H_{Grooved}$) and 236 matched control herds ($H_{Control}$) who had not grooved their floors. Data were obtained for the 6-months period prior grooving ($period_1$) and the 6-month period after grooving was finished ($period_2$). The results did not reveal any evidential proof regarding grooves effect on claw health, fertility, culling and veterinary treated disorders. Further studies need more participating farmers and a longer follow up period in order to determine how claw health, fertility and survival are affected by grooving.

SAMMANFATTNING

Det vanligaste golvet för mjölkkor är betong. Betongen slits med tiden på grund av mekanisk och kemisk inverkan, vilket kan göra golvet väldigt halt för korna. Halt golv ökar risken för att korna förlorar fästet och ramlar, vilket påverkar deras beteende. Detta kan i sin tur påverka klövhälsa, fertilitet och utslagning. En vanlig lösning för att minska risken för halka är att öka golvytans friktion, genom att rilla golvet. I denna studie undersöktes rillningens effekt på klövhälsa, fertilitet och överlevnad med hjälp av en enkät och en epidemiologisk studie. I enkäten deltog 53 av ungefär 300 mjölkföretagare som anlitat Växa Sverige under de senaste åren. De 34 frågorna berörde särskild information om rillningen, djurhälsa, beteende, och gårdsspecifik information. Lantbrukarna svarade att rillningen förstärkte brunstbeteendet (31 %), ökade aktiviteten (22 %), gav högre slitage av klövarna (10 %) och minskade frekvensen fläkskador (81 %). Övriga lantbrukare kunde inte observera några skillnader före och efter rillningen, med avseende på ovanstående. Den epidemiologiska studien omfattade 118 besättningar som hade rillat sina betonggolv ($H_{Grooved}$) och 236 matchade kontrollbesättningar ($H_{Control}$), som inte hade rillat sina golv. Data erhölls för 6-månadersperioden innan rillningens start ($period_1$) och 6-månadersperioden efter rillningen var avslutad ($period_2$) för; klövhälsa, fertilitet, utslagning och veterinärbehandlade sjukdomsfall. Rillningens inverkan på dessa parametrar kunde inte fastställas från resultaten. För fortsatta studier bör fler gårdar inkluderas och uppföljningstiden efter rillning behöver vara längre för att kunna dra några slutsatser kring golvrillningens effekt på klövhälsa, fertilitet och överlevnad.

1. INTRODUCTION

Cattle are evolutionary adapted to stand, walk and lay down on a variation of hard and soft foundations. Pasture is the natural habitat for cattle, which provides a large loafing area, a beneficial amount of claw wear, good traction, and a low presence of fecal bacteria. Pasture based systems for cattle are still common, especially for suckler cattle for meat production. However, in some parts of the world, e.g. New Zealand and Ireland, it is also common for dairy cows. In many countries in Europe, including UK, most dairy cows are kept in mixed systems, involving both a housing and a grazing period (Phillips, 2010). Free-stalls, named cubicles in Europe, is the most common dairy housing system in western countries and is associated with concrete alley floors. Floor properties is considered to be one of the most important welfare and health factor for dairy cow housing (Rushen & de Passille 2009; Bergsten *et al.*, 2015). During the last decades, Swedish dairy herds are slowly changing from tie-stalls to free-stalls due to a rationalization to larger herd size and to recommendations from the government on policy concerning the dairy business (SFS 1988:534). Despite the aim of more freedom, this change has been reported to increase the frequency of claw disorders and lameness in dairy cattle (Hultgren, 2002). One challenge with the free-stalls is therefore to design a proper floor system that is ergonomic for the animals i.e. slip-resistant, comfortable (Telezhenko *et al.*, 2017) and promoting normal locomotion (Telezhenko & Bergsten, 2005).

The most common floor type in free-stalls for dairy cows is concrete floors because of its possibility for molding constructions, affordable prize, easiness to clean and durability (Telezhenko & Bergsten, 2005; Telezhenko *et al.*, 2009). Newly installed concrete floors have a proper level of friction. However, the surface will become slippery over time due to chemical and mechanical degradation (De Belie *et al.*, 2000). Slippery floors will make cows act more carefully, which negatively affects locomotion (Rushen & de Passille, 2009), general activity (Haufe *et al.*, 2009; Telezhenko *et al.*, 2017) and social and sexual behaviors (Platz *et al.*, 2008; Norberg, 2012). Furthermore, quick movements on slippery floors increases the risk of slipping and falling, which could generate severe injuries and fatality in worst cases (Whitaker *et al.*, 2000). It is therefore common that dairy farmers restore their slippery concrete floors by grooving (Phillips & Morris, 2001). Grooving provides more friction, which supports traction (Phillips & Morris, 2001; Telezhenko *et al.*, 2017), however, if the floor becomes too abrasive it could result in an unfavorable claw wear and an increase of claw disorders (Bergsten, 2001).

Recently, the association Växa Sverige (Animal health service) introduced a service to groove slippery floors. Over 300 farmers contracted Växa Sverige during last 2 years. The aim of this study was to investigate how grooving of slippery concrete floors in free-stall herds affected claw health, fertility and survival of Swedish dairy cows. This was examined by data from the Swedish milk recording scheme and a questionnaire. The hypothesis was that grooving would provide a more secure floor surface, which would improve the fertility performance and culling rate. Furthermore, grooving was hypothesized to increase the risk for claw problems due to over wear. Other factors that has an influence, such as management, hygiene and genetics, on these traits in interest are not included in this thesis.

2. LITERATURE REVIEW

2.1 Housing and floor systems for dairy cows

This chapter describes housing and floor systems commonly used in dairy production and a short information of the design of grooving available from Växa Sverige.

2.1.1 Housing systems

Dairy management systems span from tie-stalls, free-stalls, straw yards and pasture-based operations, and mixes between them. The concept of a tie-stall barn is that all activities are made in the same stall and free movement is restricted. The cows are tied to their laying area where the cows are able to stand and lie down, but not turn around (Phillips, 2010). Free-stall systems, also named cubicles systems (Europe), are barns with stalls separated with dividers. Cows can move freely between the resting, feeding and milking areas, where automatic gates often direct them (Phillips, 2010). A straw yard is on the other hand an open area with deep bedding and undefined laying places. In pasture-based systems cows are fed on pasture most of their lactation and are moved back and forth to the milking, where the distance depends on herd size. However, this thesis will focus on cows kept in free-stall systems.

2.1.2 Floor systems

Alley floors in dairy farms is principally either solid concrete or slatted concrete (Telezhenko *et al*., 2009). Furthermore, the casting design and the patterning of a floor surface could be of several different types; smooth, tamped or grooved (Phillips, 2010). Solid concrete is the most commonly used floor material in dairy barns and the traditional concrete floor is casted with a smooth surface. This surface is often made with a wooden plank or a steel beam. The surface can also be made rougher with a broom, typical for slatted floors. Tamped concrete is made in the green concrete with different tools like a sled or a role, which leaves a specific pattern like hexagons or grooves (Phillips, 2010). Grooving can be made in the casted (hard) new or old concrete floor. However, grooving is most often made in old and slippery concrete floors, where a cutting machine is used to cut lengthwise grooves in the walking direction (Phillips, 2010). It is common to groove a diamond shaped pattern in risk areas to improve cows tracking from more walking directions (Bergsten, 2001). The most commonly used manure handling system for concrete floors is an automatic scraping system. Furthermore, straw yards for dairy cows consists of a soft bedding material and do often have a concrete alley in front of the feeding platform (Phillips, 2010). This concrete area is most often scraped by a tractor. However, an automatic scraper could be used as well.

The concrete floor surface can be finished with epoxy (milking stall and manger) or a synthetic floor cover such as rubber mats or mattresses in cubicles (Franck *et al*., 2007). In walking alleys, rubber mats can be installed on top of existing floors, solid as well as slatted floors. It is common that barns have several floor types in different sections of the barn. This thesis will however focus on the effect of concrete floors, grooved concrete in particular. Nevertheless, all of the floors cited are somehow mentioned.

2.1.3 Grooving-design by Växa Sverige

The grooves made by Växa Sverige are 3-4 mm deep, 12 mm wide and with a distance of 40 mm in between. Nearly 85 % of the floor surfaces that becomes grooved is made in lengthwise direction, the floor got a striped pattern. However, in areas where the risk of slipping is greater or if the costumer desires even more friction; grooving is made with diagonal grooves as well, the floor gets a diamond pattern.

2.2 Locomotion

This chapter describes how friction, compressibility, slurry conditions and grooves affect cow locomotion and traction.

2.2.1 Cow locomotion and behavior

Cattle are evolutionary adapted to search for food, water, shelter etc. on a large area, which demands a lot of movement (Phillips, 2002). The recommendation to maintain the physical health is therefore to walk at least one hour per day, i.e. 3-4 km (Phillips, 2002). This interferes with the way domesticated cattle is housed today, where environmental restrictions cause a shorter walking distance than recommended (Phillips, 2002). The importance of exercise has been stated by Gustafson (1993). Health status on cows in tie-stalls was observed, with or without daily exercise (0.5 – 3 km). The results showed that cows who did not receive daily exercise had an increased frequency of leg disorders, mastitis and calving disorders.

Pasture is the normal habitat for cows and this is where the normal locomotion pattern can be observed (Alsaaod *et al.*, 2017). The 'locomotion comfort' is greatest on pasture and this term is defined as when the cows are able to perform their normal activity and gait behavior on a floor which does not negatively affect claw and leg health (Telezhenko, 2007). Locomotion behavior can be assessed subjectively by locomotion scoring (Flower & Weary, 2008) and objectively by means of kinetic (describing applied forces with e.g. force plates) and kinematics (describing geometry of movement with e.g. high-speed cameras) methods (Phillips & Morris, 2000; van der Tol *et al.*, 2005; Flower & Weary, 2008). Slips are more difficult to measure (Rushen & de Passille, 2006) but would be of interest in the context of this thesis.

2.2.2 Association between different floor characteristics and locomotion

An optimal floor should provide a good grip, a compressible surface and good draining ability (Rushen & de Passille, 2009), which would help the cow to express normal locomotion. However, suboptimal floors are a major problem within modern free-stall farms and the floor quality in walking and standing areas has been strongly associated with animal welfare and health (Rushen & de Passille, 2009). One type of suboptimal floors is slippery floors, which will hinder normal locomotion behavior (van der Tol *et al*., 2005; Rushen & de Passille, 2009). The risk of injuries caused by suboptimal floors are suggested to be associated with four floor properties; the structure of the surface, amount of abrasion, compressibility and the potential of slip resistance (McKee & Dumelow, 1995). These characteristics are more or less dependent of each other and it is important to consider all of them.

Friction and abrasion

The slip-resistance of a floor is partly dependent of the structure and friction of the floor surface (Bergsten, 2001). Concrete, which is the most common floor type in dairy barns, does often have a proper level of friction when it is newly installed (De Belie *et al*., 2000). However, the floor surface in dairy houses are exposed to an aggressive environment and degradation will over time lead to a loss of friction (De Belie *et al*., 2000). Two types of degradation appear; chemical and mechanical (De Belie *et al*., 2000). Chemical degradation occurs due to reactions between the concrete and components in manure and feed, and mechanical degradation appears due to high pressure cleaning, animal movement and scrapers (De Belie *et al*., 2000). Moreover, an excessively smooth floor surface increases the risk of slipping and falling (van der Tol *et al*., 2005; Telezhenko & Bergsten, 2005; Rushen & de Passille, 2009). In contrast, a too rough and hard floor could lead to thin soles and sore feet (McKee & Dumelow, 1995; Bergsten *et al*., 2015).

One way to investigate the slipperiness of the floor is by using the coefficient of friction (COF; Franck *et al*., 2007). This is a ratio of the horizontal (frictional) and vertical (normal) force between the contact surface of the floor and the claw in this case (Franck *et al*., 2007). The COF could then be compared with the required coefficient of friction (RCOF), which tells us the amount of friction needed for the cow to maintain normal walking behavior (van der Tol *et al*., 2005). The risk of slipping increases when RCOF is higher than the floors value of COF (van der Tol *et al*., 2005). An optimum level of COF in dairy floors are suggested to be between 0.4-0.5 (Phillips & Morris, 2001). However, it has also been found that a higher COF is required in some areas. van der Tol *et al*. (2005) found that various locomotion behaviors require a RCOF value ranging between 0.3–0.85. Furthermore, acceleration movements, like start and stop, demanded the highest value of RCOF; up to 0.85.

McKee & Dumelow (1995) concluded that COF does not give a correct representation of floors slip-resistance for livestock. They found that floors covered with slurry had the highest value of COF but was not most slip-resistant. In fact, the animals were observed to slip more if the floor was covered with slurry, compared to a dry floor, even if it had lower COF (McKee & Dumelow, 1995). This result is in agreement with Telezhenko *et al*. (2017) where slipperiness of different floors was tested, focusing on four floor characteristics; COF, abrasiveness, dynamic and slip resistance. None of the four floor characteristics alone was informative enough to predict slipperiness. All of the four floor characteristics needed to be considered to get a good estimation of the slipperiness of the floor (Telezhenko *et al*., 2017). The information of slip-resistance and roughness of the surface of hard floors seems to have a better effect on locomotion compared with COF (Telezhenko *et al*., 2017). Higher COF appeared to improve the traction in general, however, floors with a low COF value did not always lead to impaired locomotion (Telezhenko *et al*., 2017). Franck *et al*. (2007) noticed that the surface of a wet floor had higher friction in general, compared with a dry one.

Compressibility

Other floor characteristics of importance for slip-resistance were presented in a study by Rushen & de Passille (2006). Locomotion of dairy cows was examined on rubber mats and concrete floors. The authors came to the conclusion that the compressibility of the floor had the greatest impact in preventing slips, independent of the surface roughness. Rubber mats had higher compressibility than concrete floors, which resulted in longer steps, decreased frequency of slips and increased walking speed (Rushen & de Passille, 2006). The largest effect of floor type was found when considering starts and stops, walking around corners and when cows jumped over small obstacles (Rushen & de Passille, 2006). This finding is in agreement with Telezhenko & Bergsten (2005) who determined that cattle's step length increased when rubber mats were added on solid and slatted concrete, even though the rubber mats had lower COF compared with solid concrete. Platz *et al*. (2008) received equal results. They observed an increase in step length and frequency of steps per day when cows walked on rubber mats compared with slatted concrete floors. Concrete floors were in general concluded to be too hard to provide normal tracking in dairy cows (Rushen & de Passille, 2006; Rushen & de Passille, 2009). Telezhenko *et al*. (2017) did also observe an improvement in traction when cows walked on rubber mats compared with smooth concrete, grooved concrete, temped concrete, slatted concrete and mastic asphalt.

Wet, dry and slurry conditions

Floors that are not drained properly increases the risk for slipping and falling (Rushen & de Passille, 2009). Several studies have shown that floors covered with slurry (adding feces/urine) becomes more slippery for the cows in comparison with dry (Albutt *et al*., 1990; Phillips & Morris, 2000; Rushen & de Passille, 2006) or wet (adding water) conditions (Phillips & Morris, 2000). Rushen & de Passille (2006) showed a decrease in walking speed and increase in frequency of steps when a thin layer of slurry was added, which indicates on poor traction. Slurry conditions was concluded to increase the risk of slipping compared with a dry floor, and this was observed even when the roughness and compressibility of the floor was increased (Rushen & de Passille, 2006). However, Phillips & Morris´ (2000) results are not in agreement with Rushen & de Pasille (2006). Their results showed that a floor covered with 5 or 12.5 cm of slurry, respectively, provided even better traction for the cows, compared with a dry or wet pathway. Especially when 12.5 cm slurry was added. The step length increased and walking speed decreased in the slurry conditions. It was therefore suggested that a thick layer of slurry could provide more secure footing because the claws is supported by a semisolid material, increasing stability (Phillips & Morris, 2000).

Grooved concrete floors

Several studies have concluded that concrete floors had too low COF to maintain normal traction (Telezhenko & Bergsten, 2005; van der Tol *et al*., 2005). Norberg (2012) came to the conclusion that cows on solid concrete floors, studied for four months, had at least three times higher problems with impaired locomotion (lameness), compared with cows held on rubber floors. A common solution to reduce locomotion problems on concrete floors is to make grooves in the concrete to provide more friction (Albutt *et al*., 1990). The surface becomes rougher and Telezhenko *et al*. (2017) observed an improvement in locomotion and slip-resistance on grooved concrete, in comparison with smooth concrete. However, tamped concrete seems to provide even better traction for the cows compared with grooved concrete (Albutt *et al*., 1990) as also rubber mats did (Telezhenko *et al*., 2017).

2.3 Claw health

This chapter describes the normal function of the claw, important claw disorders, lameness and how these problems could be associated with different kind of floors.

2.3.1 The anatomy of the claw

The cattle hoof consists of two claws, which are separated by the interdigital space. The anatomy of the claw is shown in figure 1 and 2. There are tree phalanx bones (p1-3) connected to each claw. The claw bone (p3) is placed in the claw capsule, as is the navicular bone. The corium (dermis) covers the bones and consists of connective and fat tissue, nerves and blood vessels. The corium supplies the horn-producing epithelium cells (epidermis; Manske *et al*., 2002a).

Cows should carry the main part of their body weight on the wall of the claw capsule, which is the strongest part of the claw (Manske *et al*., 2002a). The sole does usually have a thickness of minimum 5 mm and it is supposed to function as a barrier to protect the corium (Bergsten, 2001). The top of the claw wall merge with the coronary band and this is where new wall horn is formed from. The white-line is the conjunction between the claw wall and the sole, from the posterior wall around the toe and towards the interdigital space. The lamellar horn and lamellar corium merge the claw wall and the claw bone together. The white-line consists of newly produced horn produced by the connecting lamina tissues, and the color of this area is therefore white. The white-line horn is fragile, especially in the area between the bulb horn and claw wall (posterior wall; Manske *et al*., 2002a).

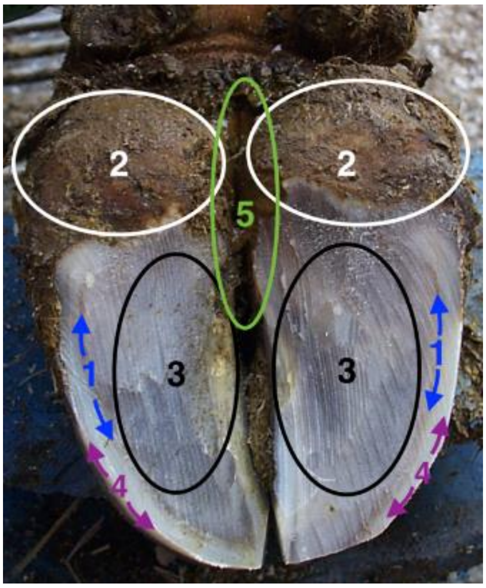

Figure 1. A bovine claw from below. 1=White line, 2=Bulbs, 3=Sole, 4=Claw wall, 5=Interdigital space (Photo Christer Bergsten).

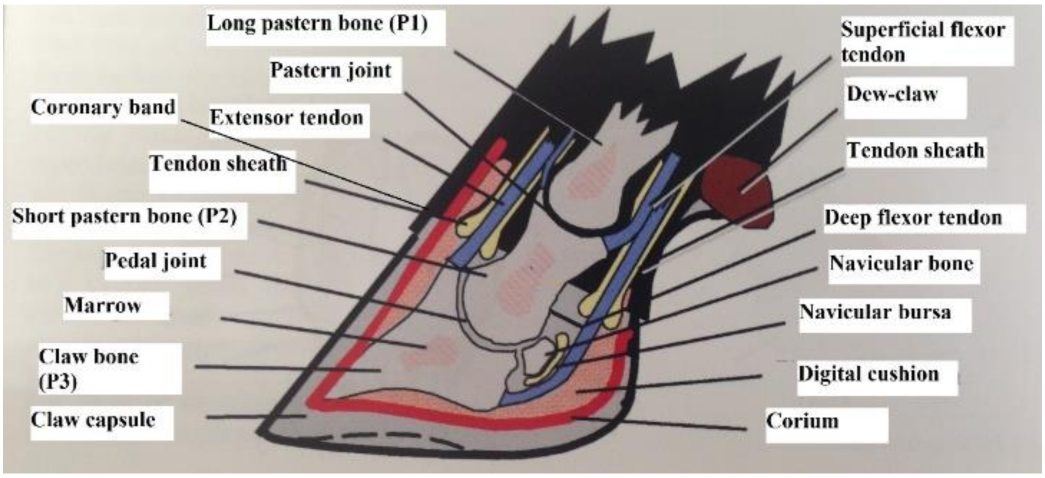

Figure 2. A cross-section of the bovine claw (from Manske *et al.*, 2002a).

2.3.2 Wear, claw conformation, weight and pressure of the claw

The conformation of the claws is essential to maintain normal locomotion and is partly influenced by genetics. However, age, nutritional changes and not at least the environment have a great influence (Bergsten, 2001). It is important to have a sufficient wear of the claw horn where the normal weight bearing role of the claw wall still is functioning (Watson, 2007). The horn growth is in general 4-6 mm per month (Manske *et al.*, 2002a). However, the horn growth is normally decreased during winter and increased in summer time, because of cattle's evolutionary function (Watson, 2007). They are adapted to walk on harder more rough areas in the summer and softer ground in the winter. This interferes with the way cattle is kept nowadays where we often house them on concrete floors during the winter, which places high demand on horn growth (Watson, 2007). However, the extent of wear is highly dependent of the roughness of the floor (Vokey *et al.*, 2001; Telezhenko *et al.*, 2008; Telezhenko *et al.*, 2009), environmental hygiene (Wells *et al.*, 1999) and level of exposure. Too abrasive floors can have unfavorable effects on the claws, such as a nonsymmetrical wear (Telezhenko *et al.*, 2008). Nonsymmetrical wear could result in an undesirable weight distribution where the cow starts to carry her body weight on the softer parts of the claw, i.e. sole (Telezhenko *et al.*, 2008).

Telezhenko *et al.* (2009) examined how the floor type in standing and walking areas affect wear, claw horn growth and claw conformation. Mastic asphalt was concluded to give a significantly shorter toe length, steeper toe angle and the greatest loss of sole concavity compared to rubber mats and slatted concrete. Mastic asphalt caused the highest extent of wear and also horn growth compared to smooth concrete, slatted concrete, rubber mats and slatted rubber floors. Rubber mats decreased the extent of horn wear and also growth due to its low abrasiveness (Vokey *et al.*, 2001; Telezhenko *et al.*, 2009).

Figure 3. Overgrown claw (Photo Christer Bergsten).

The roughness of the floor surface has also an effect on the contact pressure between the floor and the claw, where a low contact pressure is desired (Telezhenko *et al*., 2008). Telezhenko *et al*. (2008) concluded that floors with rough surfaces gave an increased contact area and therefore a decreased contact pressure, compared with softer floors. The lowest contact pressure was found on mastic asphalt in comparison with solid rubber mats, slatted rubber mats and slatted concrete floors. However, the long-term effects on mastic asphalt was concluded to have an unfavorable wear of the claw wall, which has the biggest weight-bearing role of the claw. The rubber floor, on the other hand, provided a too low extent of wear leading to an uneven weight distribution of the claw. The long-term effect of overgrown claws (fig. 3) has been seen to increase the risk of claw disorders and lameness (Bergsten, 2001; Manske *et al*., 2002b). Floors with a high surface abrasiveness can therefore be ideal to maintain normal claw shape and wear in short perspective (Telezhenko *et al*., 2008).

2.3.3 Claw disorders

The most common reason for lameness is claw disorders. In fact, 92 % of lameness was caused by claw diseases in an epidemiological study in England studying 4,837 lame dairy cows on 37 different farms (Murray *et al*., 1996). The same study found that the most common claw diseases that affected the horn capsule where sole ulcer (SU) and white-line disease (WLD). Moreover, digital dermatitis (DD) was stated to be the most frequent skin-disease in dairy cattle. Charfeddine & Pérez-Cabal (2017) came to the same conclusion, where horn-diseases were found to be the most common claw diseases. The results showed that the same three diseases (SU, WLD and DD) were the most common ones in Spanish Holstein cows, in 804 studied herds (Charfeddine & Pérez-Cabal, 2017). Furthermore, data from the Swedish milk recording scheme 2015/2016 showed that 41.5 % of the trimmed Swedish cows had some kind of reported claw disorder (Växa Sverige, 2016). Out of the 266,321 claw trimmings reported during this period, the most frequent disease was sole haemorrhage (SH; 17.9 %) and heel horn erosion (HHE; 17.4 %), followed by SU (4.6 %), interdigital hyperplasia (IH; 4.1 %) and DD (4.0 %).

Skin-disorders

Figure 4. Digital dermatitis (Photo Christer Bergsten).

Digital dermatitis (fig. 4) is a severe eczema most often found in the rear part of the interdigital space, on the bulbs and along the coronary band (Manske *et al*., 2002a). The disease is most commonly associated by the presence of spirochete bacteria and slurry conditions (Watson, 2007). Digital dermatitis could develop to more chronic disorders such as HHE (fig. 5), IH (fig. 6) and verrucose dermatitis (papillomatous digital dermatitis; PDD; fig. 7). Heel horn erosion causes a great loss of horn of the bulbs, which exposes the corium (Manske *et al*., 2002a), and IH causes an outgrowth of the interdigital skin.

Papillomatous digital dermatitis on the other hand is the stage where hyperkeratosis occurs, and a wart-like growth appears in the dermatitis earlier described (SVA, 2017).

Figure 5. Heel horn erosion (Photo Christer Bergsten).

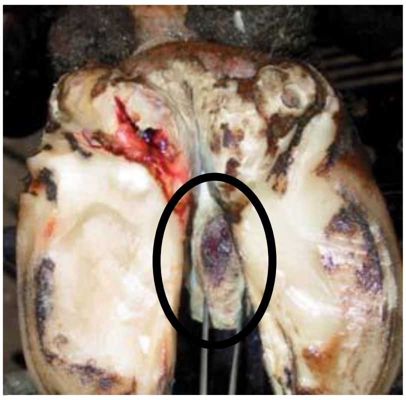

Figure 6. Interdigital hyperplasia (Photo Christer Bergsten).

Figure 7. Verrucose dermatitis (Photo Christer Bergsten).

Horn-disorders

Horn-disorders are often associated with laminitis, also known as founder, which is an inflammation of the laminar corium of the claw (Manske *et al*., 2002a). Laminitis is a painful disease, which may cause ulceration of the heel, white-line, toe or sole (Ossent & Lischer, 1998). One theory describes that the disease starts because of a disruption of the blood flow in the corium (Ossent & Lischer, 1998). Oxygen deficiency will occur in the wall of the blood vessels, damaging the tissue. This causes an outward passage for blood cells and a permeability for fluids (serum) which could cause haemorrhages and discolorations of the horn tissue. Oedema occurs and the soft tissues of the claw will push towards the horn capsule, causing a lot of pain for the animal (Ossent & Lischer, 1998). The production of keratin is disrupted because of the decreased blood flow and causes a reduction of horn production. The junction between the claw wall and the corium becomes damaged and the wall will eventually detach from the corium. The structure of the claw will therefore lose the weight-carrying function and the claw bone may sink and drop downwards, which causes an increased pressure of the corium (Ossent & Lischer, 1998). This compression could lead to several claw lesions like: SU (fig. 8), SH (fig. 9), WLD, double sole (fig. 10) and underrunning of the heel (Ossent & Lischer, 1998). The site of the compressed corium determines where the ulceration appears; in the toe, heel or white-line area (Ossent & Lischer, 1998). The WLD is a general term for disorders of the white-line area; white-line ulcer (WLU), white-line haemorrhage (WLH; fig. 11), white-line fissure and white-line abscess (WLA; Watson, 2007). The disease appears due to the same physical response as in laminitis, but it is the white-line junction of the posterior wall, in particular, that becomes weakened in the early development of the disorder (Watson, 2007).

Figure 8. Sole ulcer (Photo Christer Bergsten).

Double sole or underrunning of the heel occurs after a laminitis outbreak where the horn-production has been completely disrupted for a limited time. The horn-producing cells does thereafter recover, and new horn is produced. The problem appears when the old horn dries out, which causes a cleft between the new and old horn, placed in the sole, white-line or heel (Ossent & Lischer, 1998).

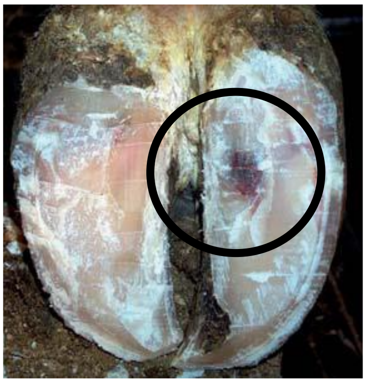

Figure 9. Sole haemorrhage (Photo Christer Bergsten).

Figure 10. Dubble sole (Photo Christer Bergsten).

Figure 11. White-line haemorrhage (Photo Christer Bergsten).

Lameness

Lameness is a symptom of a disorder in the musculoskeletal system or pain in the limb or foot, which affects cows' ability for physical movement (Bergsten, 2001). Lameness is thus affected by the same factors as claw and leg disorders such as management, nutrition, genetics, housing and environmental hygiene (Shearer *et al*., 2012). Significant symptoms of lameness are; an arched back, uneven weight distribution between legs (Flower & Weary, 2009), subnormal standing and resting behavior and decubital injuries, which indicates an increased lying time (Manske *et al*., 2002a). A study examining 340 British dairy herds found a yearly lameness incidence of nearly 24 % (Whitaker *et al*., 2000). The prevalence of lameness in Swedish dairy cows seems to be much lower. In fact, only 5 % out of 4,899 dairy cows in 101 Swedish farms with tie-stalls or free-stalls was lame year 1996 – 1998 (Manske *et al*., 2002b). A recent study in organic herds in four European countries showed that Swedish lameness figures were considerably lower (5 %) than in Spain (10 %), Germany (20 %) and France (25 %; Sjöström *et al*., 2017)

Free movement and social interactions are some of the positive aspects with a free-stall system. However, in a free-stall system, the cow is dependent on being able to walk to reach resting areas, feed stations, water cups and the milking area. A lame cow will have major difficulties in doing so (Telezhenko *et al*., 2008). Lameness is concluded to be one of the most important issues affecting animal welfare in dairy cattle (Rushen & de Passille, 2009). Venutra *et al*. (2015) summarized a dairy cattle welfare meeting held in Canada year 2012. The participants were veterinarians, students, specialists, dairy producers and academics. They discussed factors affecting animal welfare such as cow comfort, mortality, injuries and diseases. However, lameness was outspoken to be the major problem affecting animal welfare in dairy production.

This was because of its painfulness and long durability, which often leads to a loss in production and an increased culling rate.

2.3.4 Associations between housing and floor types with claw disorders and lameness

The health of the claws is affected by several factors such as housing system, management, hygiene, genetics and claw conformation (Bergsten, 2001). Especially, floor type has a great effect on the prevalence of claw disorders (Rushen & de Passille, 2009) and lameness (Faull *et al*., 1996), it is therefore the primarily focus of this thesis.

Skin-disorders

The hygiene of the floors is important to maintain good claw health, where the presence of manure make the claws moist and simplifies entrance for infectious agents (Bergsten, 2001). The draining ability is therefore an important floor characteristic regarding the risk of skin-disorders (Wells *et al.* 1999). Digital dermatitis (Rushen & de Passille, 2009) and HHE have been found to increase when the floors are not properly cleaned (Bergsten & Pettersson, 1992; Rushen & de Passille, 2009). A study in the US investigated the incidence of PDD in 4,516 dairy farms and the effect of floors with different abrasiveness, slipperiness and draining ability (Wells *et al*., 1999). The results showed that cows in farms with grooved concrete floors had the highest frequency of PDD (49.5 %) followed by farms with smooth concrete (32.3 %), textured concrete (32.2 %) and dirt pasture (23.3 %). Moreover, Norberg (2012) found an increased risk of HHE on rubber floors compared with concrete floors. However, this result is proposed to be an effect of poor hygiene management (Wells *et al*., 1999).

Horn-disorders

An abrasive floor that results in too much wear of the claws could make the sole thin and sore (McKee & Dumelow, 1995; Bergsten, 2001; Bergsten *et al*., 2015). This increases the risk for traumatic laminitis (Bergsten, 2001). Bergsten *et al*. (2015) found that concrete floors had an unfavorable effect on horn-diseases, where the prevalence of SU, SH and WLH increased when the cows were held on slatted concrete floors after calving, compared with slatted rubber floors. In accordance with Bergsten *et al*. (2015), Frankena *et al*. (1992) concluded that the floor type had a significant influence. They investigated the frequency of SH in 1,141 female calves and found that calves held in straw yards had a lower frequency (4.6 %) compared with slatted concrete floors, who had ten times higher problems (44.6 %). The frequency of hoof diseases did also seem to be affected by the season. Murray *et al*. (1996) was in agreement, they concluded that the incidence of SU, WLD, DD and HHE increased when the animals were housed during the winter season compared with pasture, during summer.

Lameness

Suboptimal floors have a great influence on the frequency of lame cows (Rushen & de Passille, 2009; Solano *et al*., 2015). Slippery floors have been found to increase the risk of lameness in cows compared with non-slippery floors (Solano *et al*., 2015). Faull *et al*. (1996) found that a smooth floor surface in walking passages was associated with an increased frequency of lame cows, compared with rougher floors. Vokey *et al.* (2001) suggested that concrete floors in general could be linked with a higher risk of claw disorders and lameness, and other studies confirm this theory (Norberg, 2012; Bergsten *et al.*, 2015). Norberg (2012) examined the frequency of lameness in cows, comparing rubber and concrete floors. The prevalence of lame cows was concluded to be higher for cows held on concrete floors. It has also been shown that cows moved from soft rubber floors to hard concrete floors directly after calving had a higher frequency of lameness, compared to cows that was moved from hard to softer floors after calving (Bergsten *et al.*, 2015). The cows are, however, stated to adapt to hard floors and the recommendation is to move the animals to the harder floor at least one month before calving (Bergsten, 2001) or better leaving them on the present floor for a time after calving. An association between farm size and lameness has also been found, where large farms had a higher prevalence of lameness compared with smaller ones (Whitaker *et al.*, 2000). Whitaker *et al.* (2000) did also find that cows housed in a free-stall barn had an increased prevalence of lameness compared with cows held in straw yards. The prevalence of lameness was found to increase from January to April, and the lowest rate was found in August, in both housing systems.

2.4 Fertility

This chapter describes some aspects regarding cattle's fertility such as common fertility parameters measured, expression and onset of *oestrus*, the importance of a proper management strategy and how fertility is influenced by different floor types and claw disorders.

2.4.1 Fertility data

The fertility on farm-level can be investigated by measuring several different fertility parameters. The most commonly used parameters are; calving to first insemination (CFI), calving to last insemination (CLI), calving interval (CI), conception rate in cows receiving artificial insemination (AI), non-returns at 56 days after AI (NR), number of AI per cow and age at calving. The traits are recorded in those farms who are affiliated to the Swedish milk recording scheme and a yearly summary of these traits is published by Växa Sverige. The results of the milk-recording year of 2015/2016 are shown in table 1, including 2,783 dairy herds.

2.4.2 Oestrus and ovulation

Estrus, also known as *oestrus* in Latin, is normally observed every 21st day in cattle and lasts for 4-24 hours (Skidmore, 2015). The mean duration of *oestrus* has been observed to be 5.2 ± 0.9 hours, by Lopez & Shipka (2003). As reviewed by Skidmore (2015), ovulation occurs 24-32 hours after *oestrus* starts and it is a short time frame of 12 hours, where it is optimal to inseminate the cow in order to have the greatest chance of conception. Furthermore, there are some physiological and behavioral signs that is strongly connected with *oestrus*; mounting behavior, swollen vulva, increased activity, increased interaction with other cows, clear and sticky vaginal fluid, decreased apatite and lower milk yield. These signs are important to take into consideration in the management strategy for heat detection. However, the most obvious sign of *oestrus* is when the cow stands still to be mounted, also known as standing heat.

Table 1. Fertility data from the Swedish milk recording year 2015/2016 (Växa Sverige, 2016). The traits included are; calving to first insemination (CFI), calving to last insemination (CLI), calving interval (CI), conception rate in cows receiving artificial insemination (AI), non-returns at 56 days after AI (NR), average number of AI per cow and average age at calving for Holstein cows and average age at calving for SRB. This is presented as mean values for the 2,783 herds included

Trait	CFI (days)	CLI (days)	CI (months)	Conception rate AI (%)	NR (%)	Average number of AI/cow	Average calving age Holstein (months)	Average calving age SRB (months)
Mean value	84	121	13.1	41.5	65.3	1.8	27.3	27.5

2.4.3 Importance of oestrus detection

In order to produce milk, the cow need to give birth, preferable once a year. Artificial insemination is the most common practice in order to get the dairy cow pregnant. However, in order to receive conception, the AI need to be performed at *oestrus*, as mentioned before. The short time frame of ovulation will therefore make the management strategy challenging and detecting *oestrus* becomes really important (Skidmore, 2015). The farm economy will suffer if the management for *oestrus* detection fails and you can expect longer CIs, lower conception rates, longer dry periods and extended lactations. Fertility disorders and poor fertility performances (e.g. stillbirths, infertility and extended CIs) have been confirmed to be one of the most common reason for culling in dairy farms in Sweden (Alvåsen *et al.*, 2014) and in England (Whitaker *et al.*, 2000). A proper strategy to detect *oestrus* could therefore improve farm economy by reducing the total culling rate on farms (Whitaker *et al.*, 2000).

2.4.4 Associations between floor type and oestrus expression

The fertility is affected by different nutritional and physiological aspects. Indirectly, floor type has a great influence on the fertility, which have been evaluated in several studies (Britt *et al.*, 1986; Platz *et al.*, 2008; Palmer *et al.*, 2012). An old and slippery concrete floor have a negative effect on the ability to express *oestrus* (Palmer *et al.*, 2012). They concluded that the frequency of mounting behavior increased in the time period around standing heat, for cows on pasture. However, no significant change was found in the cows kept in a free-stall system with concrete floors. Moreover, the frequency of cows in standing heat, was higher among cows on pasture compared with those in free-stalls. Behaviors like sniffing and licking other cows´ genital parts increased in the pastured cows, during 48 h around *oestrus*, although, no significant increase was observed in cows in the free-stalls (Palmer *et al.*, 2012). Furthermore, Platz *et al.* (2008) observed that mounting behavior was significantly higher in cows on rubber mats compared to cows on slatted concrete (112 and 23 observations of mounting behavior, respectively). Similar results were found for hygiene behavior, i.e. caudal licking, where cows on rubber mats performed the behavior four times more often compared with cows on slatted concrete (Platz *et al*., 2008). Furthermore, grooming behavior decreased in cows on concrete floors compared with those on rubber floors (Norberg, 2012). These results are in agreement with Lopez and Shipka (2003) who concluded that the surface of the floor had an effect on both expression and onset of *oestrus*. Their results showed that cows mounted each other more frequently in an open dirt lot, compared to in a free-stall barn with concrete floors. The onset of *oestrus* did also differ between the groups where 67.7 % of the *oestrus* bouts were observed in the dirt lot and only 32.3 % in the free-stall (Lopez & Shipka, 2003). Britt *et al*. (1986) did also observe a difference in *oestrus* expression when comparing cows in a dirt lot or on grooved concrete floors. In their study, they induced *oestrus* by hormonal treatment and thereafter observed the cows' behavior. They concluded that cows in a dirt lot had a higher frequency of mounting behavior and standings to be mounted, and the duration of *oestrus* increased with 4.4 hours, compared with cows on grooved concrete. It was therefore more difficult to detect *oestrus* in cows on concrete floors compared with those in a dirt lot; the detection rate was 76.8 % and 91.3 %, respectively (Britt *et al*., 1986).

These studies confirm a connection between mounting behavior and floor type, where the frequency of mounting behavior decreased when the slipperiness of the floors increased (Britt *et al*., 1986; Lopez and Shipka, 2003; Platz *et al*., 2008; Palmer *et al*., 2012). A trend of falling and slipping while trying to mount another cow was observed on slippery surfaces (Platz *et al*., 2008; Palmer *et al*., 2012). The decreased frequency of mounting behavior was therefore suggested to decrease because of too slippery floors. Mounting were forced to be aborted (Palmer *et al*., 2012).

2.4.5 Associations between claw disorders and fertility

A significant association between the presence of WLD, SU and fertility performance has been found in several studies (Hultgren *et al*., 2004; Charfeddine & Pérez-Cabal, 2017). The period of infertile days between *oestrus* cycles, also known as anestrus, increased when the cows had a claw disorder (Charfeddine & Pérez-Cabal, 2017). The white-line disease had a great influence on the CFI where a severe case of WLD increased the interval four times, compared with a mild case (Charfeddine & Pérez-Cabal, 2017). It was also found that WLD and SU increased the period of days open (DO), which is calculated by subtracting the CI (days) with the pregnancy period of 282 days. Cows with severe cases of the diseases and cows in early lactation had longer DO compared with mild cases of WLD or SU, or cows in mid/late lactation (Charfeddine & Pérez-Cabal, 2017).

2.5 Mortality

The most common culling reasons in several countries is presented in this chapter together with some methodological issues regarding mortality studies. The problem with downer cows and falling injuries are also included.

2.5.1 Culling reasons on farms

High mortality rates on farms contribute to economic losses and indicates poor animal health and welfare. Alvåsen *et al.* (2014) studied reasons for mortality and slaughter in 209,236 cows by analyzing one year of data from the Swedish milk recording scheme. Among slaughtered cows, the most common culling reason was due to udder disorders (30.6 %) followed by fertility problems (25.2 %), low milk yield (12.7 %) and claw and leg disorders (6.6 %). Cows in 2^{nd} parity had the lowest risk to be culled compared with cows in higher parities and the major risk group was cows in early lactation. The reported culling reasons from the Swedish milk recording scheme in 2015/2016 had similar results (Växa Sverige, 2016). The total percentage of culled cows were 34.1 % and the most common culling reason was due to udder disorders (9.1 %), fertility problems (7.8 %) and claw and leg diseases (3.0 %; Växa Sverige, 2016).

Thomsen *et al.* (2004) evaluated mortality in 196 Danish dairy herds, by a survey. The results showed that 58.2 % of the culled cows were euthanized and the remaining cows died unassisted. Out of the total mortality figures, disorders of the locomotor system (40 %), accidents (12 %) and digestive disorders (11 %) were the most common reasons. The milk recording scheme in Denmark is called the Danish Cattle Database and Thomsen *et al.* (2006) evaluated mortality risk factors on farm level in 6,839 herds from this database. They concluded that the management system affected the risk for mortality. Cows in free-stalls and tie-stalls had a higher risk for mortality compared with cows in straw yards. A similar study was made by Whitaker *et al.* (2000) who evaluated reasons for culling in 340 dairy farms in England, including 45,220 cows. The results showed that the mean culling rate on farms was 22.1 % over a 12-month period and the most common reason for culling was due to infertility (3.6 %), followed by low milk yield (2.0 %), lameness (2.0 %) and mastitis (1.7 %). A strategy to improve fertility performance was therefore out spoken to be of great importance to reduce the total culling rate on farms (Whitaker *et al.*, 2000). Furthermore, Charfeddine & Pérez-Cabal (2017) found that the presence of SU and WLD reduced the cows' expected length of productive life (LPL) up to 71 days. Claw health is therefore also important to have in consideration in order to reduce the mortality rate.

2.5.2 The reliability of mortality studies

Thomsen *et al.* (2012) did a necropsy of 79 Danish dairy cows to compare the cause of death with previously reported culling reasons by farmers and veterinarians. They found pneumonia and disorders in the locomotor system to be the most common reasons for culling. They also confirmed that the necropsy-result corresponded with the farmers reported culling reason in 50-64 %, while only 34-39 % of veterinary reported disease treatments in the Danish Cattle

Database resembled. Studies examining mortality reasons in dairy cows is often based on reported health data from farmers or veterinarians, and the reliability of these studies could thus be questioned (Thomsen *et al*., 2012). Thomsen & Houe (2006) stated the importance of a homogenous study design and method for sampling to be able to compare different study results. They came to the conclusion that information regarding methodology and the primary reasons for death is often presented differently in studies examining mortality.

2.5.3 Falling injuries causing downer cows and muscle strain

Downer cow syndrome is defined as when the cow is not able to raise and walk by itself and becomes non-ambulatory (Grandin, 2001). The locomotor system has been damaged as a primary traumatic insult and/or secondary after another primary reason (Green *et al*., 2008). The cause of downer cow syndrome can thus be divided into four categories; injuries caused by primary trauma, secondary to a metabolic disturbance, toxic disorder or an infectious disease (Green *et al*., 2008). The most studied cause of downer cows is hypocalcemia. However, this thesis is focusing on injuries caused by slipping and falling due to slippery floors, and there is a lack of research in this specific area.

Green *et al*. (2008) studied downer cows in 1,822 US dairy herds to find risk factors on herd level and the probability for recovery. The study was based on a questionnaire and the result showed that the most common reasons for downer cow syndrome was due to injuries at calving (23.3 %), falling, slipping or lameness (20.9 %), hypocalcemia (19.0 %) and other reasons (36.8 %; Cancer, severe mastitis, metabolic and digestive disorders etc.). Grandin (2001) stated that lame cows had a greater risk of receiving downer cow syndrome, and injuries caused by trauma increased when the floors were slippery. Slippery floors increase the risk for the type of muscle injuries seen when the cow loses her grip and falls in a spread-eagled position, stretching out with her legs extended (Constable, 2016). Traumatic injuries like this causes severe muscle strain injuries, leading to downer cow syndrome (Constable, 2016). In accordance with Constable (2016), Green *et al*. (2008) concluded that cows kept on concrete, or other potentially slippery floors have a greater risk for downer cow syndrome, compared with cows on pasture.

The proportion of cows that managed to recover from the syndrome, including all underlying causes, was 32.9 % if the cow had been non-ambulatory for less than 24 h (Green *et al*., 2008). The recovery rate decreased down to 8.2 % after 24 h. The percentage of cows that recovered from the syndrome caused by slipping, falling or lameness was only 9.3 % while 50.1 % of downer cows with hypocalcemia recovered (Green *et al*., 2008).

3. MATERIAL AND METHODS

This chapter is divided in to tree parts, the first part presents the criteria and steps used for farm selection, secondly is a description of the processes for the questionnaire study and lastly the epidemiological study.

3.1 Selection of herds and animals

A register of herds that contracted Växa Sverige to adjust their slippery concrete floors by grooving was used. The first selection of herds was made by criteria 1; grooving had been made at least 6 months prior to the start of this study. The earliest start date of grooving was 2015-10-22 and the last included herd was grooved 2017-03-31. This resulted in 287 herds with available contact details, which received an online questionnaire (Appendix 1). However, further selection was made after the farmers replied (n=83), by criteria 2; milk production was the main production form and the floors of walking and standing areas for lactating cows were grooved. This resulted in 53 respondents, which were included in the questionnaire study (see section 3.2).

A further collection of questionnaire-replies (from farmers who had not responded; n=204) was made to receive more data for the epidemiological study (see section 3.3). This was made by telephone interviews by agro technician student Janna Borell as a part of her practice. Another 65 herds replied and fulfilled criteria 1 and 2. This resulted in a total of 118 herds (including the 53 respondents from the online questionnaire). These herds were affiliated to some degree to the Swedish official milk and health recording scheme (SOMHRS), which obtains records about milk production, housing, fertility parameters, diseases and culling, and were used in the epidemiological study. Furthermore, 236 control herds, who had available data in the SOMHRS were also included in the epidemiological study.

3.2 Questionnaire

In this descriptive cross-sectional study, a questionnaire was designed to obtain information why farmers grooved their floors and their experienced effect regarding fertility and health before and after grooving. Experts in alley flooring, statistics, cattle fertility and claw health were consulted about the formulation of questions and design of the questionnaire. The questionnaire platform used was https://sv.surveymonkey.com and the final 34 questions are presented in Appendix 1. When the questionnaire was finished, a test-version was sent by e-mail to foreman Marcin Surminski at the Swedish livestock research center, SLU Lövsta, to receive feed-back from an impartial farmer who recently grooved the alley floors. However, no further changes were required. The questionnaire was thereafter sent by e-mail to 287 farmers. The farmers who did not respond to the questionnaire in the first 14 days received a reminder by e-mail and the online-questionnaire was closed day 33. The replies from the questionnaire were collected and complied in an Excel-document and thereafter summarized using descriptive statistics.

3.3 Epidemiological study

Data was obtained from the SOMHRS in order to investigate how health, fertility and culling were affected by grooving. There were available data from 118 herds that had grooved their floors ($H_{Grooved}$). Data from herds who had not grooved their floors was also collected ($H_{Control}$, n=236) where two matching $H_{Control}$ was collected per $H_{Grooved}$. The matching was based on housing- and milking system, herd size, breed and stage of location. Data was obtained for the 6-month period prior the start of grooving ($period_1$) and 6-month period after the grooving was finished ($period_2$) for both $H_{Grooved}$ and $H_{Control}$ herds. Furthermore, the time from start of grooving till end of grooving in $H_{Grooved}$ herds varied from 0 to 467 with a median of 61 days. This means that some herds grooved more than one floor section per barn on different dates. Not all herds had complete data for all variables investigated, hence, the number of observations varied. The mean CFI and CI for the cows present in $period_1$ and $period_2$ were calculated for each farm. Calculations were also made for the periods of interest for the proportion of veterinary-treated cases; in total, due to claw- and leg disorders and due to fertility problems or trauma, of total number of lactating cows. Moreover, culling in total, culling due to claw- and leg disorders and culling due to fertility problems (of total number of cows present in the herd during periods of interest) were also included. Not all herds had records of claw trimming ($H_{Grooved}$, n=86, $H_{Control}$, n=170). However, those which had information of the total number of cows with; remarks, DD, SH, HHE and SU, out of total number of claw trimmed cows during periods of interest, were included.

A paired t-test (for normally distributed variables) or Wilcoxon signed-rank test (for non-normally distributed variables) was used to compare the variables of interest between $period_1$ and $period_2$. Moreover, these values were also compared for the matched $H_{Control}$ herds, with the same time restriction ($period_1$ & $period_2$). All statistical analyses were performed in Stata 15, StataCorp LLC, 4905 Lakeway Drive, College Station, TX 77845, USA by Ann Nyman, epidemiologist, Växa Sverige.

4. RESULTS

The results are divided in to two parts, firstly the questionnaire and secondly the epidemiological study.

4.1 Results questionnaire study

Some of the questionnaire results, regarding farm and house characteristics, will not be fully described in this chapter. However, these results are included in Appendix 2, table 8.

4.1.1 Response rate questionnaire

The questionnaire was sent to 287 farmers by e-mail of which 83 responded (general response rate; 29 %). Out of these farmers, 75 % were dairy producers, 23 % beef producers and 2 % had cattle for recruitment. Out of the 62 dairy producers, 53 of them had grooved the floor in the area where dairy cows were kept and were included in the study. The actual response rate was 19.5 %, only including those herds that met the criteria, and could be of use in the study.

4.1.2 Information about grooving

Farm information regarding the section for grooving and the farmers assessments about the grooving service by Växa Sverige are shown in table 2. The results showed that he majority (76 %) of farmers grooved their concrete floors because they experienced slippery floors which restricted normal cow locomotion. 14 % of the farmers stated problems with muscle strain injuries due to falling as the primary reason for grooving, while others (3 %) decided to groove the floor because of weak *oestrus* expression. The time frame from idea to execution by booking the grooving service was mostly shorter than six months, but some waited a bit longer (tab. 2). The floor section of grooving in the stables varied between herds and most of the herds grooved more than one floor section. All of the farmers included in the questionnaire-study grooved the floors where lactating dairy cows where kept, but some of them also grooved the floors for recruitment animals, steers, bulls and dry dairy cows. The overall opinion of the satisfaction of the grooving was examined by a scale ranging from 1 (dissatisfied) to 5 (very pleased) and 80 % of the farmers replied 4 or 5 (tab. 2 and fig. 12).

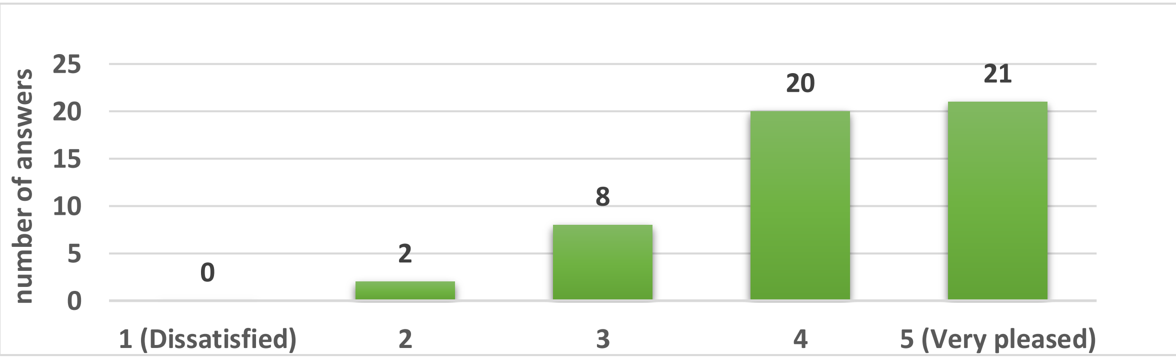

Figure 12. Farmers (51) satisfaction of the effect of grooving in a scale from 1-5, 1=dissatisfied and 5=very pleased; 1 (0 %), 2 (3.9 %), 3 (16.7 %), 4 (39.2 %), 5 (41.2 %).

Table 2. Number of answers (n) and distribution (% of actual replies) of each alternative in the questionnaire regarding the grooving. Number of missing answers (n) and distribution (% of total respondents, 53 farmers) of each question in the questionnaire

Grooving information	**n**	**%**
Reason for grooving (more than one alternative could be chosen)		
Slippery floors and/or poor traction	45	76.3
Cows had falling injuries causing muscle strain	8	13.6
Cows had weak expression of *oestrus*	2	3.4
Preventive measurement	1	1.7
Lame cows	1	1.7
Uneven floors or installation of cow brush	2	3.4
Time frame from idea to decision to groove		
< 6 months	28	53.8
6 months - 1 year	13	25.0
1 - 2 years	10	19.2
> 2 years	1	1.9
(Missing answers)	(1)	(1.9)
The reason for choosing Växa Sverige (more than one alternative could be chosen)		
Recommendations	29	49.2
Växa Sverige have the fastest alternative	8	13.6
Because of Växas Sverige´s advertising and marketing, e.g. at the Elmia fair	6	10.2
Växa Sverige have the only known company that performs grooving	5	8.5
A coincidence	4	6.8
Växa Sverige have the cheapest alternative	2	3.4
Växa Sverige receive the best results	2	3.4
Växa Sverige have the easiest and most reliable alternative	1	1.7
I want to benefit Swedish labor	1	1.7
(Missing answers)	(1)	(1.7)
The satisfaction of the result of grooving (scale 1-5)		
1 (Dissatisfied)	0	0
2	2	3.9
3	8	15.7
4	20	39.2
5 (Very pleased)	21	41.2
(Missing answers)	(2)	(3.8)

Table 2. continued

Grooving information	n	%
Floor sections grooved (more than one alternative could be chosen)		
Free-stall alleys	41	30.4
Feeding alley	27	20.0
Alley between rows	27	20.0
Holding pen	24	17.8
Alley to milking parlor/automatic milking system	15	11.1
Floor in barn for recruitment	1	0.7
(Missing answers)	(1)	(1.9)
Animal categories kept on the grooved floors		
Lactating cows	37	69.8
Lactating cows and recruitment	12	22.6
Lactating cows and dry cows	2	3.8
Lactating cows, recruitment and bulls	1	1.9
Lactating cows, recruitment and steers	1	1.9
Likelihood to recommend Växa Sverige´s service		
Likely	32	62.7
Possible	16	31.4
Less likely	3	5.9
Unlikely	0	0
(Missing answers)	(2)	(3.8)
What could the staff from Växa Sverige have made better (more than one alternative could be chosen)		
Shorter waiting time	6	25.0
Another pattern of the grooves to receive a better result	6	25.0
Nothing	4	16.7
Better information about the practical work of grooving and whether and how Växa Sverige needs assistance from the farmer	3	12.5
Cheaper prize	2	8.3
The staff from Växa Sverige should have more experience of animals	1	4.2
More accurate washing of the cutting machine	1	4.2
The staff should bring cake	1	4.2
(Missing answers)	(30)	(56.6)
Advise to someone who has slippery floors		
Groove your floors	20	74.1
Find a solution as soon as possible	4	14.8
Buy rubber mats	3	11.1
(Missing answers)	(27)	(50.9)

4.1.3 Animal health and behavior

All results regarding animal health and behavior are presented in table 4. The management strategies for *oestrus* detection varied between herds, and some of them used more than one method. The most common methods used were a combination between visual observations and predicting *oestrus* date by a calendar. Some of them had an automatic heat detecting system. The farmers and/or employees observed their cows mostly two to four times per day (range 1-7). The artificial insemination was made by the farmer himself, insemination services or employees, while some farmers had a bull as well. Regular fertility service to ensure conception was used by 58 % of the farmers. Moreover, the majority of farmers (69 %) used a breeding advisor routinely. The expression of *oestrus* was, according to most of the farmers (67 %), similar when comparing the expression before and after grooving (tab. 4 and fig. 13). However, those who observed a greater *oestrus* expression and activity after grooving (31 %) said that the cows walked more relaxed, had better traction and mounted each other more frequently because of better footing. However, one farmer said that his floors got more slippery after grooving.

According to 22 % of the farmers, the activity increased after grooving, while similar activity was observed in remaining 78 % (tab. 4 and fig. 14). The increase in activity was seen as an increased mounting behavior, higher feed intake, more AMS visits, increased interactions between cows and more walking. Furthermore, the cows were observed to have a safer, relaxed and more confident locomotion pattern, compared with before grooving (tab. 4). Most farmers (90 %) did not experience that grooving had a direct effect on the wear of the claws (tab. 4 and fig. 15). Remaining farmers answered that claw wear increased after grooving. The presence of muscle strain injuries due to falling did on the other hand have a clear improvement after grooving according to 39 out of 48 farmers (tab. 3 and fig. 16).

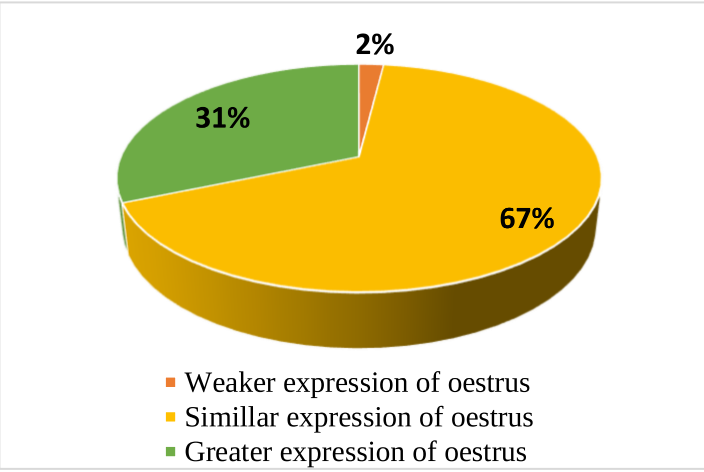

Figure 13. Farmers (51) opinion regarding the expression of *oestrus* after grooving, compared with before.

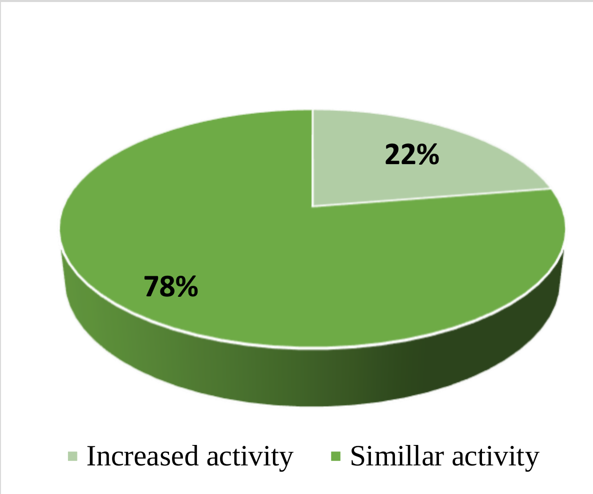

Figure 14. Farmers (49) opinion regarding cows' activity after grooving, compared with before.

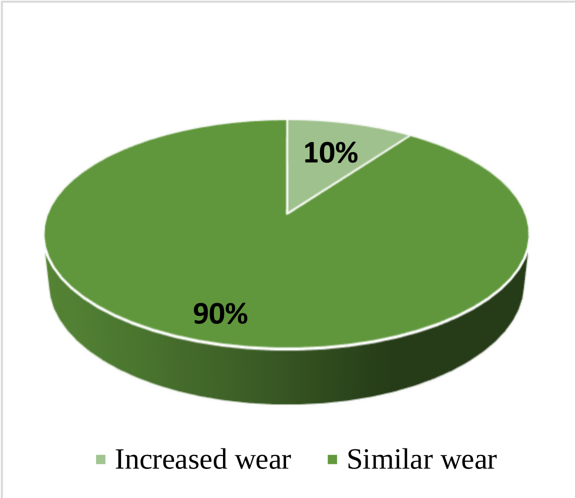

Figure 15. Farmers (50) opinion regarding claw wear after grooving, compared with before.

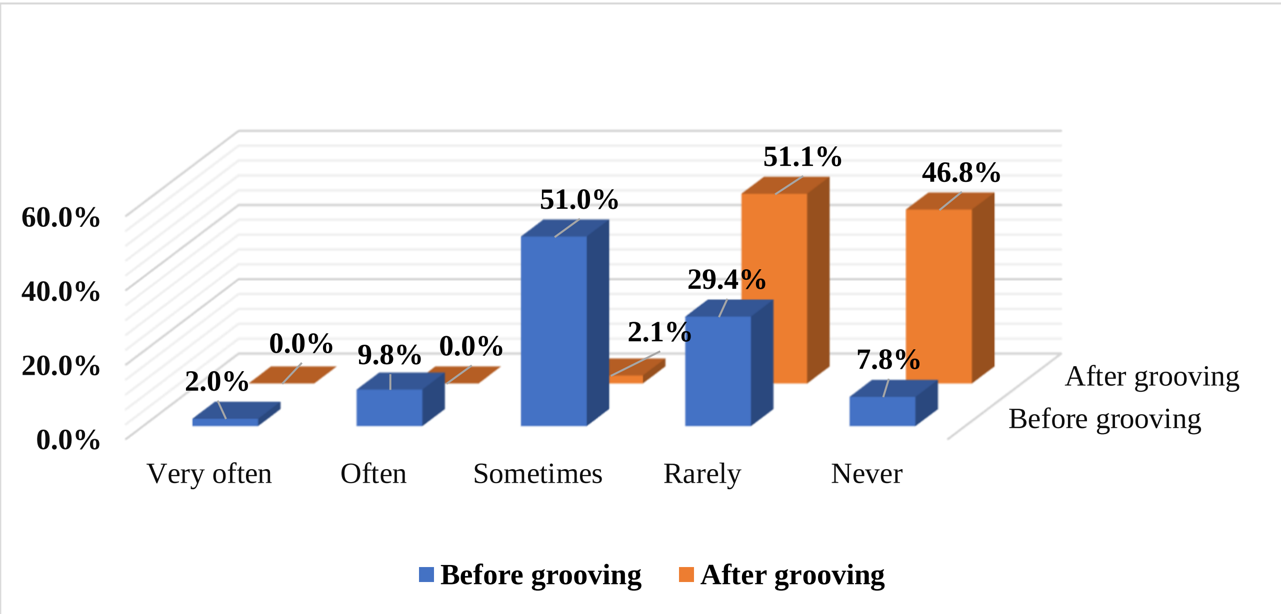

Figure 16. Farmers (48) opinion regarding the frequency of falling injuries causing muscle strain, before and after grooving.

Table 3. Farmers (48) opinion regarding falling injuries causing muscle strain before and after grooving. Number of herds (n) in each category

Before/After	Very often	Often	Sometimes	Rarely	Never	Total
Very often	0	0	1	0	0	1
Often	0	0	0	2	3	5
Sometimes	0	0	6	16	10	32
Rarely	0	0	0	0	7	7
Never	0	0	0	0	3	3
Total	0	0	7	18	23	48

Table 4. Number of answers (n) and distribution (% of actual replies) of each alternative in the questionnaire regarding animal health and behavior. Number of missing answers (n) and distribution (% of total respondents, 53 farmers) of each question in the questionnaire

Animal health and behavior	**n**	**%**
Methods used for *oestrus* detection		
Visual observation	5	9.8
Activity detector/pedometer	7	13.7
Visual observation and calendar*	16	31.4
Visual observation and activity detector/pedometer	9	17.6
Visual observation, calendar and activity detector/pedometer	10	19.6
Visual observation, calendar and manual mounting detector**	2	3.9
Calendar, manual mounting detector and activity detector/pedometer	1	2.0
Visual observation, calendar, activity detector/pedometer and analyze of progesterone in milk	1	2.0
(Missing answers)	(2)	(3.8)
** Predicting oestrus date with help of a calendar, ** e.g. tail painting/scratch card*		
Year when current method to detect *oestrus* was started		
1970 - 1998	10	23.8
1999 - 2006	10	23.8
2007 - 2009	10	23.8
2010 - 2016	12	28.6
(Missing answers)	(11)	(20.8)
Mean number of *oestrus* observations/day		
≤ 2	15	30.6
>2 - 4	20	40.8
> 4	14	28.9
(Missing answers)	(4)	(7.5)
Who performs *oestrus* detection		
Farmer	10	37.0
Employee	2	7.4
Farmer and employee	12	44.4
Automatic system*	3	11.1
(Missing answers)	(26)	(49.0)
**e.g. Heatime*		
Observed effect of grooving on the expression of *oestrus*, compared with before grooving		
Similar expression	34	66.7
Greater expression	16	31.4
Weaker expression	1	2.0
(Missing answers)	(2)	(3.8)

Table 4. continued

Animal health and behavior	**n**	**%**
In which way was the *oestrus* expression considered weaker/similar/greater after grooving		
Similar:		
No change in *oestrus* expression	5	22.7
Difficult to determine	1	4.5
Greater:		
More secure cows, resulting in an increased mounting behavior	12	54.5
Increased activity during *oestrus*	2	9.1
More apparent *oestrus* expression	1	4.5
Weaker:		
The slipperiness increased	1	4.5
(Missing answers)	(31)	(58.5)
Who inseminates the cows		
Farmer	36	70.6
Insemination service	7	13.7
Employee	2	3.9
Farmer and insemination service	3	5.9
Farmer and a bull	1	2.0
Farmer, insemination service and a bull	1	2.0
Insemination service and a bull	1	2.0
(Missing answers)	(2)	(3.8)
Methods used for pregnancy control		
Rectalization*	20	39.2
Analyze of PAG** in milk	14	27.5
Ultrasound	1	2.0
Rectalization and analyze of PAG in milk	12	23.5
Rectalization and analyze of progesterone in milk	1	2.0
Undefined***	2	3.9
No pregnancy control is performed	1	2.0
(Missing answers)	(2)	(3.9)
Rectalization at a certain stage of gestation, ** Pregnancy Associated Glycoprotein, * Pregnancy control is performed by Växa Sveriges staff*		
Regular fertility service is used to find non-pregnant cows		
Yes	29	58.0
No	21	42.0
(Missing answers)	(3)	(5.7)
An external breeding advisor is used		
Yes	33	68.8
No	15	31.3
(Missing answers)	(5)	(9.4)

Table 4. continued

Animal health and behavior	**n**	**%**
Observed effect of grooving on cow activity, compared with before grooving		
Similar activity	38	77.6
Increased activity	11	22.4
(Missing answers)	(4)	(7.5)
In which way activity was considered similar/increased after grooving		
Similar activity:		
No change in activity	3	25.0
Increased activity:		
Walks more. Better traction and less stiff gate	4	33.3
Increased mounting behavior	2	16.7
Higher feed intake	1	8.3
Increased number of milkings/day and passes in smart gate	1	8.3
Changes feeding place more often	1	8.3
(Missing answers)	(41)	(77.4)
Observed effect of grooving on claw wear, compared with before grooving		
Similar wear	45	90.0
Increased wear	5	10.0
(Missing answers)	(3)	(5.7)
Free comments given by the farmers		
- We had some problems with sole abscesses a few weeks after grooving. But this is no longer a problem. Grooving is a good way to make your floors less slippery - even if you can get a few abscesses.	1	33.3
- Grooving have stopped our problem with abscesses of the white-line.	1	33.3
- Good arrangement and well done. Expensive but profitable. However, I should have rented a machine and done it myself instead of waiting.	1	33.3
(Missing answers)	(50)	(94.3)

4.2 Results epidemiological study

4.2.1 Descriptive information about the herds

Descriptive information of the participating herds is presented in table 5.

Table 5. Mean, standard deviation (SD) of performance data, housing, milking system, breed and herd size six months before the start of grooving and six months after end of grooving for number of herds (n) which grooved and for matched control herds that had not grooved

		Herds which grooved		***Matched control herds***	
		6 mo. before	**6 mo. after**	**6 mo. before**	**6 mo. after**
Performance					
Kg milk	Mean	5 607	5 666	5 422	5 471
(6 months)	SD	695	723	777	803
	n	102	103	209	213
BMSCC	Mean	254 000	245 000	256 000	245 000
(Bulk milk,	SD	85 500	84 500	81 000	78 000
cells mL^{-1})	n	102	103	209	213
Housing					
Uninsulated free-stall	n	25	25	50	50
Insulated free-stall	n	82	82	164	164
Milking system					
AMS	n	54	54	108	108
Parlor	n	44	44	88	88
Rotary	n	3	3	6	6
Tie-stalls	n	6	6	12	12
Breed					
SRB	n	11	11	26	26
SH	n	27	27	56	56
SRB*SH	n	59	59	120	120
Other	n	10	10	12	12
Herd size	Mean	159	131	149	126
	SD	98	82	92	78
	n	103	104	211	211

4.2.2 Claw health and fertility

The results of claw health and fertility performance are presented in table 6. The proportion of almost all claw disorders did not differ significantly between the periods, neither for $H_{Grooved}$ nor for $H_{Control}$ herds. However, a decrease was found in remarks in total and SH in $period_2$, compared with $period_1$, for $H_{Control}$ (p=0.02) herds. Regarding the fertility, the CI was longer in $period_2$, compared with $period_1$, in both $H_{Grooved}$ (15 days longer, p<0.001) and $H_{Control}$ (16 days longer, p<0.001) herds. The CFI interval did also increase in $period_2$, compared with $period_1$, in $H_{Grooved}$ herds (2 days, p=0.005). However, no significant difference was found in $H_{Control}$ herds (p=0.35).

Table 6. Mean, standard deviation (SD) of claw trimming and fertility parameters six month before the start of grooving and six months after the end of grooving for number of herds (n) which grooved and for matched control herds without grooving

		Herds which grooved			Matched control herds		
		6 mo. before	**6 mo. after**	***P*-value**	**6 mo. before**	**6 mo. after**	***P*-value**
Claw trimming							
Remarks in total (%)	Mean	39	39	0.25	40	38	0.02
	SD	22	23		22	23	
	n	76	80		154	149	
Digital dermatitis (%)	Mean	3.2	3.4	0.42	3.5	3.6	0.36
	SD	6.5	6.6		6.4	6.5	
	n	76	80		154	149	
Heel horn erosion (%)	Mean	1.7	1.7	0.76	1.7	1.9	0.54
	SD	3.3	3.4		3.5	4.2	
	n	76	80		154	149	
Sole haemorrhage (%)	Mean	18	17	0.20	16	14	0.02
	SD	16	16		14	13	
	n	76	80		154	149	
Sole ulcer (%)	Mean	3.5	3.8	0.76	4.7	3.7	0.20
	SD	2.8	3.9		5.7	4.4	
	n	76	80		154	149	
Fertility							
Calving interval, CI (days)	Mean	377	392	<0.001	380	396	<0.001
	SD	19	37		23	31	
	n	105	105		207	207	
Calving to first insemination, CFI (days)	Mean	78	80	0.005	84	85	0.35
	SD	12	15		22	22	
	n	103	103		207	207	

4.2.3 Culling and veterinary treated diseases

The results of culling and veterinary treated diseases are presented in table 7. The total culling rate, culling due to claw/leg disorders and culling due to fertility disorders increased in $period_2$, compared with $period_1$, in both $H_{Grooved}$ (p<0.001) and $H_{Control}$ (p<0.001) herds. The total prevalence of veterinary treated diseases decreased in $period_2$, compared with $period_1$ for both $H_{Grooved}$ (p=0.01) and $H_{Control}$ (p<0.001) herds. Similar results were seen for the prevalence of veterinary treated cases of claw/leg disorders, which decreased in $period_2$, compared with $period_1$, but the decrease was only significant for $H_{Control}$ (p<0.001) herds. The prevalence of veterinary treated cases of trauma and fertility disorders did not differ between the periods for $H_{Grooved}$ or $H_{Control}$ herds.

Table 7. Mean prevalence (%), standard deviation (SD) of culling and veterinary treated diseases six month before the start of grooving and six months after the end of grooving for number of herds (n) which grooved and for matched control herds without grooving

		Herds which grooved			***Matched control herds***		
		6 mo. before	**6 mo. after**	***P*-value**	**6 mo. before**	**6 mo. after**	***P*-value**
Culling							
In total	Mean	17.0	30	<0.001	16.0	30	<0.001
	SD	4.8	13		5.6	13	
	n	103	103		211	211	
Due to claw and leg disorders	Mean	1.3	2.4	<0.001	1.3	2.4	<0.001
	SD	1.1	2.3		1.6	2.7	
	n	103	104		211	211	
Due to fertility disorders	Mean	3.9	6.8	<0.001	3.7	6.0	<0.001
	SD	2.8	5.3		3.0	4.9	
	n	103	104		211	211	
Veterinary treated diseases							
In total	Mean	10.6	8.7	0.01	9.8	7.8	<0.001
	SD	9.2	7.3		7.9	6.5	
	n	103	103		211	211	
Due to claw and leg disorders	Mean	1.0	0.9	0.80	1.1	0.7	<0.001
	SD	1.6	1.4		1.7	1.1	
	n	103	103		211	211	
Due to trauma	Mean	0.3	0.3	0.29	0.3	0.2	0.25
	SD	0.6	0.6		0.6	0.5	
	n	103	103		211	211	
Due to fertility disorders	Mean	1.4	1.3	0.70	1.3	1.1	0.08
	SD	2.7	2.1		1.7	1.7	
	n	103	103		211	211	

5. DISCUSSION

The most important results from the questionnaire and epidemiological study are discussed in this chapter, as are some methodological considerations.

5.1 Claw health

The purpose of grooving the floor is to increase the friction by different properties and thereby reduce slipperiness. One effect of correct grooving is an increased friction. However, if the floors become too abrasive there is a risk of over wear of the claws (Telezhenko *et al.*, 2008; Bergsten *et al.*, 2015). In the present study, the grooving of floors did not seem to make the floors too abrasive as 90% of the farmers did not recognize any effect on excess claw wear after grooving. This result does on the other hand not reveal the amount of wear or if the herds had problems regarding this. The question was formulated to find out if there was a change in wear before and after grooving. Unfortunately, there were no further questions regarding claw health in the questionnaire, and the results from the epidemiological study did not reveal any differences. The records from claw trimmers used in the epidemiological study (remarks in total, DD, HHE, SH and SU) did not show any significant difference before and after grooving for $H_{Grooved}$ herds. Moreover, there was a significant decrease of remarks in total and for SH for $H_{Control}$ herds in $period_2$. However, there is no evident explanation for this. The effect of increasing the floors friction on the frequency of claw horn-disorders have been shown in several studies (Frankena *et al.*, 1992; Bergsten *et al.*, 2015). The effect of grooving concrete floors on claw horn-disorders is therefore, in this thesis, concluded to be in need for further research.

Skin-diseases are mainly affected by the hygiene of the floors and not the type of floor in particular (Wells *et al.*, 1999; Bergsten & Pettersson, 1992; Rushen & de Passille, 2009). Hence, we did not expect any difference before or after grooving. This assumption was confirmed in the epidemiological study where no significant difference between $period_1$ and $period_2$ in the frequency of DD and HHE was found. In a study by Norberg (2012) it was concluded that HHE increased for cows kept on rubber floors compared with cows on concrete floors. Skin-diseases should, as previously mentioned, not be affected by the floor type itself but it is indirectly affected by the hygiene management and the ability to clean different type of floors. The results from the questionnaire showed that the manure handling differed among herds, which could indicate a difference in the hygiene of the floors between the herds. The herds had different methods for scraping (automatic scraper with plastic, rubber or steel bottom, tractor, manually or dirt scraper) and the scrapings frequency differed. Moreover, the stocking density, i.e. the number of cows per resting place, will affect floor hygiene and this will interact with number of scrapings per day. The stocking density, method for scraping and number of scrapings per day affect the floor hygiene, my conclusion is that the hygiene management have a greater influence on skin-diseases, than the grooving itself.

5.2 Activity and fertility

The results in the questionnaire showed that 31% of the farmers observed an increase in *oestrus* expression after grooving. This is in line with other studies that have shown that the type of floor has a great influence on *oestrus* expression (Lopez & Shipka, 2003; Platz *et al.*, 2008; Palmer *et al.*, 2012). Furthermore, the main behavior that increased in frequency after grooving, according to the farmers´ response of the questionnaire, was mounting behavior, and this is in accordance with other studies (Lopez & Shipka, 2003; Platz *et al.*, 2008; Palmer *et al.,* 2012). This behavioral improvement was suggested to be related to a safer footing and less risk of slipping and falling by some farmers in the questionnaire, and by literature (Lopez & Shipka, 2003; Platz *et al.*, 2008; Palmer *et al.*, 2012). Moreover, 22.4 % of the farmers observed an increase in cows´ activity after grooving. The increase in activity could also be related to the *oestrus* expression as an increased activity normally is observed when cows are in *oestrus* (Skidmore, 2015).

The results from the epidemiological study regarding fertility performance did not show any evidence of improvement. The CI increased in $period_2$ for both $H_{Grooved}$ and $H_{Control}$, as did the CFI interval for $H_{Grooved}$. However, it is not possible to relate the impaired CI to the grooving itself because also control herds were negatively affected, suggesting that the extended CI´s must have been affected by other factors besides grooving. Furthermore, there are no relevant explanation why $H_{Grooved}$ had longer CFI intervals in $period_2$. Probably the explanation is the same for CFI as for CI because they are connected to each other. Previous studies indicate that slippery floors have a negative effect on the fertility performance (Lopez & Shipka, 2003; Platz *et al.*, 2008; Palmer *et al.*, 2012). However, there is lack of research regarding grooving in particular and more research is needed to determine its effect on fertility.

Management factors, e.g. how often farmers observe cows in order to find cows in heat, when cows are inseminated in relation to start of *oestrus* etc., have a big impact on the fertility performance in the herd. Evaluating the effect of grooving on fertility performance on herds using the present study outline was not possible as the management strategies found in the results from the questionnaire varied much. There was a variation in management between the herds regarding methods used for; breeding, *oestrus* detection, insemination and pregnancy control. For example, three respondents used an automatic system for *oestrus* detection. These farmers would find cows in *oestrus* even though the cows did not show visual signs of heat (mounting behavior). Grooving would probably, in these cases, not have an effect on the fertility performance. In herds where methods like visual observations and activity detectors were used, grooving could have had a greater impact on the fertility performance. However, if the farmers did not have the skill and time to observe cows in heat, they would not find more cows in heat just due to grooving.

Depending on where heat was observed, the floor section and total area of grooving could affect the ability to observe an increase in activity or mounting behavior. The results from the questionnaire showed that the distribution of floor sections where grooving was performed, differed among herds. In one farm, only the holding pen was grooved. Then, mounting behavior or increased activity could not be expected to be observed at other sections. However, the report from Växa Sverige did not reveal which proportion of the total area of the barn that was grooved, which had been an advantage. The long-term effect of grooving on health parameters, claw health for example, would be easier to measure if 100 % of the barn had been grooved. An increase in activity and greater *oestrus* expression was expected in this study. The low extent of farmers who observed an improvement in activity and *oestrus* expression in the questionnaire could be related to different grooving strategies. Moreover, to have a better measurement of activity and if grooving affects the activity, individual observations of the cows before and after grooving would have been needed.

5.3 Mortality and falling injuries

Most of the farmers in the questionnaire study was satisfied with the results of grooving. The largest improvement was found in the decrease of muscle strain injuries due to falling after grooving, compared with before. However, the epidemiological study could not confirm this. Muscle strain injuries will fall under the group "trauma" in the veterinary treatments for which no significant difference was seen between the period before grooving and the period after grooving. Cows will have difficulties to heal from a muscle strain. The recovery rate for downer cow syndrome due to slipping and falling has been found to be as low as 9.3% (Green *et al.*, 2008), and these cows will eventually be culled. A reduction in total culling rate could have been expected if the number of cows with muscle strain injuries was reduced, but no such evidence was seen in the epidemiological study. In contrast the culling rate increased in period$_2$, compared with period$_1$ in both $H_{Grooved}$ and $H_{Control}$ herds. However, there are no evident explanation for this increase. The fact that culling increased in both grooved and control herds in period$_2$ leads us to the conclusion that these results are most truly dependent on some other factor besides grooving. Moreover, the actual number of cows with muscle strain injuries might not be so high to start with and then the reduction in veterinary treatments and culling would be small. More herds are needed to be included in the study in order to prove such small difference. There is lack of research regarding the effect of grooving on survival and downer cow syndrome due to falling injuries, this should be further evaluated.

5.4 Methodological considerations

More valuable results correlated to the grooving were expected from the epidemiological study. Previous studies have received credible results regarding the effect of different floors on claw health (Frankena *et al.*, 1992; Bergsten, 2001) and fertility (Platz *et al.*, 2008; Plamer *et al.*, 2012). The lack of clear associations between grooving and the variables included in the epidemiological study is probably a result of the chosen study design regarding selection criterion and parameters measured. This should be taken in to consideration when interpreting the results of the present study.

The grooving service had not been in practice for so long and the amount of data available was therefore scarce, due to a limited number of herds and a limited time period. This forced us to include herds who grooved until only six months prior to the start of the study. One confounder is that the time from the start of grooving to end of grooving varied from 0 to 467 among the herds, with a median of 61 days. This means that different floor sections have been grooved at different times. As mentioned before, the data used in the epidemiological study was collected in the 6-month period prior the start of grooving and the 6-months period after the end of grooving. The fertility variables are dependent on a confirmed pregnancy and there is only one pregnancy per year. This means that the CI and CFI have a constant value during the whole lactation, until she calves again and becomes inseminated. Most of the cows in herds with a short period from start to end of grooving should therefore have included the same cow CI and CFI before and after grooving, assuming that these herds did not have several new or culled cows. It had been preferable if the period between the start to end of grooving was long enough to include a second calving. New values for CI and CFI could then be calculated and we could have been able to find the actual effect of grooving. However, the fertility in those herds with a long period from the start to end of grooving could instead have been affected by seasonal effects. Moreover, it would have been preferable if all the herds in the study hade the same length between the start and end of grooving. Grooves effect on fertility can therefore not be neither confirmed nor ruled out.

Another problem is that the status of the floor before grooving was unknown. Most of the farmers replied that they grooved their floors due to slippery floors affecting cows' traction (76.3 %). However, the individual perception of a slippery floor could be very different. This should have been considered with an objective measurement if possible because the effect of grooving is dependent of the status of the floor before grooving. For example, the effect of grooving would be greater on a farm with an extremely slippery floor before grooving compared with a farm with less slippery floors. This means that problems with unfavorable fertility performance, claw health and survival also differed on the herds before grooving and this would affect the outcome of the study result. The management strategies on herds does also affect the outcome of the results. For example, if the farms have inadequate management, which negatively affect the fertility performance, claw health and survival, the effect of grooving itself could be hard to measure. One deficiency with this retrospective study is the lack of knowledge whether the farms had done any other changes in the barn or management in the same period of grooving, which could have affected the outcome of the results as well.

The questionnaire results are of most interest in this study. However, the response rate was very low (19.5 %) and the validity of the results is therefore less likely to be representative for the population of herds which grooved their floors in Sweden. One other thing to consider is the risk of response bias, i.e. that a certain type of farmers answered the questionnaire and that this type of farmers then also has a different strategy when it comes to e.g. management. Therefore, the results should be interpreted with caution. In summary, Växa Sverige received good feed-back from the farmers and most of them would recommended the service to others. However, some farmers would desire a shorter waiting time, better information and an improved grooving pattern.

A suggested future study design is to do an on-farm study and do objective observations of the cows (cow traction, *oestrus* behaviors, claw health, number of muscle strain injuries etc.), the management strategy and the floors status before and after grooving. Automatic mounting and activity detectors could be of great help to investigate mounting behavior and activity. Moreover, the study period should be long enough to be able to include more than one calving period.

6. CONCLUSION

Our hypotheses that grooving would provide a more secure floor was confirmed from farmers who replied the questionnaire. They were satisfied with the grooving and experienced a reduction in muscle strain injuries. Some of the farmers did also experience a higher cow activity and greater *oestrus* expression. However, an improvement of fertility and survival of dairy cows could not be confirmed from the epidemiological study, based on figures from the Swedish official milk and health recording scheme. Furthermore, no evidence was found that grooving lead to an increased risk of claw problems, neither from the questionnaire nor from the claw health reports. My conclusion is that further research is needed to be able to determine grooves effect on claw health, fertility and survival. A future continuing study would need more participating herds and a longer study period, or an on-farm study in one or more herds, with detailed observations on behavior, management and the floors status before and after grooving.

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10. APPENDIX

10.1 Appendix 1

Questions in the questionnaire

The 34 questions included in the questionnaire. The questionnaire was sent to Swedish speaking farmers, and the questions are therefore written in Swedish. Obligated questions are marked with *.

1. Stallinformation

1. *****Gårdens SE-nummer: (Fri text)

2. *****Vilken produktionstyp bedrivs i första hand i din besättning? (Välj ett alternativ)
☐ Mjölkproduktion
☐ Köttdjursproduktion
☐ Övrigt: (Fri text)

3. Vilket år tillverkades golvet där rillningen har utförts? (Välj ett år) *Om flera golv rillades, svara för det golv som avser mjölkkorna*
År 1950–2017

4. Hur gjordes golvets ytstruktur när golvet byggdes? (Välj ett alternativ) *Om flera golv rillades, svara för det golv som avser mjölkkorna*
☐ Brädrivning
☐ Kvastning
☐ Stålglättning eller stålsläde
☐ Mönstring, spårning i våt betong
☐ Annat alternativ: (Fri text)

5. Har det rillade betonggolvet tidigare genomgått golvrillning eller annan halkförebyggande åtgärd sedan byggnationen? (Välj ett alternativ) *Om flera golv rillades, svara för det golv som avser mjölkkorna*
☐ Nej
☐ Ja
☐ Vet ej

6. Om ja, vilken typ av åtgärd vidtogs och vilket år utfördes det? (Fri text)

7. Hur skrapas majoriteten av dina gångar? (Välj ett eller flera alternativ)
☐ Automatisk skrapa med stålkant
☐ Automatisk skrapa med kant av plast eller gummi
☐ Traktor
☐ Annat alternativ: (Fri text)

8. Hur ofta skrapas majoriteten av dina skrapgångar (~antal gånger/dag)? (Fri text)

9. Hur många liggbås finns i besättningen? (Fri text) *Svara endast för de liggbås där lakterande kor hålls*

10. Vilken komfort/liggplats har dina kor (Välj ett eller flera alternativ)

☐ Betong och spån
☐ Betong och halm
☐ Betong och torv
☐ Gummimatta/madrass och spån
☐ Gummimatta/madrass och halm
☐ Gummimatta/madrass och torv
☐ Gummimatta/madrass utan strö
☐ Djupströbädd halm/träspån/kutter/torv
☐ Djupströbädd fiber/torkad gödsel
☐ Sandbädd
☐ Annat alternativ: (Fri text)

11. Hur hög beläggning har du per ätplats (~antal kor/ätplats)? (Välj ett alternativ)

☐ <1
☐ 1
☐ 2
☐ 3
☐ Annat alternativ: (Fri text)

2. Golvrillningen

12. Vad är orsaken till att golvrillningen utfördes? (Fri text)

13. Hur lång tid gick det från tanke till beslut att rilla? (Välj ett alternativ)

☐ <6 månader
☐ 6 månader – 1 år
☐ 1 år – 2 år
☐ >2 år
☐ Annat alternativ: (Fri text)

14. Var i stallet utfördes golvrillningen? (Välj ett eller flera alternativ)

☐ Foderbordsgång
☐ Liggbåsgångar
☐ Samlingsfålla
☐ Drivgångar
☐ Tvärgångar
☐ Annat alternativ: (Fri text)

15. Vilken kategori av djur hålls på den yta där golvrillningen utfördes? (Välj ett eller fler alternativ)

☐ Mjölkande kor
☐ Ungdjur
☐ Dikor
☐ Tjurar
☐ Annat alternativ: (Fri text)

16. Varför valdes Växa Sveriges golvrillning som metod? (Välj ett eller flera alternativ)

☐ Det var det billigaste alternativet
☐ Det ger bästa resultatet
☐ Det var det snabbaste sättet
☐ På rekommendation
☐ Annat anledning: (Fri text)

17. Hur nöjd är du med resultatet av golvrillningen? (Uppskatta enligt skalan nedan, 1= Missnöjd, 5=Mycket nöjd)

1-2-3-4-5

18. Hur sannolikt är det att du skulle rekommendera Växa Sveriges golvrillning till en kollega eller vän? (Uppskatta enligt skalan nedan)

Osannolikt - Mindre sannolikt - Möjligt - Sannolikt

19. Vad hade kunnat göras annorlunda för att göra dig nöjdare? (Fri text)

20. Ge gärna ett gott råd till den som har halkiga golv! (Fri text)

3. Djurhälsa & beteende

21. Vilken/vilka metoder används vid kontroll av brunst? (Välj ett eller flera alternativ)

☐ Visuell observation
☐ Brunstkalender
☐ Manuell upphoppsdetektor (ex. svansfärg/skraplott)
☐ Elektronisk upphoppsdetektor (ex. Heat Watch/Heat mount detector)
☐ Aktivitetsmätare/stegräknare (ex. Heatime)
☐ Analys av mjölkprogesteron (ex. snabbtest, inskickat prov eller Herd Navigator)”
☐ Annat alternativ: (Fri text)

22. När började nuvarande brunstpassningsmetod/teknik att användas? (Ange år och månad)

23. Hur många gånger per dygn görs brunstkontroll, vilka tider och av vem? (Fri text)

24. Hur upplever du styrkan på kornas brunsttecken <u>efter</u> golvrillningen jämfört med innan? (Välj ett alternativ)

☐ Likvärdiga brunsttecken
☐ Svagare brunsttecken
☐ Starkare brunsttecken

25. På vilket sätt anses brunstttecknen vara bättre/sämre? (Fri text)

26. Vem inseminerar/betäcker korna? (Välj ett eller flera alternativ)
☐ Inseminering av djurägare
☐ Inseminering av assistentsemin
☐ Tjur
☐ Annat alternativ: (Fri text)

27. Hur kontrolleras dräktighet? (Välj ett eller flera alternativ)
☐ Inte alls
☐ Rektalisering vid ett visst dräktighetsstadium
☐ Genom tjänsten "Dräktighet Analys" (PAG i mjölken)
☐ Analys av progesteron (ex. Herd Navigator)
☐ Annat alternativ: (Fri text)

28. Används regelbunden fruktsamhetsservice som upptäcker icke-dräktiga djur och åtgärdar det? (Välj ett alternativ)
☐ Ja
☐ Nej
☐ Övrigt

29. Använder du dig av extern avelsrådgivning? (Välj ett alternativ)
☐ Ja
☐ Nej
☐ Annat alternativ: (Fri text)

30. Hur upplever du kornas allmänna aktivitet <u>efter</u> golvrillningen jämfört med innan? (Välj ett alternativ)
☐ Minskad aktivitet
☐ Likvärdig aktivitet
☐ Ökad aktivitet

31. På vilket sätt anses aktiviteten har ökat/minskat? (Fri text)

32. Hur upplever du att slitaget på klövarna har förändrats <u>efter</u> golvrillningen jämfört med innan? (Välj ett alternativ)
☐ Mindre slitage
☐ Likvärdigt slitage
☐ Högre slitage

33. I vilken omfattning har kor halkat så att de har fläkts… (Uppskatta enligt skalan nedan)

<u>Före</u> golvrillningen: Väldigt ofta - Ofta - Ibland - Sällan - Aldrig

<u>Efter</u> golvrillningen: Väldigt ofta - Ofta - Ibland - Sällan - Aldrig

34. Har du några övriga kommentarer?
☐ Nej
☐ Ja (Fri text):

10.2 Appendix 2

Questionnaire results regarding farm and house characteristics

Table 8. Number of answers (n) and distribution (% of actual replies) of each alternative in the questionnaire regarding farm and house characteristics. Number of missing answers (n) and distribution (% of total respondents, 53 farmers) of each question in the questionnaire

Farm and house characteristics	**n**	**%**
Construction year for the floors where grooving was performed		
1974 - 1999	14	26.4
2000 - 2006	13	24.5
2007 - 2010	15	28.3
2011 - 2017	11	20.8
Method used for surface structure during floor construction		
Surface made with a wooden plank or steel beam	16	31.4
Surface made with a broom	16	31.4
Tamping	7	13.7
Slatted floors	7	13.7
Surface made with a sled or rake longitudinal	3	5.9
Do not know	1	2.0
Surface made with a broom, combined with sand painting	1	2.0
(Missing answers)	(2)	(3.8)
Previous floor reconstruction before grooving		
No	40	75.5
Yes	13	24.5
If the floor was previously reconstructed, what kind of method was used?		
Grooving in concrete	8	88.9
Rubber mat	1	11.1
(Missing answers)	(4)	(30.8)
Method for floor scraping		
Automatic scrape with plastic or rubber bottom	24	46.2
Automatic scrape with steel bottom	14	26.9
Not at all due to slatted floors	9	17.3
Tractor	3	5.8
Manually	1	1.9
Dirt scraper	1	1.9
(Missing answers)	(1)	(1.9)

Table 8. continued

Farm and house characteristics	n	%
Number of scrapings/day		
1-7	10	21.7
8–11	10	21.7
12–21	11	23.9
22–96	11	23.9
Continuously	2	4.3
No scrapings due to slatted floors	2	4.3
(Missing answers)	(7)	(13.2)
Number of cubicles		
31 – 70	13	24.5
71 – 83	13	24.5
84 – 130	13	24.5
131 – 380	14	26.4
Bedding materials (more than one alternative could be chosen)		
Foundation		
Rubber mat/mattress	52	96.3
Concrete	1	1.9
Deep bedding	1	1.9
Litter material		
Wood shaving	41	73.2
Straw	13	23.2
Peat	1	1.8
Manure solids/fiber	1	1.8
Number of cows per feeding space		
<1	3	5.7
1	17	32.0
2	20	37.7
3	12	22.6
Absence of feeding stalls	1	1.9