Institutionen för husdjursgenetik

Genetic variation in dairy cattle claw health traits recorded by claw trimmers

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Examensarbete 300

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Agrovoc: Genetic variation, Claw diseases, Dairy cattle

Övrigt: Trimming, Claw trimming, Trimming records

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Examensarbete ingår som en obligatorisk del i utbildningen och syftar till att under handledning ge de studerande träning i att självständigt och på ett vetenskapligt sätt lösa en uppgift. Föreliggande uppsats är således ett elevarbete och dess innehåll, resultat och slutsatser bör bedömas mot denna bakgrund. Examensarbete på D-nivå i ämnet husdjursgenetik, 20 p (30 ECTS).

Preface

This is my master's thesis performed at the Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences (Hgen, SLU), in cooperation with the Swedish Dairy Association. I still cannot believe that I am finished with my thesis and was able to do it on claw health in dairy cows. About two years ago I started to promote myself to Anki Roth who works for the Swedish Dairy Association. I really wanted to do this claw health project for my thesis but I did not realize that I would be here today. There are some persons I would like to thank for helping me through this thesis:

Jette Jakobsen, Hgen, Interbull. Special thanks for the daily support and answers to all of my e-mails. I couldn't have found a more dedicated, interested and helpful supervisor. But above all else, I couldn't have found a better friend.

Erling Strandberg, Hgen. Thank you for the help throughout this project, for answering questions and for bringing up good ideas.

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Jan Philipsson, SLU. Thank you for taking the time to read through my work even if you were in Africa.

Sandra Naeslund

Uppsala, December 2007

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Abstract

Claw health has been recorded by claw trimmers at trimming in Sweden since 1996, but data was then captured at each AI association. From 2003 data was captured by central scanning and entered directly to the national cow data base at the Swedish Dairy Association (SDA). This reporting was introduced because SDA wanted to be able to use these records to improve dairy cow claw health by breeding. It is desirable with cows that have healthy claws, because poor claw health can contribute to impaired production and fertility.

The claw health report begins with some information about herd, claw trimmer, date et cetera and continues with the part where the claw health is recorded. Here the ID of each cow is filled in and on the same row the conditions for dermatitis, heel horn erosion, sole haemorrhage and sole ulcer are recorded as no lesion (blank), slight lesion (/) or severe lesion (X).

The aim of this study was to estimate genetic parameters and repeatabilities between lactations for dermatitis, heel horn erosion, sole haemorrhage and sole ulcer from the reported claw health records. Data collected between 2003 and June 2007 for Swedish Holstein (SH) and Swedish Red dairy cattle (SR) were used in the study. The edited data sets consisted of 65 816 records from first and 24 121 records from second lactation of SH, and of 58 457 records from first and 22 282 records from second lactation of SR. Results show that heritabilities for the claw diseases were relatively low. For SH, heritabilities in first lactation were between 0.035 (sole ulcer) and 0.079 (dermatitis) and in second lactation between 0.032 (sole ulcer) and 0.079 (sole haemorrhage). For SR they were between 0.038 (sole ulcer) and 0.059 (sole haemorrhage) in first lactation and between 0.028 (sole ulcer) and 0.085 (heel horn erosion) in second lactation. Correlations between the claw diseases were estimated and showed highest correlations between dermatitis and heel horn erosion (0.86 for SR and 0.64 for SH) and also between sole haemorrhage and sole ulcer (0.70 for SR and 0.72 for SH). The genetic correlation for the same disease between lactations was high (0.84 and higher).

The conclusions of this study are that the claw health reports are very useful. Heritabilities was relatively low but were sufficient enough to be possible to improve claw health through breeding. Correlations were very high within disease between lactations and also high between dermatitis and heel horn erosion as well as between sole haemorrhage and sole ulcer.

Sammanfattning

Klövhälsan har sedan 1997 registrerats av klövverkare i Sverige i samband med klövverkning. Data har sedan rapporterats in till Svensk Mjölk. Denna rapportering introducerades på grund av en önskan att kunna använda registreringarna för att förbättra klövhälsan hos mjölkkor genom avel. Det är önskvärt med kor som har friska klövar då försämrad klövhälsa kan bidra till försämrad produktion och nedsatt fertilitet.

Klövrapporterna börjar med information om gård, klövverkare, datum etc. och fortsätter med delen där klövhälsan fylls i. Här skrivs djurets ID-nummer upp och på samma rad fylls bedömningen för klöveksem, klövröta och sulblödning i, som ingen skada (tom ruta), lättare skada (/) eller svårare skada (X).

Syftet med denna studie var att skatta genetiska parametrar och upprepbarhet för klöveksem, klövröta, sulblödning och klövsulesår utifrån de inrapporterade klövrapporterna. Data insamlade mellan 2003 och juni 2007 för både SH och SRB användes i studien. Efter editering bestod data setet av 65 816 resp. 24 121 observationer från 1:a och 2:a laktationen för SH, och 58 457 resp. 22 282 observationer från 1:a och 2:a laktationen för SRB Resultaten visade att arvbarheten för de olika klövsjukdomarna var relativt låg, för SRB låg de mellan 0,038 (klövsulesår) och 0,059 (sulblödning) i laktation ett och i laktation två mellan 0,028 (klövsulesår) och 0,085 (klövröta). För SH låg arvbarheterna i laktation ett mellan 0,035 (klövsulesår) och 0,079 (klöveksem) och i laktation två mellan 0,032 (klövsulesår) och 0,079 (sulblödning). Korrelationerna mellan de olika sjukdomarna skattades och var högst mellan eksem och röta (0,86 för SRB och 0,64 för SH) och mellan sulblödning och klövsulesår (0,70 för SRB och 0,72 för SH). Genetiska korrelationer mellan laktation 1 och 2 för en och samma sjukdom var höga (0,84 och högre).

Slutsatsen av studien var att klövhälsorapporterna är mycket användbara. Arvbarheterna för klövsjukdomarna i studien var relativt låga men tillräckliga för att kunna förbättra klövhälsa genom avel. Korrelationerna var höga inom sjukdom mellan laktationer och dessutom höga mellan eksem och klövröta likväl som mellan sulblödning och klövsulesår.

Introduction

Dairy cows of today produce a lot of milk and have a higher live weight than before (Jokinen, 2005). This leads to a larger weight on feet and legs which makes it more important with good claw health. There has been a trend over the years of more and more free stall barns and this trend could result in poorer claw health in our dairy cows. It has been found in several studies, that foot and leg disorders are more common in cubicles than in tied stalls (Hultgren, 2002; Fjeldaas *et al.*, 2006; Sogstad *et al.*, 2005). A poorer claw health could affect milk production and fertility negatively (Swedish Dairy Association, 2007a; Fleischer *et al.*, 2001; Petersson *et al.*, 2006; Maizon *et al.*, 2004) This makes it even more important to keep a good claw health (e.g., through proper management).

Claw trimming is carried out to accomplish correct loading of the claws and thereby prevent claw lesions (Manske *et al.*, 2002). Through regular claw trimming, the frequencies of the most serious claw lesions are reduced. How often the claws should be trimmed varies between individuals but generally dairy cows should be trimmed at least twice a year. According to §4 in chapter 2 in the Swedish legislations for animal welfare (L100) it can be found that “The animal’s claws should be inspected regularly and be trimmed when needed”(DFS, 2007:5).

Despite this, a large part of our dairy cows are culled because of feet and leg disorders: in Red Dairy Cattle (SR) annually 5.7 % and in Holstein (SH) 7.5 % of those culled (Swedish Dairy Association, 2007a). Veterinary costs for examination of feet and legs of a lame cow is about 1 800 Swedish crowns (Bergsten, 2007). The cost for a sole ulcer that has not come to treatment in time is about three times as much. This higher cost is partly due to a larger risk of her not getting pregnant again and consequently being culled.

Because profitability in milk production depends on the cow’s lifetime production (Hamann & Distl, 2002), selection for longevity is also an important part to consider in breeding. From an economic perspective feet and leg disorders mean a lot more than the cost for treatment (Stokka *et al.*, 1997). Reduced milk production, impaired reproduction, increased involuntarily culling, discarded milk and increased work hours to treat cows are factors that have the largest effect on economy (van der Waaij *et al.*, 2005; Van Dorp *et al.*, 2004; Boettcher *et al.*, 1998).

Claw lesions

Dermatitis

Dermatitis appears in the skin in the rear part of the interdigital space and in the border between skin and claw horn (Manske *et al.*, 2002), and more frequently of the hind claws which are more exposed to dirt. The first sign of dermatitis is lengthened hairs and reddening of the dermis (Manske *et al.*, 2002). Mild dermatitis does not show lameness, and can be hard to detect without cleaning the claws (Claw Atlas in Appendix 3, 2007). However, dermatitis can progress to more serious forms of aching dermatitis, like coronary dermatitis and digital dermatitis and this can lead to drastic lameness. Dermis is gradually loosened up so that the corium is laid bare, which leads to lesions that bleeds spontaneously or when gentle touching (Manske *et al.*, 2002). The lesions are gradually extended and later expose large parts of the corium.

Heel horn erosion

Heel horn erosion, also called “slurry heel” is one of the most common of the four claw diseases described by Blowey, (1992). About one fourth of the cows in the data of this project had heel horn erosion. In other studies, up to half of all cows had heel horn erosion (Manske *et al*, 2002). Heel horn erosion affects the claw horn in the bulbs on the claws (Bergsten, 1997). Erosions with V-formed cracks or circular craters that can undermine the horn of the bulb, Figure 1, (Claw Atlas in Appendix 3, 2007). Simply put, heel horn erosion is “loss of horn tissue on the bulbs” (Manske *et al.*, 2002) and can be caused by chemical, enzymatic deterioration or through ceased new production due to dermatitis. Heel horn erosion does not lead to lameness except in severe cases (Bergsten, 1997).

Sole haemorrhage

The visible signs of sole haemorrhage are blood staining in the solar horn and/or in the white line (Claw Atlas in Appendix 3, 2007). Sole haemorrhage may be an indicator of sub clinical laminitis, which is an inflammation in the soft tissue (corium) of the claw (Bergsten, 1996). This can lead to weakening of the attachment of the claw bone in the claw capsule. Trauma to the horn producing tissue (corium) can lead to sole horn haemorrhages and disruption of the horn production resulting in poor horn quality. A severe sole haemorrhage can progress to a sole ulcer if not properly treated.

Sole haemorrhages are often contralaterally, evenly distributed and are most common in the outer (lateral) hind claws. When symptoms in the front feet are seen, the inner (medial) claws are more affected. (Bergsten, 1996). The lower incidence of lesions in the front claws can be explained by the fact that it is easier for the cow to unburden the inner claws on the front feet by crossing the front legs. There is no such way to unburden the outer claws of the hind feet.

Sole ulcer

Sole ulcer is a defect in the claw capsule with exposed corium (Manske *et al.*, 2002). Sole ulceration is most often found in the rear part of the sole of the lateral claw of the hind feet (Blowey, 1992). As for sole haemorrhages sole ulcers of the front feet are most often found in the medial claw. A sole ulcer can be visualized through removal of the medial ledge of the solar horn, Figure 1. Sole ulcers can be very painful and can cause a generally lowered titillation threshold (Manske *et al.*, 2002).

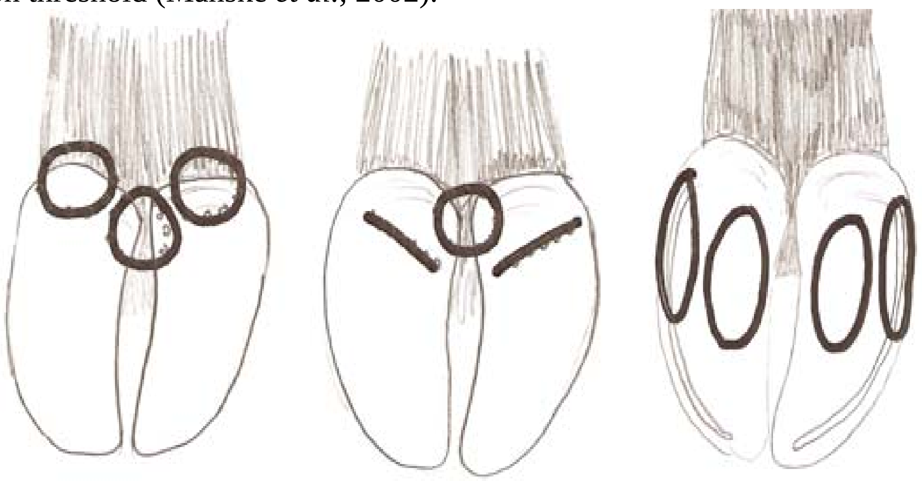

Figure 1. A schematic description of where the different lesions can be localized. Left claw: dermatitis; claw in the middle: heel horn erosion; right claw: sole haemorrhage or sole ulcer (Claw Atlas in Appendix 3, 2007).

Projects for improved claw health

Animal Health Database

Since 1975 all claw lesions treated by a veterinarian in Sweden have been recorded in an animal health database (Bergsten, personal communication, 2007). Claw diseases reported in this database have a very low frequency, 2.3 % (Swedish Dairy Association 2007a). These data can be difficult to use for genetic studies of claw health as some claw disorders are merged into larger groups and are not reported separately (Ral *et al.,* 1994). Many of the claw diseases are not treated by veterinarians but by claw trimmers or by the farmers themselves (Ral, 1999). This is why a claw health registration scheme performed by claw trimmers was introduced in 1996 (Manske, 2003).

KOFOT 2000

The aim of the KOFOT 2000 project was to improve the claw health and thereby the productive lifetime of dairy cows (HMH homepage, 2007). This was to be done through education and management actions based on results from scientific studies. The project lasted from 1996 to 1999 and in charge of this project were Christer Bergsten, Jan Hultgren and Thomas Manske. The claws of dairy cows in a hundred Swedish herds were judged at claw trimming during two seasons. All together around 5000 cows were examined. Claw health of these cows was matched against the environment of the stall, management, and feeding and production data from the dairy herd recording program. The results from this project showed that claw lesions were very common in Swedish dairy herds. About three quarters of all cows had some kind of claw lesion at the time of claw trimming and five percent showed lameness (HMH homepage, 2007).

FRISKKO – claw health

FRISKKO is a generic term for the production-applied animal health counselling for dairy cow herds that has been developed by the Swedish Dairy Association (Swedish Dairy Associations homepage, 2007). Here veterinarians, consultants and animal technicians can work together with herdsmen that want to improve health, milk quality and fertility. FRISKKO–claw health is the part of FRISKKO that concentrates upon claw health. The claw health reports are filled in by claw trimmers when claw trimming is performed at the farm. Later the report is scanned in and sent to Swedish Dairy Association. Claw lesions are noted and afterwards the farmer and consultant might come up with some possible changes in environment, management or feeding and thereby see possible improvements at next claw trimming (Swedish Dairy Associations homepage, 2007).

The claw health report

The claw health report is relatively easy to use, Appendix 1 (Swedish Dairy Association, 2007b). First the claw trimmer fills in the specific number for the herd, his or her own claw trimmer number and then the date of trimming. On each line of the rest of the report, the ID of the animal and the status with respect to dermatitis (digital or interdigital), heel horn erosion, sole haemorrhage (sole or white line haemorrhage) and sole ulcer (ulceration of sole or white line). The latter condition is reported for each claw (Eriksson, 2006). The diagnosis for sole ulcer is made per claw because of more interest from the farmer to be able to follow up this disease. There are also fields for reporting locomotion, claw shape, other diseases, treatments, and notes (Swedish Dairy Association, 2007b).

Codes for the lesions

These fields for dermatitis, heel horn erosion, sole haemorrhage and sole ulcer are marked either with a / (degree 1) for a minor/slight lesion, or with an X (degree 2) for a major/severe lesion (Figure 2).

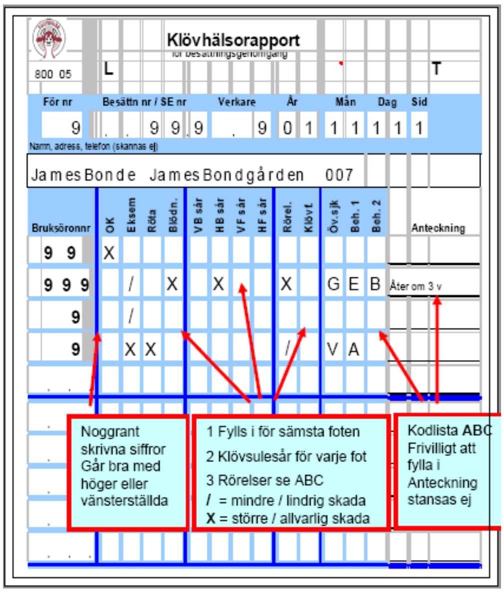

Figure 2. Claw health report, filled in by a claw trimmer (Swedish Dairy Association, 2007b).

Dermatitis

/ = redden / secretion / crusts eschars
X = bleeding circular ulceration, painful

Heel horn erosion

/ = shallow erosion of the bulb horn
X extensive deep cracks (to the corium)

Sole haemorrhage

/ solitary / shallow hemorrhage
X Extensive several / profound hemorrhage

Sole ulcer

/ Ulceration of sole, toe, white line; dermis exposed but looks fresh
X Ulceration of sole, toe, white line; discolored corium, necrotic / scar tissue / swollen

In the box for locomotion, / stands for walking with arched back and numb. X stands for standing and walking with arched back, lameness (Appendix 2). In the box for claw shape, different letters can be filled in as following:

A = asymmetric, diverged shape
B = bear foot
S = scissors claw
X = overgrown claws
Z = corkscrew claws
In the box for other diseases, different letters can also be filled in as following:

A = abscess, festering? sore in the white line
B = lesion on the leg, hock wounds or abscess

D = double sole, new sole + old
F = hard ship groove, concave toe wall
H = white line separation
K = Interdigital phlegmon
L = limax, interdigital hyperplasia growth in the interdigital space
S = sandcrack in horn wall, horizontal fisurre
T = toe abscess, wound / pus / necrosis
V = wart (verroucous dermatitis)

In the boxes for treatment of claws, different letters can be filled in as follows:

A = local antibiotics treatment
B = bandages / plaster
C = “Cowslip”
D = drainage (open abscess)
E = “Easy block”
K = copper sulphate or similarly, locally
O = operation (anaesthesia)
R = cut clean claw horn
S = “Shoof”, claw shoe
T = wooden block, “Bovi bond”

Literature review

Heritabilities and correlations for claw lesions

Because there is not so much research in this area yet, it has been difficult to find heritabilities and correlations for claw health traits. In a study by Philipsson *et al.* (1980) Swedish veterinary records of disease treatments on 8 639 SR and 3 158 Swedish Friesian (SLB) first lactation cows were used to estimate genetic parameters. Disease codes were yes or no for "foot, leg or locomotory disease" and heritability for SR was 0.07 and for SLB it was 0.13.

Van der Waaij *et al.* (2005) used claw health data collected from 27 198 Dutch Holstein-Friesian cows in their study. The data was collected between May 2003 and October 2003 and claw health was reported by 39 professional claw trimmers during their visits to 466 dairy farms. The presence of claw disorders on rear legs were recorded by a yes or no. Claw disorders registered were: digital dermatitis (DD), interdigital dermatitis with heel horn erosions (IDHE), sole haemorrhage (SH), chronic laminitis, sole ulcer (SU), white line disease, interdigital hyperplasia and interdigital phlegmona (van der Waaij *et al.*, 2005). Heritabilities and correlations are shown in Table 1.

In a study by Koenig *et al.* (2005) claw health was registered on 5643 Holstein cows by 9 different claw trimmers at farms in eastern Germany. The recorded claw disorders were: digital dermatitis, sole ulcer, wall disorder and interdigital hyperplasia. Heritabilities and correlations are shown in Table 2.

Table 1. Heritabilities (diagonal) and genetic (above diagonal) and phenotypic correlations (below diagonal) with SE for various claw lesions (from van der Waaij *et al.*, 2005)

	Trait[1]			
Trait	DD	IDHE	SH	SU
DD	**0.10 ± 0.02**	0.74 ± 0.09	-0.12 ± 0.16	-0.18 ± 0.25
IDHE	0.11 ± 0.01	**0.05 ± 0.01**	0.13 ± 0.17	-0.11 ± 0.25
SH	0.01 ± 0.01	0.04 ± 0.01	**0.08 ± 0.02**	0.81 ± 0.26
SU	-0.00 ± 0.01	0.01 ± 0.01	0.08 ± 0.01	**0.01 ± 0.01**

[1] DD = digital dermatitis, IDHE = interdigital dermatitis heel horn erosion, SH = sole haemorrhage, SU = sole ulcer.

Table 2. Heritabilities (diagonal) and genetic correlation (above diagonal) with SE for digital dermatitis (DD) and sole ulcer (SU) (from Koenig *et al.*, 2005)

	Trait[1]	
	DD	SU
DD	**0.073 ± 0.009**	0.561 ± 0.086
SU		**0.086 ± 0.006**

[1] DD = digital dermatitis, SU = sole ulcer.

Data from the Danish health recording system was used in a study by Sander Nielsen *et al.* (1997). Heritabilities and correlations between lactations were estimated for feet and legs (including heel erosion, interdigital dermatitis, sole ulcer and other claw and leg diseases). Cows initiating a lactation (first, second or third) between the years 1990 and 1994 were included.

Heritabilities were estimated to be very low (~1 %) but genetic correlations between lactations were very high (0.58–1.0).

Material and methods

Data and editing

Claw trimming data and pedigree records were provided from the Swedish Dairy Association. The original data set consisted of 167 371 claw trimming records of dermatitis, heel horn erosion, sole haemorrhage and sole ulcer collected from cows in first, second or third lactation from 2003. Of these, 72 649 were Swedish Red Dairy Cattle (SR), 84 638 were Holsteins (SH), and 10 084 were other breeds. The pedigree of the animals was traced five generations back, where generation one was the same as the animal with claw data. The pedigree files consisted of 274 059 SR and 269 555 SH observations and these were included in the relationship matrix **A** used in the later analysis. Claw trimming data has been collected since 1996 but in this project, data between 2003 and 2007 was used because of a new, better system of reporting than earlier. Figure 3 shows the frequency of recording between 2003 and 2007. Year 2007 is incomplete, because data for this project were extracted in the beginning of July 2007.

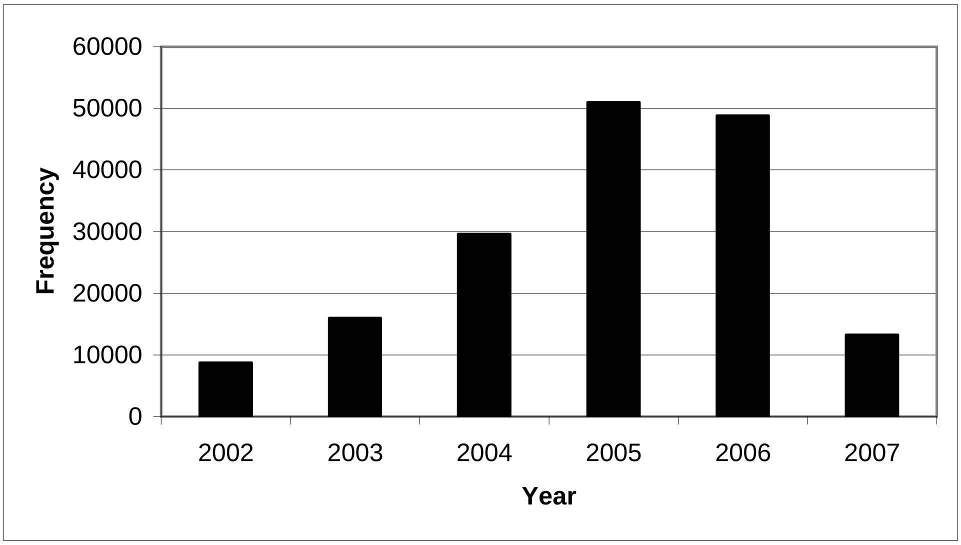

Figure 3. Frequency of cows (first and second trimming in first, second and third lactation) recorded by claw trimmers in Sweden 2003-2007.

The original data contained information about first and second trimming in first, second and third lactation. Due to time constraints, it was decided only to estimate genetic parameters for recordings of first trimming in first and second lactation. For that reason, the following phenotypic graphs are presented for first trimming in first and second lactation only.

Recording frequency was different depending on month of trimming (Figure 4 for recordings from first lactation cows and Figure 5 for recordings from second lactation cows) The trend over year was very similar for the two lactations.

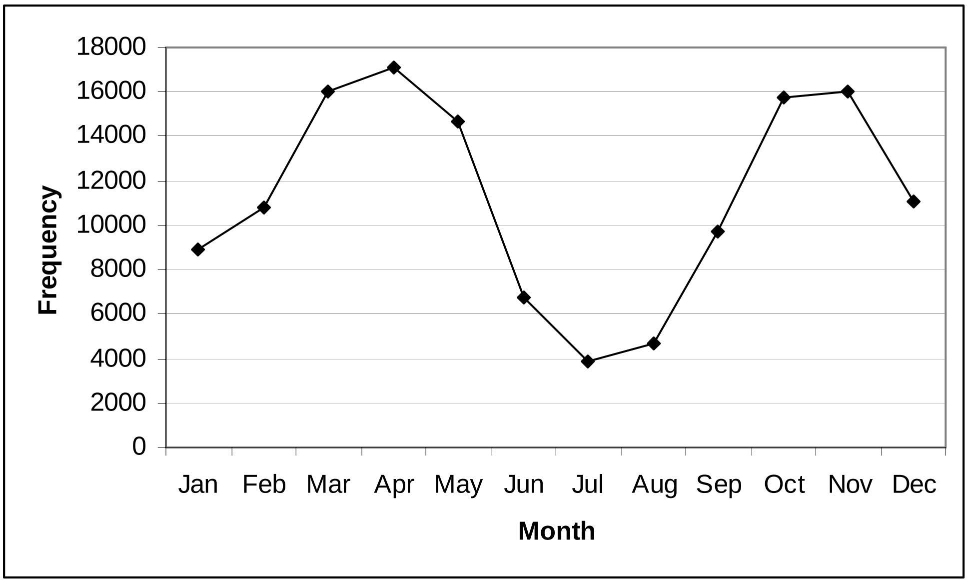

Figure 4. Frequency of claw trimmings per month at first claw trimming in first lactation.

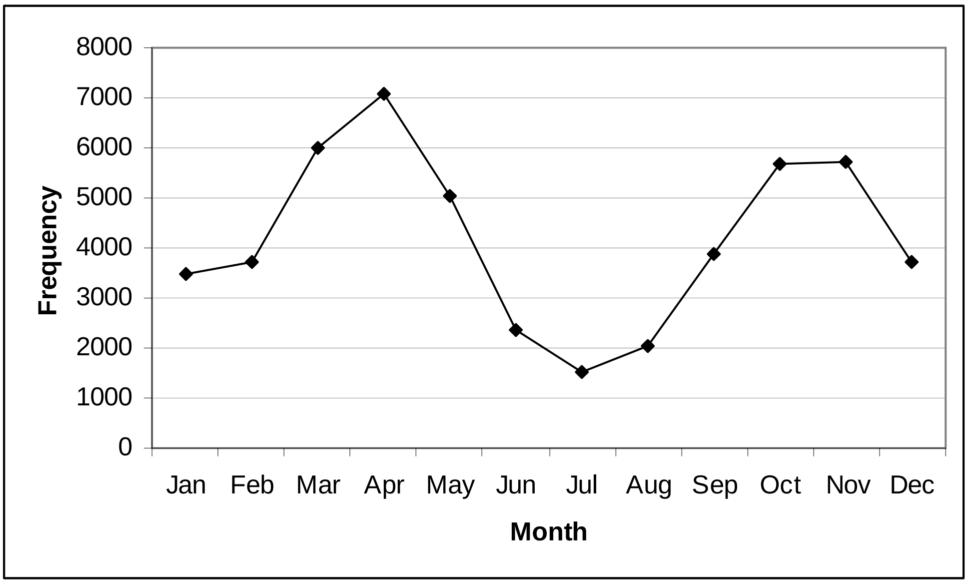

Figure 5. Frequency of claw trimmings per month at first claw trimming in second lactation.

Some editing or the original data set was done with SAS (1999). Cows with no claw trimming were excluded. An upper and a lower limit for first calving age were set, because there may appear cows where all lactations have not been reported to the Swedish production recording system. This means that her first reported lactation not necessarily is the first lactation in her life. Limits set were 20-38 months for first calving, 34-58 months for second calving and 45-68 months for the third calving. In cases where age of calving was outside these intervals, that lactation was excluded. A lactation length maximum of 18 months was used. The edited data sets consisted of 65 816 records from first and 24 121 records from second lactation of SH, and of 58 457 records from first and 22 282 records from second lactation of SR.

Statistical models

To estimate heritability for the four different claw diseases at first claw trimming within first and second lactation, separate analyses were done for each disease, lactation and breed. The following animal model was used to estimate heritabilities and correlations for the four claw diseases:

$$y_{ijklm} = lactst_i + calvage_j + training_k + herd\text{-}year_l + cow_m + e_{ijklm} \quad (1)$$

where:

y_{ijklm} = claw trimming observation
$lactst_i$ = fixed effect of stage of lactation in months at time of claw trimming, i=1,..,18
$calvage_j$ = fixed effect of calving age in months, j=20,..,38; 34,..,58; 45,..,68
$training_k$ = fixed effect of training of claw trimmer, k=1,..,4
$herd\text{-}year_l$ = random effect – herd * year, year goes from July one year to June the next, ~ND (0, σ^2_{hy})
cow_m = random effect of cow, ~ND (0, $\mathbf{A}\sigma^2_A$)
e_{ijklm} = random residual. ~ND (0, σ^2_E)

Training was used to appreciate how "good" the claw trimmers were, or at least how much training they have. They were separated into four classes depending on how many trimmings they have done (Table 3). There were 231 claw trimmers totally in this data set, over all lactations, breeds and years.

Table 3. Proportion of claw trimmers in each class over all lactations, breeds and years

Class	Number of trimmings	Percent
1	<10	31.17
2	10 up to 100	33.77
3	100 up to 1000	19.05
4	above 1000	16.02

It was not clear if all classes of the observations were going to be used. Using all classes would mean three classes (0, 1, 2) for dermatitis, heel horn erosion and sole haemorrhage, and nine classes (0,..,8) for sole ulcer. Sole ulcer was measured and reported from the four claws separately. It was decided to simply sum the information to one number for each animal resulting in a 0 to 8 scale As an alternative, these classes could be merged to two classes (0-1), either the cow was free from the lesion (0) or she had a lesion (1). Both of these alternatives were tested for all lesions and both for SR and SH.

In some way, herd by year needed to be in the model. It was not a priori clear if year was going to be calving year or if it should be trimming year. The effect of herd-year is an interaction, where year is calving year or trimming year and goes from July one year to June next year. This classification of the year was done to take differences in feed, management, weather conditions and so on into consideration. The herd-year effect was as random because of some very small classes.

Model Testing

The significance level was tested with PROC GLM for the fixed effects in model (1). The significance levels showed that all these effects should be included in the model.

Four different models were run for each breed and each trait in first lactation. These were

Model 1: Dependent variable is in three classes (0-1-2) (for sole ulcer in nine classes (0-1-2-3-4-5-6-7-8)) and the random herd-year effect is herd * trimming year

Model 2: Dependent variable is in three classes (0-1-2) (for sole ulcer in nine classes (0-1-2-3-4-5-6-7-8)) and the random herd-year effect is herd * calving year

Model 3: Dependent variable is in two classes (0-1) and the random herd-year effect is herd * calving year

Model 4: Dependent variable is in two classes (0-1) and the random herd-year effect is herd * trimming year

Other effects in the models were always the same. Variance components estimated from the four models and the four traits are shown in Table 4 and 5. In general, the variance was larger in models 1 and 2 compared with models 3 and 4 where disease code 1 and larger was merged into one class. Two different approaches to modeling the herd-year effect were tested – one with calving year and one with trimming year. The hypothesis was that trimming year might better account for the environment when the trimming is done than calving year. Results showed large similarity in variance components using either of the herd-year effect definition. It was decided to perform the rest of the analyses using all categories of data and to use calving year as the random herd * year effect (Model 2). This could also make the joint analysis with other traits, where calving year is used, e.g. type traits, easier.

Heritabilities were computed as $h^2 = \sigma_A^2 / (\sigma_A^2 + \sigma_E^2)$, where σ_A^2 is the additive genetic variance and σ_E^2 is the residual variance.

Table 4. Biological year variance (σ^2_{hy})[1], additive genetic variance (σ^2_A), residual variance (σ^2_E), phenotypic variance (σ^2_P), and heritability (h^2) for dermatitis, heel horn erosion, sole haemorrhage, and sole ulcer using four different models[2] for **SR**, for first trimming first lactation. In the last column, heritability with biological year variance included in the phenotypic variance (h^2_{hy}).

Disease	Model[2]	σ^2_{bio}	σ^2_A	σ^2_E	σ^2_P	h^2	h^2_{hy}
Dermatitis							
	1	0.011042	0.003458	0.076440	0.079898	0.043279	0.038024
	2	0.010615	0.003657	0.076594	0.080251	0.045568	0.040245
	3	0.006240	0.001681	0.042794	0.044476	0.037805	0.033153
	4	0.008741	0.002371	0.050918	0.053288	0.044490	0.038221
Heel horn erosion							
	1	0.066225	0.008680	0.136378	0.145057	0.059836	0.041081
	2	0.063524	0.009160	0.136797	0.145957	0.062759	0.043728
	3	0.036655	0.003657	0.079278	0.082935	0.044096	0.030580
	4	0.049071	0.005644	0.091027	0.096671	0.058388	0.038729
Sole haemorrhage							
	1	0.085660	0.018855	0.256588	0.275443	0.068455	0.052216
	2	0.079884	0.021094	0.254948	0.276043	0.076417	0.059266
	3	0.031221	0.006233	0.111158	0.117391	0.053095	0.041941
	4	0.043760	0.008728	0.130839	0.139567	0.062536	0.047609
Sole ulcer							
	1	0.007875	0.006020	0.144967	0.150987	0.039873	0.037896
	2	0.007674	0.006010	0.144846	0.150856	0.039840	0.037911
	3	0.001326	0.001004	0.028778	0.029782	0.033718	0.032281
	4	0.001915	0.001592	0.034757	0.036349	0.043798	0.041606

[1] Biological year was in model 1 and 4 defined as: herd * trimming year and in model 2 and 3 defined as: herd * calving year. [2] Dependent variable was in model 1 and 2 in three classes (0-1-2) and in model 3 and 4 in two classes (0-1) for Dermatitis, Heel horn erosion, and Sole haemorrhage, while it was in 9 classes (0-1-2-3-4-5-6-7-8) for model 1 and 2 for Sole ulcer.

Table 5. Biological year variance (σ^2_{hy})[1], additive genetic variance (σ^2_A), residual variance (σ^2_E), phenotypic variance (σ^2_P), and heritability (h^2) for dermatitis, heel horn erosion, sole haemorrhage, and sole ulcer using four different models[2] for **SH** for first trimming first lactation. In the last column, heritability with biological year variance included in the phenotypic variance (h^2_{hy}).

Disease	Model[2]	σ^2_{bio}	σ^2_A	σ^2_E	σ^2_P	h^2	h^2_{hy}
Dermatitis							
	1	0.013756	0.006854	0.088886	0.095740	0.071589	0.062596
	2	0.013256	0.007608	0.088793	0.096402	0.078922	0.069381
	3	0.009362	0.003308	0.055199	0.058507	0.056538	0.048739
	4	0.009829	0.003025	0.055003	0.058028	0.052130	0.044579
Heel horn erosion							
	1	0.057090	0.007369	0.124773	0.132142	0.055765	0.038941
	2	0.055631	0.008805	0.125129	0.133934	0.065741	0.046448
	3	0.039135	0.004464	0.083426	0.087889	0.050786	0.035139
	4	0.039400	0.003900	0.082925	0.086825	0.044917	0.030897
Sole haemorrhage							
	1	0.091114	0.011233	0.278449	0.289683	0.038778	0.029499
	2	0.087624	0.012717	0.277304	0.290021	0.043849	0.033675
	3	0.046529	0.004326	0.139639	0.143965	0.030046	0.022707
	4	0.047982	0.003737	0.139697	0.143434	0.026054	0.019523
Sole ulcer							
	1	0.010219	0.007543	0.213289	0.220832	0.034158	0.032647
	2	0.009670	0.007657	0.213403	0.221060	0.034637	0.033185
	3	0.002047	0.001760	0.045028	0.046789	0.037625	0.036047
	4	0.002213	0.001706	0.044982	0.046688	0.036541	0.034887

[1] Herd-year was in model 1 and 4 defined as: herd * trimming year and in model 2 and 3 defined as: herd * calving year. [2] Dependent variable was in model 1 and 2 in three classes (0-1-2) and in model 3 and 4 in two classes (0-1) for Dermatitis, Heel horn erosion, and Sole haemorrhage, while it was in 9 classes (0-1-2-3-4-5-6-7-8) for model 1 and 2 for Sole ulcer.

Results and Discussion

Disease frequencies

Frequencies of the four diseases differed: sole ulcer had the lowest prevalence (~5 %), followed by dermatitis (5-10 %), heel horn erosion (~15-20 %) and sole haemorrhage (~25-30 %). The prevalence of claw diseases was similar between the breeds Swedish Red Dairy Cattle (SR) and Holstein (SH) – some small differences between breeds and diseases were found but none were significant. Differences in frequencies of diseases between months show that there is an even distribution of diseases throughout the year, possibly some lower prevalence of dermatitis and heel horn erosion during the summer but not much. This is in accordance with the study by Murray *et al.* (1996), where they could see that the majority of the lesions occurred during the winter time. If the prevalence of lesions between the years that claw trimming has been registered (2003-2007) were compared, there has been no visible changes.

Heritabilities and correlations

Heritabilities and correlations for the selected model for dermatitis (DD), heel horn erosion (HE), sole haemorrhage (SH) and sole ulcer (SU), for first lactation and second lactation for the breeds SR and SH can be found on the diagonal in Tables 6 and 7, respectively. A comparison of heritability estimates between breeds is shown in Figure 6. Heritabilities were obtained from univariate analyses and correlations from bivariate analyses.

For SR heritabilities were between 0.038 and 0.059 for first lactation. And for second lactation between 0.028 and 0.085. In comparison to SH these heritabilities are in a similar range, Figure 6. These results are similar to results from the literature, (7-10 % for dermatitis), (5 % for heel horn erosion), (8 % for sole haemorrhage), and (1-9 % for sole ulcer) (Van der Waaij *et al.* (2005), Koenig *et al.*, 2005).

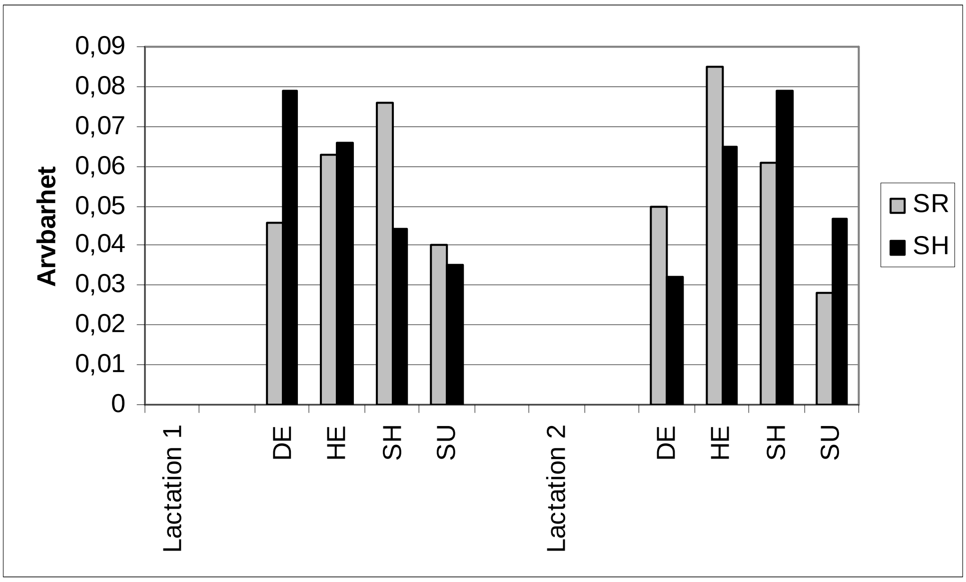

Figure 6. Comparison between heritabilities of the claw diseases in the first two lactations for SR and SH.

Genetic correlations were very high between the same trait in lactation one and two, the lowest for sole haemorrhage for SH (0.84 ± 0.068) and the highest for dermatitis for SH (1.00 ± 0.021) (Tables 6 and 7). The bivariate analysis for dermatitis in lactation one and two did not converge. This may be due to a high genetic correlation between the two traits. This is in accordance with Sander Nielsen *et al.* (1997) who estimated very high genetic correlations for feet and leg diseases between lactations.

Genetic correlations were high between dermatitis and heel horn erosion on one side and between sole haemorrhage and sole ulcer on the other. While genetic correlations were low (some close to zero) between dermatitis and sole haemorrhage, dermatitis and sole ulcer, heel horn erosion and sole haemorrhage, heel horn erosion and sole ulcer. This is in accordance with results from the literature (Van der Waaij *et al.* (2005). According to Manske *et al.* (2002a) dermatitis and heel horn erosion seems to be two different stages or parts of one process and Bergsten (1996) states that sole ulcer is a progression of sole haemorrhage. This explains the strong genetic correlations between dermatitis and heel horn erosion and between sole haemorrhage and sole ulcer.

Residual correlations are shown in Tables 6 and 7. They were often low and rarely above 0.1 within lactation (except for the correlation between DE and HE) and between 0.08 and 0.1 for the same trait across lactations.

The way of recording claw lesions (0-2 for DE, HE and SH and 0-8 for SU) in the Swedish claw report can be compared with the study by Somers *et al.* (2005) where they studied development of interdigital dermatitis and heel horn erosion (IDHE) and digital dermatitis in both hind feet. IDHE was defined on a scale of 1-4 and DD on a scale of 1-5 for each hind foot. It can also be compared with the study by Philipsson *et al.* (1980) where they intended to use several disease codes but were not able to because of too low frequencies of some codes. This seemed to be the case for SU in the Swedish claw report. About 95 percent of all trimmed cows were free from sole ulcer, which means that ~5 percent should be distributed between codes 1-8. Furthermore, the order of the categories is somewhat unclear, there are several ways of getting a certain score, e.g., a score of 4 could be achieved as 1+1+1+1, 2+2+0+0, 1+1+2+0, and similarly for the other intermediate scores. It is doubtful that all these situations that give the same score have the same underlying liability. An indication of the problems of the scale could also be seen from that frequencies always were higher for 4 than 3, about twice as high. Because the scale with fewer categories (0-1) gave lower heritability estimates for all traits but SU, it seems that the scale (0-8) is not the optimal one for SU. One the other hand, the scale (0-1-2) seems to add information for the other three traits.

Table 6. Heritabilities (diagonal), genetic correlations with SE (above diagonal) and residual correlations (below diagonal) for dermatitis (DE), heel horn erosion (HE), sole haemorrhage (SH), and sole ulcer (SU) in first and second lactations for **SR**. Model 2

		Lactation 1				Lactation 2			
		DE	HE	SH	SU	DE	HE	SH	SU
Lactation 1	DE	**0.040**	0.864 ± 0.046	-0.017 ± 0.112	-0.037 ± 0.127	N.C.	0.819 ± 0.066	0.005 ± 0.149	0.032 ± 0.177
	HE	0.126	**0.044**	0.352 ± 0.093	0.294 ± 0.112	0.897 ± 0.053	0.970 ± 0.026	0.293 ± 0.131	0.390 ± 0.146
	SH	0.020	0.065	**0.059**	0.703 ± 0.072	0.297 ± 0.135	0.104 ± 0.125	0.984 ± 0.025	0.652 ± 0.130
	SU	0.004	0.074	0.059	**0.038**	0.212 ± 0.150	0.222 ± 0.134	0.431 ± 0.135	0.926 ± 0.049
Lactation 2	DE	N.C.	0.037	-0.014	-0.004	**0.050**	0.848 ± 0.074	0.049 ± 0.173	0.040 ± 0.203
	HE	0.046	0.100	0.017	0.022	0.149	**0.085**	0.307 ± 0.144	0.398 ± 0.164
	SH	0.027	0.017	0.079	0.045	0.026	0.075	**0.061**	0.645 ± 0.152
	SU	0.009	0.023	0.012	0.104	0.033	0.082	0.103	**0.028**

[1]N.C. = The analysis did not converge

Table 7. Heritabilities (diagonal), genetic correlations with SE (above diagonal) and residual correlations (below diagonal) for dermatitis (DE), heel horn erosion (HE), sole haemorrhage (SH), and sole ulcer (SU) in first and second lactations for **SH**. Model 2

		Lactation 1				Lactation 2			
		DE	HE	SH	SU	DE	HE	SH	SU
Lactation 1	DE	**0.069**	0.640 ± 0.067	0.085 ± 0.102	0.008 ± 0.105	0.997 ± 0.021	0.651 ± 0.082	0.044 ± 0.116	0.281 ± 0.122
	HE	0.125	**0.046**	0.290 ± 0.102	0.305 ± 0.104	0.542 ± 0.130	0.977 ± 0.026	0.397 ± 0.107	0.426 ± 0.119
	SH	0.002	0.060	**0.034**	0.715 ± 0.080	0.237 ± 0.154	0.320 ± 0.131	0.837 ± 0.068	0.408 ± 0.141
	SU	0.002	0.078	0.056	**0.033**	0.143 ± 0.159	0.382 ± 0.126	0.883 ± 0.069	0.902 ± 0.069
Lactation 2	DE	0.095	0.025	-0.007	-0.010	**0.032**	0.685 ± 0.111	0.181 ± 0.169	0.252 ± 0.181
	HE	0.025	0.073	0.006	0.027	0.139	**0.065**	0.441 ± 0.126	0.366 ± 0.147
	SH	0.013	0.000	0.077	0.036	0.015	0.053	**0.079**	0.816 ± 0.099
	SU	-0.009	0.009	0.024	0.086	-0.002	0.065	0.059	**0.047**

Future research areas

Some questions related to studies of variation for claw trimming data of dermatitis, heel horn erosion, sole haemorrhage and sole ulcer were answered in this thesis but further questions have been raised.

It was decided to analyse data using a linear model even if the assumption of a normal distribution of these categorical data may not be well fulfilled. A modelling of data on the underlying liability scale and analysis using a threshold model might be more appropriate.

Even if data was there, time did not allow splitting each lactation in two separate time periods, which could be analyzed as two separate traits. This could be interesting in the sense, to see, if susceptibility to these claw diseases genetically are the same trait early and late in lactation. It might even be possible to analyze data using a random regression model, and with that get correlations between all possible days within lactation.

As genetic analysis of dermatitis, heel horn erosion, sole haemorrhage and sole ulcer collected from claw trimmers is rather new, many correlations to other traits still need to be estimated. These can for example be:

- Correlations to longevity. Cows with poor feet and legs may get culled earlier. But is the correlation to longevity genetic?
- Correlations to cell count and udder health. Do cows with poor feet and legs have a higher cell count and more mastitis? And is this relation genetic or environmental?
- Correlations to milk production. We know that cows with poor feet and legs have a lower milk production, but is this relation genetic or environmental?
- Correlations to feet and leg traits from conformation registrations (type traits).

Sweden is one of the three countries participating in Nordic genetic evaluation NAV. Some traits are registered in some of the countries only. For example locomotion is registered in Denmark, but not in Sweden. And claw trimming records are collected in Sweden, but not in Denmark. It could indeed be interesting to correlate the information of locomotion in Denmark with the information of claw trimming records in Sweden in a bivariate sire model.

Sweden already has a genetic evaluation for claw trimming traits, but this is not a trait that is currently evaluated by Interbull. However, it would be possible to conduct a pilot study computing MACE-correlations between breeding values for claw trimming data from Sweden and breeding values for locomotion from other countries.

Some possible model changes for the current analysis

- Possibly separate each lactation into different periods (traits)
- Use trimming year instead of calving year
- Currently a random herd-year effect was used because of some small herds, perhaps the small herds should be deleted and a fixed herd-year could be used instead
- The scale for sole ulcer (today 0-8) should probably be changed in some way
- It could be possible to analyze the effects of housing system of the herds; there is a box at the bottom of the claw report that should be filled in with housing system, loose housing or tie-stall.

Conclusions

Claw trimming reports have been shown in this study to be very useful. Heritabilities for the claw lesions in this study were relatively low (~3-8 %) but sufficient enough for it to be possible to improve claw health through breeding, given that the breeding program is based on large enough daughter groups. Another prerequisite is that the willingness by the claw trimmers to report will continue to be high or even increase.

Genetic correlations between the same traits over lactations is very high, this could mean that it is only necessary to record a cow's claw health once, or at least to use only one record in genetic evaluation. Dermatitis and heel horn erosion is very strongly correlated as were sole haemorrhage and sole ulcer, but they were not as highly correlated that one could exclude one of them in the claw health report.

Some changes may be made in the statistical model used for this study but there was too little time for such model optimization in this setting. Future studies are suggested to analyze the effects of housing system and the correlations of claw lesions with production, longevity, cell count and feet and leg conformation.

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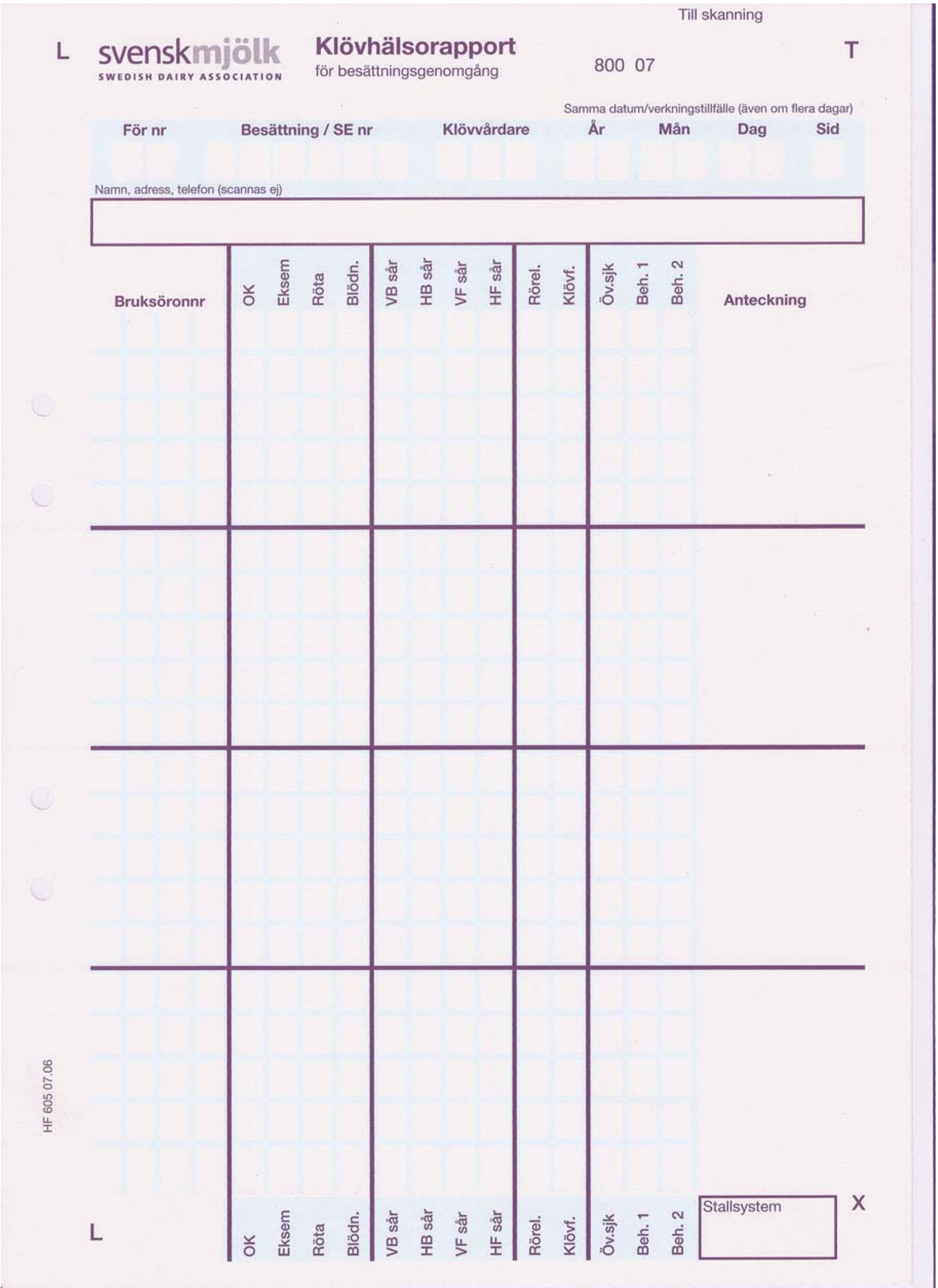
Appendix 1



Till skanning

L svenskmjölk SWEDISH DAIRY ASSOCIATION

Klövhälsorapport
för besättningsgenomgång

800 07

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Samma datum/verkningstillfälle (även om flera dagar)

För nr	Besättning / SE nr	Klövvårdare	År	Mån	Dag	Sid

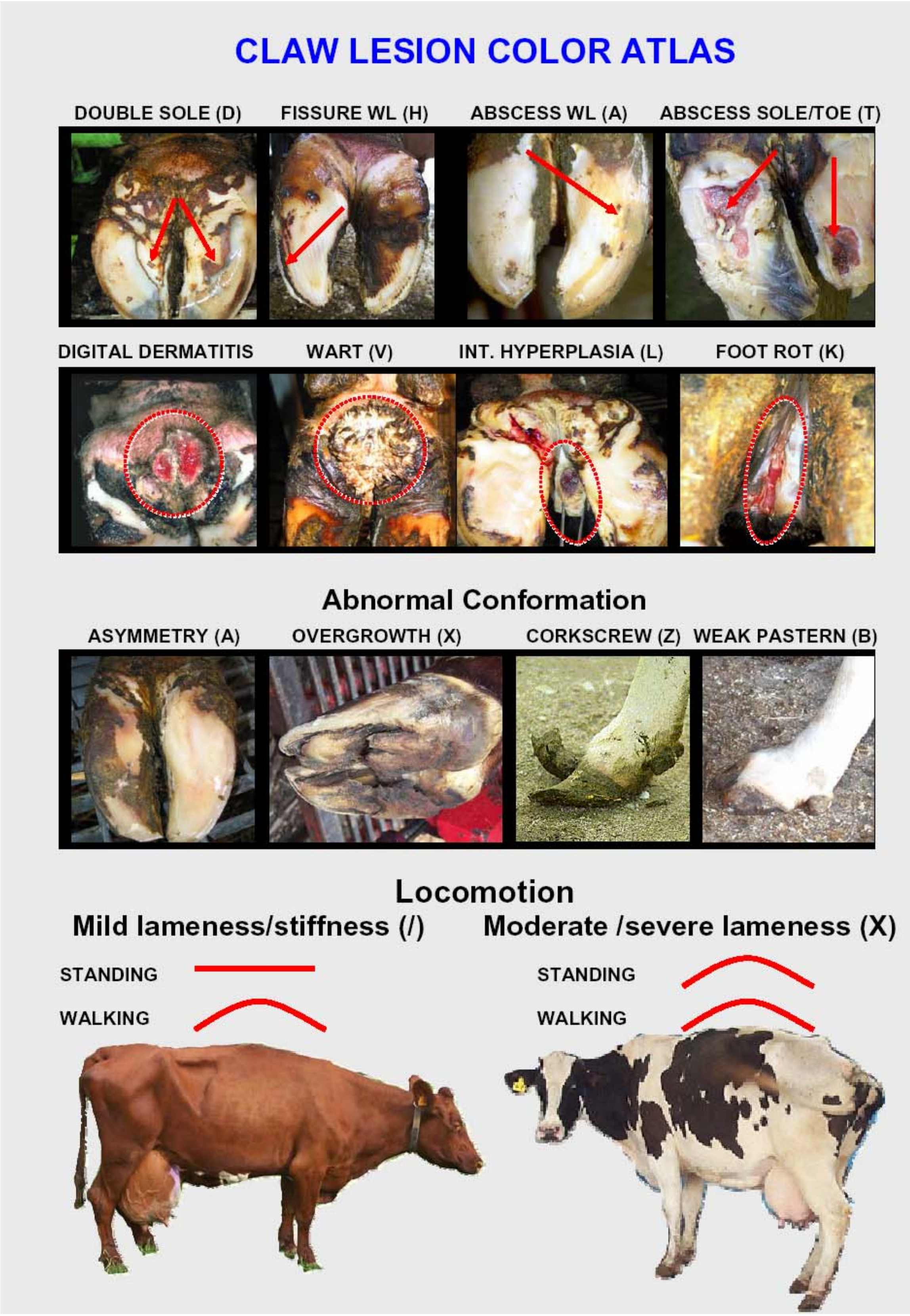
Namn, adress, telefon (scannas ej)

Bruksöronnr	OK	Eksem	Röta	Blödn.	VB sår	HB sår	VF sår	HF sår	Rörel.	Klövf.	Öv.sjk	Beh. 1	Beh. 2	Anteckning
L	OK	Eksem	Röta	Blödn.	VB sår	HB sår	VF sår	HF sår	Rörel.	Klövf.	Öv.sjk	Beh. 1	Beh. 2	Stallsystem

X

HF 605 07.06

Appendix 2


CLAW LESION COLOR ATLAS
DOUBLE SOLE (D)
FISSURE WL (H)
ABSCESS WL (A)
ABSCESS SOLE/TOE (T)
DIGITAL DERMATITIS
WART (V)
INT. HYPERPLASIA (L)
FOOT ROT (K)
Abnormal Conformation
ASYMMETRY (A)
OVERGROWTH (X)
CORKSCREW (Z)
WEAK PASTERN (B)
Locomotion
Mild lameness/stiffness (/)
Moderate /severe lameness (X)
STANDING
WALKING
STANDING
WALKING

Appendix 3

CLAW LESION COLOR ATLAS

MODERATE/SUPERFICIAL (/) SEVERE/PROFOUND (X)

SOLE HAEMORRHAGE

Haemorrhagic discoloration of the sole horn and/or white line. Diffuse symptom of (subclinical) laminitis 2-3 months after calving. Hard floors and intensive unbalanced feeding associated with poor rumination are important risk factors. Normally heals spontaneously but can develop to more severe lesions as ulceration of sole/toe/white line and/or double sole/white line lesions

Treatment and prevention

Trimming, balancing the outer and inner claws, and dishing out to unload the ulcer area is recommended. Rubber mats where the cows are walking and standing and optimized cow comfort are measures to prevent and reduce the risk for complications.

SOLE ULCER

Open wound (ulceration) of the sole, toe or white line often complicated by a deeper infection and or inflammation. Common cause of lameness. The ulcer is caused by compression of the corium between the claw bone and sole. Laminitis and trauma predisposes to or causes ulcers.

Treatment and prevention

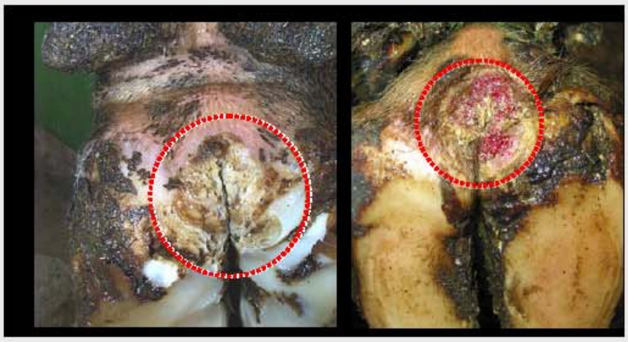
Trimming and balancing of the outer and inner claws and dishing-out of the sole to unload the ulcer area. Blocking of the healthy claw to reduce pain and improve healing. Balanced diets, proper feeding, rubber mats where the cows are walking and standing, and optimized cow comfort prevent the condition.

DIGITAL DERMATITIS

Inflammation of the digital and/or interdigital skin with ulcerations or crusts. Mild/early stages do not cause lameness and are often neglected if feet are not cleansed. The dermatitis can progress to more severe, painful lesions causing severe lameness. Most often A hygiene related herd problem that can spread from animal to animal and from herd to herd if biosecurity precautions are not undertaken.

Treatment and prevention

Mild to moderate dermatitis heals spontaneously with improved hygiene of stalls and feet. Proper foot bathing cleanses and disinfects feet and thus reduces the symptoms and controls spreading.



HEEL HORN EROSION

V-shaped erosions and clefts in the bulbs or circular craters that can undermine the heels. Most often double-sided and more common in the rear feet. Associated with dermatitis. Deeper erosions progressing to the corium may cause lameness.

Treatment and prevention

Trimming away diseased horn and treatment of dermatitis with antibacterial compounds locally. Foot bathing can prevent herd problems but most important to improve environment and foot hygiene.