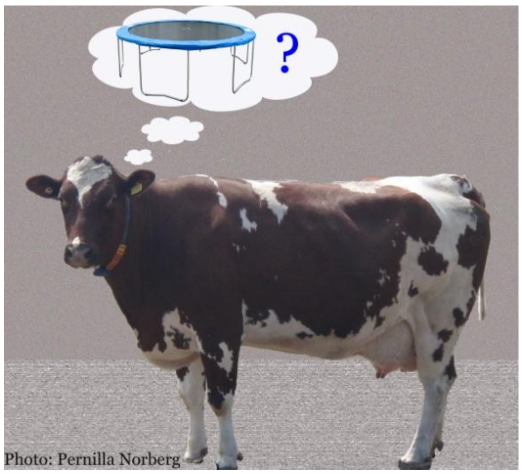
Effects of rubber alley flooring on cow locomotion and welfare



by

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Sveriges lantbruksuniversitet	**30 hp A2E-nivå**
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In cooperation with

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Contents

Abstract

This study investigated the effects of rubber alley flooring on cow locomotion, claw and leg health, production, cleanliness, grooming behaviour and cow exclusion rate in a free stall herd. The study was conducted in a new dairy house with a rotary milking system, with a matched group of cows on traditional scraped concrete alleys used for comparison. All claws were trimmed and lesions recorded at the beginning and end of the 4-month study. Locomotion, claw and leg health, behaviour and hygiene were observed and scored at regular intervals during the study. The results showed that cows on rubber alley floors displayed significantly ($p<0.001$) less lameness than cows housed on concrete. By the end of the study, the risk of disturbed locomotion was at least threefold higher in cows kept on concrete than in those on rubber floors. The results also revealed a negative effect of claw trimming on cow locomotion, with cows in both groups having a higher locomotion score (indicating more severe lameness) after trimming than before. Two out of five cows improved their locomotion after being moved to the rubber floor group due to sore feet. Cows on rubber floors had more heel horn erosion (χ^2; $p<0.001$), but the majority was of a mild form. Only sole ulcers had a slight tendency to affect locomotion. Hair loss on the hocks was the most common hock injury in both groups and, together with hock ulcers, was more common in the cows on concrete. All cows became cleaner during the study period, but cleanliness did not differ between the two treatments. Social grooming behaviour was significantly more common in the cows on rubber (χ^2; $p<0.05$), but milk production was not affected by flooring, possibly owing to differences in feeding systems. The number of excluded cows was greater in the concrete group, mainly owing to thin soles.

Sammanfattning

Syftet med studien var att undersöka hur rörelser, klöv- och benhälsa, produktion, renlighet, putsningsbeteende samt utslagning påverkades med användningen av gummimattor i gödselgångar och vid foderbord hos mjölkkor i liggbåssystem. Studien genomfördes i ett nybyggt stall med mjölkning i karusell och jämförelsegruppen var kor som hade traditionella skrapade betonggolv. Samtliga djur verkades vid studiens början och slut efter 4 månader varvid klövskador registrerades. Rörelser, hasskador, beteende och hygien observerades däremellan. Resultaten från rörelsebedömningen visade att kor på betonggolv hade signifikant mer hälta ($p\leq0.001$) än korna på gummigolv över hela försökstiden. I slutet av studien var risken för rörelserubbning minst 3 gånger högre hos korna som gick på betong än korna som gick på gummigolv. Korna i båda grupperna fick försämrade rörelser efter klövverkningen och två av fem kor förbättrade sina rörelser efter att de flyttats från betonggruppen till gummigruppen på grund av ömma klövar. Klövröta var vanligare hos korna på gummigångar än hos dem på betong (χ^2; $p<0.001$), och det var den milda graden av klövröta som dominerade. Det fanns en tendens till korrelation mellan klövsulesår och hälta men ingen effekt av andra klövsjukdomar. Håravfall på hasor var den vanligaste hasskadan och var tillsammans med hassår vanligare hos kor på betong- än på gummigångar. Samtliga kor blev renare med tiden men det var ingen skillnad i renligheten mellan korna i de två behandlingarna. Socialt putsningsbeteende var signifikant vanligare hos korna på gummigolv ($p<0.05$), men ingen effekt av golvsystem på mjölkproduktionen

sågs, vilket kan ha påverkats av skillnaderna mellan gruppernas fodersystem. Utslagna kor var fler i betonggruppen och främsta anledningen var att korna var ömma på grund av tunna sulor.

Introduction

Dairy farming is a worldwide business. To achieve sustainable milk production, especially in herds with intensive production and high milk yield per cow, careful management is of the utmost importance in ensuring wellbeing, health and longevity.
The free stall system is designed to improve the wellbeing and natural behaviour of cows and to reduce the labour costs per cow. Unfortunately, technical solutions of this type also involve compromises with animal health, such as claw and leg disorders. Due to an increased ability to move around (compared with tie stall systems), the animals´ claws and legs are exposed to more challenges such as contagious agents, traumatic injuries and slippery floors. There is shocking information that mortality figures are increasing in free stall systems. Cow mortality in Danish and Swedish dairy herds is about 5% (Thomsen & Sørensen, 2008) and lameness caused by claw and leg disorders is believed to be one of the main reasons for mortality (Thomsen *et al*., 2007; Christer Bergsten, personal communication 2011). The most critical period for the dairy cow´s health is the transition period. If the cow becomes ill in the period around calving, the whole lactation and fertility can be disturbed, which increases the risk of premature culling.

Management such as claw trimming, feeding and hygiene are important measures in sustaining good claw health in a shorter perspective. In a longer perspective, claw and leg disorders can also be prevented by breeding. However, the most appropriate and efficient approach in daily practice and in the long run is to provide cow comfort in resting and walking areas and thereby minimise the negative influence of free cow traffic in the free stall system.

Aim

The aim of the present study was to assess the influence of rubber floors compared with concrete floors in the alleys (*Figure 1*) and feeding area on cows' locomotion, claw and leg health, cleanliness, grooming and social behaviour, as well as milk production and the number of excluded cows.

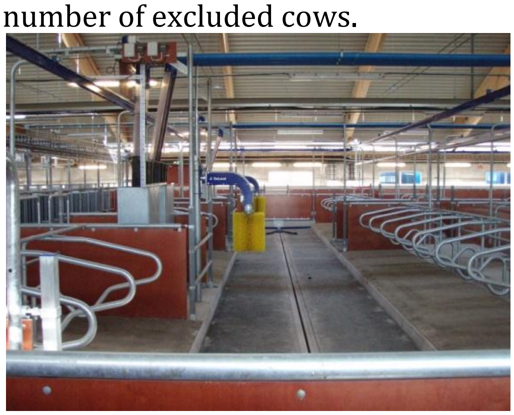

Figure 1. Alley area with rubber floor at Lövsta. Photo: Pernilla Norberg.

Hypothesis
The starting hypotheses for the project were that:

Rubber flooring has a positive impact on locomotion, claw and leg health, grooming and social behaviour and milk yield in dairy cows;

the number of excluded cows is fewer in free stall systems with rubber floors; and

cow cleanliness is not directly influenced by flooring type, though it is interesting to observe.

Literature review

Background

The claw
The claws of a cow are intended for walking on soft surfaces such as grass, sand and mud. This is not the situation in dairy systems today, where more and more cows are housed in loose housing systems, usually on solid or slatted concrete floors.

The foot consists of two claws or digits, one medial (inner) and one lateral (outer). The sole area of the claw is divided into four parts: The sole, the wall, the heel and the white line, which is the fusion between the wall and the sole. In a cross-section of a claw, different layers can be seen: Hoof wall, corium, pedal bone and the arteries for blood support (*Figure 2*). The lateral claws of the rear feet of a milking cow are usually larger and therefore carry more weight than the medial claws. The opposite relationship is found in the fore feet, where the medial claws are larger and carry more weight than the lateral claws (Ossent *et al*., 1987).

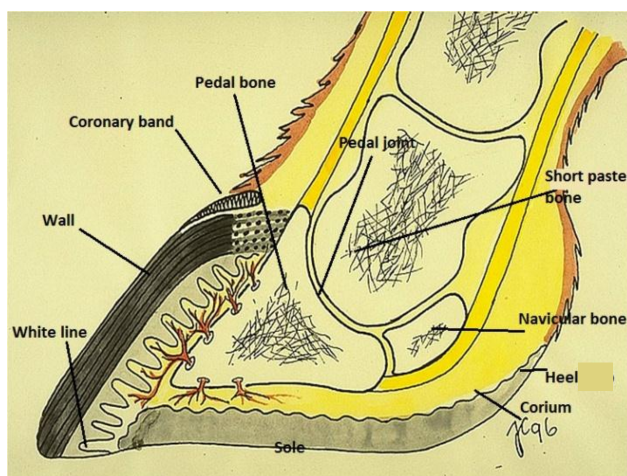

Figure 2. Cross-section of cow claw. Picture J. Carlsson.

Housing and flooring

Concrete is the most common flooring material in facilities for animal production, in tied-stall and loose houses. It is cheap and easy to install and the moulded concrete floors are ready for use as soon as they have dried out. However, concrete floors for loose-housed animals need a surface structure to avoid slipperiness. It is easier to detect heat in cows that feel comfortable with the surface on which they are walking. The duration of heat and sexual behaviours such as standing and mounting are also longer for cows housed on less slippery floors (Britt *et al.,* 1986). Nowadays dairy herds are becoming increasingly large and accurate heat detection is therefore of great importance in maintaining good fertility.

Rubber matting is a possibility to improve alley flooring comfort. There are a lot of different rubber floors on the market today, with different thicknesses and designs. Jungbluth *et al.* (2003) showed that a thickness of at least 5 mm of rubber mat is needed to produce a floor that minimises the risk of slipping on both clean and manure-fouled alleys. However, removal of manure is very important, since having a dirty alley increases the risk of slipping and impairs locomotion, regardless of floor type (Rushen & Passillé, 2006). Softer rubber floors increase cow stride and step length (Telezhenko & Bergsten, 2005; Platz *et al.,* 2008; *Appendix 4*) and decrease the risk of slipping (Hultgren, 2001). The stride length of a cow on a softer floor is similar to that of a cow on pasture (Jungbluth *et al.*, 2003; Rushen & Passillé, 2006). The cows not only take longer steps, but also take more steps per day than cows on concrete, and are therefore more active. The frequency of mounting is also significantly higher, because cows slip much less often on rubber floors than on concrete (Platz *et al.,* 2008).

Just as humans enjoy spending time on softer surfaces such as beds and sofas and walking in cushioned shoes, animals may also prefer softer places to stand, walk and lie on.

Locomotion

Prevalence of lameness

The prevalence of lameness seems to vary greatly among different countries. A study of 4899 cows in 101 herds in Sweden showed a relatively low prevalence of lameness of 5% (Manske *et al*., 2002b). However, in Switzerland it is reported to be 10% (Bielfeldt *et al*., 2005) and in the United States approximately 25% (Espejo *et al.,* 2006). In a study of 340 British dairy herds, lameness afflicted almost 24% of the cows (in one year) (Whitaker *et al*., 2000). In the same study, the top 10% of the best herds had a prevalence of lameness of 2.4%, whereas the worst quartile had a prevalence of 50%. This indicates a great variation between herds. Whitaker *et al*. (2000) also found that lameness was more prevalent in cows housed in free stalls than in straw yards. Although lameness prevalence differs widely between herds, it is a very common disorder in dairy production and it causes a lot of pain for the animals.

Causes of lameness

The most common cause of lameness is injuries and disorders in the claws. Claw disorders can be infectious, traumatic or diet-related.

In a British study, 90% of cases of lameness were caused by claw lesions (Murray *et al*., 1996). Sole ulcers and white line abscesses were the two most common causes. Sole haemorrhages, double sole and fissures in the white line were also found to have a great impact on lameness in a Swedish study (Manske *et al*., 2002a). Among the risk factors behind claw diseases causing lameness in cows, feeding and diet are reported to have a significant impact. Cows fed a high concentrate ratio (11 kg concentrate/day) suffer more severe lameness than cows eating a low concentrate ratio (7 kg concentrate/day) (Manson

& Leaver, 1988a). High crude protein level in the diet and poor claw trimming are also reported to cause a higher incidence and severity of lameness (Manson & Leaver, 1988b). Furthermore, the risk of lameness is reported to increase with the age of the cow, due to several physiological reasons such as previous claw disorders and breakdown of ligaments and joints, which causes less alertness and activity (Groehn *et al*., 1992). Overgrown claws is a common reason for lameness (Manske *et al*., 2002b), and it is known that regular claw trimming reduces lameness issues in dairy production (Manske *et al*., 2002a).

Lameness and flooring

Softer surfaces have been shown to have a positive impact on lame cows (Vanegas *et al*., 2006; Flower *et al*., 2007). Walking comfort in the house is believed to affect cow locomotion. Telezhenko & Bergsten (2005) demonstrated that both lame and non-lame cows had better locomotion on soft rubber flooring than on concrete slatted or solid flooring.

In a study comparing concrete floors with rubber floors, Vanegas *et al*. (2006) found that cows on concrete floors had a greater risk of lameness than those on rubber floors and consequently needed more treatments and claw trimming than those on rubber floors. Bergsten *et al*. (2009) found that first calving heifers housed on slatted concrete floors had an approximately 3.5-fold higher risk of getting lame than heifers housed on slatted rubber floors.

Cow behaviour can reflect cows' preferences for a particular flooring type. For example, Telezhenko *et al*. (2007) showed that cows preferred to stand and walk on a softer (rubber-covered) side of a holding pen alley than a side with concrete. Surprisingly some lame cows were observed walking on the "wrong", concrete side, which those authors attributed to the lower social ranking of cows that were lame at the moment. This would have prevented them from access to the softer side due to their obligation to make way for the higher ranked cows.

There are many reasons why cows become lame, but one explanation is that modern cows spend a lot of time on hard, slippery floors and change their locomotion pattern, which results in strain injuries to their outer rear claws. This causes sole lesions to develop and gradually leads to lameness (Blowey, 2005; Telezhenko *et al*., 2009).

Tests of locomotion by cows with or without sole ulcers on concrete and rubber floors using different locomotion scorings have revealed that both groups of cows walk more securely, with longer and higher strides, more symmetrical steps and at a higher speed on rubber floors than on concrete floors (Flower *et al.,* 2007). This verifies the claim that rubber floors are more comfortable and secure to walk on than concrete floors.

Activity is well known to enhance the health of cows. Thus tied cows with exercise during summer as well as winter are reported to be less affected by disorders related to calving, or to leg and udder problems (Gustafsson, 1993). Similarly, Bielfeldt *et al*. (2005), found that cows in tie stalls with the ability to exercise every day and cows exercised in loose house systems displayed a lower incidence of lameness than non-exercised cows in tie stalls. Thus, giving cows opportunities to move around and softer surfaces to walk on seems to provide them with what they need to stay in shape and be healthy.

Welfare aspects

It is not always easy for an untrained farm person to detect lameness and the cause of claw or leg disorder in a cow (Wells *et al*., 1993). Moreover, the cows´ instincts make them cover signs of lameness well, so as not to be seen as injured and weak by predators. It is therefore difficult to make an evaluation of their sense of pain arising from lameness and claw disorders. However, Whay *et al*. (1998) found that the threshold for pain was lowered for a long time after a severe claw lesion. Posture scoring can indicate the rate of lameness (Sprecher *et al*., 1997; Flower & Weary, 2006). Higher posture scores and more severe lameness have been shown to be very well correlated, indicating that the cow is in pain and trying to unburden the injured claw or leg as much as she can. In addition, lame cows have been shown to have significantly lower activity during daytime, as well as per hour observed, which indicates that cows in pain avoid movement (Callaghan *et al*., 2003). In conclusion, lame cows limp for a reason –their foot hurts. Thus this aspect of cow welfare needs to be taken into account to achieve sustainable dairy production with healthy, happy and high-yielding cows.

Lameness and economic aspects

When a cow is unwell, there is not only a direct cost for veterinary treatment and extra labour for the farmer, but also indirect financial losses due to decreased yield. Milk production has been shown to decrease up to several months before and after the onset of a disease/disorder such as lameness (Green *et al*., 2002). The great need for food and therefore long feeding periods required for high-yielding cows, which involves standing on their injured claws and legs, is thought to be one reason for the drop in milk yield. It has also been shown that cows that are more severely lame drop even more in daily yield, as do older cows in later parity (Warnick *et al*., 2001). This can result in up to 360 kg of milk losses for each lame cow and year, a huge economic loss for the farmer (Green *et al.,* 2002).

Bach *et al.* (2007) found a correlation between high locomotion score and decreased milk yield in cows in an automatic milking system (AMS). Cows with more severe lameness went to the AMS less often than cows with lower locomotion scores, which meant extra labour time for the farmer to move those cows.

The cost of lameness can differ depending on the severity and duration of the claw lesion causing the lameness. A Swedish calculation estimated the cost of a severe sole ulcer to be SEK 5358 (Oskarsson, 2008). An Australian study concluded that the mean cost per lame cow in a herd with a lameness prevalence of 7% is USD 42.90, an estimate that included reduced milk production, cost of culling, treatment and extra labour (Harris *et al*., 1988). Cha *et al*. (2010) found that the cost for a lame cow caused by a sole ulcer, foot root and digital dermatitis was USD 216, USD 120 and USD 133, respectively. The relative contribution to the costs differed between the disorders. A reduction in milk yield was the largest economic loss in cases with sole ulcers (38%), while impaired fertility was the main cost in the case of foot root (50%), and treatment was the largest expense for digital dermatitis (42%) (Cha *et al*., 2010).

Claw health

Claw diseases and flooring

Free stall houses give more freedom for the cows to move around and socialise. However, it is a major challenge to improve claw health in dairy production, since the system is not always beneficial for the cows´ feet. The cows in free stall systems move around in each other's faeces and switch free stalls. Poor manure removal increases the risk of problems related to the claws. The floors are often soaking wet and the risk of bacterial contamination from one cow's feet to another is high.

In a Dutch study, as many as 80% of the cows on concrete floors were diagnosed with at least one claw disorder after examination by a claw trimmer (Somers *et al*., 2003). Those authors also concluded that the risk of claw disorders was less (55-60%) in cows housed on straw yards, which are softer to lie on and rise from and help cows with claw disorders, giving them more time to rest and the injured claw to recover.

Sole haemorrhages

A sole haemorrhage is a blood stain in the sole horn originating from a haemorrhage from the horn-producing corium beneath (*Figure A2 in Appendix 2*). Haemorrhages of the sole corium can be related to traumatic and/or metabolic laminitis (Bergsten, 2003). Most sole haemorrhages recover spontaneously, but can exaggerate to a sole ulcer if the pressure on the area is not relieved (Lischer & Ossent, 1998).

Haufe *et al*. (2012) found that the risk of sole haemorrhages was lower on mastic asphalt and rubber floors, and most common on concrete floors. This agrees with a study by Ouweltjes *et al*. (2010), where sole haemorrhages proved to be more common in cows on hard concrete floors than on rubber. This was believed to be caused by the high load on the cows´ claws; a softer floor may decrease the risk of strain injury and therefore minimise the risk of sole haemorrhages. According to Kremer *et al.* (2007) and Fjeldaas *et al*. (2010), sole haemorrhages are more common in cows on concrete floors than on rubber floors.

Sole ulcers

A sole ulcer is a painful claw disease often causing lameness (Flower & Weary, 2006). A sole ulcer normally appears in the lateral claw of the rear feet (*Figure A3 in Appendix 2*) and is described as a canal through the diseased, haemorrhagic sole horn to the corium. Treatment of a sole ulcer involves immediate claw trimming and unburdening the injured claw with a plastic or wooden block applied on the healthy claw (Manske *et al*., 2002a). Sole ulcers can be prevented by breeding, proper diet, claw trimming and softer flooring.

Heifers housed on concrete slatted floor have been shown to be more afflicted (2.2-fold more) by sole ulcers (sole haemorrhages included) than heifers on rubber slatted floors (Bergsten *et al*., 2009).

Dermatitis

Dermatitis (*Figure A4 in Appendix 2*) is a contagious claw disease that is rather common in loose housing systems and is related to a wet, humid environment. The bacterial infection affects the interdigital or digital skin adjacent to the heel horn. Severe dermatitis with painful strawberry-like ulcerations is called digital dermatitis.

Somers *et al*. (2005) showed less dermatitis in cows that were housed on slatted floors compared with solid concrete floors because of improved drainage of manure and better hygiene. However, in a comparison between two different types of slatted floors for growing beef bulls, there was no difference in the risk of contracting dermatitis (Graunke *et al*., 2011).

Heel horn erosion
Heel horn erosion (*Figure A5 in Appendix 2*) is the most common claw disease. It often starts with eczema (dermatitis) in the border between interdigital/digital skin and heel horn. It is very important to keep the foot clean and dry from manure to reduce the risk of the disease. Clefts and undermined horn of the heel have to be trimmed away or treated with antibacterial substances in order to heal. If not treated, more severe dermatitis or erosion will occur and the cow can become lame (Christer Bergsten, personal communication, 2012).

Vanegas *et al*. (2006) showed that cows on concrete floors had a higher risk of developing heel horn erosion or worsening existing heel horn erosion compared with cows on rubber floors. However, other studies have found a tendency for more heel horn erosion in cows on rubber floors than on slatted concrete floors (Bergsten, 2009; Fjeldaas *et al*., 2010; Haufe *et al*., 2012). One explanation could be less drainage area on slatted rubber than on corresponding slatted concrete floors, and thus it is very important to have very good hygiene management in alleys to avoid wet or moist surfaces.

Recording of claw health in Sweden
Claw health recording in Sweden is carried out by claw trimmers using a system developed about 15 years ago. The trimmers have been specially trained to score claw lesions and injuries in a standardised way according to a colour atlas (Manske, 2003; Swedish Dairy Association, 2011b; *Appendix 2*).

The records are important for cow well-being and health at farm level and the information is also used in research and breeding (Uggla *et al*., 2008). Since 2011, a claw health index is available from Viking Genetics. The claw records also aim to reduce the farmer’s cost of veterinary treatments by keeping the claw health status on a good level in the herd, and by preventing instead of treating lameness. However, the number of claw trimmings with reports of disease has slowly increased in Sweden during the last five years, partly because of increased prevalence of digital dermatitis and sole ulcers (Svensk Mjölk, 2012). This increase is probably related to the development of larger, more confined free stall systems.

Common claw disorders in dairy production
According to the Swedish claw records (Svensk Mjölk, 2012), the prevalence of claw disorders has slowly increased in recent years. During the milk-recording year 2010/11, approximately 274 000 trimmings were recorded and 61% of the cows were classified as healthy. Furthermore, the prevalence of sole ulcers (SU) was 5%, sole haemorrhages (SHH) 19%, heel horn erosion (HE) 20%, and severe dermatitis (DD) 3%.

In a Norwegian study in 57 free stall herds, claw trimmers recorded DD in 5.7% of cows, HE in 38%, white line haemorrhages (WLH) in 13.6%, SHH in 20.4%, white line fissures (WLF) in 9.7%, and SU in 3.2%. In total, almost 72% of the cows in free stalls had one or more disorders in their rear feet, while only 48% of cows in tie stalls had abnormalities (Sogstad *et al.*, 2005).

Hock injuries

Prevalence of hock injuries

Hock injuries have become a bigger problem in dairy cows nowadays. A Swedish study showed that the prevalence of hock injuries is 30% (Rytterlund, 2009). The same study showed that cows in free stall systems had a higher risk of getting hock injuries than tie stall cows, and that AMS cows had more hock injuries than cows milked in parlours. These results differ from earlier comparisons, where tied cows had more hock lesions than loose housed cows (Thysen, 1985; Krohn & Rasmussen, 1992; Gustafsson, 1993).
In a Canadian study where 1752 cows were scored for lesions, 73% had at least one hock lesion (Weary & Taszkun, 2000). A British study compared organic dairy farms with non-organic dairy farms and found that the 40 organic dairy farms in the study had a lower prevalence of hock lesions (37%) than the 40 non-organic farms (49%) (Rutherford *et al.*, 2008). In that study, housing and management such as type of litter in the stalls and alley cleanliness proved to have a great impact.

Causes of hock injuries

The hocks (tarsal joints) are extremely exposed and sensitive to pressure when the cow is lying down on a hard, abrasive surface with poor hygiene. Injuries to the hocks can appear as loss of hair, swellings or ulcerative lesions. Severe hock lesions force the animal to stand up or lie down for longer intervals, because of the pain. Just like the elbows or knees of a human, the bony surface with lack of soft, shock-absorbing tissue beneath the skin makes the area vulnerable. Lying comfort is therefore very important to prevent injuries of the hocks. The bed or bedding material (litter) is of great importance, because it creates a comfortable surface for the cows to lie down and get up. It is also important to use a bedding material that reduces the risk of bacterial contamination. The same pathogens which infect the hocks also are able to infect the udder, which increases the risk of mastitis (Rytterlund, 2009).

In a study in the United States, herds with higher hock lesion scores also had higher somatic cell counts, locomotion scores and culling frequency (Fulwider *et al.*, 2007). In an English survey, 75% of practitioners and welfare experts thought that action should be taken to reduce lameness and hock injuries in more than 80% of 53 farms investigated (Whay *et al.*, 2003).

Hock injuries and flooring

Weary & Taszkun (2000), showed that sand stalls had a lower negative impact on the hocks than geotextile mattresses. This is perhaps not surprising, since the sand is very close to the cows' natural bedding. Weary & Taszkun (2000) also found that the length of the free stalls is important. In an experiment with farms using sawdust in the free stalls, the shorter ones gave more severe hock lesions than the longer stalls. The longer stalls probably allowed easier change of position in the stall and thus gave shorter exposure time to the lesion.

Furthermore, Livesey *et al.* (2002) found that hock lesions were more common and severe in heifers housed on rubber mats in free stalls than on rubber mattresses. Straw yards had significantly lower lesion scores than stalls with either mats or mattresses. Both mats and mattresses are somewhat abrasive and can lead to hair loss and skin injury if not enough litter is used on top. This will then facilitate the entry of bacteria to the injured area. The feature of mattresses is that they follow the cow´s body and therefore probably decrease the pressure on the hocks more than rubber mats. Concrete, on the other hand, is much harder and increases the pressure on the hocks, creating injuries.

As hock injuries are dependent on exposure time, floors where the animals normally stand and walk indirectly contribute by reducing lying time. Severe hock lesions can be avoided by installing rubber in the alleys and sand in free stalls, instead of concrete alleys and concrete free stalls (Vokey *et al*., 2001). Bergsten (2009) surprisingly found 2.6-fold more hock lesions in cows on concrete slats than on slatted rubber floors, although identical free stalls with comfortable bedding were used in both groups. The reason for this is probably that rubber in alleys made it more comfortable for the cows to stand there, resulting in less resting time, which decreased the time lying on the hocks.

Grooming behaviour

Grooming on three legs

When cows groom themselves, they use their nose and tongue against their sides. To groom their rear parts (stomach including the udder), they stand on three legs with one of the hind feet in the air (*Figure 3*). There is a lack of studies on the impact of different floorings on cows' grooming behaviour and social grooming behaviour, such as licking each other. In a study by Platz *et al*. (2008), cows on rubber floors were found to groom themselves by standing on three legs fourfold as often as the cows on concrete.

This may indicate that the cows on rubber floors felt more secure about standing on three legs on that surface.

Figure 3. Cow grooming herself standing on three legs. Photo: Pernilla Norberg.

Social grooming

Cows groom each other as a social act, but also to help each other clean the parts of their bodies that they cannot reach by themselves. Around 78% of social lickings seem to be located at the head and neck, where cows cannot groom on their own (Sato *et al*., 1991). Interesting, those authors also found that cows with restricted access to feed groomed each other more frequently than cows fed *ad libitum*.

Cleanliness and welfare

Apart from the unpleasant sight of dirty animals, there are several other factors to consider in maintaining clean cows in dairy production. Consumers demand high quality milk, but cows´ health is also of the highest interest. It is well-recognised that a dirty environment also is favourable for many pathogens, which could make the cows unwell. In addition, claw health is commonly affected by bad hygiene. Common disorders related to poor hygiene include heel horn erosion and interdigital dermatitis (Bergsten & Pettersson, 1992). Dirty cows are at higher risk of bacterial udder infections and therefore hygiene is very important. Moreover, spores originating from silage can contaminate the milk if udder and teats are polluted by manure and not cleaned sufficiently. Manure can be brought up to the stall from dirty alleys and contaminate the udder (Magnusson *et al*., 2008).

Another pathway of contamination is that free stalls are often the same length, regardless of cow size. Faeces from smaller cows may more often land in the free stall, resulting in dirty cows and dirty udders. Furthermore, large cows may avoid lying down in narrow free stalls and may lie in the manure alley instead, resulting in even dirtier cows.

Cleanliness on different types of flooring has been studied in tie stall systems, where cows on rubber slatted floors are significantly cleaner than those on solid concrete floors (Hultgren & Bergsten, 2001). Ward *et al.* (2002) found that the farm with the lowest prevalence of mastitis also had the cleanest cows. In a Norwegian study, cows that were scored as “very good” in terms of cleanliness had significantly lower somatic cell counts than those that were scored as “good” or “average” (Valde *et al*., 1997). Furthermore, herds with higher somatic cell counts had lower milk production. These findings show that good hygiene in the house can give the farmer several advantages, such as healthier cows, fewer treatments and higher milk yield. Even more interesting, cows in herds with a free stall wood base, rubber mats or litter bed have on average 14% fewer cases of clinical mastitis than cows in herds with concrete free stalls. Ruud *et al*. (2011) found that the most important factor correlated to cleanliness of the stalls was the amount of bedding material, followed by a stall length diagonal of ≤1.96 m, no lower head rail and a stall length of <2.30 m. These results prove that stall bedding, stall design and type of floor surface have a great impact on the cleanliness of stalls and cows. However, even if a shorter stall reduces the amount of dirt in the stall, it is not recommended because of less good cow comfort.

Milk production

It is most likely that healthier cows will yield more. A lame cow will not only drop in milk yield during the illness, but also months before and after (Green *et al.,* 2002). Thus, poor flooring has an indirect effect on milk yield by causing lameness and claw disease. However, studies by Kremer *et al*. (2007) showed no differences in milk yield between cows on rubber or concrete floors.

On the other hand, Hultgren *et al*. (2004) showed that high-yielding cows were more likely to be diseased with sole ulcers, while Warnick *et al*. (2001) showed that loss in milk yield is greatest for sole ulcers.

A questionnaire survey in Sweden revealed that tie stall herds with concrete stalls had lower milk yield than those with rubber mats (Bengtsson *et al*., 2009). Furthermore, cows without rubber mats had higher somatic cell counts than both the Swedish average and the studied herds with mats.

The effect of different softness of stall surface on milk yield was studied by Ruud *et al.* (2010). The results showed lower milk yield in cows housed in concrete free stalls compared to those with mats or mattresses of different softness. The cows on softer beds also had improved teat health, less clinical mastitis and fewer cullings.

In a study in Norway, cows with digital dermatitis had lower milk yield than cows without the disease and newly trimmed cows yielded more after than before trimming (Sogstad *et al*., 2007). It is difficult to distinguish the cause of this milk reduction, since a lot of factors are involved and the different factors influence each other. As seen in some of the sources mentioned above, a softer floor may reduce the risk of lame cows, which could reduce the loss in milk yield.

Materials and methods

Abbreviations used in the text

H1: Rubber-covered area of dairy house, **H2:** Concrete-covered area of dairy house, **H1_A:** Cows in rubber floor area, **H2_A:** Cows in concrete floor area, **SR:** Swedish Red Cow, **SH:** Swedish Holstein Cow, **1:** Primiparous Cows, **≥2:** Multiparous Cows, **AMR:** Automatic Milking Rotary, **AMS:** Automatic milking system, **SU:** Sole Ulcer, **D:** Dermatitis, **DD:** Digital Dermatitis, **SHH:** Sole Haemorrhages, **HE:** Heel horn erosion, **HL:** Hair loss, **SW:** Swellings, **HU:** Hock ulcer, **A:** Asymmetric claw, **D:** Double sole, **WLA:** White line abscess, **B:** Bandage, **C:** Cow slip, **DY:** Daily milk yield.

Housing and animals

This study was performed in the new built university dairy house at The Swedish University of Agricultural Sciences (SLU) at Lövsta, Uppsala (*Appendix 1*) during autumn-winter 2011/2012. The milking house has four sections of which two (H1 and H2) were used in present study. There are 65 free stalls (1.97 m x 1.25 m) in H1 and 53 in H2, in a three-row design and all are equipped with rubber mattresses, which are bedded with shavings from an automatic rail wagon three times daily. In H1 there are 22 individual feeding troughs and in H2 32 self-locking places along the feeding table. Concentrates is fed in automatic feeding stations, 4 in each section. The solid concrete alleys are scraped every two hours with a CleanMatic manure system.

The newly established herd was made up of equal proportions of Swedish Red and Swedish Holstein cows which originated from three different herds and from different housing systems (free stall and tie stall systems). The cows in the study had never been housed on rubber floors before and they were moved into the house approximately 25 days before the first observation. The total number of cows was on average 50.8 and 49.6 in H1 and H2, respectively, during the study. Not all of these cows were included in the study, but they had an impact on the competition at the feeding table. The cows from H1 and H2 were milked together with a third group (H3) twice a day in the same Automatic Milking Rotary (DeLaval), and milk yield and activity were recorded automatically by DelPro.

Approximately 35 cows were allocated to each study group. The stocking rate during the study is presented in *Table 1*. The groups were matched by breed, parity (mainly first calvers) and days in milk (*Table 2*). The smaller number of primiparous SR cows in H1 was due to an outbreak of interdigital phlegmone in connection with the introduction of the cows into the house. These cows were never introduced into the groups.

The solid concrete alley flooring, including feeding area, in H1 was covered with 18 mm solid interlocking rubber mats (R18P, DeLaval International AB; *Table 3, Figure 4*), while that in the H2 area had solid concrete.

Table 1. *Stocking rate in H1_A & H2_A during the study*

Total number of cows		Number of feeding places	Cows/feeding place
H1	50.8	22	2.3
H2	49.6	32	1.5

Table 2. *Distribution of cows in the two groups at the start of the study*

Group	Breed	Parity			Days in milk		DY (kg)	Total
		1	2	≥3	<100	≥100		
H1	SR SH	7 13	6 5	4 2	11 13	6 8	33.8	37
H2	SR SH	11 10	5 4	6 2	14 9	8 7	32.2	38

Table 3. *Characteristics of the De Laval rubber mats used in the study*

Material	Rubber
Thickness	18 mm
Weight	21 kg/m^2
Hardness (Shore A)	68
Upper side	Slip resistance grip
Under side	4 mm grooves

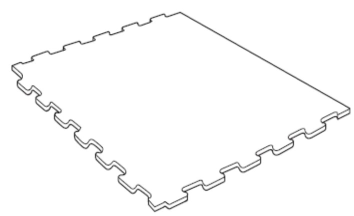

Figure 4. The design of the De Laval rubber mats

Assessment of the dependent parameters

Table 4. *Assessment methods used for the parameters studied*

Parameter	Method	Frequency	Interval	Description
Locomotion	Locomotion scoring	7 times	Every 2 weeks	Scoring from 0-3 on cows on their way out from the AMR (by Pernilla Norberg).
Claw health	Claw health report at trimming	2 times	Before and after the study	Claw trimming performed by a professional claw trimmer two days before and immediately after the end of the study
Hock injuries Hair loss, swellings and ulcers	Lesion scoring	4 times	Once a month	Scoring by measuring the injured area on the hocks for hair loss, swelling and/or ulcerations. Only the worst injured hock was included in the statistical calculations (by Pernilla Norberg).
Cleanliness	Cleanliness scoring	4 times	Once a month	Scoring from 1-4 (by Pernilla Norberg)
Grooming behaviour	Subjective observation on 3 legs and social grooming	6 times	Every 2 weeks	Observations during 1 hour, at a fixed time before and after feeding (by Pernilla Norberg).
Milk yield	DelPro	16 weeks	Daily	Automatically sampled
Excluded cows/ Moved to another group	By staff		During the study	Information from staff

Figure 4. Tagging the cows with spray paint (left) and marking stick (right).
Photo: Carl Johan Ohlsson.

Locomotion scoring

Locomotion scoring was carried out using a system modified from Sprecher *et al*. (1997) (*Table 5*). In order to identify the cows at a distance, they were tagged with a number on

their right side; H1 from 1-50 and H2 from 50-100. Two different types of marking paint were used. Spray paint (Porcimark maerkespray, 200 ml) in blue, red and green were used on cows with white areas (*Figure 4*). Completely black cows were painted with red marking stick and completely red cows with blue marking stick (RAIDL Maxi, 60 ml) (*Figure 4*), because the green spray paint gave allergic reactions in the red cows in the shape of hair loss and swellings.
The marking stick paint was less resistant to the cow brush than the dried spray paint and cows with poor readable numbers were repainted every two weeks.

When the cows left the AMR one by one, they were completely mixed between milking groups. Scoring was made from a ladder placed 10 m from the exit of the AMR (*Appendix 1*), in a 90^0 turn, 10 m before the selection gate where the cows were sorted into their respective group. Thus the cow was observed from both front and rear and in the turn. The flow of cows from the AMR was sometimes irregular. Some of them stopped and blocked the passageway. This made it difficult to score the cows when they finally walked through together. The scoring of the cows was dependent on the function of the AMR and the time for scoring varied from 2-5 hours. The temperature was considered after the study by looking at the recorded temperatures in the house on that specific date. During the last locomotion scoring the temperature in the house had fallen below zero.

Table 5. *Scoring of locomotion in cows leaving the AMS*

Locomotion	Scored every second week
0	**Normal locomotion**, normal standing and walking, symmetrical movement, with the same support from all four legs. The rear claw in the same track as the front claw. Flat back posture while standing and walking
1	**Mild locomotion disruption**, normal standing but arched back while walking. Head lower to the ground and stretched neck. Stiff and slow walk, but with the same support from all four legs
2	**Moderate lameness**, arched back while standing and walking. Shorter, asymmetric and slower steps. No support with one or more legs, hard to distinguish the lame leg
3	**Severe lameness**, arched back while standing and walking. No support on injured leg/legs while standing and walking, and/or walking avoided. Easy to distinguish the lame leg

Claw scoring

Claw health was assessed at maintenance functional trimming one day after the first locomotion scoring in the beginning of the study, and one day after the last locomotion scoring at the end of the study. The professional claw trimmer was familiar with scoring using the Swedish claw health reporting system, but the scoring was carried out according to particular instructions. In contrast to the normal routine, both right and left foot were scored for SU (mild, severe) D (mild dermatitis) DD (severe dermatitis=ulcerative digital dermatitis), HE (moderate, severe) and SHH (mild and severe; *Figures A2-A5 in Appendix 2*). The trimming data were therefore more detailed than those obtained from the normal trimming procedure.

Hock scoring

The hocks of the cows were examined once a month. Both hocks were evaluated for HL, SW and HU according to *Table 6*. The score value was taken as the total sum of injuries on the point of the hocks and hock surface for each cow. The injuries were measured with a carpenter's rule in the least obvious cases where visual estimates were not enough. The hocks were evaluated for HL, SW and HU according to Graunke *et al*. (2011). The cows were examined while standing in the free stalls, in the feeding area or in the manure alleys. Some of the dirtiest cows were brushed at the specific locations at the hocks before scoring.

Table 6. *Scoring procedure for hock injuries*

Hock injuries	Once a month, on both hocks, total sum of the point of the hock and hock surface (Photos: Pernilla Norberg)
	Hair loss (picture example of score 1) 
0	No hair loss
1	Hair loss less than 10 cm^2
2	Hair loss more than 10 cm^2
	Swelling (picture example of score 3) 
0	No swellings
1	Hardly not visible, only with palpation
2	Distinct visible swellings
3	One single swelling more than 10 cm in diameter
	Ulceration (picture example of score 1) 
0	No lesion
1	Minor lesion less than 2 cm^2, with no signs of inflammation
2	Major lesion more than 2 cm^2 and no signs of inflammation Or ulcer regardless of size with signs of inflammation

Grooming behaviour

The cows´ grooming behaviour was observed during one hour every two weeks, before locomotion scoring. The observations in the study were evenly distributed over the day, before and after feeding and the same time in both groups. The method used was applied with the assistance of C. Hallén Sandgren (Personal communication 2011), as was the method for observation of social grooming.

Observations of grooming on three legs

The score was based on the number of individual cows that groomed themselves with their tongue, nose or foot standing on three legs. The cow number was noted to avoid the same cow being recorded twice for the same behaviour.

Observations of social grooming
Observation of social grooming was made during the same hour as observation of "grooming on three legs". All the cows that were grooming each other were counted and recorded, including their cow number, in order to avoid the same pair of cows being recorded twice or more for the same behaviour. However, if the same cow started to groom another cow during the observation period, a new pair was recorded.

Cleanliness scoring
The cleanliness of the cows was scored once a month, at the same time as hock injury scoring. The scoring was carried out according to *Table 7* using a procedure originating from "*Fråga kon*" (Swedish Dairy Association, 2011a). The cows were scored while standing in the free stalls, feeding area or in the manure alleys (*Figure 5*). The cows were scored straight from behind from the flank and towards the rear legs and the final score was a total estimate of the whole scoring area, *i.e*. udder, rump and flanks.

Table 7. *Scoring procedure for cleanliness*

Cleanliness	At a fixed time once a month (Figure 5)
1	Completely clean, or minor spatter of manure on the udder, rump and flanks
2	Spatter of manure on the udder, rump and flanks
3	Several manure regions (at least three) with dry manure larger than 10 cm^2 in diameter, on the udder, rump and flanks
4	Manure regions on more than 1/3 of the udder, rump and flanks (altogether)

Figure 5. Cleanliness scoring 1-4, from left to right (scores 2 & 3 are not easy to distinguish from these pictures).

Milk yield

Data on milk yield (kg) were gathered daily from the DelPro system during the study (16 weeks). Daily yield was correlated for both breed and parity.

Statistical analysis

The Mixed procedure in SAS version 9.1 (SAS, 2003) was used for the statistical analysis. Cow was treated as a random effect and group (H1 and H2), observation date, breed (SR and SH), lactation number (primiparous and multiparous) as fixed effects. The interaction between fixed effects was also included in the statistical models. Cows that were moved during the study were recorded with reason for moving, date, group they came from and group they moved to (*Table A1 in Appendix* 3). Their last score was used as final score including exposure time.

The SAS procedure Genmod was used to calculate odds ratio (OR) with group (H1 and H2), breed (SR and SH) and lactation number (primiparous and multiparous) as fixed effects.

The significance levels can be seen in *Table 8*; p-values greater than 0.05 but less than 0.1 are referred to in the results as a "tendency".

Table 8. *Significance levels used in the study*

Significance level	
Ns	p>0.05
*	p<0.05
**	p<0.01
***	p<0.001

Results

Descriptive statistics

The results presented below comprise the raw data observed directly after the last observation/scoring of all cows in areas H1_A & H2_A, regardless of moved cows (due to sickness/thin soles or other), *i.e*. non-continuous number of cows from one date to another in the respective areas just on particular observation occasion.

Locomotion

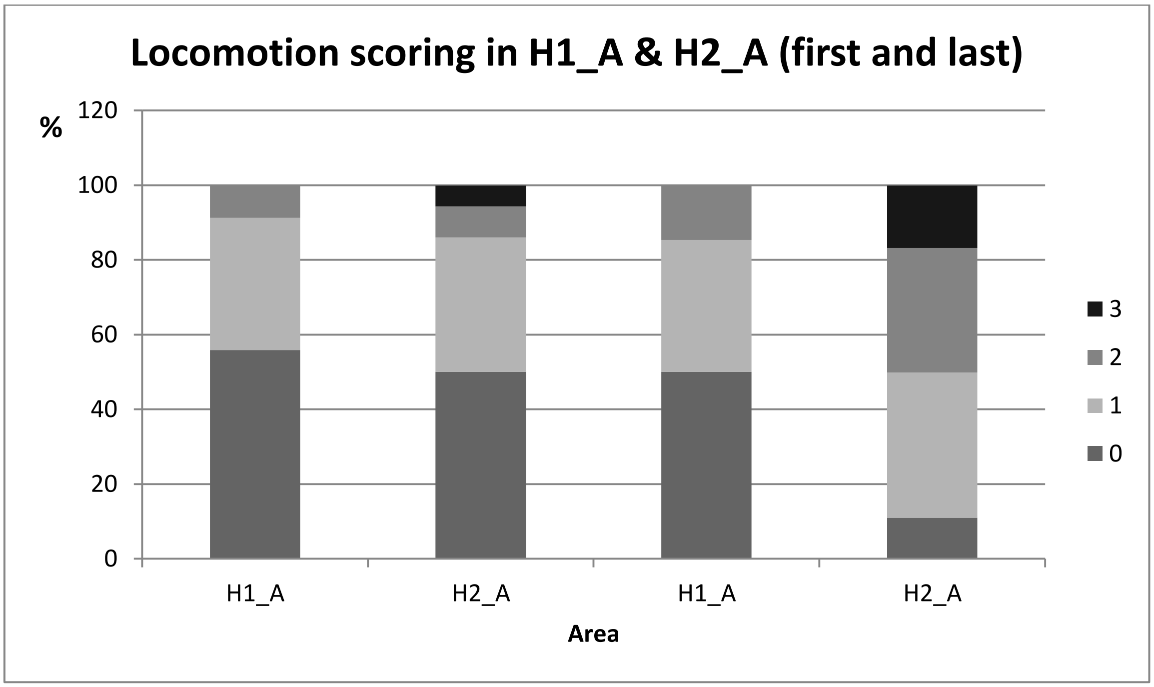

Figure 6. Results of the first and last locomotion scoring in H1_A & H2_A. 0=normal locomotion, 1=mild locomotion disruption, 2= moderate lameness, 3= severe lameness.

The incidence of non-lame cows in H1_A (locomotion score 0) decreased slightly from the first to the last scoring (*Figure 6*), while mild lameness (score 1) remained stable. There was a slight increase in moderate lameness (score 2) but no severe lameness (score 3) was recorded at any scoring in H1_A.

There was a large decrease in non-lame cows (score 0) from the first to the second scoring in H2_A (*Figure 6*). Mild locomotion disruption (score 1) increased by a few percent, while moderate (score 2) and severe lameness (score 3) increased considerably.

Consequences of the first claw trimming
This was studied in the cows that had been claw trimmed before the study, and which were observed and scored one time before (2011-10-10) and three times after claw trimming (dates: 2011-10-25, 2011-11-08 and 2011-11-22) (*Table 9*).

The results showed that the cows in both groups were affected by claw trimming. In both H1_A and H2_A the locomotion scorings were worse after the first trimming. Before claw trimming, 56% of H1_A cows and 51% of H2_A cows were scored as not lame (score 0). After the first claw trimming, the numbers of not lame cows decreased to 41% in H1_A and 24% in H2_A. However, no cow in H1_A was scored as severely lame after the trimming. No scoring was carried out after the second claw trimming at the end of the study.

Table 9. *Percent of claw trimmed cows in each area, sorted by date and locomotion scores (0, 1, 2, 3), where 0 is normal and 3 severely lame*

Distribution of cows in different locomotion scoring in %						
Date	Area	0	1	2	3	Total
2011-10-10	H1_A	56	37.5	6	0	32
	H2_A	51	38	5.5	5.5	37
First claw trimming 2011-10-11						
2011-10-25	H1_A	41	41	17.5	0	34
	H2_A	23.5	44.5	24	8	38
2011-11-08	H1_A	47	36	14	3	36
	H2_A	38	38	16	8	37
2011-11-22	H1_A	71	26.5	2.5	0	38
	H2_A	24	38	16	21.5	37

Hock injuries

Table 10. *Percentage of cows scored and distribution of hock injury scorings*

		Percentage of cows in different hock injury scorings										Total no. of cows
		Hair loss			**Swellings**				**Ulcer**			
Date	**Area**	**0**	**1**	**2**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	
2011-10-05	H1_A	11.5	71.5	17	86	5.5	5.5	3	71.5	20	8.5	35
	H2_A	15.5	64.5	20	87	11	2	0	87	4.5	9	45
2011-11-02	H1_A	5.5	55	39.5	95	0	2.5	2.5	87	5.5	8	38
	H2_A	4.5	55.5	62	87	9	2	2	78	6.5	15.5	45
2011-12-06	H1_A	8.5	53	38.5	93.5	4	0	2	85	15	0	47
	H2_A	6	43	51.5	97	0	3	0	71.5	20	8.5	35
2012-01-04	H1_A	2	48	50	89.5	4	2	4	83.5	12.5	4	48
	H2_A	0	24	76	83.5	2.5	12	2.5	90.5	2.5	7	42

HL was the most common hock injury in the herd, while SW and HU were less common (*Table 10*). The status of the hock injuries in the herd seemed to deteriorate in both areas during the study.

Grooming behaviour

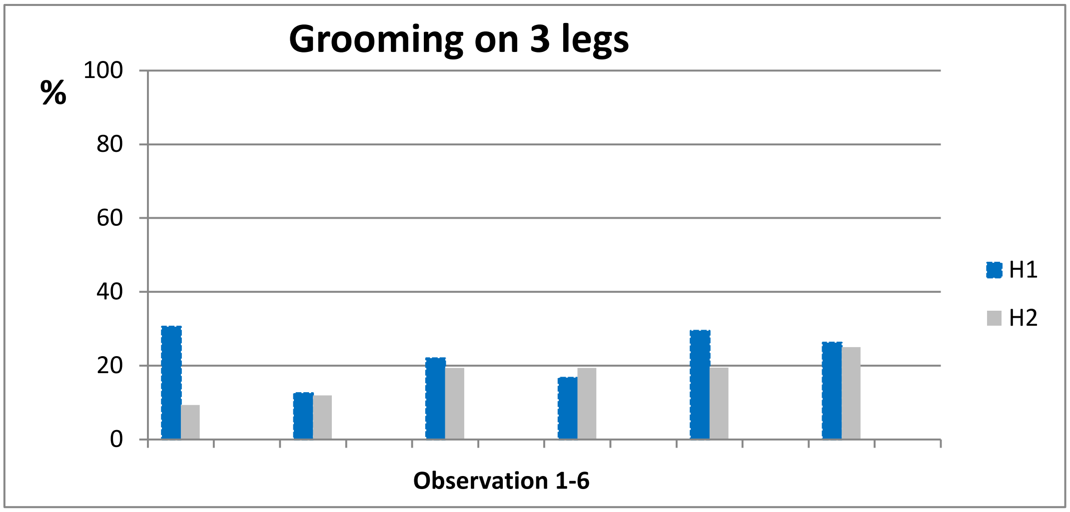

Figure 7. Frequency of grooming on three legs at the six observations occasions in H1_A and H2_A.

Grooming on three legs

The observed incidence of grooming on three legs tended to increase over time in the herd (*Figure 7, Table 11*). On five of six observation occasions, grooming on three legs was more frequent in H1_A than in H2_A.

Table 11*. Frequency of cows grooming themselves standing on three legs during the six grooming observations*

	% on 3 legs	
Date	**H1_A**	**H2_A**
2011-10-25	30.6	9.3
2011-11-22	12.5	11.9
2011-12-02	22.0	19.4
2011-12-06	16.7	19.4
2011-12-29	29.4	19.5
2012-01-12	26.2	25.0

The statistical analysis showed no significant differences between the cows in H1_A and H2_A regarding grooming on three legs.

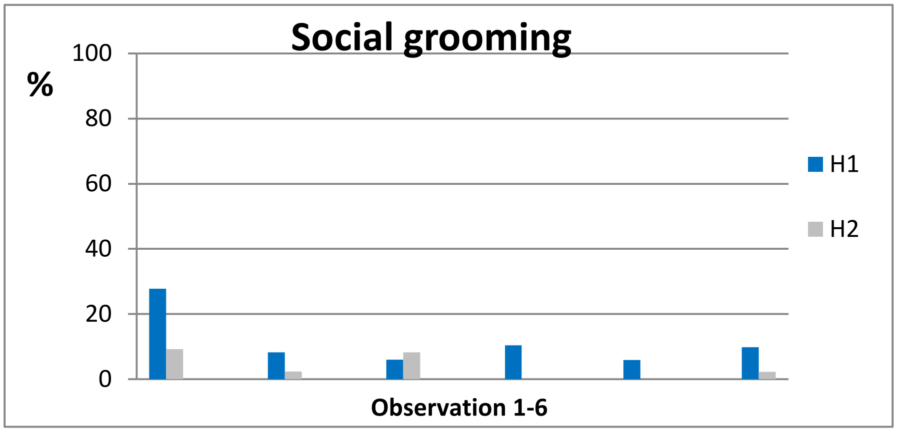

Figure 8. Frequency of social grooming in H1_A and H2_A.

Social grooming

The observations of social grooming tended to be rather stable over time in the herd (*Figure 8, Table 12*), although a slight increase in H1_A and a slight decrease in H2_A could be seen over time. Furthermore, social grooming tended to be higher in H1_A on five of six observation occasions. However, on the three last observation occasions social grooming in H2_A was almost negligible.

Table 12**.** *Frequency of cows grooming each-other during the six grooming observations*

	% of social grooming	
Date	H1_A	H2_A
2011-10-25	27.8	9.3
2011-11-22	8.3	2.4
2011-12-02	6.0	8.3
2011-12-06	10.4	0
2011-12-29	5.9	0
2012-01-12	9.8	2.3

The statistical analysis showed a significant difference between the two areas regarding social grooming (χ^2; $p<0.05$), with the cows in H1_A performing more social grooming than the cows in H2_A.

Cleanliness

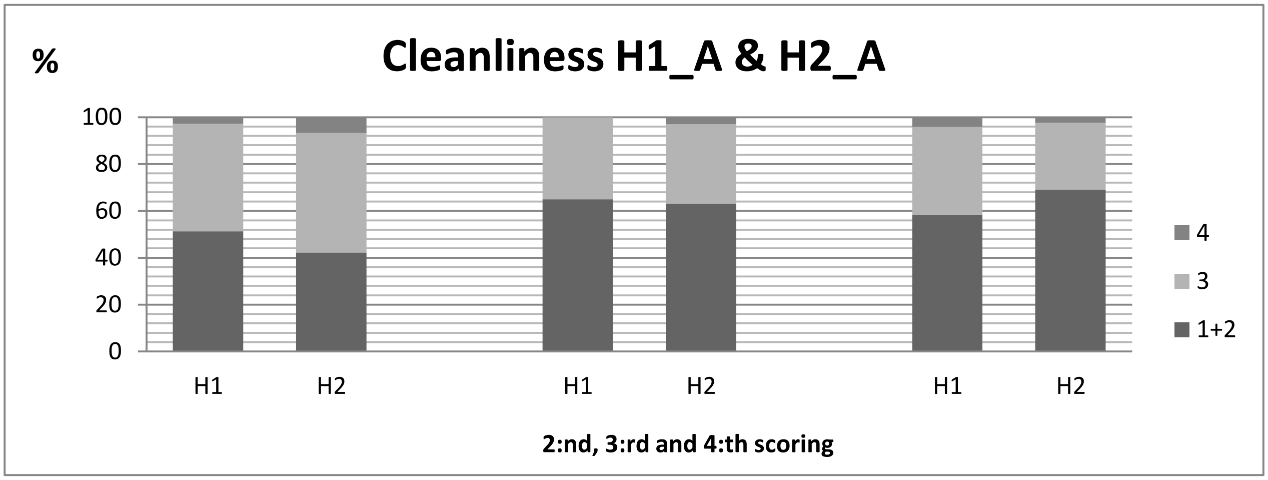

Figure 9. Results of the second, third and fourth scoring of cleanliness in H1_A and H2_A. 1+2=clean animals, 3=slight dirtiness, 4=severe dirtiness.

Because scores 1 and 2 represented a true clean cow, they were added together in the diagram (*Figure 9*). The results showed an increase in clean cows during the study, and scores 3 and 4 tended to decrease (*Table 13*).

Table 13**.** *Percentage of cows in the four cleanliness scorings, sorted into "Clean cows" (cows with score 1 & 2), and "Unclean cows" (cows with score 3 & 4)*

Date	**Area**	**Clean cows (1+2) %**	**Unclean cows (3+4) %**	**Total number of cows**
2011-10-05	H1_A	50	50	32
	H2_A	62	38	37
2011-11-02	H1_A	48.5	51.5	37
	H2_A	45	55	38
2011-12-06	H1_A	66	34	38
	H2_A	63	37	35
2012-01-04	H1_A	57	43	37
	H2_A	70.5	29.5	34

The results from the statistical analysis showed no significant difference between H1_A and H2_A regarding cleanliness scorings (*Table 13*). However, the results showed that both groups became significantly cleaner throughout the study ($p<0.01$). The change in cleanliness over time was the same in both areas ($p<0.05$).

In a modified statistical model to test the effects of parity and breed on the cleanliness of the cows, the results showed a small tendency ($p<0.1$) for an effect of breed, with SH cows being dirtier than SR cows. No effect of parity could be seen.

Results of treatment

The following results comprise observations made on cows that were continuously observed throughout the study in their intended area, *i.e*. the cows in the respective group remained in their starting area during the whole study.

Locomotion

Table 14*. LS-means of group, breed, observation date and parity on locomotion*

Effect		**LS-mean**	**Significance level**
Group	H1	0.642	***
	H2	1.251	
Breed	SR	0.771	**
	SH	1.122	
Date	2011-10-10	0.689	***
	2011-10-25	1.053	
	2011-11-08	0.925	
	2011-11-22	0.920	
	2011-12-06	0.953	
	2011-12-29	0.850	
	2012-01-16	1.236	
Parity	1	0.624	***
	≥2	1.270	
Date*Group	2011-10-10*H1	0.588	***
	2011-10-10*H2	0.790	
	2011-10-25*H1	0.858	
	2011-10-25*H2	1.249	
	2011-11-08*H1	0.814	
	2011-11-08*H2	1.036	
	2011-11-22*H1	0.370	
	2011-11-22*H2	1.469	
	2011-12-06*H1	0.648	
	2011-12-06*H2	1.257	
	2011-12-29*H1	0.481	
	2011-12-29*H2	1.218	
	2012-01-16*H1	0.736	
	2012-01-16*H2	1.736	

The effects of group, breed, observation date and parity were tested on locomotion (*Table 14*). The results showed that there were significant differences between groups (*$p<0.001$*), breeds (*$p<0.01$*), date (*$p<0.001$*) and parity (*$p<0.001$*). Significant interactions could be seen between date and group (*$p<0.001$*). A tendency was observed for an interaction between breed and parity (*$p<0.1$*). The farm of origin of the cows was also included in the test and showed no significant effect on locomotion.

From 6 weeks after the first claw trimming, the odds ratio for higher locomotion scores in H2 was at least threefold higher than in H1 (*Table 15*).

Table 15. *Effect on locomotion in H2 compared with H1. Odds ratio (OR), 95% confidence interval (CI) and results of likelihood ratio test (P LR)*

Observation date	OR	CI	P LR
2011-10-10	1.24	0.42 – 3.67	0.70
2011-10-25	2.70	0.77 – 9.25	0.12
2011-11-08	1.34	0.47 – 3.82	0.56
2011-11-22	9.84	2.89 – 33.4	<0.001
2011-12-06	3.14	1.03 – 9.56	<0.05
2011-12-29	4.10	1.35 – 12.4	0.01
2012-01-16	10.2	2.41 – 42.9	<0.01

Table 16*. LS-means of dermatitis, heel horn erosion, sole haemorrhages and sole ulcers on locomotion. ns=no significant difference*

Effect		LS-mean	Significance
Dermatitis	Without	1.247	ns
	With	1.389	
Heel horn erosion	Without	1.325	ns
	With	1.311	
Sole haemorrhages	Without	1.227	ns
	With	1.409	
Sole ulcer	Without	0.900	Tendency
	With	1.736	

Tests of the effects of claw disorders on cows' locomotion showed no effect of D, HE, SHH or SU rear claws (*Table 16*). However, SU seemed to have a slight tendency to affect locomotion in the cows (*p<0.1*).

Claw health

Table 17. *Prevalence of cows with or without claw health abnormalities at the first (2011-10-11) and the second trimming (2012-01-18), for cows trimmed on both occasions*

Date of claw trimming	**2011-10-11 %**		**2012-01-18 %**	
Group	H1	H2	H1	H2
With abnormalities	69	80.5	96.5	84
Without abnormalities	31	19.5	3.5	16
Total no. of cows	29	31	29	31

The results from the first and second claw trimming displayed an increase in the number of cows with some kind of abnormality in both H1 and H2 (*Table 17*).

Table 18. *Total number of cows and number of claw abnormalities at the first (2011-10-11) and the second trimming (2012-01-18), for cows trimmed on both occasions*

Date of claw trimming	2011-10-11		2012-01-18	
Group	H1	H2	H1	H2
Total no of cows	29	31	29	31
Dermatitis, total	8	7	10	8
(Digital dermatitis)	(2)	(3)	(2)	(2)
Heel horn erosion	10	15	25	14
Sole haemorrhage and sole ulcer	31	45	30	41
Interdigital necrobacillosis	1	0	1	0
Interdigital hyperplasia	0	0	0	1
White line abscess	1	0	0	0

At the first trimming, there were no significant differences between the two groups for any claw health abnormality (D, HE, SHH right/left, SU front/rear (*Table 18*).

Effect of group, parity, breed and date of claw trimming on claw score

Heel horn erosion

Table 19. *Prevalence of heel horn erosion (LS-means) related to claw trimming date, group and parity. ns=no significant difference*

Effect		LS-mean	Significance level
Date	2011-10-10	0.447	**
	2012-01-18	0.690	
Group	H1	0.623	ns
	H2	0.514	
Parity	1	0.459	*
	≥2	0.677	
Date*Group	2011-10-10*H1	0.364	**
	2011-10-10*H2	0.530	
	2012-01-18*H1	0.881	
	2012-01-18*H2	0.498	

There were significant effects of date of claw trimming (*p<0.01*), parity (*p<0.05*), and interaction between date and group (*p<0.01*) on HE (*Table 19)*. There were no significant differences between group, breed or interaction between group and breed or between breed and parity on HE.

A chi-square test displayed that after the second trimming, the prevalence of HE was higher (χ^2; *p<0.001*) in H1 than H2.

Dermatitis

Table 20. *Prevalence of dermatitis (LS-means) related to claw trimming date, group, parity and breed on dermatitis. ns=no significant difference*

Effect		**LS-mean**	**Significance level**
Date	2011-10-10	0.310	ns
	2012-01-18	0.360	
Group	H1	0.355	ns
	H2	0.314	
Breed* Parity	SR*1	0.303	**
	SR*≥2	0.188	
	SH*1	0.168	
	SH*≥2	0.681	

The results showed that there were no significant effects of date, group, parity, breed or interaction between date and group or breed and group on D (*Table 20*). However, a significant difference could be seen between breed and parity, with the prevalence of D being significantly (*p<0.01*) higher in multiparous SH cows.

Sole haemorrhages and sole ulcers

Table 21*. Prevalence of sole haemorrhages and sole ulcers (LS-means) related to claw trimming date, group and parity. ns=no significant difference*

Effect		**LS-mean**	**Significance level**
Date	2011-10-10	0.641	ns
	2012-01-18	0.744	
Group	H1	0.642	ns
	H2	0.743	
Parity	1	0.678	ns
	≥2	0.707	

There were no significant effects of date, group, parity, breed or interaction between date and group, breed and group or breed and parity on SHH/SU *(Table 21)*. A slightly ($p<0.1$) higher prevalence of SHH/SU was found in SH cows.

Hock injury

The first results of the statistical analysis of hock injuries displayed a negative trend in both groups regarding HL scorings over time ($p<0.001$). In addition, the negative trend in H2 was twice as severe as in H1. There were no significant trends regarding SW and HU in the material.

Effect of group, parity, breed and date of claw trimming on hock injuries

Hair loss

Table 22*. LS-means for hair loss related to observation date, group and breed, ns=no significant difference*

Effect		**LS-mean**	**Significance level**
Date	2011-10-05	1.085	***
	2011-11-02	1.350	
	2011-12-06	1.370	
	2012-01-04	1.604	
Group	H1	1.254	Tendency
	H2	1.450	
Breed	SR	1.332	ns
	SH	1.372	

There were significant differences for hair loss between dates (*Table 22*). However, no significant difference in hair loss was found for group, breed, parity or the interaction between breed and parity or date and parity. There was a tendency for more HL in H2 cows ($p<0.10$) and also more HL in cows with two or more lactations ($p<0.10$).

Swellings

Table 23. *LS-means of observation date, group and breed on swellings. ns=no significant difference*

Effect		**LS-mean**	**Significance level**
Date	2011-10-05	0.190	ns
	2011-11-02	0.120	
	2011-12-06	0.095	
	2012-01-04	0.220	
Group	H1	0.173	ns
	H2	0.139	
Breed	SR	0.053	*
	SH	0.259	

SH cows had more (*p<0.05)* SW than SR cows (*Table 23*). However, there was no significant effect of group, date, parity, or the interaction between breed and parity or date and parity on SW.

Ulcers

Table 24*. LS-means of observation date, group, breed and parity on sole ulcers. ns=no significant difference*

Effect		**LS-mean**	**Significance level**
Date	2011-10-05	0.284	ns
	2011-11-02	0.320	
	2011-12-06	0.244	
	2012-01-04	0.174	
Group	H1	0.181	Tendency
	H2	0.330	
Breed	SR	0.185	Tendency
	SH	0.326	
Parity	1	0.177	Tendency
	≥2	0.334	

The statistical analysis showed no significant differences for any of the effects tested. However, the results showed a tendency (*p<0.10*) for more HU in H2 than in H1 (*Table 24*), for less HU in the SR breed (*p<0.10*), and for older cows to be more (*p<0.10*) afflicted than first calvers. No interaction between those parameters could be seen.

Milk yield

The average daily milk yield and the lactation curves for H1 and H2 are presented in *Table 25* and *Figure 10.* No significant differences could be seen between the groups at the start of the study. The average DY was corrected for breed.

Table 25. *Daily milk yield in average in H1 and H2*

Daily milk yield (kg)	
H1	32.3
H2	32.1

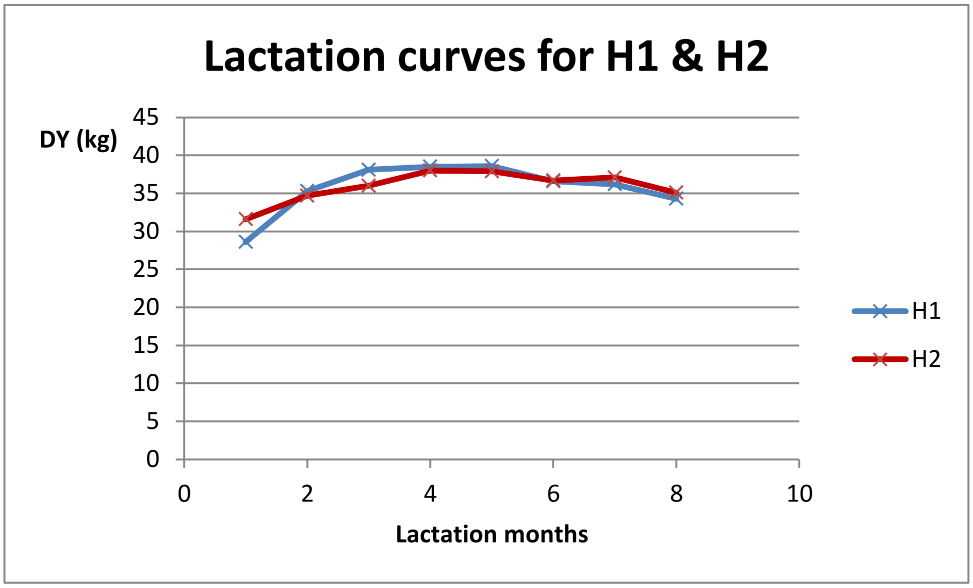

Figure 10. Lactation curves for H1 and H2, corrected for breed and parity

Three cows in H1 with high locomotion score values (2 or 3), indicating lameness, had a drop in DY, while the cows in H2 did not seem to be affected, regardless of locomotion score.

Excluded cows

The claw health data and locomotion scores for the five cows moved from H2 to H1 during the study can be seen in *Table A1* in *Appendix 3*. The reason for moving the cows was that they had thin soles and needed to walk on a softer floor. The abbreviations used in the table are explained in the beginning of Materials and methods section. No statistical analysis was made because the cows were too few in number, but two of the five excluded cows improved their locomotion score when moving into H1, two were unchanged and one developed a poorer locomotion score.

Discussion

Locomotion

The cows in H2_A became lamer throughout the study, while those in H1_A were rather consistent *(Figure 6*). For example the highest score (3) did not appear in H1_A on the first or the last locomotion scoring occasion. Meanwhile, among H2_A cows the incidence of a 3 score (severely lame) increased from 7% to 17% by the end of the study, even though five "thin sole" cows had been moved to H1_A. In general, there was a more negative change in the locomotion scores in H2_A than H1_A. Significant differences were found between the two groups, with cows on concrete being more afflicted by lameness than cows on rubber flooring. These results confirm findings by *e.g*. Vanegas *et al*. (2006). The differences observed between the cows on concrete and rubber floors also support findings by Bergsten *et al.* (2009) that heifers on slatted rubber floors suffer several-fold less from lameness than heifers on slatted concrete floors. At the end of the present study, there was at least a threefold higher risk of cows on concrete floors having disturbed locomotion than cows on rubber floors.
Furthermore, there were higher locomotion scores in SH cows compared with SR cows, and cows in later parity were also more afflicted by lameness than primiparous cows. The Swedish Holstein is a larger and more high-yielding cow than the Swedish Red, while a cow in later parity is older and also higher yielding than a younger cow. For physiological reasons, older cows are more sensitive to factors causing lameness (Groehn *et al*., 1992), as are older humans, so these results are not surprising. Therefore the tendency for an interaction between parity and breed can be expected. An interaction between date and group could also be seen, with locomotion in both groups deteriorating during the study, but the negative change was more drastic in the cows on concrete (*Table 14*).

Several previous studies have shown that locomotion in cows improves on rubber floors, even in lame cows and cows with SU (Manske *et al*., 2002a; Telezhenko & Bergsten 2005; Vanegas *et al*., 2006; Flower *et al*., 2007). Because lameness is a very common problem in dairy herds, it is important to improve conditions for all individuals in the herd, *i.e*. healthy individuals and those with claw disorders and lameness issues. A reduction in milk yield and visits to the AMS and an associated increase in time spent bringing cows to the AMS are very time- and money-consuming (Bach *et al.,* 2007). For that reason, preventing the cows from becoming lame is of the highest interest to increase profits for the milk producer and reduce unnecessary costs as much as possible. Softer flooring in dairy houses may therefore be the solution to one of the many problems in keeping the dairy herd healthy.

The significant effect of date found in this study indicates that the first claw trimming affected the cows' locomotion negatively. It has to be mentioned that the second locomotion scoring was made when the temperature in the house had fallen below zero and faeces and spilled water may have caused slippery walking surfaces for the cows. However, the possible effect of the temperature in the house would most likely have affected both groups at the same rate. When considering the differences in slipperiness on the two floor types, there is a possibility that one of the floor types was more slippery than the other and therefore caused more injuries in the cows before the last locomotion scoring.

Furthermore, the claw trimming data confirmed the suspicion that claw trimming affected the cows negatively regarding locomotion scoring. The cows from both groups walked with a better score before trimming than directly after trimming. These facts can possibly be explained by incorrect trimming or too few trimmings per year.

Regarding claw health and lameness, the results in this study did not indicate that any claw disorder affected the locomotion of the cows, although there was a tendency for an effect of sole ulcers. The material was too limited to investigate this further, but it agrees with previous findings that SU and WLA have a great impact on lameness (Whay *et al*., 1998; Manske *et al*., 2002a; Flower & Weary, 2006; Bergsten *et al*., 2009). We could not see any obvious effects of claw disorders, although Murray *et al*. (1996) showed that claw disorders are the reason for 9 out of 10 lameness cases in dairy production. However, their study included many more cows in several herds, whereas in the present study only one herd consisting of 70 continuously observed cows was examined.

While scoring for locomotion, the most favourable method would have been if some person outside the study could have allocated the cows' random numbers before scoring to make the locomotion scoring as impartial as possible. However, that would have been time-consuming and complicated, since the scorings were made in late evening and had to be very flexible.

Claw health

Claw disorders are common in dairy herds and the incidence varies widely between herds, but up to 80% of cows can have some kind of abnormality at claw trimming (Somers *et al*., 2003). Sole ulcers are rather common in dairy herds and can be prevented by softer flooring. Meanwhile, it has to be taken into account that unslatted rubber floors can cause more HE in cows than concrete floors (Bergsten, 2009; Fjeldaas *et al*., 2010; Haufe *et al*., 2012).

In general, the incidence of abnormalities at claw trimming increased in both H1 and H2 from the first claw trimming to the last and taking into account that some of the cows were moved from H2 to H1 due to thin soles. Unfortunately the rate of abnormalities increased in both groups, for reasons that are unknown. However, the higher frequency of HE in H1 is most likely the reason for the greater increase in abnormalities in that group. At the beginning of the study there were no significant differences between the groups regarding claw disorders (D, DD, HE, SHH and SU).

Overall, the claw disorder that showed the most change over time was HE, which is known to be the most common claw disorder in dairy herds (Svensk Mjölk, 2012). It was more common in H1 than in H2 (χ^2; $p<0.001$). This could have been caused by less wearing of the claws on rubber than on concrete, which could mean that HE was as common in the concrete group as in the rubber group, but not as visible. However, it is known from the literature that HE is more common on rubber floors due to the wetter surface (Fjeldaas *et al*., 2010). Rubber as a material is less "porous" than concrete, which means that a concrete surface will dry out faster than a rubber surface. Haufe *et al*. (2012) showed similar results and also stated the importance of clean, dry manure alleys with well-functioning scrapers. However, Vanegas *et al*. (2006) found the opposite, *i.e*. that HE was more common in cows on concrete, but this is quite likely a matter of manure handling system.

The majority of the HE recorded in the present study was of the mild kind and no effect of HE on lameness could be seen, which is a positive result to bear in mind when taking a decision on investing in rubber mats.

Even though the effects of breed, parity and date were included in the statistical model, the incidence of SHH and SU did not differ significantly. The reason is that the material in the study was too limited to make further evaluations. However, earlier studies have shown that SU is more common in cows on concrete floors than on softer surfaces such as rubber (Bergsten *et al*., 2009). The fact that harder surfaces partially cause SU, by forcing the pedal bone down against the sole of the claw, mean that the use of softer floors may prevent SU or relieve the symptoms in cows already suffering from SU. SU is often treated by attaching a wooden block to one of the claws to unburden the injured one, confirming that relieving pressure is important (Manske *et al*., 2002a). By preventing SU through using softer floors, the risk of SHH will also be lowered (Lischer & Ossent, 1998). Here, no effects of flooring could be seen for the rest of the claw disorders studied, but that may have been because of the somewhat different reporting method used by the claw trimmer at the first trimming compared with the last.

Hock injury

Hock injuries are very common in dairy herds, ranging in incidence from 30% (in Sweden) to 70% (in Canada). The most common hock injury in both groups in this study was HL, which tended to be more prevalent in the H2 cows *($p<0.1$)*. One reason for that, since both groups had the same rubber mattresses in their stalls, can be that the cows on rubber spent more time standing and walking on their softer alleys than those on concrete. Therefore they may have reduced the risk of HL by the friction from the mattresses on the hocks while lying down in the stalls (Vokey *et al*., 2001). There was also a tendency *($p<0.1$)* for more HU in H2 than H1. These results agrees with Bergsten *et al*. (2009), who found that hock injuries were more common (2.6-fold) in cows on slatted concrete floors than in cows on slatted rubber floors.

Here, SW and HU were more common in SH cows than SR cows. One reason for that could be that the SH breed is larger and heavier than SR, and therefore has less space in the stall to change position and unburden sensitive hock areas.

In addition to the unattractive appearance of cows with hair loss and ulcers on their hocks, this is also a matter of animal well-being, since such injuries cause a lot of pain to the animal. The injuries also attract bacteria, which can cause high somatic cell count and mastitis and consequently reduce the profits from the milk (Fulwider *et al*., 2007; Rytterlund, 2009). In addition to higher somatic cell count, the number of lame and excluded cows is correlated to hock injury scoring (Fulwider *et al*., 2007), proving that

those relatively small injuries in fact have a great impact on other factors besides those mentioned.
With this in mind and expert statements on the serious problem of hock injuries in herds nowadays (Whay *et al*., 2003), it is definitely something to try to improve in dairy herds.

Grooming behaviour

Grooming on three legs

The results in *Figure 7* show an increase in grooming on three legs in both groups over time and also a higher frequency in the H1 group compared with the H2 group. These observations agree with Platz *et al*. (2008), who found a fourfold higher frequency of cows on three legs grooming themselves on rubber than on concrete. This is probably because the cows felt more secure on rubber floors, indicating that the risk of slipping was lower on rubber (Hultgren, 2001; Platz *et al*., 2008).
The stride length of a cow on softer surfaces has been shown to be similar to that of a cow on pasture (Jungbluth *et al*., 2003; Rushen & Passillé, 2006), which also supports the theory that the cows felt more secure on softer flooring. The lack of significant statistical differences could be explained by the new concrete floors with high friction in the newly built house, together with the low number of observations. In addition, newly introduced cows or maybe distractions in the form of noise and activity from the animal keepers, broken feeding machines or such could have disturbed the animals and reduced this type of behaviour.

Social grooming

As with grooming on three legs, social grooming was more frequent in the H1 group compared with the H2 group (*Figure 8*). In the three last observations there was almost no social grooming seen in H2. Since there is a lack of these kinds of studies, the literature does not give a hint about the possible reason behind this. One potential reason for the increasing social grooming in H1 could be simply that the cows felt more comfortable on the rubber floors and therefore showed more social behaviour. Moreover, since lameness was less frequent in H1 and lame cows are not as active as healthy cows (Manson, 1989), the social behaviour of H2 cows might have been inhibited. However, Sato *et al*. (1991) found that cows with restricted access to feed groomed each other more than cows with full access to feed. Thus, the higher frequency of social behaviour in H1 could be due to a higher number of cows per feeding place compared with H2.

Cleanliness and welfare

The cleanliness improved in both groups throughout the study. One explanation could be that the cows from different herds and different systems started to adapt to the new system including stalls and ranking.

The tendency for dirtier SH cows could possibly be a scoring error, because dirt contrasts more to white than to brown. The free stalls however are discussed whether they are too long or not, but since the SH cows was dirtier and they are larger than the SR cows, the

smaller cows should practically be dirtier while lying down in the "long free stalls" (1.97 m), since manure from the smaller cows may land in the stall instead of in the manure alley.
It also has to be mentioned that according to G. Pettersson (personal communication, 2012), some cows which originated from tie stall systems lay in the manure alley in the beginning of the study.

It is a positive result that there were no differences in cleanliness between cows on rubber and cows on concrete floors. The advantages with clean cows are that the overall appearance of the herd is nicer and the mastitis risk and the somatic cell count are reduced (Ward *et al.*, 2002), so the farmer gets more money for the milk. Good hygiene is also favourable for claw health (Bergsten *et al*., 2009), resulting in lower treatment costs.

Milk yield

The results showed a drop in milk yield in three cows with higher locomotion scores (2 & 3) in H1, which agrees with Green *et al*. (2002). Earlier studies have shown a positive impact of rubber floors on milk yield (Bach *et al*., 2007; Ruud *et al.,* 2010), although no difference was seen in this study.
The feeding places in H1_A were fewer than in H2_A, which could have caused higher competition at the feeding places in H1_A. This could have resulted in lower feed consumption in this group, which explains the reduction in DY in some of the cows in H1_A.

Bach *et al*. (2007) found that cows with high locomotion score yielded less in AMS because the lamer cows did not visit the AMS as often and needed to be fetched for milking. However in this study at Lövsta (Uppsala), the cows were fetched to the AMS twice a day, group by group, so the number of milkings per day did not affect the DY in the cows.

Furthermore no effect of claw disorders could be seen on DY. According to the literature, cows with DD give less milk than cows without DD (Sogstad *et al*., 2007). However, since the cows in this study were not severely afflicted by DD, we could not see any tendencies for this kind of effect. The same applies for SU, where there were too few SU cases observed in the study to analyse it further. However, SU is really important to consider, since the largest financial loss (38%) when dealing with a SU cow is the loss in milk yield (Cha *et al*., 2010).

Excluded cows

Five cows were moved from H2 to H1 after the first claw trimming because they needed to unburden their claws on a softer floor to stop them wearing even more. None of the H1 cows was moved to H2 during the study period. It is very positive that 2 out of 5 cows improved their locomotion scoring after they had moved to the rubber floor area. This agrees with findings by Flower *et al*. (2007) that cows' locomotion will improve on a softer floor, regardless of their physical condition. Of course other factors such as a changing environment and new ranking of the cows have an impact on their locomotion and, as the cows originated from three different farms, we do not know about their earlier trimmings and their previous claw health status.

Conclusions

Softer flooring seemed to have a positive impact on the dairy cows studied, especially on their locomotion scoring.

Heel horn erosion seemed to be more common in cows on rubber floors than on concrete, but did not seem to affect the incidence of lameness in the cows.

The frequency of cows grooming themselves seemed to be higher in cows on rubber floors than on concrete floors. However, the difference between the groups was not statistically significant.

Rubber flooring significantly increased the frequency of social grooming compared with concrete flooring.

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APPENDIX

Appendix 1

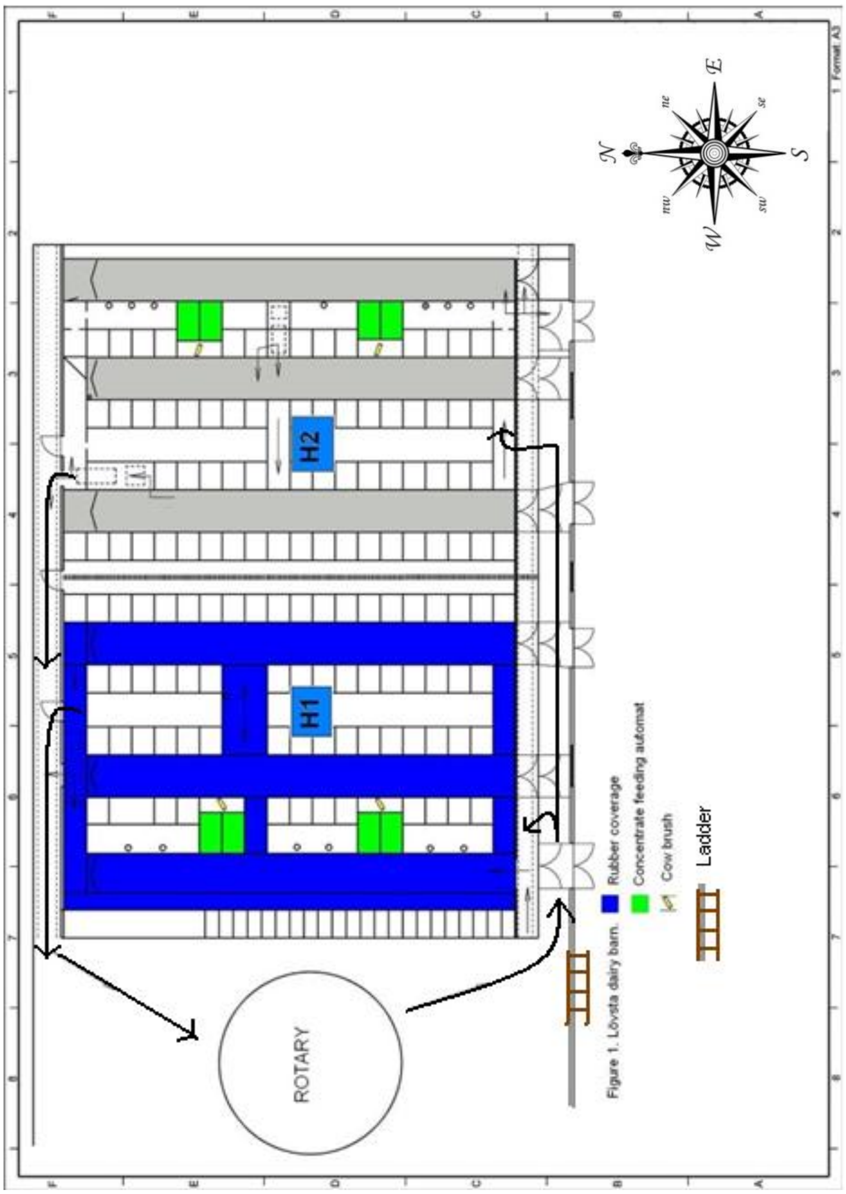

Figure A1. ***Drawing of the Lövsta dairy house.***

Appendix 2

Colour atlas

Parts from the colour atlas of The Swedish Dairy Association

MILD SEVERE

Figure A2. **Sole haemorrhage.**

Figure A3. **Sole ulcer.**

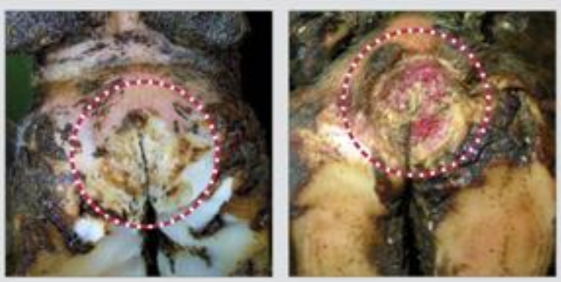

Figure A4. **Dermatitis and digital dermatitis.**

Figure A5. **Heel horn erosion.**

Appendix 3

Excluded cows

Table A1. *Claw and locomotion scorings for cows moved from H1 to H2 during the study*

Cowno	Observation date	Group	Lameness score	OK	Sole hem. left	Sole hem. right	Sole Ulcer left rear	Sole Ulcer right rear	Claw shape	Other disorders	Treatment	Dermatatis	Heel horn erosion
1473	2011-10-10	H2	1										
1473	2011-10-11	H2										1	
1473	2011-10-25	H2	1										
1473	2011-11-22	H2	3										
1473	2011-12-06	H1	1										
1473	2011-12-29	H1	1										
1473	2012-01-16	H1	3										
1473	2012-01-18	H1				1		1		D	C		
1535	2011-10-10	H2	0										
1535	2011-10-11	H2			1	1						1	1
1535	2011-10-25	H2	1										
1535	2011-12-06	H1	1										
1535	2011-12-29	H1	1										
1535	2012-01-16	H1	2										
1535	2012-01-18	H1			1	1	1		A		B	1	1
1541	2011-10-10	H2	0										
1541	2011-10-11	H2			1	1						1	1
1541	2011-12-06	H1	0										
1541	2011-12-29	H1	0										
1541	2012-01-16	H1	0										
1541	2012-01-18	H1			1	1			A			1	1
6305	2011-10-10	H2	1										
6305	2011-10-11	H2			1	1						1	1
6305	2011-10-25	H2	3										
6305	2011-12-06	H1	1										
6305	2011-12-29	H1	0										
6305	2012-01-16	H1	0										
6305	2012-01-18	H1				1				H		1	1
6472	2011-10-10	H2	0										
6472	2011-10-11	H2			1	1							
6472	2011-10-25	H2	3										
6472	2011-12-06	H1	0										
6472	2011-12-29	H1	0										
6472	2012-01-16	H1	1										
6472	2012-01-18	H1											1

Appendix 4

Stride and step length

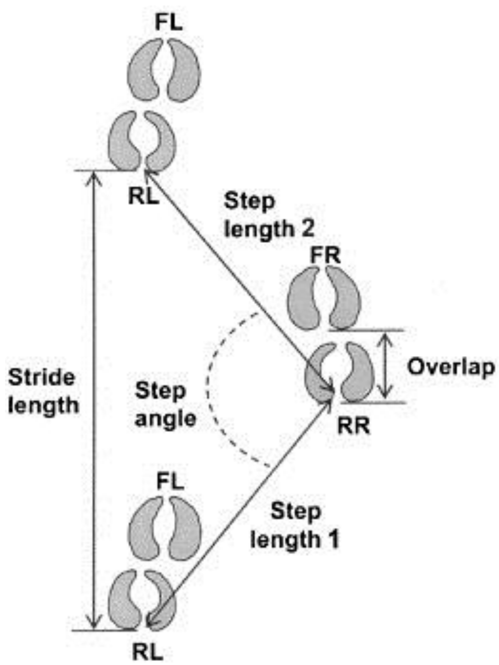

Figure A6. Measured stride and step length of the cows in the study by Telezhenko & Bergsten (2005).

Nr	Titel och författare	År
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