Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Veterinary Medicine and Animal Sciences

The effects of floor system on production in automatic milking systems

Golvsystemets betydelse för produktionen i automatiska mjölkningssystem

Isabella Odmark

Department of Animal Nutrition and Management

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Isabella Odmark

Supervisor:	Jan Olofsson, SLU, Animal Nutrition and Management
Assistant supervisor:	Cecilia Lindahl, RISE
	Christer Bergsten, SLU, Department of Biosystems and Technology
Examiner:	Rolf Spörndly, SLU, Animal Nutrition and Management

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Abstract

Based on the results of a previous Master's thesis, the hypothesis was that farms with slatted floors have lower milk production, both per milking unit and per cow, than farms with solid floors in automatic milking systems. A survey with questions about the farm, the flooring system, cleaning and claw trimming routines was sent to 123 farmers with DeLaval's VMS and additional farmers with DeLaval VMS were invited to the survey via social media. If the farmers had more than one group of milking cows, they were asked to respond for the best-functioning group. The farmers' responses were analysed for variances in milk yield and claw health on the farms.

The result showed that farms with slatted floors did not have lower milk yield than farms with solid floors. In contrast, the milk yield per cow was higher if the floor in the area in front of the VMS was grooved than if it was not (32.7 kg and 30.1 kg respectively, $p = 0.035$). Of the 38 farms that had renovated the floor in the free-stall alley, milk yield per milking unit was higher in those who had installed new rubber mats than in those who had grooved the floor (2232 kg and 1921 kg, respectively, $p = 0.027$).

The flooring system and how the floors were cleaned were shown to have a greater impact on the claw health. Claw health, according to the veterinarians reports to Kokontrollen (CHv), was better in farms with solid floors in the area in front of the VMS than in those with slatted floors (CHv = 0.77 and 2.38, respectively, $p = 0.016$). In a comparison of floor cleaning routines in the alleys, the results showed that claw health was better in alleys with slatted floors than with solid floors that were cleaned with automatic scrapers. In farms where the feed alley was wider than 3.5 meters, the claw health according to the claw trimmers reports to Kokontrollen (CHt) was better than on farms where the alley was narrower than 3 meters (CHt = 4.93 and 11.77 respectively, $p = 0.027$).

The claw trimming strategy did not affect either production or claw health. However, the use of claw bath had a positive effect on the amount of milk produced per cow (32.9 kg and 29.6 kg respectively, $p = 0.00$) but according to the veterinary reports, claw baths had a negative effect on claw health (CHv = 1.3 and 2.5 respectively, $p = 0.046$). However, this could be due to the fact that farms with poor claw health install claw baths as a preventive measure. According to the reports to Kokontrollen from both veterinarians and claw trimmers, claw health was better on organic farms than on conventional farms.

Keywords: flooring system, milk production, claw health.

Sammanfattning

Baserat på resultaten från ett tidigare masterarbete var hypotesen i studien att gårdar med spaltgolv har lägre mjölkavkastning än gårdar med helt golv i automatiska mjölkningssystem. En enkät med frågor om gården, golvens utformning, rengöring och klövverkningsrutiner skickades ut till 123 lantbrukare som mjölkar med DeLavals VMS och ytterligare lantbrukare med Delaval VMS bjöds in till enkäten via sociala medier. Om lantbrukarna hade fler än en grupp med mjölkande kor uppmanas de svara för den bäst fungerande gruppen. Enkätsvaren jämfördes därefter med mjölkavkastning och klövhälsa på gårdarna.

Resultatet visade att gårdar med spaltgolv inte hade lägre mjölkavkastning än gårdar med helt golv. Däremot var mjölkavkastningen per ko högre om golvet i uppsamlingsfållan var rillat, än om golvet inte var det (32,7 kg respektive 30,1 kg, p = 0,035). Av de 38 gårdar som hade renoverat golvet i liggbåsgången, var mjölkavkastningen per robot högre hos dem som hade installerat gummimattor än hos de som hade rillat golvet (2232 kg respektive 1921 kg, p = 0,027).

Golvsystemet och hur golven rengörs visades påverka klövhälsan. Klövhälsan enligt veterinärernas rapporter till kokontrollen (CHv) var bättre på gårdar med helt golv i uppsamlingsfållan än på de gårdar som hade spaltgolv (CHv = 0,77 respektive 2,38, p = 0,016). I en jämförelse av hur golvet i gångarna rengörs, visade resultaten att klövhälsan var bättre i spaltgångar än i gångar med helt golv som rengjordes med automatiska skrapor. Enligt klövverkarnas rapporter till kokontrollen (CHt) var klövhälsan bättre på gårdar där foderbordsgången var bredare än 3,5 meter, än på gårdar där gången var smalare än 3 meter (CHt = 4,93 respektive 11,77, p = 0,027).

Gårdens strategi för klövverkning påverkade varken produktion eller klövhälsa, däremot hade användning av klövbad en positiv effekt på mjölkproduktionen per ko (32,9 kg respektive 29,6 kg, p = 0,00) men hade enligt veterinärernas rapporter en negativ påverkan på klövhälsan (CHv =1,3 respektive 2,5, p = 0,046). Dock skulle detta kunna bero på att gårdar med sämre klövhälsa installerar klövbad som en förbättringsåtgärd.

Enligt rapporter till Kokontrollen från både veterinärer och klövverkare var klövhälsan bättre på ekologiska gårdar än på konventionella.

Nyckelord: golvsystem, mjölkproduktion, klövhälsa.

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Abbreviations

AMS	Automatic milking system
CHc	Cows culled due to leg or claw problems
CHt	Claw health according to the claw trimmer
CHv	Claw and leg health according to the veterinarian
DD	Digital Dermatitis
DS	Double sole
HHE	Heel horn erosions
MPc	Average milk production per cow and day
MPu	Average milk production per milking unit and day
PMR	Partly mixed ration
SH	Sole haemorrhages
SU	Sole ulcers
TMR	Total mixed ration
VMS	Voluntary milking system
WLF	White line fissures

1 Introduction

In today's dairy production, cattle spend much time standing and walking on barn floor, making the floor system important for health, welfare and behaviour (Philips, 2010; Tucker et al., 2006). Floors must manage wear from high stocking density but still provide good cow comfort and be gentle to the claw (Phillips, 2010). In loose-housed systems with voluntary milking, a proper flooring system is vital to sustain a functioning cow traffic (Telezhenko et al., 2008). In contrast, the prevalence of claw lesions and lameness are more common in loose-housing systems than in tied stalls (Sogstad et al., 2005; Telezhenko and Bergsten, 2005). This is a huge concern in automatic milking systems because it impairs locomotion and decreases the cow's willingness to walk around in the barn. If the cows are unwilling to walk to the milking unit, milk production decreases and the need of labour for fetching cows increases (King et al., 2016).

Concrete are the most commonly used floor material in dairy barn alleys (Telezhenko et al., 2009), but the use of concrete is also associated with impaired claw health and locomotion (Bergsten et al., 2015). Due to these reasons, the usage of softer and more yielding rubber floors increases (Tucker et al., 2006). Floors can be either solid or slatted. Slatted floors often create a dry surface, which is important to maintain a good hygiene in the stall (Fjeldaas et al., 2011; Somers et al., 2005, 2003). Meanwhile, solid floors gives full support to the claw and therefore reduce the mechanical stress on the claw (Hinterhofer et al., 2006).

The aim with this study was to investigate the effects of floor system on milk production in automatic milking systems (AMS). Based on findings in an earlier master thesis by Gustafsson (2017), the hypothesis was that farms with slatted floors have lower milk production, both per milking unit and per cow, than farms with solid floors.

2 Literature review

2.1 Floor systems

A good floor system is important to sustain good animal health and a functioning cow traffic. A successful flooring system encourages locomotion, and has a good slip resistance at the same time as it is gentle to the claw. It also needs to be easy to clean, durable and reasonably priced (Telezhenko et al., 2008).

2.1.1 Concrete

Concrete is the most common material in both solid (figure 1) and slatted (figure 2) stable floors. Concrete is relatively cheap, durable and easy to clean (Philips, 2010; Telezhenko et al., 2007). New concrete floors are often abrasive and provoke undesired wear on the claw. However, older concrete floors often become slippery due to wear from manure removal equipment and acids from urine and manure (Bergsten, 2001). Concrete can also become slippery when wet (Telezhenko et al., 2017). Slatted floors are made of concrete slats, placed together with a small slot in between

Figure 1. Solid concrete floor. Photo: Christer Bergsten

(Philips, 2010). According to Swedish regulations, maximum allowed slot width for adult animals are 35 millimetres (17 § SJVFS 2017:24). A good functioning slatted

floor often creates a clean environment, meanwhile a poorly designed slatted floor can have negative impact on claw health and locomotion (Philips, 2010).

Figure 2. Slatted floor with and without rubber mats. Photo: Christer Bergsten.

To increase friction and minimize slipperiness, grooving can be performed on solid and slatted concrete floorings (figure 3). Grooving is done by creating a pattern in the concrete. The pattern can for example be grooves made lengthwise in the walking direction or shaped like hexagons or diamonds (Philips, 2010). Grooving can be performed on both old and new floors (Bergsten, 2001).

Figure 3. Grooved concrete floor. Photo: Isabella Odmark

2.1.2 Rubber mats

Rubber mats (figure 4) can be placed on both solid and slatted floor and are used to increase cow comfort (Telezhenko et al., 2007). Rubber mats create a yielding and

Figure 4. Slatted rubber mats. Photo: Christer Bergsten

less slippery surface (Telezhenko and Bergsten, 2005). In loose-housed systems, rubber mats are often used in areas where the cows spend a large amount of time standing or walking. Rubber mats can be of various thickness, where a thicker mat creates a softer and more yielding floor (Telezhenko et al., 2007).

2.1.3 Manure removal

To maintain a healthy claw and reduce the occurrence of injuries, a clean and dry environment is important (Borderas et al., 2004). Good drainage that creates a dry floor surface is considered to be the most important factor for a successful floor system (Sarjokari et al., 2013). According to Swedish regulations, manure removal and floor drainage must be designed and used in a way that minimize risks for injuries and are not allowed to have negative impact on animal health or behaviour (SJVFS 2017:24). Sarjokari et al. (2013) identified two common problems with manure removal systems. First, wet surfaces on alley floors due to lack of drainage and inclinations. The second problem was claw trauma caused by inappropriate design of manure removal equipment.

Regular removal of manure reduces the risk for diseases to spread. Automatic manure scrapers (figure 5) are the most commonly used manure removal system on solid alley floors, but the alleys can also be cleaned with for example a tractor (Philips, 2010). Slatted floors are self-draining but can also be combined with automatic manure scrapers (Magnusson et al., 2008).

Urine drainage are a system that allows urine and other fluid to drain away and are used to create a drier alley surface on solid floors (6 § SJVFS 2017:24).

Figure 5. Automatic scraper on solid floor. Photo: Christer Bergsten

2.2 Cow traffic

For a functional AMS, cows must be motivated to visit the milking unit. To control the visits in the milking unit and the movement in the barn, various types of traffic systems has been developed (Melin et al., 2005). Free traffic systems allow the animals to access both feeding and resting areas in the barn without restrictions (Rodenburg, 2017). Cows with milking permission can enter the milking unit or the waiting area through a one-way gate. In forced traffic systems, gates are installed between the various sections in the barn. One-way gates allow cows to enter another section, but not to go back the same way. Selection gates are used in front of the

milking unit, allowing cows with milking permission to enter the milking unit and be supplied with concentrate.

Feed first systems allow the cows to enter the roughage area from the resting area by one-way gates. To get back to the resting area, the cows need to pass through the milking unit. In front of the milking unit, there is a selection gate directing cows with milking permission to the milking unit and cows without permission back to the resting area or to a separated section with concentrate feeders. In milk first systems, the cows need to pass through the milking unit to get from the resting area to the roughage area. When leaving the resting area, the cows pass a selection gate. In this gate, cows with milking permission are directed to the waiting area in front of the milking unit and cows without milking permission are directed to the roughage area.

The motivation to be milked has been shown to be weak and changeable. However, the motivation for feed has been shown to be stronger and are therefore often used in controlled traffic systems (Melin et al., 2005). Cows need a milking permission to be allowed to visit the milking unit. Milking permission is set by the farmer and controls how often the cow is allowed to visit the milking unit. This permission is usually based on time since previous milking (Bach et al., 2009).

2.3 Milk production

A difference in milk production between herds with and without slatted floors in the alleys has been found, where farms with slatted floor had lower production compared to the farms with solid floors (Gustavsson, 2017). In a study by Kremer et al. (2007) a comparison of milk production on slatted concrete floor and slatted rubber floor was performed. The result showed no significant differences in milk production between the various floorings. Eicher et al. (2013) compared milk production between solid rubber and grooved concrete floors. The authors found that the total milk production was not affected by floor system. However, the results showed that fat and protein levels were higher in milk from cows on rubber floors. In a study by Deming et al. (2013), a correlation between milk yield and space in the feed bunk were found.

One advantage with AMS are that cows can be milked more than twice per day, which has been proven to increase milk yield (Spahr and Maltz, 1997). However, AMS are based on voluntary visits to the milking unit which leads to variations in milking frequency between cows. In a study by Hogeveen et al. (2001), the average milking frequency was 2-2.5 milkings per day. However, six percent of the cows had less than two visits and 9 percent had more than three visits in the milking unit per day. Milking frequency are positively correlated to both production and udder

health (Hogeveen et al., 2001). Parity has also been found to affect milking frequency, where primiparous cows visit the milking unit more often than multiparous (Borderas et al., 2007). Deming et al. (2013) found that lower stocking density at the AMS increased milking frequency.

Also, variations were found for milking interval. In the study by Hogeveen et al. (2001), the average milking interval was 9.2 hours. However, 17.2 % of the cows had longer milking intervals than 12 hours and 9.7% had a shorter interval than 6 hours between milkings. Long milking intervals have a negative impact on milk production. According to Hogeveen et al. (2001), the individual cow has a huge impact on the variations in milking interval and frequency, and this is important to take into consideration when selecting cows to get a functioning AMS. Both low frequency and changes in the frequency of visiting in the milking unit can be indicators of illness or lameness (Borderas et al., 2007). Therefore, data from the milking system can also be used as indicators on the well-being in the herd.

2.4 Claw and leg health

Claw disorders are, together with udder disorders, the most common production diseases in dairy production (Hultgren and Bergsten, 2001). In fact, claw and leg disorders has been shown to be the fourth most common reason for culling in Swedish dairy herds (Ahlman et al., 2011). Claw and leg disorders reduce animal welfare (Bergsten et al., 2015; Bruijnis et al., 2010). The prevalence of claw lesions (Häggman and Juga, 2015; Sogstad et al., 2005) as well as lameness (Hultgren, 2002) are more common in loose-house systems than in tied-up stalls.

2.4.1 Claw conformation

Claw conformation (figure 6) are affected by the flooring system. Hard and abrasive flooring increase wear and the risk for impaired claw health (Bergsten, 2001). The claw wall is the most important weight bearing part of the claw. An abrasive floor surface leads to increased wear of the claw wall and translocate weight pressure on the claw (Telezhenko et al., 2008). However, an abrasive flooring can also have positive effects on claw conformation, as wear from the floor surface creates an increased contact area and decreased average contact pressure on the claw (Telezhenko et al., 2008).

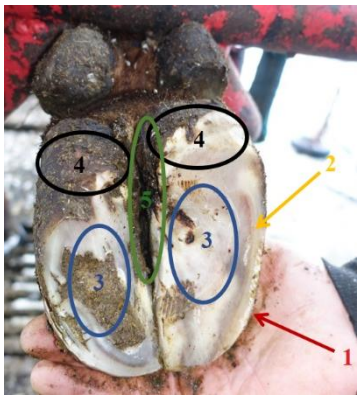

Figure 6. Claw from below. 1 = Claw wall, 2 = White line, 3 = Sole, 4 = Bulbs & 5 = Interdigital space Photo: Christer Bergsten

Soft rubber flooring is less abrasive with increased friction (Bergsten, 2001). Soft floorings preserve the important claw wall (Telezhenko et al., 2008). However, overgrown claws due to lack of wear or lack of claw trimming are a risk factor for developing lameness (Bergsten, 2001). Lack of wear can also affect weight pressure and are shown to translocate weight distribution towards the bulb region. For optimal wear and maintenance of a functional claw shape, short term exposure to abrasive surface can be beneficial in soft flooring systems (Telezhenko et al., 2008).

Bergsten et al. (2015) found that both wear and growth of the wall were greater on solid concrete floor than on deep straw bedding. On concrete flooring, the wear was greater than the growth which lead to negative net growth. Ouweltjes et al. (2009) found wear to be greater on slatted concrete flooring compared to on slatted rubber flooring. Claws become larger and the claw-floor contact area become smaller on slatted floor with rubber mats

Hinterhofer et al. (2006) compared the mechanical stress on the claw on floor systems with various hardness. The results showed that solid floors created less mechanical stress on the claws compared to all investigated types of slatted floor. This result can be explained by the fact that solid floors gives support to the whole claw. However, according to the authors, factors like cleanliness and grip can affect which type of floor system that is best suited for the claw.

Borderas et al. (2004) studied the relationship between water content and claw lesions. The results showed that all parts of the claw easily absorbed water. Most of the absorption of water occurred during the first hour of soaking. Absorption was shown to be bigger than the water loss during drying. All parts of the claw become softer after exposure to water. Softer claws become more sensitive towards environmental challenges. A correlation between claw softness and the occurrence of severe claw lesions was found in the study. This indicated that the claw is sensitive to wet and humid surroundings.

2.4.2 Claw lesions

Claw lesions are a widespread problem in Swedish dairy herds (Manske et al., 2002a) which causes decreased milk production and economical losses for the farmer (Bruijnis et al., 2010). Claw lesions can be divided into two groups, infectious and non-infectious. Infectious claw lesions are for example digital dermatitis (DD, figure 9) and heel horn erosions (HHE) (Fjeldaas et al., 2011). Infectious claw lesions develop due to inadequate hygiene, with contamination of the claws by manure and urine (Philips, 2010). Functioning manure removal are important to minimize the risk for infectious claw lesions (Oliveira et al., 2017). Non-infectious, also called metabolic claw lesions, are related to laminitis and these are for example sole haemorrhages (SH), sole ulcers (SU, figure 7), white line fissures (WLF) and double

soles (DS). These types of lesions are often due to metabolic disorders (Fjeldaas et al., 2011) but can also be due to mechanical trauma (Cramer et al., 2009). Other types of disorders can be overgrowth and corkscrewed claws. In a study by Manske

Figure 7. Sole Ulcer.
Photo: Christer Bergsten

Figure 8. White line abscess.
Photo: Christer Bergsten

Figure 9. Digital Dermatitis.
Photo: Christer Bergsten

et al. (2002a) DD, SH and HHE were found to be the most common claw lesions in Swedish dairy herds. Häggman and Juga (2015) found that non-infectious were more common than infectious claw lesions in loose-house systems.

In a study by Fjeldaas et al. (2011), the occurrence of claw disorders between various alley floorings were investigated. The floorings included were solid rubber, solid concrete, slatted concrete, and mixed rubber and concrete flooring. The results showed that solid rubber floorings were favourable for most laminitis-related lesions, but slatted concrete was most favourable for infectious claw lesions. One explanation for these results can be that more manure and urine are gathered in solid alleys compared to slatted, and that manure contamination of the claw is increased. According to Fjeldaas et al. (2011), slatted rubber floors were considered to be the best flooring to maintain good claw health due to good drainage and a yielding surface.

In a study by Ouweltjes et al. (2009), rubber mats were found to reduce the occurrence of SH on cows kept on slatted floors. In tied stall with solid floors, rubber mats decreased the occurrence of DD, HHE, SU and SH (Hultgren and Bergsten, 2001). In contrast to earlier results, Häggman and Juga (2015) found the lowest occurrence of both infectious and non-infectious claw lesions on solid floors compared to slatted. As the results in different studies are diverse, there may be some uncertainty about which floor that causes most claw lesions. Bergsten et al. (2015) found that early experiences of various floors affected claw health later in life, and that heifers reared on deep straw bedding had less occurrence of claw disorders after calving compared to heifers reared on solid concrete.

Parity and lactation stage are correlated with the incidence of claw lesions (Häggman and Juga, 2015). The risk for SU and HHE increases with parity (Bergsten et al., 2015). However, Somers et al. (2005) found that lactating and first-parity cows were at greater risk of developing DD. In a study by Kremer et al. (2007), occurrence of SU and SH was found to be highest in mid-lactation, around 105 days in milk. In the same study, the occurrence of DD and HHE was found to increase with lactation stage.

Claw lesions are a common reason for lameness (Green et al., 2002). However, in several studies the prevalence of lameness is lower than the prevalence of lesions (Manske et al., 2002b, 2002a; Sogstad et al., 2005; Tadich et al., 2010). These findings indicate that not all hoof lesions cause lameness. However, all claw lesions, except from DD, are found to be more prevalent in lame cows than in non-lame cows. Lameness was strongest associated with the occurrence of SU followed by occurrence of DS or WLF (Manske et al., 2002a). Even though not all lesions cause lameness, they probably still cause discomfort for the cow (Tadich et al., 2010).

2.4.3 Lameness

Lameness is one of the main factors affecting production and behaviour in AMS herds (King et al., 2016). Lameness is negatively correlated with milk production, both regarding daily milk yield per cow and per AMS unit. Lameness also increases labour and reduces animal welfare (Miguel-Pacheco et al., 2014). Early detection of lameness is important to minimize the negative impact on animal health and the reduction in milk production (Green et al., 2002). Lameness can easily be underrated if not measured during optimal circumstances (Manske et al., 2002b) and the occurrence of lameness can often be underestimated by the farmer (Espejo et al., 2006; Fjeldaas et al., 2011). Yielding surfaces reduce the signs of lameness which makes it harder to identify (Telezhenko and Bergsten, 2005).

Lame cows visit the milking unit less often than non-lame cows (Borderas et al., 2008; King et al., 2016; Miguel-Pacheco et al., 2014). In a study by Borderas et al. (2008), the relationship between the incidence of lameness and the milking frequency was estimated. Based on the daily visit to the milking unit, the cows were classified as high or low visitors. On average, the high visitors visit the milking unit 4.8 times per day compared to 2.3 times for low visitors. In the study, a five-point numerical rating scale was used to judge the degree of lameness, where 1 indicated a normal gait and 5 indicated sever lameness. Cows with scoring over three were considered to be lame. The results showed that low-visiting cows had higher gait scores than high-visiting animals, and that 32 % of the low-visiting cows were considered to be slightly or severely lame compared to only four percent of the high-visiting ones. Also, heifers reared on solid concrete flooring were found to have

higher locomotion scores after calving compared to heifers reared on deep straw bedding.

Green et al. (2002) investigated the impact of clinical lameness on milk yield in five different farms in England, and data were collected between the years 1997 to 1999. Clinical lameness was found to reduce milk production from up to four months before lameness was identified and treated, and until five months after treatment. In the study, the average lactation length were 305 days and milk yield per cow varied between 5500 to 7500 kg. Occurrence of lameness was found to cause milk production losses between 160 kg to 550 kg per cow, with an average loss of almost 360 kg over a lactation. King et al. (2017) also found that lame cows produced less milk and visited the milking unit less often compared to non-lame cows. Lame cows produced an average of 1.6 kg less milk per day and had 0.3 fewer visits in the milking unit/day than non-lame cows during the study. High yielding cows are at greater risk to become lame and even though lameness reduces milk production, high yielding cows that become lame can still have higher production compared to non-lame low milk producers. This means that the reduction in milk production also must be compared to the cow's own potential (Green et al., 2002).

Sarjokari et al. (2013) evaluated housing related risk factors associated with lameness. Lameness was found to be correlated with walking alley slipperiness, feed barrier model and feeding alley width. Higher risk for lameness was found on slippery floors. A negative correlation was found between feeding alley width and occurrence of lameness in the herd. Lowest occurrence of lameness was found in herds with a feeding alley wider than 340 cm. According to Swedish regulations, alleys in loose-house systems must be of sufficient width (14 § SJVFS 2017:24). Smallest approved alley widths in Sweden are specified in table 1. Sarjokari et al. (2013) also found that the occurrence of lameness was lower in herds with separated feeding places.

In a study by Bergsten et al. (2015), clinical lameness was higher on slatted concrete flooring, compared to slatted rubber flooring. Concrete floors have also been found to be associated with the occurrence of knee injuries in cows, due to higher risk for slips and falls (Zaffino Heyerhoff et al., 2014). Eicher et al. (2013) compared locomotion scores during the two first lactations between concrete and rubber floors. In first lactation, no significant differences were found. In the second lactation, cows on concrete floor had higher locomotion scores.

Table 1. Approved alley widths in stables with over 25 adult cattle in Sweden.

Alley between:	**Meter:**
- **Free-stall and a wall** - **Feed-stalls and a wall**	2.00

- **Two free-stall rows** - **Free-stall and feed-stalls**	2.20
- **Feed bunk and a wall** - **Feed bunk and free-stall**	3.00

2.4.4 Cleaning of alleys

Clean alleys are important for good claw health. More frequent alley scraping reduced the occurrence of clinical lameness (King et al., 2016). Oliveira et al. (2017) found that more frequent alley scraping (over 8 times per day) reduced the occurrence of DD. DeVries et al. (2012) found that more frequent alley scraping increased cleanliness on legs and udder. In the study, the frequency of 3, 6, 12 and 24 scrapings per day was compared, and the results showed that hygiene improved with increased frequency of alley scraping.

Magnusson et al. (2008) compared hygiene and manure accumulation in slatted rubber floor alleys with or without automatic scrapers. The study showed that the use of scrapers significantly decreased manure accumulation in the alleys (figure 10) and improved udder hygiene. Reduced amount of manure in alleys also resulted in less manure in free stalls. Even though this study was conducted on slatted rubber floors, the authors claim that manure scrapers should have the same positive effect on slatted concrete floor. In studies by Somers et al. (2005, 2003), concrete slatted floor with automatic scrapers created a dry floor surface and decreased the risk of infectious claw disorders like DD, interdigital dermatitis and HHE compared to slatted floor without scrapers.

Stefanowska et al. (2001) compared manure accumulation on slatted and grooved concrete floors with automatic scrapers and found that the slatted floor stayed cleaner with less accumulation of manure.

Figure 10. Manure gathered in the alley. Photo: Christer Bergsten.

Manure scrapers in motion can cause trauma on the claw and be the reason for development of non-infectious claw lesions (Cramer et al., 2009). In a study by Stefanowska et al. (2001), the occurrence of stumble accidents of cows were observed on grooved and slatted concrete floor with manure scrapers. Of a total of 114 stumble accidents, where cows slipped with fore or hind limb, the manure scraper provoked 107 of the accidents. Most accidents occurred when cows were walking and tripped over the manure scraper, and when cows were standing together in the

alley without noticing the manure scraper until it touched the cow and made her lose her balance. The number of stumble accidents were not influenced by floor type.

In a study by Solano et al. (2017), the prevalence of DD was found to be correlated to leg cleanliness. Nielsen et al. (2011) found that parity, lactation stage and daily laying time affected cow cleanliness in loose-house systems. Older cows (≥ parity 3) and cows in late lactation (> 240 DIM) had cleaner hind legs. Also, an increased daily laying time was associated with cleaner hind legs. On herd level, access to pasture was found to be associated with cleaner hind legs. In a study by Hultgren and Bergsten (2001), cows stayed cleaner on slatted floors than on solid floors.

2.4.5 Footbath

Footbaths are used to prevent the occurrence of infectious claw lesions. Footbaths often contain one or more antibacterial (Cook et al., 2012). The frequency of the use of footbath varies, but the use of footbath has been shown to reduce the prevalence of infectious claw lesions like DD (Faye and Lescourret, 1989; Logue et al., 2012; Solano et al., 2017).

2.4.6 Claw trimming

Claw trimming is important to prevent claw lesions and lameness. Claw trimming are also used to sustain normal claw shape and to prevent abnormal growth (figure 11). Trimming are recommended at least two times per year, but how often trimming is needed varies between farms and individual animals (Manske et al., 2002b). According to Swedish regulations, regular inspection of claws must be implemented, and trimming must be performed when needed (6 § SJVFS 2017:24).

Figure 11. Overgrown claw. Photo: Christer Bergsten

In a study by Manske et al. (2002b), claw lesions recovered and the prevalence of lameness decreased after claw trimming. Trimming in the autumn also reduced the need for acute treatments between planned trimmings and reduced the prevalence of lameness and claw lesions in the spring. In a study by Cramer et al. (2009) the prevalence of white line abscess (figure 8) was reduced when trimming heifers before calving.

Faye and Lescourret (1989) found that the prevalence of claw lesions and lameness were positively correlated with regular claw trimming. However, the authors assumed that the findings could be explained by the fact that more claw and leg problems were reported in herds with regular claw trimming. Eicher et al. (2013) found less need of claw and leg treatments for cows on rubber floors compared to on grooved concrete floor.

2.4.7 Animal welfare compensation to dairy farmers

In Sweden, there is a possibility to apply for subventions for supplemental claw health care for cows and heifers older than 24 months (so called Klövpeng). To be eligible for compensation, the farmer needs to fulfil some demands. For example, trimming must be performed at least 2 times a year by a certified claw trimmer. Also, routines to control, estimate and follow up the claw health in the herd must be implemented on the farm. A plan for claw health care in the herd must be set up together with the claw trimmer or other advisor. This plan must include information about planned claw trimmings, current claw health in the herd and planned actions for improving claw health. This plan must be updated after each visit by the claw trimmer. The claw trimmer also needs to report information about claw disorders, treatments and lameness for each individual animal after each visit to the farm (Swedish Board of Agriculture, 2019).

2.5 Locomotion on various floorings

Floor systems and surface affect locomotion. On rubber flooring, locomotion becomes more similar to locomotion on natural surfaces (e.g. pasture). In a study by Telezhenko and Bergsten (2005), rubber mats decreased step asymmetry and improved the locomotion of moderately lame cows. Studies has shown that rubber flooring gives longer stride length of cows (Haufe et al., 2009; Platz et al., 2008; Telezhenko and Bergsten, 2005), measured as the distance between the two following imprints of the same rear foot (Telezhenko & Bergsten, 2005). Increased stride length indicates that the cow feels more comfortable and secure on the surface (Flower et al., 2007). In the study by Haufe et al. (2009), stride length increased with approximately 10 cm on solid rubber floor compared to slatted concrete floor. In the study by Telezhenko & Bergsten (2005), slatted rubber mats were compared to continuous rubber mats. The results showed that stride length was longer in solid rubber mats.

In a study by (Telezhenko & Bergsten, 2005), cows walk with the slowest pace on slatted concrete floors compared to on solid concrete, slatted rubber and solid

rubber. One reason for this result can be that concrete are more slippery than rubber floorings. High risk for slipping have a negative effect on cows' welfare and impair their ability to sustain normal behaviour and locomotion (Philips, 2010). Slips and falls are harmful and can lead to damaged ligaments and muscles and can in worst case cause bone fractures. These types of accidents can also cause extreme wear of the hoof or damage the sole of the hoof (Philips, 2010). Slippery concrete floor has been found to impair locomotion of cows (Telezhenko and Bergsten, 2005) and slipping when walking is most frequently observed on slatted concrete floors (Haufe et al., 2009). Slipperiness are mainly affected by the floor surface. In a skid resistant test, the results showed that slatted concrete was the most slippery. On dry surfaces, highest skid resistance where found on rubber mats (Telezhenko et al., 2017). Slipping can be reduced by increasing the friction of the floor. The coefficient of friction can be explained as the force that are needed to move an object over a floor divided by the weight of that same object (Philips, 2010). According to Philips (2010), a friction coefficient over 0.4 reduce the risk for slips and falls and over 0.5 can cause abrasive wear of the claw. A coefficient of friction between 0.4 – 0.5 has been show as optimal (Phillips and Morris, 2000). In a study by Telezhenko and Bergsten (2005), the coefficient of friction on solid concrete was 0.58, on slatted concrete it was 0.31 and on rubber mats 0.46 (both solid and slatted). This indicates that the friction of rubber mats is most beneficial. Low friction leads to more and shorter steps (Phillips and Morris, 2000).

Phillips and Morris (2000) found that wet floors and floors covered with slurry have a great impact on the movement pattern of dairy cows. On floors with deep slurry, cows walked slower than on drier floors. Also, the cows' movement pattern for both forelimb and hindlimb changed. These changes occurred probably to reduce the risk for slipping. The authors found it to be more difficult for the cow to lift the limbs from a slurry surface.

2.6 Behaviour on various floorings

2.6.1 Behaviour

Floor system affects animal behaviour (Phillips and Morris, 2000; Platz et al., 2008). Insufficient floor surface can constrain the cows to perform their natural behaviours (Phillips and Morris, 2000). Reduced grooming, especially on hindquarters, is a sign of insecurity and insufficient flooring (Philips, 2010). On slatted rubber floor, self-grooming behaviour of cows, like licking while standing on three legs and caudal licking, were found to be more frequently occurring compared to on slatted concrete

floor (Platz et al., 2008). However, Haufe et al. (2009) found no difference in self-grooming behaviour on solid rubber floorings compared to slatted concrete. Stefanowska et al. (2001) compared self-grooming and aggressive behaviour on slatted concrete and grooved concrete floors. There were no differences found for either grooming or aggressive behaviours between the two floor types.

Kremer et al. (2007) and Ouweltjes et al. (2009) found a higher activity level in cows on slatted floor covered with rubber compared to cows on slatted concrete. Platz et al. (2008) found changes in resting behaviour, with higher occurrence of cows resting in alleys with rubber floors than in alleys with concrete floor. Ouweltjes et al. (2009) also found that rubber mats increased time spend standing on slatted floors. Overcrowding is another reason for increased time cows spent standing in the alleys (Philips, 2010). Low-ranked cows spend less time standing in the alleys than high-ranked cows (Wierenga and Hopster, 1990). Cows display more signs of estrus on slatted floor covered with rubber than on slatted concrete floor (Platz et al., 2008).

According to Proudfoot et al. (2010), changes in behaviour can be used as an early indicator of claw lesions. However, according to the authors there is a lack of knowledge about whether lesions are the cause of behavioural changes or if the behavioural changes are causing the lesions. One indicator of lesions is when cows are standing halfway into the cubicles, with front claws in the cubicle and hind claws in the alley (Dippel et al., 2011; Galindo and Broom, 2000; Proudfoot et al., 2010). Galindo and Broom (2000) found that lame cows spend more time standing half in the cubicle. The weeks around calving, cows that later developed lesions had an increase duration of standing with the front claws halfway into the cubicle. They also spent more time standing in the feeding alley. Galindo and Broom (2000) also found that low-ranked cows spend more time standing half way into the cubicles.

2.6.2 Cow preferences for various types of flooring

In a study by Platz et al. (2008), a preference test for various types of flooring was performed. In the study, the alley to the milking parlour had one side with rubber flooring and one with concrete. Two-third of the cows preferred to walk on rubber flooring. Telezhenko et al. (2007) found similar results, where cows preferred to walk on rubber floorings rather than on concrete. Cows also preferred to walk on solid rubber mats compared to slatted mats. Within the same study, also a comparison between 22- and 33 mm thick rubber mats was performed, and cows were found to preferer to walk on the thicker rubber mat.

According to Telezhenko et al. (2007), lame cows did not prefer rubber floorings over concrete. Which, according to the authors, may be due to the competition for

the softer flooring with other, higher ranked cows. However, the majority the cows preferred rubber mats over concrete.

Tucker et al. (2006) compared preferences for various floors in front of the feed bunk. Sawdust and rubber floors were compared with concrete flooring. In both experiments, cows preferred to stand and walk on the softer material compared to on concrete.

2.6.3 Fetching of cows to the milking unit

In AMS, little time spent on fetching cows are one indicator of functional cow traffic and a successful dairy farming (King et al., 2016). According to Bach et al. (2009), more time was spent on fetching cows in free traffic systems compared to forced systems. In the study by King et al. (2016), the average need of fetching cows was 8.1 % of the herd, and the need of fetching cows decreased with more frequent alley scraping. The authors also found a positive correlation between stocking density in the barn and the need of fetching cows, and that lame cows needed to be fetched more often compared to non-lame cows. Fetching cows for milking increases the need for labour, which counteract the reduction in labour the AMS are supposed to create (Rossing and Hogewerf, 1997).

3 Materials and Methods

3.1 Online Survey

An online survey on Swedish was created in the web-based tool Netigate. The survey included 57 questions connected to the purpose of the study (appendix 1). Farms were provided by DeLaval and a total of 123 farmers with DeLaval Voluntary Milking System (VMS) were invited to answer the survey. Farms with slatted floor were of high interest for the study, wherefore care was taken that a sufficient number of farms with this type of floor system was included among the selected farms. An invitation to participate in the study was sent to the farmers, containing information about the study and a link to the survey. The invitation was sent to the farmers both by conventional post and by email. One week before the survey was closed, one additional email was sent with a reminder to the farmers. The invitation to the survey was also posted on RISE Bioscience and material's page on Facebook and shared in the group called 'Vi med robot' (We with robot; a group of Swedish dairy farmers with AMS). Only farmers using DeLaval VMS could answer the survey. The farmers had 21 days to answer the survey (12 March – 2 April). A powerbank from DeLaval was offered as a gift to all responding farmers. The participation in the survey was voluntary and all personal information were handled according to the Personal Data Act (PUL).

In the survey, the question of floor system was limited to the feed alleys, freestall alleys and the area in front of the VMS (for example the waiting area) for the best functioning group in the barn. No other barn areas or floor sections were included in the survey.

3.2 Data Collection

Milk production data (table 2) was collected from all participating farms' management program (DelPro, Delaval). Data was gathered from DelPro by using the web-based tool LogMeIn. Data from each farm's milking unit was collected for the period March 2018 to May 2018. All cow-specific data was gathered on 26-27 April, for a period of the last seven days. All information about claw health for each farm (table 2) was collected from the database Kokontrollen (Växa Sverige) and was provided by Växa Sverige. Key figures for claw and leg health according to the veterinarian (CHv), claw health according to the claw trimmer (CHt) and cows culled due to leg or claw problems (CHc) were calculated by Växa and were supposed to be as close to zero as possible. Calculations for these key figures are found in table 3. In the online survey, the farmers had to approve access to DelPro and Kokontrollen to be able to respond to the rest of the survey.

Table 2. Information gathered from DelPro and 'Kokontrollen'.

Variables	Time period of data
Milk production per cow and day	Average for seven days, gathered from the farms at 180426 and 180427
Milk production per milking unit and day	Average for the period 180301-180501
Claw and leg health according to the veterinarian	Average for a period of 3 month in the spring 2018
Claw health according to the claw trimmer	Average for a period of 3 month in the spring 2018
Cows culled due to leg or claw problems	Average for a period of 3 month in the spring 2018

Table 3. Calculations for key figures for claw and leg health from Kokontrollen (Växa Sverige). The unit is percent. T^2 = Time correction factor for the three-month outcome so that it corresponds to a twelve-month period, the so-called twelve-month forecast. T^2 is used only when calculating the twelve-month forecast.

Key Figure	Mathematical formula	Reports of:
Claw and leg health according to the veterinarian (CHv)	$\frac{\text{Number of reported claw and leg health problems from veterinarian or farmer}}{\text{Average number of cows}} * T^2$	Interdigital phlegmone Arthritis Bone fracture Wrenches Osteoarthritis Interdigital hyperplasia Abscesses Sole ulcer Laminitis

		Polyarthritis Claw or leg problems reported from test milking.
Claw health according to the claw trimmer (CHt)	$\frac{\text{Number of reported claw problems from claw trimmer}}{\text{Number of claw trimmings}}$	Sole ulcer White line abscesses Digital Dermatitis Limax Interdigital phlegmone Wart Toe abscess.
Cows culled due to leg or claw problems (CHc)	$\frac{\text{Number of cows culled due to claw and leg problems}}{\text{Average number of cows}} * T^2$	Claw or leg problems as the reason for culling.

3.3 Definition of traffic system

In the survey, two questions were asked to state what type of traffic system each individual farm had. This system to define cow traffic was also used in an earlier master thesis by Gustafsson, (2017). Various combinations of answers in those two questions resulted in various interpretations of traffic system (see table 4). The questions were:

Question 1: Are the lying- and roughage area separated by one-way gates?

1. Yes
2. Yes, but there are a few cubicles in the feeding area as well
3. No

Question 2: Is there a selection gate selecting the cows to the milking unit?

1. No
2. Yes, where the cows are leaving the combined lying- and roughage area
3. Yes, where the cows are leaving the lying area
4. Yes, where the cows are leaving the roughage are

Table 4. Description of how the combinations of answers regarding traffic system were interpreted. Combining the farmers answers for question 1 and 2 in the same column, and then follow the column down to the circle and the cow traffic system can be found in the first column to the left on the same row as the circle. The combination of answers in the last two columns is contradictive and therefore not possible (Gustavsson, 2017). O = True, X = False.

	Answering options

Question 1	1	1	1	1	2	2	2	2	3	3	3	3
Question 2	1	2	3	4	1	2	3	4	1	2	3	4
Feed first	**X**	**O**	**X**	**O**	**X**	**O**	**O**	**X**	**X**	**O**	**X**	**X**
Milk first	**X**	**X**	**O**	**X**	**X**	**X**	**X**	**O**	**X**	**X**	**X**	**X**
Free Traffic	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**O**	**X**	**X**	**X**
Forced traffic	**O**	**X**	**X**	**X**	**O**	**X**	**X**	**X**	**X**	**X**	**X**	**X**

O = True, **X** = False.

3.4 Statistical Analysis

The answers in the survey were partly used to only describe the farms and are called the describing part of the study. In the epidemiological part of the study, results from the online survey and the farms management systems were analysed for variances in milk production, both per cow and per milking unit on the farm, and claw health. Milk production per cow (MPc) was defined as average kg milk produced per cow and day, for a period of seven days. Milk production per milking unit (MPu) was defined as average production per unit and day for three months (March-May 2018). For claw health, key figures was used for claw health according to veterinary (CHv), claw health according to claw trimmer (CHt) and cows culled due to leg or claw problems (CHc). Claw health data was gathered for three months during spring 2018.

First, the independent variables were analysed in Minitab (2017) with ANOVA and correlation test for the dependent variables MPc, MPu, CHc, CHv and CHt. A p-value below 0.05 was considered to be significant. There after a comparison test were conducted for all significant results in the ANOVA.

4 Results

A total of 91 farmers responded to the survey, of them were 66 from the group of 123 farmers invited to respond to the study and 23 volunteered from the invitation to the survey on Facebook. Two farms did not answer how they found the survey. Of the 91 answered surveys, 87 was completed and could be used in the describing part of the study. For the statistical analysis for milk production, data could be used from 83 farms. Three farms could not be identified and on two farms the floor system could not be defined, and they could therefore not be included. Växa thereafter provided claw health data for 69 of the farms (table 5). All significant differences and correlations are presented in the results below.

Table 5. The number of farms data were collected from in the various part of the study.

	n	**%**
Epidemiological part (Online survey)	87	100
Milk production data (MPc and MPu)	83	95.4
Claw health data (CHv, CHt and CHc)	69	79.3

4.1 Farm information

Both conventional and organic farmers responded to the survey. The respondents had between 45 to 420 cows, with an average of 116 milking cows. The number of milking units varied between 1 and 6, with an average of 1.8 milking units per farm. Most of the farms did not have any other milking system than VMS (table 6).

Table 6. Descriptive information about the farms included in the survey study (N = 87).

	n	%
Type of production		
Conventional	61	70.1
Organic	25	28.7
(Missing answers)	1	1.2
Total number of milking cows		
0-49	2	2.3
50-99	44	50.6
100-149	22	25.3
150-199	11	12.6
200-250	5	5.8
More than 250 cows	3	3.5
Total number of milking units (VMS)		
1	41	47.1
2	33	37.9
3	8	9.1
4	3	3.5
5	1	1.2
6	1	1.2
Other milking system than VMS		
No other milking system	61	70.1
Milking parlor	2	2.3
Tied-up stall	18	20.7
Other	6	6.9
Number of groups with milking cows		
1	53	60.9
2	27	31.0
3	3	3.5
4	3	3.5
(Missing answers)	1	1.1
Cow traffic		
Feed first	56	64.4
Milk first	19	21.8
Free traffic	10	11.5
Forced traffic	1	1.2
(Missing answer)	1	1.2

Organic farms had better claw health according to reports from both veterinarians and claw trimmer (table 7). For the key figure CHc, no significant results were found for any of the independent variables.

Table 7. Leg and claw health according to veterinary (CHv) and claw health according to claw trimmer (CHt) on conventional and organic farms.

	Conventional		Organic		
	n	**mean**	**n**	**mean**	**p**
CHv	45	2.4	22	1.2	0.05
CHt	38	9.1	16	4.6	0.023

Based on the farm information, significant correlations were found for both MPc and MPu. However, all found correlations are weak. These correlations are presented in table 8.

Table 8. Correlations for milk production per cow (MPc) and milk production per milking unit (MPu). ns = non-significant.

	MPc		MPu	
	r	**p**	**r**	**p**
Total number of milking cows	0.258	0.02	0.264	0.017
Total number of milking units	0.252	0.023	0.072	*ns*
Rows with cubicles	0.252	0.026	0.247	0.03
Number of cows in the section	0.248	0.026	0.355	0.001
Number of cows fetched per milking	0.246	0.032	0.217	*ns*
Daily number of feedings in feed bunk	0.354	0.001	0.340	0.002

4.1.1 Grouping of cows

In the study, only 35 of the 91 farms had more than one group of milking cows. On most of these 35 farms, the farmer based their grouping on udder health (36 %), by newly calved cows (33 %) or claw and leg health (27 %). The farmers could on this question choose more than one answer. However, a majority of the farms only based their grouping on one criterion (58 %) and 15 % did not base their grouping on any specific criteria at all. Of the farms with more than one section, 27 % did not move cows between sections during lactation. On farms where cows were moved during lactation, changes in udder health was the most common reason for moving cows (21 %). On the 19 farms that moved cows between sections, independent of the reason, CHv were better than on those 13 farms that did not move cows (1.43 and 3.11 respectively, $p = 0.032$).

4.1.2 The need of fetching cows for milking

On most of the farms, one to four cows needed to be fetched for milking per day (figure 12). According to the farmers, the most common reason for fetching cows to the milking unit was that the cow or heifer was newly introduced to the system (30 %). The second most common reason was cows that by the farmer was considered to be lazy (24 %). Also, the need of manual handling in the milking unit was a common reason for fetching (17 %). Fetching due to claw problem and lameness was not as common (10 %). A weak positive correlation was found for the number of cows that needed to be fetched for milking and MPc (table 8). However, no significant difference for neither milk production or claw health was found for the number of fetched cows or for the reason for fetching cows.

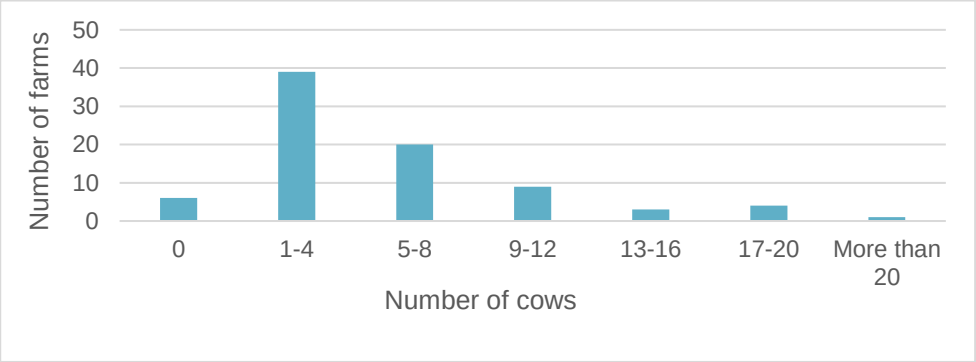

Figure 12. Number of cows that needed to be fetched for milking. If one cow is needed to be fetched more than one time per day, every time is counted separately.

4.1.3 Feeding

The most common feeding strategy were to use only roughage in the feed bunk, combined with concentrates in the milking unit and in the automatic feeders. How often feed was delivered in the feed bunk varied a lot between farms (table 9), however MPc was found to increase with the number of times feed was filled in the feedbunk (table 8). There was no significant difference for milk production or claw health between the number of times feed was filled in the feed bunk.

Table 9. Feeding strategies on the responding farms (N=87).

	n	%
Type of feeding used on the farm		
TMR + rewarding feed in milking unit	2	2.3
PMR + additional concentrate in milking unit and automatic feeders	36	41.4
Only roughage + concentrate in the milking unit	1	1.2

Only roughage + concentrate in the milking unit and automatic feeders	45	51.7
Other	3	3.5
How many times per day is feed delivered in the feed bunk?		
1-4	14	16.1
5-8	23	26.4
9-12	32	36.8
More than 12 times	16	18.4
(Missing answers)	2	2.3

4.1.4 Animal behaviour

On most farms, the farmer rarely experienced the cows to stand half way into the cubicles (figure 13). However, on the 18 farms where the farmer experienced that cows often stood with front feet in the cubicle and hind feet in the alley, the CHv were found to be higher than on those 47 farms where it was considered to be less common (3.62 and 1.42 respectively, p = 0.002).

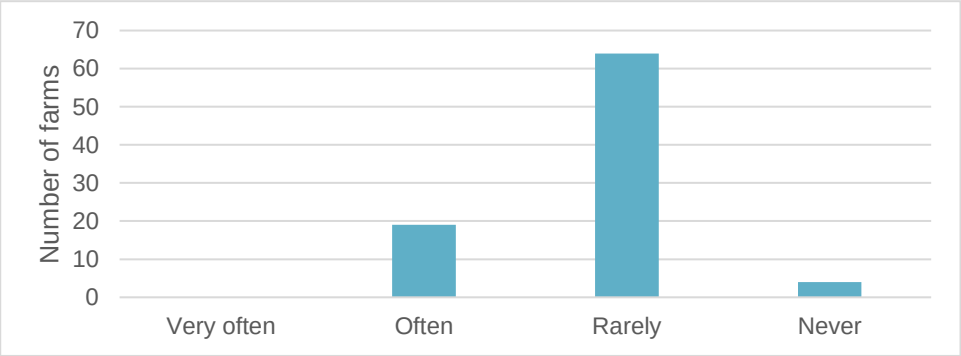

Figure 13. How often the farmer experiences cows to stand half way in to the cubicle.

4.1.5 Use of advisory service

Almost all responding farmers (91 %) used some type of advisory service. Most common was the use of breeding (68 %) and production (66 %) advisory service (figure 14). Animal health advisor was the third most commonly used advisory service and was used by 39 % of the 91 farmers. Of the responding farmers, 26 % used three or more types of advisory services. Only 22 farmers named which company they used for the advisory service, and Växa was the most common company and was used by 16 of the 22 farms.

Five of the responding farms in the epidemiological part did not use any type of advisory service. According to the veterinary report, these five farms had more leg and claw health problems than those 63 farms that used advisory service (4.1 and 1.8 respectively, p = 0.042). Farms using economic advisors had on average 2.53 kg higher MPc, than farms that did not use that type of advisory service (p = 0.042).

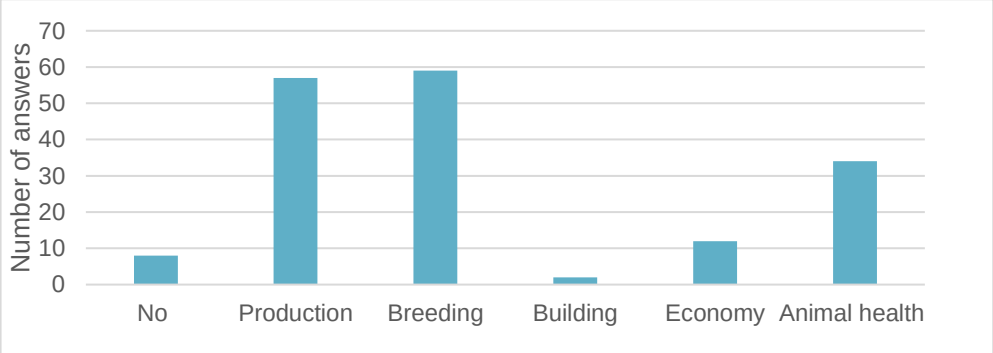

Figure 14. Type of advisory service used on the farms. More than one answer was possible.

4.2 Flooring system

In the epidemiological part, the farmers responded to questions about the flooring system in the feed alley, in the free-stall alleys and in the area in front of the VMS in their best functioning section. No other sections of the barns were included. On most of the farms with more than one section with VMS, the floor system in the other sections was the same as in the chosen section (n = 19) or mostly the same (n = 7). Only on two farms, the floor system in the other sections was different from the chosen section.

Most commonly, floor systems differed in all parts of the section and the distribution of flooring type and material in the various sections are presented in figure 15 and figure 16. There was no significant difference for MPc, MPu or claw health for the various floor systems.

Figure 15. Floor system in the different parts of the barn.

4.2.1 Feed alley

In the feed alley, rubber flooring was more common (59 %) than concrete flooring (41 %). Of the farms with solid or slatted concrete floors, 65 % had grooved floors. Of the 56 farms that had solid floors, 89 % had urine drainage. An alley width between 3-3.5 meters were most common. The reported CHt was significantly lower with an alley width over 3.5 m than if the alley were less than 3 m (4.93 and 11.77 respectively, $p = 0.027$).

4.2.2 Free-stall alley

In the free-stall alley, concrete floors were more common (76 %) than rubber floor (24 %). Of the farms with solid or slatted concrete floors, 63 % had grooved floor. Of the 58 farms that had solid floor, 91 % had urine drainage. An alley width less than 3 meters were most common. Properties of the free-stall ally did not affect milk production or claw health.

4.2.3 Combinations of both alleys

The combinations of floor systems in feed and free-stall alleys are presented in table 10. It was most common to have solid floors in both alleys. Concrete and a combination of concrete and rubber in the alleys was more common than only rubber. No significant differences were found for milk production or claw health based on the combination of floor type or material.

Table 10. Floor system in feed and free-stall alley (N=87).

Floors in both alleys	**n**	**%**
Type		
Slatted	28	32.2
Solid	55	63.2
Both	4	4.6
Material		
Concrete	34	39.1
Rubber	20	23.0
Both	33	37.9

4.2.4 Area in front of the VMS

In the area in front of the VMS, slatted floor was most common (76 %) and 54 % of the farms had concrete floors. Grooved concrete floor was more common (61 %) than floors without grooving. On the 16 farms that had solid floors in the area, the CHv were lower compared to on those 52 that had slatted floor (0.77 and 2.38 respectively, $p = 0.016$). When the concrete floor was grooved, MPc where higher compared to when the floor was not grooved (32.7 kg and 30.1 kg respectively, $p = 0.035$).

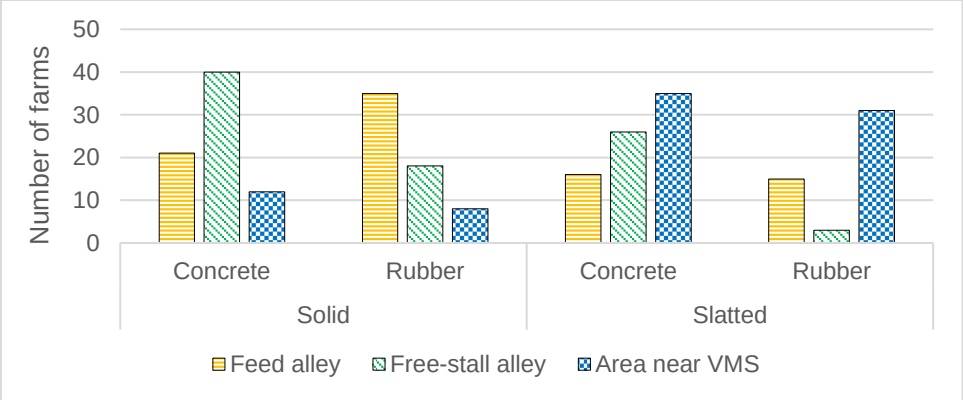

Figure 16. The distribution of floor type and material in the various sections.

4.2.5 Building year and maintenance

Building year of the flooring systems are presented in figure 17. It was more common to groove concrete floors than install new rubber mats and most maintenance were made during the last four years (table 11). On farms that had maintained the floor in the free-stall alley by installing new rubber mats the MPu was higher, compared to on those farms that had choose to groove the floor (2232 kg and 1921 kg respectively, p = 0.027). No significant differences were found for neither building year or year for maintenance.

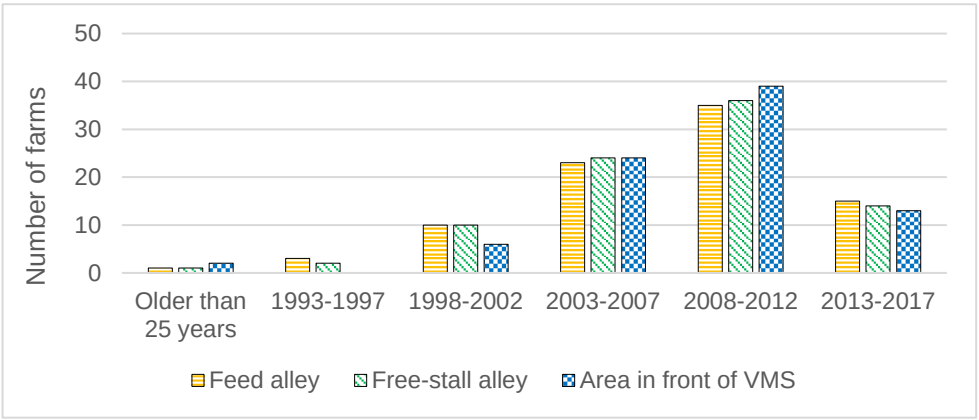

Figure 7. Building year of barn.

Table 11. Type of and number of years since maintenance (2018).

	Feed alley		Free-stall alley		Area in front of VMS	
	n	**%**	**n**	**%**	**n**	**%**
Type of maintenance						
New rubber mats	8	28.6	8	19.5	8	24.2
Grooving	20	71.4	33	80.5	25	75.8
Years ago						
0 - 3	19	67.8	27	65.9	20	60.6
4 - 7	7	25.0	11	26.8	8	24.2
8 - 11	1	3.6	1	2.4	2	6.1
(Missing answer)	1	3.6	2	4.9	3	9.1

4.2.6 Alley cleaning

Type of cleaning in the feed and free-stall alleys and in the area in front of the VMS is presented in figure 18. In all farms, the feed alley was either cleaned by automatic scrapers or only by slatted floor. However, in the free-stall alley, other cleaning methods occurred.

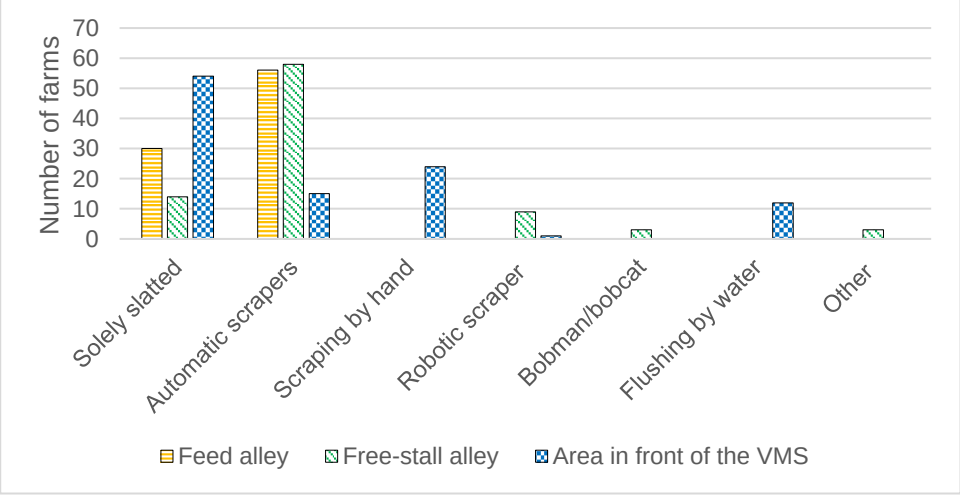

Figure 88. Type of cleaning in the alleys and in front of the VMS. For the area in front of the VMS, more than one answer was possible.

The reported CHt was lower on farms with slatted floors in the feed alley, compared to solid floors cleaned with automatic scrapers (5.0 and 9.0 respectively, p = 0.036). Only one farm had manure scrapers on slatted floor in the feed alley and was therefore not included.

For the free-stall alley, a comparison was made between farms with only slatted floors, slatted floors with robotic scraper/bobman and solid floors with scrapers. The reported CHv was found to be significantly lower on the 46 farms with only slatted floor than on those 10 farms with solid floors with scrapers (table 12).

Table 12. Claw health according to veterinarian (CHv) at farms with different floors and cleaning systems (N=66, p = 0.049). Means that do not share superscript letters are significantly different at p<0,05.

	n	CHv, mean
Slatted floor	46	0.3^{a}
Slatted floor with robotic scraper	10	$2.1^{a,b}$
Solid floor with scrapers	10	$2{,}4^{b}$

The number of times per day the feed- and free-stall alleys were scraped are shown in figure 19. This figure also shows how often the area in front of the VMS was cleaned, regardless of type of cleaning. Almost all farms with solid floors had urine drainage in both feed alley and free-stall alleys (table 13).

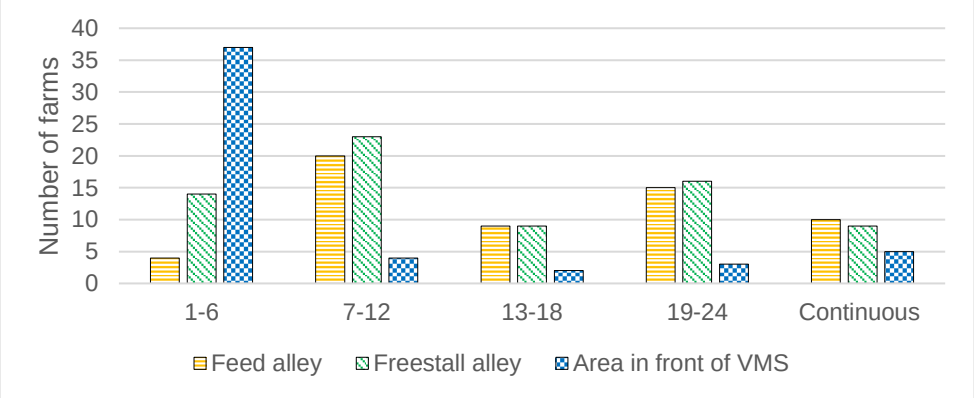

Figure 19. Times per day the alleys were being scraped and the floor in front of the VMS were cleaned.

Table 13. Number of farms with solid floors with urine drainage.

	Feed alley		Free-stall alley	
Solid floor with urine drainage	**n**	**%**	**n**	**%**
Yes	50	89.3	53	91.4
No	6	10.7	5	8.6

4.3 Claw trimming

Claw trimming routines for all responding farms are presented in table 14. Most farms hired a professional claw trimmer (70 %). Only on 2 % of the farms, the farmer or an employee performed all the trimming. Two visits by the claw trimmer per year was most common (56 %). Most common strategy for trimming was to trim all cows at the same time, one or a few times per year (81 %). Almost all responding farms (90 %) had applied for "Klövpeng". Neither trimming routines nor number of visits by the claw trimmer had a significant impact on milk production or claw health.

Table 14. Claw trimming routines on the farms.

	n	%
Performer of claw trimming		
Professional claw trimmer	61	70.1
Farmer or a staff member	2	2.3
Professional claw trimmer and acute cows are trimmed by the farmer	24	27.6
Visits per year by claw trimmer		
1	3	3.5
2	49	56.3
3	21	24.1
4 or more	6	6.9
Every 5 months	5	5.8
Other	3	3.5
Trimming strategy		
All cows at the same time, in one or a few times per year	70	80.5
Adapted after dry period and calving (According to SOP)	5	5.8
When needed, or by the occurrence of lameness	2	2.3
All cows 2 times per year, and when needed	7	8.1
Other	3	3.5
Applied for "Klövpeng"		
Yes	78	89.7
No	9	10.3

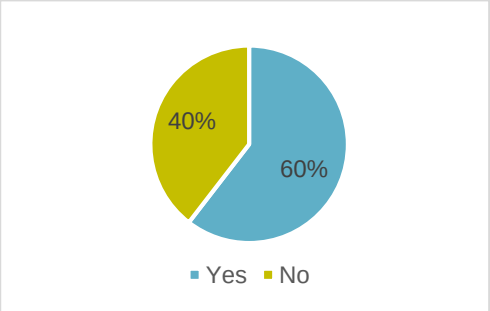

Figure 209. Usage of claw bath.

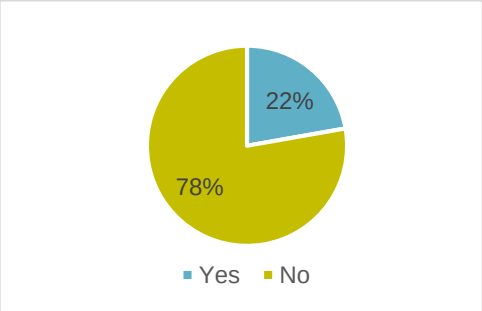

Figure 21. Farms that perform trimming themselves and report claw disorders.

It was more common to use claw bath, than not (figure 20). Farms that used claw bath had higher MPc than farms that did not (32.9 kg and 29.6 kg respectively, p = 0.00). However, according to the veterinary report claw health was better on farms that did not use claw baths (1.3 and 2.5 respectively, p = 0.046). Of the 26 farms that preformed claw trimming themselves, only 4 farms reported claw disorders (figure 21).

Most of the responding farmers considered claw health in their herd to be good (figure 22). The farmers opinion of claw health agreed well with the report from the claw trimmer (table 15). On the farms where the farmers considered the claw health to be bad, the most common problem were DD.

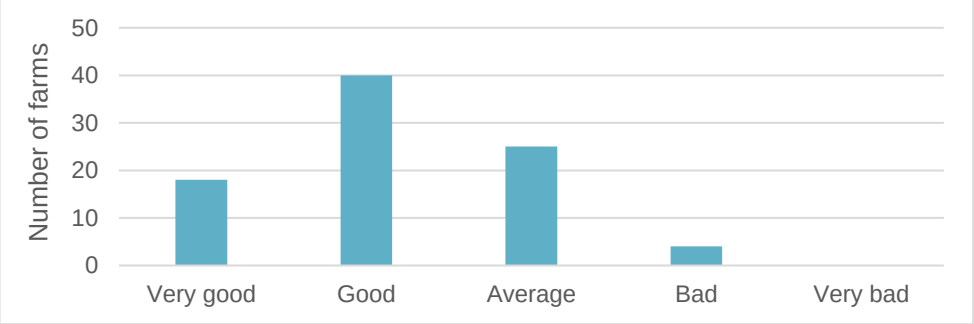

Figure 22. The farmers opinion about the claw health status in their own herd (N = 87).

Table 15. The farmers opinion of the claw health status compared to the claw health reports by claw trimmer (CHt)(N = 55). Means that do not share superscript letters are significantly various at p<0,05.

	n	CHt, Mean
Bad	2	19.3^{a}
Average	15	$10.7^{a,b}$
Good	26	$6.9^{b,c}$
Very good	12	3.5^{c}

5 Discussion

The discussion is divided into four different parts, based on the independent variables (type of production, flooring system and cleaning routines, management and animal behaviour) that had a significant impact on the dependent variables claw health and milk production. In the fifth and last part, the methodology is discussed.

5.1 Type of production

Claw health was found to be better on organic farms, than on conventional. Bergsten et al. (2015) also found better claw health and lower occurrence of claw disorders in organic farms. According to the authors, this can be due to a less intense diet, which can reduce the risk of claw diseases in two different ways. Partly by reducing manure contamination of the floors, and partly by reducing the risk of metabolic disturbances and susceptibility to diseases. A longer grazing period and more hours on pasture in organic farms can also improve claw health according to the authors. In a study by Sjöström et al. (2018), Swedish organic dairy herds were found to have better claw health compared to organic herds in France, Germany and Spain.

MPc was found to be positively correlated to the total number of milking cows, number of milking units, number of rows with cubicles and number of cows in the group. MPu was also positively correlated to total number of milking cows, rows with cubicles and number of cows in the chosen section. Although the correlations were weak, this may indicate that milk production was better in larger farms, but it may also be due to other reasons.

5.2 Flooring system and alley cleaning routines

The hypothesis of the study was that farms with slatted floors have lower milk production, both per milking unit and per cow, than farms with solid floors. However, no significant differences in milk production were found when comparing type of

floor system. These findings are consistent with the results of a study by Kremer et al. (2007), where no differences in milk production between slatted floors with or without rubber were found, and a study by Eicher et al. (2013), that did not find any differences in milk production between solid and slatted concrete floors. The hypothesis was based on a master thesis by Gustavsson (2017), who found that milk production was significantly lower in farms with slatted floors. However, in that study there was no specific question about flooring system. Instead, the responding farmers answered the question "How many times per day is the manure removed from the paths?" and was there instructed to state in a textbox if the floor was slatted. This can be considered a vague question to define flooring system, which could have caused a reduced reliability regarding the results.

Floor system was found to have a greater impact on the claw health than on the milk production. Regarding how the alleys were cleaned, CHt was better on farms that had slatted floors, without scrapers, in the feed alley and CHv was found to be better on farms that had slatted floor without scrapers in the free-stall alley. This can be due to less mechanical stress. According to Cramer et al. (2009), manure scrapers in motion often cause claw lesions, and Sarjokari et al. (2013) found that inappropriate design on manure removal equipment are a common reason for claw trauma. Also, slatted floors are self-draining (Magnusson et al., 2008), and might therefore also create a drier floor surface. According to Philips (2010), a good functioning slatted floor often creates a clean environment, and according to Borderas et al. (2004), a clean and dry environment is important to maintain healthy claws because they are sensitive to wet and humid surroundings. Also, Sarjokari et al. (2013) found that a dry surface is the most important factor for a successful flooring system.

On farms where the feed alley was wider than 3.5 meters, the CHt was better. These results are in line with a study by Sarjokari et al. (2013), that found a negative correlation between the occurrence of lameness and feeding alley width, and that the occurrence of lameness was lowest on farms with a feeding alley width over 3.4 meter. According to the authors, more space may reduce the level of agonistic and aggressive behaviour, which often can occur in the feed alley, and which can be the reason for longer standing periods and claw trauma.

In the area in front of the milking unit, CHv was better in farms with solid floor system. According to Hinterhofer et al. (2006), solid floors causes less mechanical stress because it supports the whole claw. Also, on farms with grooved concrete floors in the area in front of the VMS, MPc was higher than if the floor was not grooved. Grooving reduce slipperiness, which might be particularly beneficial in crowded parts of the barn. The area in front of the VMS are often cleaned with water or is scraped by hand which creates a cleaner environment and better hygiene for the claws, compared to if it is only cleaned by automatic scrapers. Also, this type of cleaning reduces the risk of claw trauma.

In terms of maintenance, farms that installed new rubber mats in the free-stall alley had higher MPu than the farms that chose to groove the floor. According to both Platz et al. (2008) and Telezhenko et al. (2007), cows prefer to walk on rubber and therefore rubber mats may increase the cows willingness to walk to the milking unit, which might increase milk production per unit.

5.3 Management

Milk production was found to be affected by other factors included in the study, for example if the farmer used economic advisory service and the use of claw bath. These findings, together with weak positive correlations for example number of cows fetched for milking and times feed are delivered in the feed bunk, may indicate that the management might be more important than floor system for milkproduction. These findings are supported by the findings of Gustafsson (2017), who also found that management had an important impact on milk production.

Farms that used an economic advisory service had better milk production per cow and the results also showed that farms that did not use advisory service at all had more problems with CHv. Together, these results indicate that the use of an advisory service has a positive impact on both health and production in farms with AMS. One reason for these findings can be that farmers that use advisory services are more willing to adapt, and it can also be an indicator of a higher level of ambition.

On farms where the farmers moved cows between groups, independent of the reason, claw health was better according to the veterinary report. One reason for these results is that farmers that move cows, may be more active in their management and work more with preventive measures. Also, they probably spend more time with the cows which could make it easier to detect injuries and treat them in an early stage.

MPc was higher on farms that used claw bath. However, CHv was found to be better on farms that did not use claw bath. The reason for this finding can be that farms that have problems may choose to install claw baths because it is one way to reduce the prevalence of infectious claw lesions (Faye and Lescourret, 1989; Logue et al., 2012; Solano et al., 2017). The responding farmers also experienced that DD, which is infectious, was one of the most common claw problems.

5.4 Animal behaviour

Results from the study showed that on farms where cows were reported to more frequently stand half-way into the cubicles, the claw health were worse according to the veterinary recordings. This result can be reinforced by the results in the studies of Dippel et al. (2011), Galindo and Broom (2000) and Proudfoot et al. (2010), that found that this behaviour can be an indicator for claw lesions. Galindo and Broom (2000) also found that lame cows spend more time standing half-way into the cubicles. However, it is still unknown whether the changed behaviour is due to claw problems or lameness, or whether the behaviour is the cause for leg and claw health problems. When cows stand halfway into the cubicles, the hind claws become more exposed to environmental stress and manure. Stefanowska et al. (2001) found that the manure scraper caused a lot of stumble accidents, especially when the cow did not notice that it is approaching, which may be the case when the cow stands with only the hind limbs in the alley.

5.5 Methodology

A strength of this study is the high number of responding farmers, which creates a good and representative result for farms with DeLaval AMS. However, there is no analysis made for the responses, and therefore there is a lack of knowledge about which farmers that chose to respond and which that did not, which may have caused some bias in the result. It is also a risk that farmers that have low milk production or bad claw health choose not to participate in the study.

Also, because all farms used the same brand of automatic milking units, it is not a sample representative for all farms with AMS in Sweden. The selection of farms could have been confined by the fact that DeLaval provided all the farms that were invited to the survey and that care was taken to guarantee that a sufficient number of farms with slatted floors was included.

All responding farmers could also have interpreted the questions in different ways, and there is also a risk that some questions were unclear or hard to understand. In some questions, too low numbers of answers for some of the answering alternatives meant that no statistical analysis was possible.

Another strength in this study is that data from DelPro was gathered at the same time and for the same period. However, some farmers did not name their sections in DelPro as they did when they answered the survey, which caused some confusion. However, based on the number of cows and milking units in the different sections it was possible to figure out which section the farmer meant in the answer.

Due to limitations in the data collection, data from “kokontrollen” was collected for the whole herd and not for the chosen section in the barn. Although most

farms with more than one section with VMS stated that the flooring system in the other sections was the same as the one in the chosen section, there may be some differences that did affect claw health. Therefore, it is harder to draw certain conclusions about how the flooring system actually affected claw health. Data from "kokontrollen" was gathered for three months in the spring, but there were no data available for the same months on all farms. Therefore, it varied which months were used for different farms, which also could have created some weaknesses in the results. Especially since cows on some farms had access to pasture, which according to Bergsten et al. (2015), has a positive impact on claw health.

The use of reports from various veterinarians and claw trimmers could also have caused some uncertainty in the results. This because the reports are based on subjective evaluations from various persons and that there is no certainty that they report their findings at all. As an example, Häggman and Juga (2015) found a large difference in the reporting of claw disorders between claw trimmers, which according to the authors indicates that knowledge varies and that it can be hard to get a consistent classification of claw disorders when the judgement is made by various persons.

An attempt to explain how the combination of floor systems in the feed- and free-stall alleys was carried out. However, no significant impact on either milk production or claw health was shown. Despite this, it is difficult to draw any conclusions about how the combination of floor system in the different parts of the barn affects milk production and claw health. It is also difficult to determine which floor in which part has the greatest impact. There is a great deal of complexity and there are many factors that can have an impact. Each farm is unique, and it is therefore somewhat risky to put farms together in groups and draw conclusions about specific issues. Even though there was a high response rate, the unique properties of each farm makes it difficult to draw conclusions with high certainty. To obtain reliable results, a controlled study may be needed for each specific independent variable.

However, there is a strength that data was collected from commercial farms because it makes the results more applicable on Swedish dairy farms compared to if data was only gathered in an experimental study. To get more certainty in the results, the best would have been to visit all the farms to get a more objective evaluation for both flooring system, management and claw health. It would also be better if one claw trimmer and one veterinarian reported from all the farms. However, this would reduce the number of farms that could be included in the study, due to lack of resources.

In this study however, the farmers opinion about the claw health corresponded well with the report from the claw trimmer. This indicated that the responding farmers had good knowledge about their herd and increases the credibility of the other answers.

Collecting data in a more objective way is something that could be done in a continuation of this study, and because most of the significant differences were found for cleaning system and management, these parameters could be interesting to evaluate further. It would also be interesting to see if there are any correlations between different parameters in the flooring system and management that together affect milk production or claw health.

6 Conclusions

In this study, no significant differences were found for milk production between farms with solid or slatted floor. Floor system was found to have a greater impact on the claw health than on the milk production. Also, cleaning system were found to have a great impact on claw health. The claw trimming strategy did not affect either production or claw health. However, the use of claw bath had a positive effect milk production. Claw health were found to be better on organic farms than on conventional farms.

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Appendix 1

Online Survey - English translation.

SE-number:
Textbox

Questions about the farm

1. Type of production?
    - Conventional
    - Organic

2. Total number of milking cows?
   (Textbox)

3. Total number of milking units?
   1-10 units

4. Do you have any other milking system than VMS?
    - No
    - Milking parlor
    - Tied-up stall
    - Other: *(textbox)*

5. Number of groups with milking cows?
   With groups we mean cows divided into separated sections
   1 – 10 groups

6. Is the grouping of cows based on any criteria?
   More than 1 answer are possible
    - No, the groups are not separated on any specific criteria
    - Milk yield
    - Number of lactations
    - Number of days since calving
    - Udder health
    - Pregnancy status
    - Newly calved
    - Claw and leg health
    - Other: (*Textbox*)

7. Do you move the cows between sections during the lactation? If you do, of what reason?

- No
- Milk yield
- Udder health
- Claw and leg health
- Pregnancy status
- Other: (*Textbox*)

8. How often does the cows stand half way in feed-stalls?
   With front claws in feed-stalls and hind claws in the alley
   - Very often
   - Often
   - Rarely
   - Never

9. Do you use any type of advisory service?
   Specify used company below "other" – More than one choice is possible
   - No
   - Production advisor
   - Breeding advisor
   - Building advisor
   - Economy advisor
   - Animal health advisor
   - Other: (*Textbox*)

Choose one section with VMS

1. Specify which section you choose
   State the sections name in DelPro
   (*Textbox*)

2. How many cows do you have in the section?
   (*Textbox*)

3. How many milking units are there in the section?
   1 – 6 units

4. If you have more than one section, specify which milking units in chosen section:
   (*Textbox*)

5. How many free-stall alleys are there in the section?
   1 – 6 alleys

6. How many cows do you have per feeding place?
   If you don't have separated feed-stalls, specify the number of meter feed-bunk below "other"
   - < 1
   - 1
   - 2
   - 3
   - Other: (*Textbox*)

7. How many cows needs to be fetched for milking per day?
   Do you fetch the same cow repeated times shall each individual time be counted
   - 1 – 20 cows
   - More than 20 cows

8. What do you considered to be the most common reason for the need of fetching cows?
   - Do not fetch any cows
   - Newly calved
   - Lameness or claw problems
   - Cows requiring manually handling in the milking unit
   - "Lazy cows"
   - Other: (*Textbox*)

9. Are the lying area and the roughage area separated from each other with one-way gates?
   - Yes
   - Yes, but there are cubicles in the roughage area as well
   - No

10. Is there a selection gate that is selecting cows to milking?
    - No
    - Yes, where the cows are leaving the combined lying- and roughage area
    - Yes, where the cows are leaving the lying area
    - Yes, where the cows are leaving the roughage area

11. What type of feed are you using?
   What is before the "+" refers to the feed served in the feed bunk

   - Total mixed ration + rewarding feed in milking unit
   - Partly mixed ration + additional concentrate in milking unit and automatic feeders
   - Only roughage + concentrate in the milking unit

- Only roughage + concentrate in the milking unit and automatic feeders
- Other: (*Textbox*)

12. How many times per day is feed delivered in the feed bunk?
    Textbox

Feed alley

Following questions apply to the feeding alley in chosen section

1. Which type of floor are there in the feed alley?
    - Solid concrete floor
    - Slatted concrete floor
    - Slatted rubber floor
    - Solid floor with rubber covering

2. Is there feed-stalls or "klövpall" in the feed alley?
    - Feed-stalls
    - "Klövpall"
    - No
    - Other: (*Textbox*)

3. If solid concrete floor or slatted concrete floor, is it grooved?
    - Yes
    - No

4. How wide is the feed alley? Width
    - Less than 3 m
    - 3 m – 3.5 m
    - More than 3.5 m

5. Approximately what year was the floor built?
    - Older than 25 years
    - Year 1992 – 2017

6. Is it done any maintenance on the floor surface, approximately which year?
    - No maintenance
    - Year 1997 – 2018
    - More than 20 years ago

7. Type of maintenance?
    - New rubber mats
    - Grooving

- Other: (*Textbox*)

8. How is the alley cleaned?
    - Only slatted floor
    - Automatic scrapers
    - Robotic scrapers
    - Other: (*Textbox*)

9. Approximately, how many times a day is the alley scraped?
    - Continuous
    - 1 – 24 times
    - Not being scraped

10. If solid floor, does it have urine drainage?
    - Yes
    - No

Free-stall alleys

Following questions apply to the free-stall alley in chosen section

1. Which type of floor are there in the free-stall alley?

    - Solid concrete floor
    - Slatted concrete floor
    - Slatted rubber floor
    - Solid floor with rubber covering
    - Don’t have any free-stall alleys

2. If solid concrete floor or slatted concrete floor, is it grooved?

    - Yes
    - No

3. How wide is the feed alley?
    - Less than 2.5 m
    - 2.5 m – 3 m
    - 3 m – 3.5 m
    - More than 3.5 m

4. Approximately what year was the floor built?
    - Year 1992 – 2017
    - Older than 25 years

5. Is it done any maintenance on the floor surface, approximately which year?

- No maintenance
- Year 1997 – 2018
- More than 20 years ago

6. Type of maintenance?
    - New rubber mats
    - Grooving
    - Other: (*Textbox*)

7. How is the free-stall alley cleaned?
    - Only slatted floor
    - Automatic scrapers
    - Robotic scraper
    - Other: (*Textbox*)

8. Approximately, how many times a day is the alley scraped?
    - Continuous
    - 1 – 24 times
    - Not being scraped

9. If solid floor, does it have urine drainage?
    - Yes
    - No

Area in front of the milking unit

Following questions apply to the area in front of the milking unit in the chosen section

1. Type of flooring system in the area in front of the milking unit?
    - Solid concrete floor
    - Slatted concrete floor
    - Slatted rubber floor
    - Solid floor with rubber covering

2. If solid concrete floor or slatted concrete floor, is it grooved?
    - Yes
    - No

3. Approximately what year was the floor built?
    - Year 1992 – 2017
    - Older than 25 years

4. Is it done any maintenance on the floor surface, approximately which year?
    - No maintenance
    - Year 1997 – 2018
    - More than 20 years ago

5. Type of maintenance?
    - New rubber mats
    - Grooving
    - Other: (*Textbox*)

6. How is the area cleaned?
   More than one answer is possible
    - Only slatted floor
    - Scraped by hand
    - Automatic scrapers
    - Robotic scraper
    - Flushed with water
    - Other: (*Textbox*)

7. Approximately, how many times a day is the area cleaned?
    - Continuous
    - 1 – 24 times

8. If you have more than one section with VMS, is the floor system in other sections comparable with the one in the chosen section?
   If the floor system is different, please give a short explanation
    - Yes
    - Yes, mostly
    - No, it is different: (*Textbox*)

Claw trimming

Following questions apply to the trimming routine on the whole farm

1. Who does the trimming?
    - Professional claw trimmer
    - Myself, or staff member
    - Professional claw trimmer and trim acute cows by my self

2. Have you applied for “Klövpeng”?
    - Yes
    - No

3. How many times a year does the claw trimmer visit yore farm?
    - 1

- 2
- 3
- Other: (*Textbox*)

4. Do you have any trimming strategy?
    - No
    - All cows are trimmed at the same time, in one or a few times per year
    - Trimming are adapted after the cow's dry period and calving (According to SOP)
    - Trimming when needed, or by the occurrence of lameness
    - Other: (*Textbox*)

5. If you do the trimming, do you report claw disorders?
    - Yes
    - Yes, sometimes
    - No

6. Do you use claw baths?
    - Yes
    - No

7. How do you estimate the claw health in your herd?
    - Very good
    - Good
    - Average
    - Bad
    - Very bad

8. If you experience the claw health to be bad, which type of problem is most common in your herd?
   Textbox

9. How did you find the survey?
    - Invitation by post and email
    - On Facebook
    - Other: (*Textbox*)