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Master thesis

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Descriptive study of foster cows in Danish herds with prolonged cow-calf contact

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Preface

This paper is a 30 ECTS master thesis written by Solveig Bjerg and Kathrine Skriver Schøning at the University of Copenhagen, concluding our master's degree in veterinary medicine. The master is based on clinical examinations that seek to describe the clinical conditions in foster cows in systems with prolonged cow-calf contact.

We would like to thank our academic advisors, Mette Bisgaard Petersen and Kirstin Dahl-Pedersen, for their support and guidance in the making of this master thesis, as well as the owners and staff at the participating farms. We would also like to thank Line Svennesen for her help and guidance with the statistical analyses of the udder health variables.

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Solveig Bjerg

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Abstract

There is a growing interest in improving animal welfare among consumers. Systems with prolonged cow-calf contact (CCC) are a possible way to meet this growing interest. The systems can be designed in many different ways, and there is still limited scientific evidence regarding the effect of CCC-systems on both the cows and the calves. The aim of this master thesis was to describe the clinical condition of foster cows in Danish herds with prolonged CCC as well as to describe the development of the foster cows after four to five weeks. In total, 61 foster cows from seven Danish herds were examined, and 57 cows were included in the statistical analyses. A clinical examination was performed within the first week of the cows becoming foster cows and again after four to five weeks. Two blood samples were taken at both the first and the second examination to evaluate the level of serum amyloid A (SAA) and plasma fibrinogen. Furthermore, the farmers were interviewed about the design of their foster cow system.

The results of the study showed that 65% of the foster cows were in second to fourth parity, and it was primarily cull cows that were used to nurse the calves. This could be related to an increased risk of several health issues with increasing parity. The udder health was examined using the California Mastitis Test (CMT), indicator paper, and evaluation of hyperkeratosis. There was no significant difference in any of these three variables between the two examinations when using a Chi-squared test which indicates that, overall, the udder health was not affected in neither a positive nor a negative direction. The number of foster cows with wounds or tears (score > 1) did, however, increase significantly from 23% at the first examination to 52% at the second examination possibly due to the suckling calves. The prevalence of hocks without swelling (score 0) increased from 44% at the first examination to 67% at the second examination, and this difference was statistically significant using a Chi-squared test. However, no significant change was found in the prevalence of lame cows, despite housing them in deep bedded pens. Using a T-test a significant improvement in the average level of SAA was observed with a decrease from 22.97 mg/L to 8.05 mg/L. The average level of plasma fibrinogen was elevated at the first and second examination (11.7 g/L and 10.8 g/L, respectively). However, the change between examinations was not significant. In conclusion, although the majority of the foster cows are cull cows, the clinical examinations indicate that the foster cows in the system are not systemically ill. The system has both positive and negative effects which makes it difficult to determine whether foster cow systems are a good alternative to conventional and organic rearing. Therefore, further research, such as studies with a control group, is still necessary.

Resume

Der er stigende interesse for øget dyrevelfærd blandt forbrugerne. Systemer med forlænget ko-kalv kontakt (CCC) er en mulig måde at imødekomme denne stigende interesse. Systemerne kan dog indrettes på mange forskellige måder, og der er stadig begrænset videnskabelig evidens for virkningen af ko-kalv kontaktsystemer på både ko og kalve. Formålet med dette projekt var at beskrive den kliniske tilstand hos ammetanter på danske gårde med forlænget ko-kalv samvær samt at beskrive udviklingen hos ammetanterne over fire til fem uger. Der blev undersøgt 61 ammetanter på tværs af syv danske besætninger, hvoraf 57 køer indgik i den statistiske analyse. Der blev udført en klinisk undersøgelse af alle køer indenfor en uge efter indsættelse som ammetante og igen efter fire til fem uger i systemet. Der blev taget to blodprøver på køerne ved både første og anden undersøgelse for at evaluere niveauet af serum amyloid A (SAA) og plasma fibrinogen. Desuden blev landmændene interviewet om indretningen af deres ammetantesystem.

Resultaterne af specialet viste, at 65% af ammetanterne var imellem anden og fjerde paritet, og at det hovedsageligt var udsætterkøer, der blev brugt til at passe kalvene. Det kan være relateret til en øget risiko for flere sundhedsproblematikker med stigende paritet. Yversundheden blev undersøgt ved hjælp af California Mastitis Test (CMT), indikator papir og vurdering af hyperkeratose. Der var ingen signifikant ændring i disse tre variabler mellem første og anden undersøgelse ved brug af Chi-i-anden test, hvilket indikerer at den overordnede yversundhed ikke blev påvirket i hverken positiv eller negativ retning. Antallet af køer med sår eller rifter (score > 1) steg dog signifikant fra 23% ved første undersøgelse til 52% ved anden undersøgelse, hvilket formodes at skyldes de diende kalve. Prævalensen af haser uden hævelse (score 0) steg fra 44% ved første undersøgelse til 67% ved anden undersøgelse. Forskellen var statistisk signifikant ved brug af en Chi-i-anden test. Der blev til gengæld ikke fundet nogen signifikant ændring i prævalensen af halte køer trods opstaldning i dybstrøelsesbokse. Ved anvendelse af T-test var der en signifikant forbedring af det gennemsnitlige niveau af SAA med et fald fra 22,97 mg/L til 8,05 mg/L. Det gennemsnitlige niveau af plasma fibrinogen var forhøjet ved første og anden undersøgelse (henholdsvis 11,7 g/L og 10,8 g/L), dog var ændringen i gennemsnittet ikke signifikant. Det kunne konkluderes, at selvom størstedelen af ammetanterne er udsætterkøer, indikerer den kliniske undersøgelse, at det ikke er systemisk syge dyr, der sættes ind i systemet. Systemet har både positive og negative effekter, så overordnet er det svært at konkludere, om ammetantesystemer er et godt alternativ til konventionelt og økologisk hold af malkekvæg. Det er derfor stadig nødvendigt med yderligere undersøgelser for eksempel studier med en kontrolgruppe.

Abbreviations

BCS	Body Condition Score
CCC	Cow-calf contact
CI	Confidence interval
CMT	California Mastitis Test
DIM	Days in milk
SAA	Serum amyloid A
SCC	Somatic cell count

1. Introduction

1.1 Cow-calf contact systems

Consumers increasingly value animal welfare as a key aspect of producing animal products such as milk and meat. In some cases, they even value animal welfare higher than climate and environment (Denver *et al*., 2023). This has led to the development of more brands and campaigns focusing on increased animal welfare due to consumer demand. It has also led some farmers to think of new ways to meet this demand. One way is to implement systems with prolonged cow-calf contact (CCC).

The reason for implementing these CCC-systems differ. A study interviewed 12 Danish farmers with varying experience with systems with prolonged CCC (Bertelsen and Vaarst, 2023). The farmers were asked what had motivated them to use a system with prolonged CCC. Most of them cited practical reasons, as they felt that it eased the workload with the calves and therefore gave them more flexibility. Furthermore, three farmers cited image as their motivation. They felt that it would improve the farm's image by giving them an advantage and attract more customers interested in a production system with better animal welfare. Lastly, three of the farmers cited ethical reasons; they wanted better animal welfare and to allow for more natural behaviour between the cow and calf. However, according to Sirovica et al. (2022), most consumers in Canada and the United States preferred systems where the calf was not separated from its biological mother. In the study, the consumers did not view foster cow systems any better than systems with separation of cow and calf followed by individual or group housing of the calves. So, these consumers were not actually interested in foster cow systems as a way to improve animal welfare, even if that was the farmers' reason for implementing the system.

Traditionally, the cow and calf have been separated shortly after birth. In Denmark the cow and calf are separated after a minimum of 12 hours (BEK nr. 1743, §89) in conventional herds and after a minimum of 24 hours in organic herds (Økologisk Landsforening, 2024). However, in nature the calf stays with the cow for about 6-14 months (Vaarst & Christiansen, 2020; Köllmann *et al*., 2021). In the first days and weeks after calving it is primarily the cow that initiates nursing-bouts, but in the following weeks it is the calf that seeks out the cow to nurse (Tucker, 2020). In the first month's, calves typically stay together in small groups.

The calves are left in these groups while the cows graze, but the cows return several times a day to allow nursing (Tucker, 2020). The weaning then occurs gradually, as the calf nurses fewer and fewer times a day.

In systems with prolonged CCC the calf stays with its biological mother or with a foster cow for an extended period of time. The duration of the CCC can vary from a few days to several months. Furthermore, these systems can be designed with “whole day CCC” where the cow and calves have access to each other all the time, or it can be designed with “part time CCC” where the cow and calves are separated some of the time (Sirovnik *et al*., 2020). This diversity can make it difficult to draw definitive conclusions about the advantages and disadvantages of these systems.

One of the advantages of CCC-systems is that cows get the ability to express their maternal behaviour (Flower and Weary, 2003). Later separation also has behavioural benefits for the calves, as they exhibit more normal social activity and fewer abnormal behaviours such as “cross-sucking” and licking objects (Meagher *et al*., 2019). Disadvantages of later separation include an increased stress response (e.g. increased vocalization and activity at separation) in both the cows and the calves (Flower and Weary, 2003). In cows, later separation also results in decreased rumination (Flower and Weary, 2003).

Many Danish farmers choose to implement foster cow systems instead of housing the calves with the lactating cows (Vaarst & Christiansen, 2020). In these systems, the calves and foster cows are typically together for 24 hours a day (Vaarst & Christiansen, 2020). The foster cows nurse two to four calves and are usually not additionally milked. Sometimes the foster cow also nurses her own biological calf (Sirovnik *et al.*, 2020). They are often housed on straw in smaller groups of one or two foster cows in the first few days after the cows and calves are paired. Later, they are housed in larger groups in straw yards with or without access to pasture (Christiansen & Bertelsen, 2024). The CCC-systems are often calf-driven, which means that the calves take the initiative to make contact, as the straw yards are designed with a partition or creep area that provides the calves with space for eating and resting, which the cows cannot enter *(Sirovnik et al.*, 2020). The calves are usually offered extra concentrate within this space. Furthermore, the farmers are required to give the foster cows access to pasture on organic farms (Mejeriforeningen, 2024).

1.2 Reasons for selecting a foster cow

Farmers select foster cows for several reasons. One study, that included 44 European herds with foster cows, found that cows in early lactation were selected based on high somatic cell count (SCC), good maternal behaviour, and/or difficulties with milking (Eriksson *et al.*, 2022). Cows in late lactation were selected based on the same criteria, but also because they were selected for culling (Eriksson *et al.*, 2022). According to Bertelsen & Vaarst (2023) foster cows in Danish herds were also chosen if they had a low yield, were lame, difficult to work with, or were weak in the herd.

Because some foster cows are selected based on health status (e.g. lameness or high SCC), it is even more important to examine whether CCC-systems have a negative impact on these cows. In Bertelsen & Vaarst (2023) one farmer stated that they saw the CCC-systems as a way to "save" cows that would otherwise have been slaughtered. This gives the cows selected for culling another purpose on the farm until they are ready for slaughter. However, the farmers did not mention the possible ethical dilemmas related to using cows with impaired health status as foster cows.

Foster cow systems and other systems with prolonged CCC might be a possible compromise on the path towards better animal welfare, but only if the health of both the calves and cow benefits from the system. Most studies on CCC-systems focus on the health, behaviour, and development of the calves in these systems (Fröberg *et al.*, 2008; Beaver *et al.*, 2019; Meagher *et al.*, 2019). Several studies do examine the effect of the system on the cows. However, they mostly focus on the effect on udder health, milk composition, or amount of saleable milk (Krohn, 2001; Beaver *et al.*, 2019; Barth, 2020; Köllmann *et al.*, 2021). Krohn et al. (2001) and Beaver et al. (2019) described a reduced risk of mastitis and retained placenta, while Fröberg et al. (2008) found a tendency for improved udder health based on California Mastitis Test (CMT) scores. Köllmann et al. (2021) found no evidence of decreased udder health in a study based on 99 foster cows from Germany, though they did find an increase in pathogen transmission and in lesions on the teats and udder. Similarly, an older study referenced by Beaver et al. (2019) found a higher risk of teat damage in cows that nursed four calves which is common in foster cow systems. Regardless, there is still a lack of knowledge about how systems with prolonged CCC affect the clinical conditions of the foster cows.

1.3 Aims and objectives

As mentioned, there is a need for knowledge about the general condition of foster cows in systems with prolonged CCC and about how these systems affect the cows compared to systems with conventional calf rearing. Therefore, this study had two objectives.

The first objective was to examine and describe the clinical condition of cows entering as foster cows in 7 Danish herds. This was done by collecting data from clinical examinations of 61 foster cows including blood samples and questionnaires about the design of the system on each farm. The second objective was to evaluate how the condition of the cows developed after four to five weeks in the foster cow system and to determine if there was a statistically significant difference from the first examination to the second.

2. Materials and methods

2.1 Literature search

The literature search was primarily done using PubMed and Web of Science. The keywords used included variations of cow-calf contact, foster cow, dairy cow, Denmark, Danish, health, udder, CMT, hyperkeratosis, lameness, hock, fibrinogen, and SAA. The keywords were combined with OR or AND. The language of the articles was limited to English and Danish. Furthermore, the snowballing method was used.

2.2 Ethical approval

The laboratory animal permit (2023-15-0201-01520) was issued on the 2nd of October 2023. The local ethical approval (2023-012) was issued on the 4th of September 2023.

2.3 Data collection

Different herds with foster cows in Jutland were contacted by our supervisors, Mette Bisgaard Petersen and Kirstin Dahl-Pedersen. From there, eight herds (Herd A – H) agreed to participate in the project "Health and disease in Cow-Calf contact systems". All herds were visited before the start of the study except for Herd G, as they had seasonal calving starting in October and, therefore, did not have any foster cows until later in the study period. The visits were conducted to assess the practical feasibility of performing the clinical examination and lameness evaluation as well as to obtain written consent from the farmers.

In September 2024 Herd H informed us that they no longer use foster cows. Therefore, this herd was excluded from the project before any data had been collected from the farm.

From 3rd of September 2024 to 25th of November 2024 data was collected from 61 foster cows across the seven herds. All cows assigned as foster cows during this period were examined twice except for four cows that were excluded from the project for various reasons after the first examination. In this study, a foster cow was defined as a cow caring for 2-4 calves and not being additionally milked.

During one of the visits to each herd the farmers were interviewed about the setup of their cow-calf contact system and management. They were asked when and why they started using foster cows, how their routines around the system are organized, and how they pair foster cows and calves (see Appendix 1).

2.3.1 The Clinical Examination

The examination was performed twice on 57 foster cows, while they were restrained in headlocks. The first examination took place zero to seven days after being assigned as a foster cow, and the second examination occurred four to five weeks later. The clinical examination was performed based on a clinical examination protocol (see Appendix 2) that included general condition, body condition score (BCS), temperature, skin and hair, auscultation of heart and lungs, type of respiration, cough, respiratory and heart rate, rumen fill, auscultation of the abdomen, udder examination (indicator paper, CMT, hyperkeratosis, wounds on the udder and teats), hock score, hygiene score of udder and legs, as well as a lameness evaluation on solid ground. The clinical examination protocol included scores based on preexisting literature and new scoring tables developed by the authors of this study with the help from the supervisors on this project. Definitions of all scores can be seen in Appendix 2. For each cow an examination form (see Appendix 3) was filled out for both the first and second examination based on the results of the clinical examination, data from The Central Husbandry Register (CHR), and help from the farmer.

2.3.2 Blood samples

The blood samples were taken from the tail of the cows either from the *V. caudalis mediana* or *A. caudalis mediana*. In some cows, the blood sample was taken from *V. jugularis*, if it was not possible to take it from the tail. Before blood sampling the area was sanitized with 70% alcohol. Four blood samples were taken from each cow, two during the first examination and another two four to five weeks later during the second examination. On both occasions, the samples were first drawn into serum gel tubes (BD Vacutainer SST II Advance, 8.5 ml) and then into citrate tubes (BD Vacutainer 9NC 0.109M Sodium Citrate, 2.7 ml).

All blood samples were centrifuged at 1800 G (4327 RPM) for 10 minutes using a “Hettich EBA 200”. They were centrifuged between 30 minutes and two hours after collection. Serum and plasma were transferred into separate cryotubes each labelled accordingly.

From the time they were centrifuged until they could be frozen, they were stored in a Styrofoam box with ice packs to keep them cold.

The blood samples were sent to The Veterinary Diagnostic Laboratory (VetLab) at Grønnegårdsvej 3, st., Building 1-61, 1870 Frederiksberg C. The level of serum amyloid A (SAA) was measured using an immunoturbidimetric assay (VET-SAA, Eiken Chemical Co., Japan). The level of fibrinogen in plasma was measured using an ACL Top 500, Instrumentation Laboratory (ILS).

The level of SAA was measured twice in 57 foster cows. A cut-off interval of 20-25 mg/L was used to group the cows (Petersen, 2024). Cows with a result below 20 mg/L were grouped as "Normal", cows with a result between 20-25 mg/L were grouped as "Intermediate", and cows with a result above 25 mg/L were grouped as "Elevated".
The level of fibrinogen in plasma was measured twice in 55 foster cows. A reference interval of 3-7 g/L was used (Smith *et al.,* 2020). Cows with a result below 3 g/L were grouped as "Low", while cows with a result between 3-7 g/L were grouped as "Normal" and cows with a result above 7 g/L were grouped as "Elevated".

2.4 Level of agreement using the Kappa value

Before our data collection we assessed the body condition of 34 cows to calibrate our evaluations (Table 1). We based our assessments on the body condition scoring system developed by Jim Ferguson (Appendix 2), with all cows rated on a scale from one to five through palpation and visual inspection from behind.

		Observer 1				
	BCS	2.75	3	3.25	3.5	> 3.5
Observer 2	2.75	4	1	1		
	3	1	6	3	1	
	3.25		1	3	1	
	3.5			1	3	2
	> 3.5				3	3

Table 1. Distribution of observations.

The assessment was made independently without communication between evaluators. Afterwards, we calculated a kappa value to assess the degree of agreement. The kappa value was calculated to be 0.5 which indicates an acceptable level of agreement between our evaluations.

2.5 Statistical analysis

The collected data were transcribed into Microsoft Excel (version 16.91). The data were then analysed using the statistical program R (version 4.3.2 (2023-10-31)). Descriptive statistics (prevalence) were performed using R. The questionnaire was used as a reference to further discuss the results.

Before statistical analysis the Body Condition Score (BCS) of the cows was compared to the optimal range of BCS for the different stages of lactation based on Heinrichs et al. (2024) (see Table 2).

Stage of lactation	Days in Milk (DIM)	min. BCS	max. BCS
Early lactation	1-30	2.75	3.25
Peak milk	31-100	2.50	3.00
Mid lactation	101-200	2.75	3.25
Late lactation	201-300	3.00	3.75
Dry off	> 300	3.25	3.75

Table 2. Optimal range of BCS. Based on table 2 from Heinrichs et al. (2024).

A Chi-squared test was used to examine the change in distribution between the first and the second examination. It was applied to 8 variables: Cleanliness of the udder, pH of the milk at cow level, CMT-score at quarter level, CMT-score at cow level, hyperkeratosis at cow level, wounds on the teats at cow level, lameness, and hock score.

A paired T-test was used to compare the average levels of SAA between the first and the second examination. This was also done on the average level of fibrinogen.

The confidence interval (CI) for the variables was calculated in R using a proportion test. A significant level (α) of 0.05 was used on all tests.

3. Results

3.1 Description of the herds

This study included a final dataset of 57 foster cows from seven different Danish dairy herds. On average, the cows were examined three days after becoming foster cows (min.: 0 days; max.: 9 days). For logistical reasons, one cow was examined on day nine instead of within the first seven days. The second examination was performed, on average, 30 days later (min.: 26 days; max.: 40 days).

At the first examination, the farmer was asked whether the cow had been used as a foster cow before or not (see Appendix 3). All 57 cows had been in the milking system before this study began, and 14% (n = 8) of the cows had been used as foster cows before, though none of them came directly from another group of calves. There were 18% (n = 10) of the cows (all from the same herd) where the owner did not remember. The foster cows nursed between two and four calves each, but at the second examination the cows were housed in larger groups of approximately 3-20 foster cows with their calves. All farmers except farmer E calculated the number of calves based on the cow's milk yield as seen in Table 3.

Herd	Production	Herd size*	n**	Breed	Foster cows since	Reason for choosing foster cow system	All calves/heifers	Milk yield	Duration of fostering	Feeding of foster cows
A	Organic	381	19	Pro-cross	2019	Wanted more natural behavior	All calves	8-10 kg pr. calf	3.5-5 mth.	Fresh grass
B	Organic	184	16	Holstein	2020	Wanted more natural behavior	All calves	10 kg pr. calf	3-5 mth.	Cow feed or fresh grass
C	Organic	174	4	Holstein	2020	Changes in legislation, new building	All calves	8 kg pr. calf	3-4 mth.	Cow feed and concentrate
D	Conventional	66	4	Mixed	2022	Image	All calves	10 kg pr. calf	3 mth.	Cow feed
E	Conventional	155	1	Jersey	1999	Easier when rebuilding after a fire and decided to continue with the system	All calves	No set amount	3 mth.	Cow feed
F	Organic	237	3	Holstein	2021	Image	Heifers	10 kg pr. calf	3-4 mth.	Cow feed
G	Organic	212	10	Holstein	2020	Space, available buildings	Heifers	12 kg pr. calf	3-4 mth.	Cow feed

Table 3. Overview of the herds.

****From Key Performance Indicators in DMS (Average over the last 12 months from 30/11/24)***

*****Number of foster cows included in the project from the herd***

Cows in all stages of lactation were selected as foster cows, though 53% (n = 30) of the cows in this study were in late lactation, defined as > 200 days in milk (DIM), when entering as foster cows. Out of the 57 foster cows, 30% (n = 17) were in early lactation (0-100 DIM) and 18% (n = 10) were in mid lactation (101-200 DIM). The parity of the foster cows varied from first to seventh (see Figure 1). The number of cows in each parity increased from the first to the third parity after which it started to decrease. The biggest group was cows in third parity (26%, n = 15).

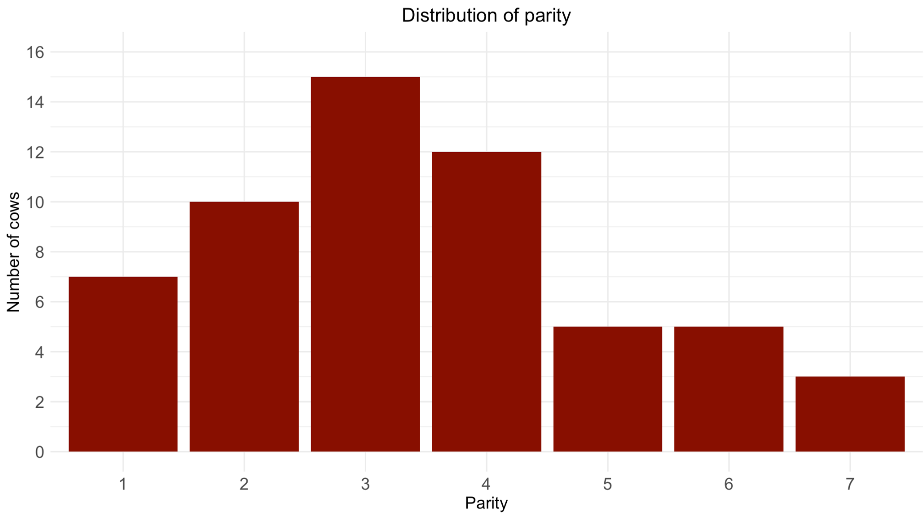

Figure 1. Distribution of parity.

3.2 Reasons for selecting a foster cow

During the first examination of every foster cow the farmer was asked why the cow was selected (see Appendix 3). Out of the 57 foster cows, 11 cows were selected based on more than one reason. This meant that we ended up with 70 answers which could be grouped into 8 categories (see Figure 2).

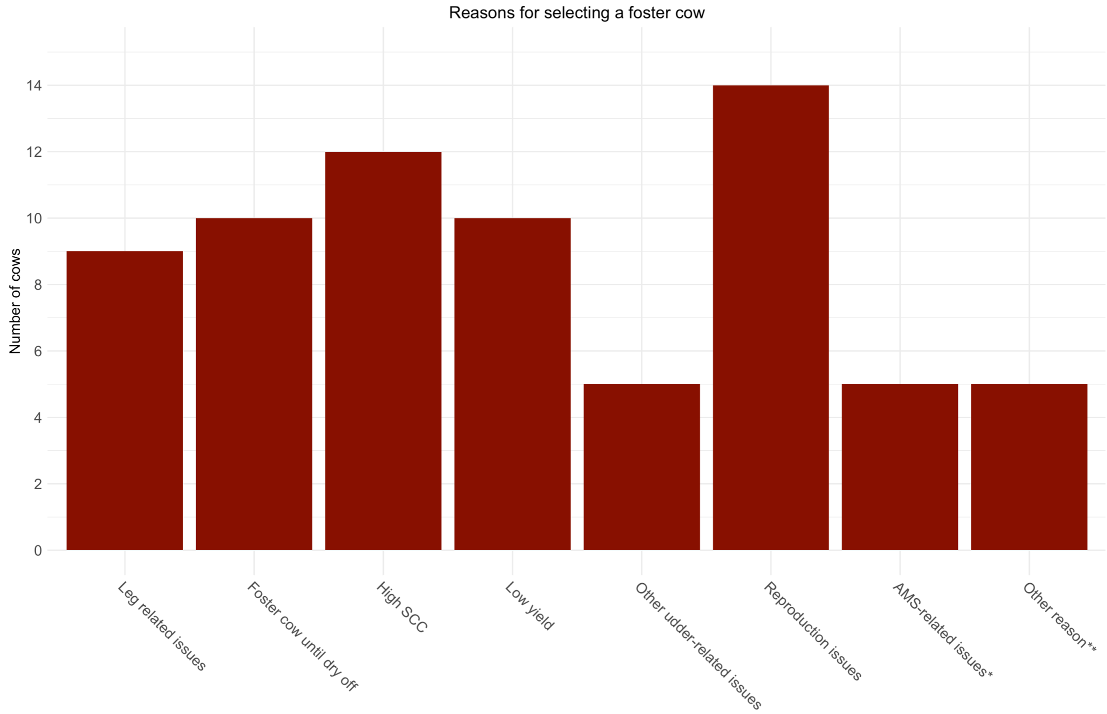

Figure 2. Reasons for selecting a foster cow.
****Issues with milking the cow in the automatic milking system (AMS).***
*****The category of "Other reason" included postpartum hypocalcaemia, hindleg cramps and fresh cows with a poor start of lactation.***

From the interview, one of the farmers (Farmer G) answered that they selected foster cows based on good health when possible. Farmer G recalled having had bad experiences when selecting foster cows with preexisting health issues, therefore, they started selecting foster cows without lameness and high SCC. On the other six farms, the farmers answered that they typically selected foster cows based on lameness, high SCC, low milk yield, or other health or management issues. Farmer B pointed out that, while foster cows were often selected for a specific reason (e.g. high SCC), the most important aspect was that the cow exhibited good maternal behaviour and that it would take good care of the calves.

3.3 Comparison of first and second examination

3.3.1 Udder health

The cleanliness of the udder was evaluated at both examinations for all 57 cows. At the first examination, 77% [(n = 44), 95% CI: 65:86] of the cows across all seven herds had a score of one or two on udder cleanliness. It was 79% [(n = 45), 95% CI: 67:88] at the second examination.

The pH and CMT-score of the milk were not examined in six cows which meant that the dataset for these variables included 51 cows. The pH was elevated in one or more quarters in eight of the foster cows (16%, 95% CI: 8;28) at the first examination. Out of these eight cows, six of them had a normal pH on all functional quarters at the second examination. The other two went from having an elevated pH in one quarter to having an elevated pH in all functional quarters. Furthermore, ten new cows had elevated pH in one or more quarters, meaning that in total 12 of the cows (24%, 95% CI: 14;37) had an elevated pH in one or more quarters at the second examination. When applying a Chi-squared test the change from the first to the second examination was not significant (p-value = 0.45).

The development in CMT-score at quarter level can be seen in Table 4. The number of functional quarters with a CMT-score of one, four, or five had increased between the first and second examination, while the number of functional quarters with a CMT-score of two or three decreased. Applying a Chi-squared test showed no significant difference between the two examinations (p-value = 0.9) when the quarters were categorized as "Increased CMT-score" (CMT-score ≥ 3) and "Normal CMT-score" (CMT-score ≤ 2).

CMT-score*	**SCC (cells/ml)**	**1st exam. n (%)**	**95% CI (min-max)**	**2nd exam. n (%)**	**95% CI (min-max)**
1	0 – 150,000	127 (64.5)	57.6 – 70.6	143 (72.6)	67.0 – 78.9
2	150,000 - 400,000	48 (24.4)	18.6 – 30.2	34 (17.3)	12.2 – 22.3
3	400,000 - 1,200,000	19 (9.6)	6.8 – 15.2	11 (5.6)	3.0 – 9.1
4	1,200,000 – 5,000,000	2 (1.0)	0.3 – 3.5	7 (3.6)	1.9 – 7.3
5	> 5,000,000	1 (0.5)	0.1 – 2.7	2 (1.0)	0.3 – 3.4

Table 4. Development of CMT-score at quarter level.
****Maximum CMT-score at quarter level.***

The change in CMT-score at quarter level followed a normal distribution (see Figure 3). The CMT-score of 59% [(n = 117), 95% CI: 52;66] of the quarters did not change between the first and second examination.

There were 26% [(n = 52), 95% CI: 21;33] of the quarters that increased or decreased with one score. Lastly, 8% [(n = 15), 95% CI: 5;12] increased with 2-4 levels whereas 7% [(n = 14), 95% CI: 4;12] decreased with 2-3 levels.

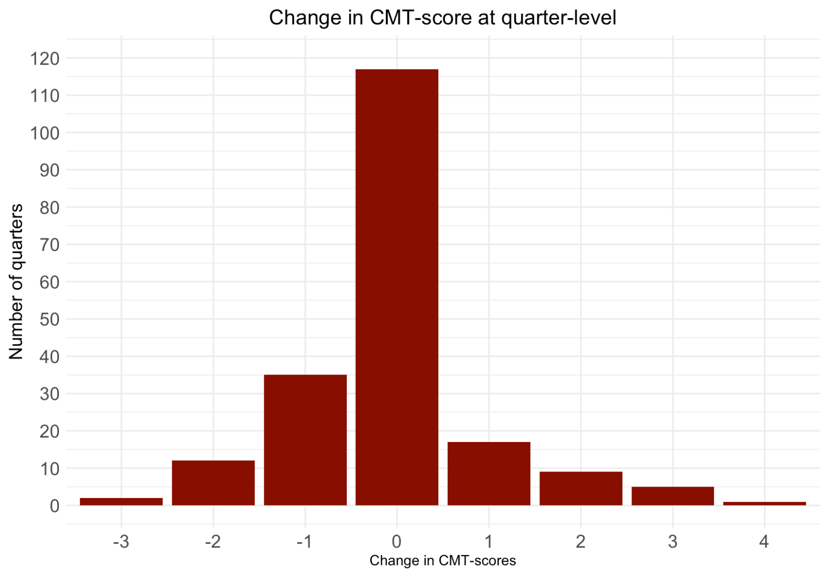

Figure 3. Change in CMT-score at quarter level.

The distribution of maximum CMT-score in one or more functional quarters at cow level can be seen in Table 5. Applying a Chi-squared test to the distribution showed no significant difference between the two examinations (p-value = 0.3) when the cows were categorized as "Increased CMT-score" (CMT-score ≥ 3) and "Normal CMT-score" (CMT-score ≤ 2).

CMT-score*	**SCC (cells/ml)**	**1st exam. n (%)**	**95% CI (min-max)**	**2nd exam. n (%)**	**95% CI (min-max)**
1	0 – 150,000	16 (31.4)	20.3 – 45.0	22 (43.1)	30.5 – 56.7
2	150,000 - 400,000	21 (41.2)	28.8 – 54.8	15 (29.4)	18.7 – 43.0
3	400,000 - 1,200,000	12 (23.6)	14.0 – 36.8	8 (15.7)	8.2 – 28.0
4	1,200,000 – 5,000,000	1 (2.0)	0.4 – 10.3	5 (9.8)	4.3 – 21.0
5	> 5,000,000	1 (2.0)	0.4 – 10.3	1 (2.0)	0.4 – 10.3

Table 5. Distribution of maximum CMT-score in one or more functional quarters at cow level.

****Maximum CMT-score in one or more functional quarters.***

Hyperkeratosis was examined on 48 out of 57 cows during the first examination. A maximum score of one on one or more teats was given to 52% [(n = 25), 95% CI: 38;66) of the cows, 40% [(n = 19), 95% CI: 37;54] had a maximum score of two, and 8% [(n = 4), 95% CI: 3;20] had a maximum score of three. At the second examination, 63% [(n = 30), 95% CI: 48;75] of the cows were given a maximum score of one, 27% [(n = 13), 95% CI: 17;41] were given a maximum score of two, and 10% [(n = 5), 95% CI: 5;22] were given a maximum score of three. Based on the maximum hyperkeratosis score the cows were categorized as "No hyperkeratosis" (score = 1) and "Hyperkeratosis" (score ≥ 2). When applying a Chi-squared test to the distribution, it showed no significant difference between the two examinations with a p-value of 0.4. The maximum hyperkeratosis score did not change in 52% [(n = 25), 95% CI: 38;66] of the cows. Lastly, the maximum hyperkeratosis score had decreased by one score in 29% [(n = 14), 95% CI: 18;43] of the cows, while it had increased by one score in 17% [(n = 8), 95% CI: 9;30] of the cows and by two scores in 2% [(n = 1), 95% CI: 0.4;11] of the cows.

During the first examination, one cow had a wound on the udder (score 2), while two cows had redness on the udder (score 1). At the second examination, these three cows showed improvement and were all given a score of zero, but two other cows had wounds on their udder (score 2), and one cow had redness on the udder (score 1).

In relation to tears and wounds on the teats, 23% [(n = 12), 95% CI: 14;36] of 52 cows got a score above one at first examination. Out of these 12 cows, seven of them were from the same farm (Farm G). At the second examination, four of these cows got a score of zero on all four teats, while five cows got a lower score on one or more teats but also a higher score on one or more of the other teats. Furthermore, two cows got a lower score on all the affected teats, and one cow got the same score (score 5) on the left back teat, and the right back teat went from a score of zero to two. In total, there were 52% [(n = 27), 95% CI: 39;65] with a score above one (including the eight cows mentioned above) at the second examination which is a statistically significant increase (p = 0.002) from the first examination when applying a Chi-squared test.

3.3.2 Legs

At the first examination, 39 out of 56 cows (70%, 95% CI: 57;80) were given a lameness score of one. A lameness score of two was given to seven (13%, 95% CI: 6;24) of the cows, while eight (14%, 95 % CI: 7;26) of the cows were given a lameness score of three.
Additionally, two (4%, 95% CI: 1;12) cows were given a lameness score of four and no cows were given a lameness score of five (see Figure 4). At the second examination, 48 cows (84%, 95% CI: 74;93) got at lameness score of one, while nine cows (16%, 95% CI: 9;28) got a lameness score above one. There were 40 foster cows (71%, 95% CI: 59;82) who got the same lameness score as the first time, 12 cows (21%, 95% CI: 13;34) got a lower lameness score than the first time, and four cows (7%, 95% CI: 3;17) got one lameness score higher at the second examination. When the cows were categorized as "Lame" (Lameness score $\geq$ 2) and "Not lame" (Lameness score = 1), it showed no significant difference (p-value = 0.1) in distribution between the two examinations when applying the Chi-squared test.

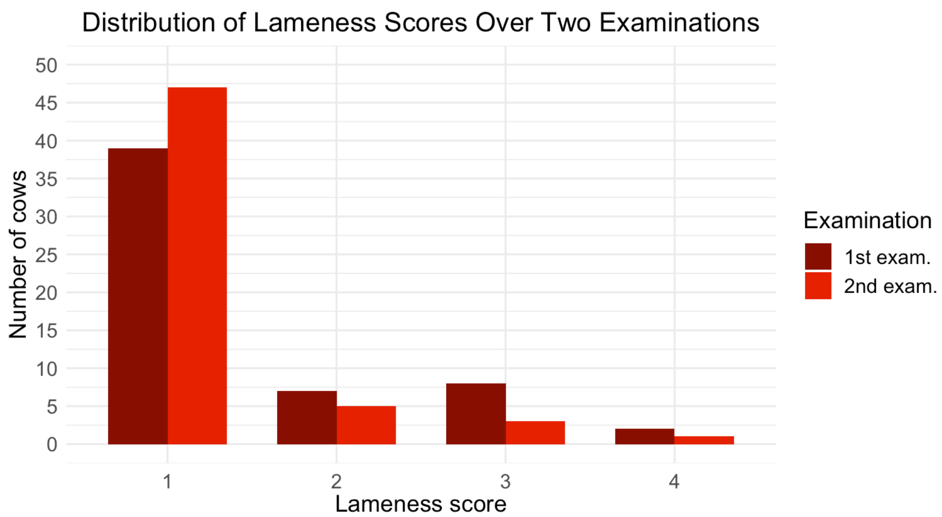

Figure 4. Distribution of lameness score at first and second examination.

The hocks of 57 foster cows were also scored using a score from zero to four describing the degree of swelling of the hocks. At the first examination, 25 (44%, 95% CI: 32;57) of the cows got a score of zero, while 32 (56%, 95% CI: 43;68) of the cows got a score above zero (see Figure 5). At the second examination, the hock score of 27 cows (43%, 95% CI: 35:60) was unchanged and 23 cows (40%, 95% CI: 29;53) had gotten a lower hock score, while seven (12%, 95% CI: 6;23) cows got a higher hock score. The hock score of six out of those seven cows increased from a score of zero to a score of one, while the last one increased from a score of one to a score of two.

In total there were 19 (33%, 95% CI: 23;46) of the cows with a score above zero at the second examination. A significant difference (p-value = 0.02) in hock score between the two examinations was found when categorizing the hocks as "Swelling" (Hock score ≥ 1) and "No swelling" (Hock score = 0) and applying a Chi-squared test.

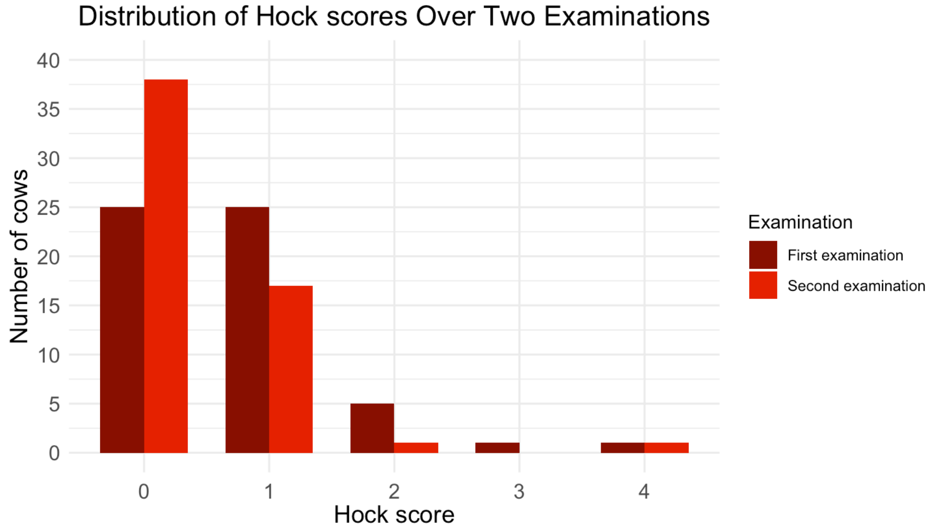

Figure 5. Distribution of hock scores at first and second examination.

At the first examination, 44% [(n = 25), 95% CI: 32;57] of the foster cows had hair loss, swelling, wounds, or open wounds on the legs. Swelling of the hocks was not included here but was addressed in the hock score (see above). The development of the findings from the first to the second examination can be seen in Figure 6.

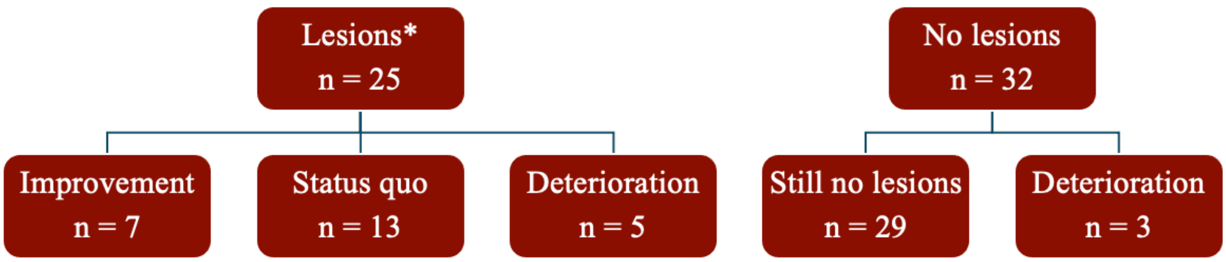

Figure 6. Development of lesions on the legs from the first to the second examination.
****Lesions includes hair loss, swelling and wounds on the legs (except s welling of the hocks)***

There were nine cows (16%, 95% CI: 9;27) with wounds on the body, tail, head, or neck at the first examination, while five cows (9%, 95% CI: 4;19) had wounds on the body, tail, head, or neck at the second examination. Lastly, four foster cows had a dull hair coat at the first examination and two foster cows had a dull hair coat at the second examination.

3.3.3 Body Condition Score

The BCS was evaluated on all 57 foster cows and the distribution can be seen in Figure 7. At the first examination, there were 56 % [(n = 32), 95% CI: 43;68] of the cows within the normal BCS-range, while 30% [(n = 17), 95% CI: 20;43] of the cows got a BCS higher than the optimal range and 14% [(n = 8), 95% CI: 7;25] got a score below. At the second examination, 58% [(n = 33), 95% CI: 45;70] of the foster cows were within normal BCS-range, while 30% [(n = 17), 95% CI: 20;43] were above and 12% [(n = 7), 95% CI: 6;23] were below.

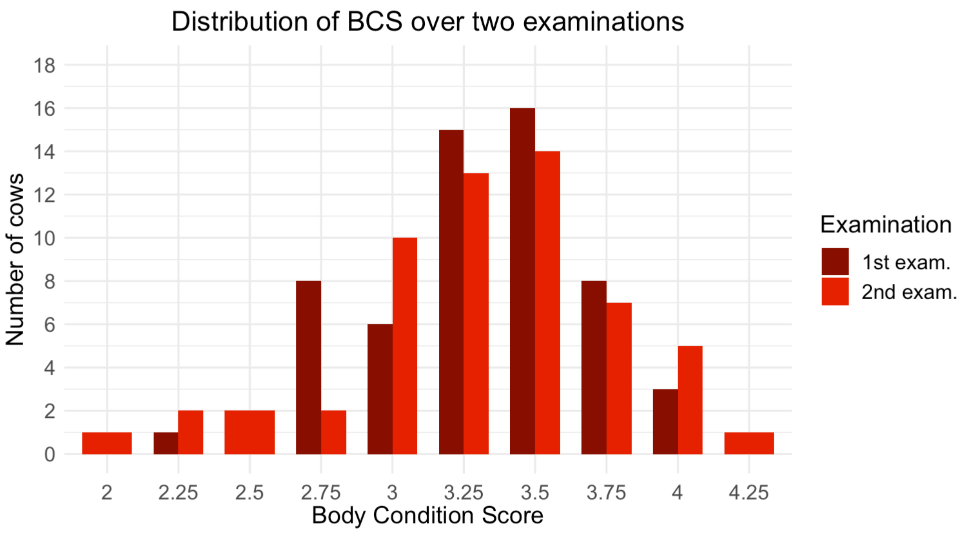

Figure 7. Distribution of BCS at first and second examination.

The distribution at the second examination resembles the distribution from the first examination (see Figure 7), but the cows were not necessarily given the same BCS during the first and second examination. The same BCS was given to 37% [(n = 21), 95% CI: 26;50] of the foster cows, 30% [(n = 17), 95% CI: 20;43] got a lower BCS and 33% [(n = 19), 95% CI: 23;46] got a higher BCS the second time (see Figure 8).

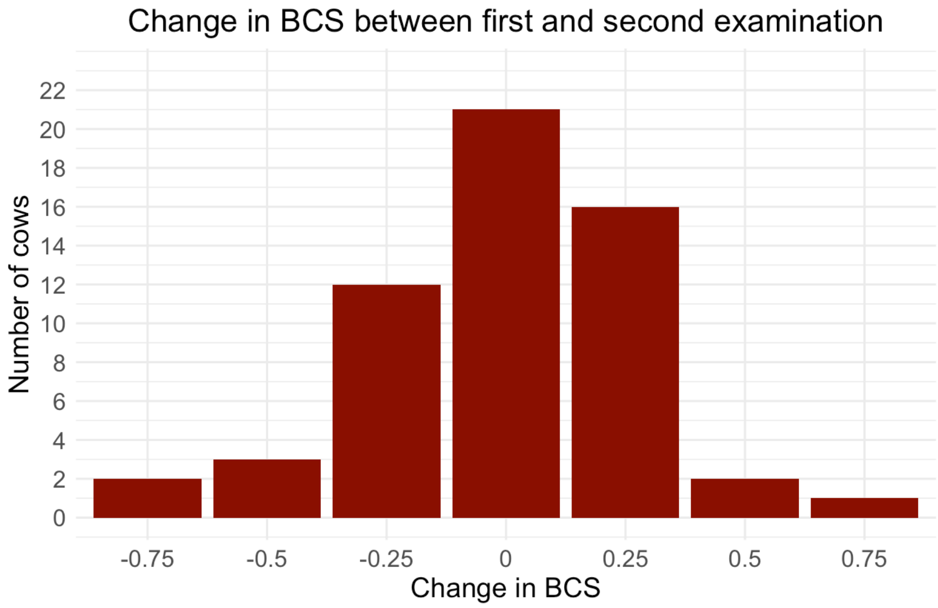

Figure 8. Change in BCS.

3.3.4 Other clinical results

General condition:

At the first examination, two cows got a score above zero. One of them had been injured by the other cows. The cow did not rise with mild interaction, was depressed, had an increased respiratory rate of 60 breaths per minute, and had several wounds. The other cow was standing with an arched back and was grinding her teeth. She had a swollen hindleg and a lameness score of three. At the second examination all cows got a score of zero.

Temperature:

Only two cows had a temperature above 39^{o}C at the first examination. Both cows had a temperature of 39.2^{o}C. For one of the cows, we attributed it to the stress of being restrained in headlocks, and the other cow had a rough respiration and increased respiratory rate of 44 breaths per minute. Both cows were within normal range at the second examination and none of the other foster cows had an elevated temperature at the second examination.

Respiratory system:

When auscultating the lungs at the first examination, 44 (77%) out of 57 foster cows were given a score of zero, 12 (21%) cows were given a score of one, and one (2%) cow were given a score of two. At the second examination, there were 46 (81%) cows with a score of zero, 10 (18%) cows with a score of one, and one (2%) cow with a score of two. This was the cow who had an elevated temperature and rough respiration at the first examination as mentioned in the section above. The cow who got a score of two at the first examination got a score of zero at the second.

The mean respiration frequency was 36 breaths per minute at the first examination and 37 breaths per minute at the second examination. Both ranging from 20 to 72. None of the cows had abdominal respiration at first or second examination. There was one cow who was coughing (score 2) at both the first and the second examination.

Circulatory system:

The heart was examined by auscultation in 56 foster cows. All 56 cows got a score of zero at both examinations.

The heart rate was counted in 54 foster cows. The mean heart rate was 76 beats per minute, ranging from 48 to 100, at the first examination. At the second examination, the mean heart rate was 82 beats per minute ranging from 56 to 108.

Abdomen:

The rumen fill was examined in 56 foster cows. At the first examination, four foster cows got a rumen fill score of one (low rumen fill). One of the foster cows also got a score of one at the second examination. The other three cows got a score of three at the second examination. In total, three foster cows got at score of one at the second examination.

The abdomen was examined by auscultation in 56 foster cows. At the first examination, three cows got a score of one. One of these foster cows also got a score of one at the second examination and was the only cow that deviated from normal at the second examination.

3.3.5 Blood samples

The level of SAA was examined twice in all 57 foster cows. At the first examination, 70% [(n = 40), 95% CI: 57;81] of the foster cows had a normal level of SAA (< 20 mg/L), while 5% [(n = 3), 95% CI: 2;14] of the cows were intermediate. Lastly, 25% [(n = 14), 95% CI: 15;37] had an elevated level of SAA (> 25 mg/L). At the second examination, 90% [(n = 51), 95% CI: 79;95] of the foster cows had a normal level of SAA (< 20 mg/L). The SAA was elevated in 9% [(n = 5), 95% CI: 4;19] of the cows and intermediate in 2% [(n = 1), 95% CI: 0.3;9] of the cows.

The average level of SAA was 22.97 mg/L at the first examination. This had decreased to 9.88 mg/L at the second examination. When performing a T-test, the difference was statistically significant with a p-value of 0.007. The level of SAA changed from “Normal” to “Increased” in two foster cows between the two examinations.

The level of fibrinogen in plasma was examined twice in 55 foster cows. At the first examination, 18% [(n = 10), 95% CI: 10;30] of the foster cows had a normal level of fibrinogen (3-7 g/L), while 82% [(n = 45), 95% CI: 70;90] of the foster cows had an elevated level of fibrinogen (> 7 g/L). At the second examination, 29% [(n = 16), 95% CI: 19;42] of the cows were grouped as “Normal” and 69% [(n = 38), 95% CI: 56;80] cows were grouped as “Elevated”. Furthermore, one cow [2%, 95% CI: 0.3;10] was grouped as “Low” at the second examination with a result of 2.9 g/L.

The average fibrinogen level was 11.7 g/L at the first examination and 10.8 g/L at the second examination. When performing a T-test, the difference was not statistically significant with a p-value of 0.09.

4. Discussion

The objectives in this study were to describe the clinical condition of cows entering as foster cows and to evaluate the development of their condition within the next four to five weeks. Clinical examinations were performed twice on 57 foster cows from seven Danish herds, and the farmers were asked about the design of the system on each farm as well as their motivations for choosing the foster cow system.

4.1 Motivations for CCC and selection of foster cows

In our study, farmers C, E, and G had adopted a CCC-system for practical reasons. The image from a consumer's point of view was an important motivation for implementing a foster cow system at farm D and F. These two farms both have a lot of visitors and one of them has a farm shop. Farmer A and B's motivation for using foster cows was a desire to allow for more natural behaviour. These three key themes (*Practical considerations, Image* and *Ethical responsibility*) are also highlighted in a Danish study, by Bertelsen and Vaarst (2023), who interviewed 12 Danish farmers about their motivations and considerations behind their CCC-systems. Eriksson et al. (2022) found that European farmers were motivated by improved calf health, more natural calf rearing, and less time-consuming management which aligns with the first two categories from Bertelsen and Vaarst (2023). However, the European farmers also mentioned practical reasons (e.g. improper barn construction) as barriers for implementing CCC-systems.

Our results show that 14% of the cows in this study had been used as foster cows before. Even though the owner could not remember in 18% of the cows, it still indicates that most cows are not used as a foster cow more than once. This could be related to the reasons for selecting the foster cows. Only one of the farmers (Farmer G) selected the foster cows based on good health. His foster cows were pregnant and would re-enter the milking system after parturition; however, these cows would not necessarily be selected as foster cows again. The other farmers in this study primarily selected cows that were going to be slaughtered after the foster cow period (i.e. after three to five months). They selected foster cows based on health or behavioural issues that would be a disadvantage in the milking system (Figure 2). This was also the case in Eriksson et al. (2022) where European farmers typically selected foster cows with high SCC or difficulties with milking. In the same study, several farmers chose cows with good maternal behaviour which was also mentioned as an important quality by Farmer B in this study.

Furthermore, some farmers also chose cows that had been selected for culling (Eriksson *et al.*, 2022). Generally, the reasons for selecting foster cows seem to resemble the reasons for slaughtering dairy cows. In this study, 20% of the foster cows were selected because of reproduction issues, while Thomsen & Houe (2023) found that 21% of Danish dairy cows were selected for culling because of reproduction issues. The same issue was also the most frequently cited reason for removing cows from farms in Canada (Stojkov *et al.*, 2020). Lameness (locomotor disorders) accounted for 13% in this study, for 12% in Thomsen & Houe (2023), and for 7% in Stojkov et al. (2020). Culling in Thomsen & Houe (2023) included slaughter, unassisted death, and euthanasia, but as the majority (83%) of the culled cows were slaughtered it is possible to compare the results.

The distribution of parity in this study also resembled the distribution of parity in cull cows in Thomsen & Houe (2023). In this study and in Thomsen & Houe's study the percentage of culled cows increased from first parity to third parity, after which it started to decline again until the sixth parity. Almost half of the foster cows (47%) in this study were in third or fourth parity. This could be related to a higher risk of several diseases and health issues (including lameness, clinical ketosis, and displaced abomasum) with increasing parity (Lean *et al.*, 2023).

4.2 Udder health

The proportion of cows with a clean udder (score of 1 or 2) was almost the same at the first and second examination (77% and 79%, respectively). A dirty udder (score 3 to 4) increases the risk of udder infection (Cook and Reinemann, 2007); hence, the goal is that a minimum of 90% of the cows in a herd are given a score one or two (Woudstra, 2024) to help reduce the risk of mastitis. Because of the sample size it was not possible to compare the proportion of cows with a clean udder on each farm in this study. Overall, the cleanliness of the udder was below the preferred level.

The distribution of pH, CMT, and hyperkeratosis did not differ significantly from the first to the second examination. The number of cows with increased pH of the milk in one or more quarters increased from 16% at the first examination to 24% at the second examination. The number of CMT-scores of one increased on both quarter level and cow level between the first and the second examination (Tables 4 and 5).

Fröberg et al. (2008) similarly found a tendency to decreased CMT-scores in restricted suckling cows, while Köllmann et al. (2021) found a decrease in SCC in foster cows. At the second examination, 73% of the quarters were given a CMT-score of one indicating that most of the quarters had a normal SCC (below 150,000 cells/mL). In total, a maximum CMT-score of one was given to 43% of the cows. The difference in proportion between cow level and quarter level occurs, because many of the cows had more than one quarter with an increased CMT-score.

The number of quarters with a high CMT-score (score of 4 or 5) also increased at the second examination. Barth (2020) found a marginal increase in SCC in suckled cows, but it decreased again after the nursing period ended, which would mean that some foster cows in this study could potentially re-enter the milking system and regain a normal SCC.

At the first examination, 52% of the foster cows showed no sign of hyperkeratosis (score of 1), while 8% of the foster cows had a rough ring of hyperkeratosis (score of 3) on one or more teats. This had increased to 63% and 10% respectively at the second examination. Hyperkeratosis can be affected by several factors, including weather conditions, disinfectants, and time with low milk flow rate (Mein, 2001) which could explain why we do not see any significant changes in this study. Furthermore, improvement in degree of hyperkeratosis might also take up to eight weeks in some cows (Mein, 2001). Overall, this study could not demonstrate a positive or negative effect of CCC-systems with foster cows on the udder and the teats regarding pH, CMT, and hyperkeratosis.

There is, however, a significant increase in the number of cows with tears and wounds on the teats. At the first examination, 23% of the cows had tears and/or wounds on the teats. At the second examination, this had risen to 52% of the cows, indicating that nursing two to four calves puts stress on the skin of the teats. These findings were supported by Walsh (1974) and Köllmann et al. (2021), who also found an increase in teat lesions. Furthermore, Rasmussen & Larsen (1998) found that suckling resulted in more rough teat skin than machine milking which could potentially lead to cracks and lesions.

We could not rule out that some of the teat lesions were caused by other causes than the calves. Bluetongue reached Denmark in August 2024, and we started collecting data for this project in September 2024. None of the foster cows we examined had tested positive for Bluetongue, but Farmers A and F have had confirmed cases of Bluetongue.

Farmers B, C, D, E, and G had not tested any cows. Farmer G vaccinated all his cows, but this does not prevent infection with Bluetongue virus. None of the cows we examined had been systemically ill, but infected cows can present with only mild/limited clinical signs (including lesions on the teats) (Fødevarestyrelsen, 2024), so we could not rule out that some of the teat lesions had been caused by Bluetongue virus. Bluetongue typically results in swollen red teats (erythema) and smaller confluent erosions or ulcerations on the teats with irregular borders (van den Brink *et al*., 2024; Fødevarestyrelsen, 2024) and the lesions observed in this study had been tears or larger rounded wounds with a smooth border. Hence, we suspect that most of the lesions observed in this study were caused by the calves.

4.3 Lameness and legs

The prevalence of lameness (when categorised as a lameness score 3-5) in this study was 14% at the first examination and 7% at the second, but the difference was not statistically significant. According to Thomsen et al. (2023), the prevalence of lameness (score 3-5) can range from 5% to 41% between countries with a mean of 23%. Hence, the prevalence of lameness in this study was relatively low, even though nine (16%) of the foster cows were selected based on locomotor issues. As discussed earlier, the distribution of lame cows selected for culling and lame cows selected as foster cows seem to resemble each other. However, the prevalence of lameness in cull cows was notably higher at 31% (Dahl-Pedersen *et al*., 2018).

There was no significant change in the prevalence of lameness between the first and the second examination. However, we can see in Figure 4 that more cows had a score of zero (not lame) at the second examination than at the first, and that the number of lame cows (with a lameness score > 1) decreased. The foster cows were all housed in deep bedded pens (straw yards) and in relatively small groups, so we had expected to see a significant positive effect of the deep bedding and the reduced competition for resources. A study by Thomsen et al. (2023) found that housing lame cows in hospital pens (with softer bedding material) had a positive effect on lameness, while Thomsen et al. (2019) found that the majority of lame cows (with a lameness score of 3 or 4) housed in hospital pens improved or were no longer lame within 3 weeks. Even though foster cows are not housed in actual hospital pens, they are still housed in a similar way in straw yards.

Hock health is an important indicator of cow comfort, as it reflects on the abrasiveness of the bedding material and, therefore, on the comfort/discomfort of the bedding material (Rutherford *et al*., 2008). In this study, 56% and 33% of the foster cows had a score above zero at the first and second examination, respectively, which indicates different levels of swelling. The prevalence is supported by a Norwegian study (Kielland *et al*., 2009), where hock lesions (hair loss, swelling, wounds, and open wounds) were present in all 232 included herds. In their study, 75% of the herds had a prevalence of hock lesions higher than 45% (Kielland *et al*., 2009). When comparing the first and second examination of the foster cows the prevalence of hock swelling (hock score > 0) was significantly lower at the second examination (p-value = 0.02). This implied that the housing conditions of the foster cows had a positive effect on the swelling of the hocks. This statement is supported by Rutherford et al. (2008), who found improved hock health when cows were housed in straw yards and/or on pasture. A review by Kester et al. (2014) also found that the risk of hock lesions could be reduced further by housing cows in straw yards.

The results from the first examination showed that 16% of the foster cows had wounds on the body, tail, head, or neck. Furthermore, 44% had some kind of lesions, hair loss, or swellings on the legs (this is in addition to swelling of the hocks which were addressed in Hock score). This was twice as much as in a study by Dahl-Pedersen et al. (2018) which described the clinical condition of cull dairy cows before transport to slaughter. They found wounds on 22% of the cows which were primarily located on the legs. Our findings were expected because of the above-mentioned high prevalence of hock lesions in Kielland et al. (2009). The hock scoring and the lesions were done as two individual assessments and scores in this study, but to obtain an even more reliable result of the clinical condition, it could have made sense to assess it as one variable, as done in other articles, such as Kielland et al. (2009) and Kester et al. (2014).

4.4 Body condition

The BCS did not change in 37% of the foster cows. Furthermore, the number of cows that received a lower or a higher BCS at the second examination was almost the same (17 and 19 cows, respectively). We might have seen a more significant change in one direction if the first and second examination had been further apart, as the scores from the first examination were centred around score 3.25-3.5, a normal BCS for cows in late lactation (Heinrichs *et al*., 2024), whereas more of the scores from the second examination were located at the extremes of the scale (see Figure 7).

Furthermore, several of the farmers in this study stated that they usually received a higher slaughter settlement from their foster cows than their milking cows.

Only two cows decreased 0.75 in BCS between the first and second examination. Both cows had sustained injuries prior to the first examination and should probably have been housed in sick pens based on our assessment. While two cows are not enough to make definitive statements, they demonstrate that the foster cow system cannot serve as a substitute for sick pens. The foster cows are housed in deep bedding (like a sick pen), but it is still a demanding job to nurse two to four calves (or more in the larger groups).

4.5 Fibrinogen and SAA

At the first examination, 70% of the foster cows had a normal level of SAA (< 20 mg/L), when using a reference level of 20-25 mg/L (Nielsen *et al.*, 2024), indicating that they were healthy. This had increased to 90% at the second examination. As mentioned in the results, the level of SAA only changed from “Normal” to “Increased” in two foster cows between the two examinations. Both foster cows also got an increased CMT-score at the second examination.

There is no official reference level for SAA in cattle. Trela et al. (2022) mentioned that SAA in healthy cows could range from 0-70 mg/L, while a study by Nielsen et al. (2024) indicated that the upper reference level could be placed around 20-25 mg/L (i.e. levels above 20-25 mg/L indicate inflammation). However, it would require a larger study with more cows to determine a reliable reference level in cattle. In this study, the mean level of SAA was 22.97 mg/L and 9.88 mg/L at the first and second examination, respectively. This was a significant decrease in mean SAA level which suggested a lower prevalence of inflammation at the second examination. This was supported by a decrease in lame foster cows and foster cows with a high CMT-score (though not significant in both cases) as well as a significant decrease in hocks with swelling (a hock score > 0).

When using the reference level of 3-7 g/L for fibrinogen there were 82% and 69% with elevated plasma fibrinogen level at the first and second examination, respectively. Similarly, almost 75% out of 134 clinically healthy cows had a plasma fibrinogen above 7.5 g/L in a master project by Knudsen (2019).

In this study, the mean level of fibrinogen was 11.7 g/L at the first examination and 10.8 g/L at the second examination. Both results would be categorised as "Elevated" based on the reference level of 3-7 g/L from Smith et al. (2020). However, the reference level might be too low. Based on the clinical examination, veterinarians declared patients healthy even though the plasma fibrinogen levels were still above 7 g/L (Knudsen, 2019). Furthermore, according to Petersen (2024) fibrinogen usually increased to around 12-15 g/L, before they started to see accompanying clinical symptoms at The Large Animal Teaching Hospital in Taastrup, Denmark.

4.6 The overall clinical condition of foster cows

The cows selected as foster cows typically had some kind of health issue, but they were not systemically ill. Only two cows had an elevated temperature (above 39.0°C) at the first examination, and no cows had an elevated temperature at the second examination.
The majority of the foster cows (79% and 81% at the first and second examination, respectively) had a normal respiration. The average respiratory rate was 36 breaths per minute at the first examination and 37 breaths per minute at the second. This was at the high end of the reference interval, but it was expected given the stress associated with being restrained and examined by strangers. The deviation from normal was also very limited, when examining the circulatory system and abdomen of the foster cows, which further demonstrated that the selected cows were not systemically ill.

The difference between the first and second examination was significant in only three of the nine variables that were tested. There was a significant decrease in the prevalence of hock swelling, a significant increase in wounds and tears on the teats, and a significant decrease in the mean level of SAA. The clinical condition of some cows improved in the system, while it worsened for others. The difference in how the cows develop in the system might be affected by several different variables. One possible variable is the number of calves they nurse. Several of the farmers in this study reported that some cows had stronger maternity behaviour than others and nursed more than their own calves. Overall, our results suggest that the foster cow system does not unambiguously improve or worsen the condition of the cows and, therefore, further studies examining the clinical condition in foster cow systems are still needed.

4.1 Limitations

The sample size was very small on some of the farms which meant that comparison between farms was not possible. For future projects it would be desirable to obtain a larger sample size, so that comparison between the herds was possible. This is especially relevant because the CCC-systems are designed in so many different ways.

Furthermore, this study was limited by time. We examined the foster cows twice; once within seven days of becoming a foster cow and again after an average of 30 days. To fully understand the impact of the system on the cow it would have been more appropriate to perform the second examination around weaning (after three to five months on these farms) or to have performed a third examination around the time of weaning. This way, we would be able to describe the changes that occur over the entire period that they are nursing the calves. However, this was not possible due to the limited period of time for this master thesis.

Lastly, this was a pilot study that only included the development of the foster cows' condition. It would have been advantageous to include a group of control cows, that stayed in the milking system, to determine which changes more precisely were caused by the system and not preexisting conditions or external variables.

5. Conclusion

This study described the clinical condition of foster cows and included data from 57 foster cows across seven Danish herds. Furthermore, it was evaluated how the clinical condition of the foster cows developed over four to five weeks. Based on the answers from the farmers, this study found that the majority of cows used as foster cows were cull cows with some kind of behavioural or health issue. This was also reflected in our clinical examinations. However, both clinical examinations also showed that the foster cows were not systemically ill.

This study found no significant changes regarding the BCS and the udder health. Variables such as pH, CMT-scores, and hyperkeratosis showed minimal change between the two examinations, suggesting that the foster cow system neither significantly improved nor worsened the udder health of the cows at least not over such a relatively brief period of time. Regarding lameness, a slight improvement was observed but not enough to be statistically significant. This study found a significant decrease in the prevalence of hock swelling between the two examinations. This improvement was likely related to the housing of the foster cows. Furthermore, this study also found a significant increase in tears and wounds on the teats which could be caused by the teeth of the suckling calves.

The results of the blood samples showed a significant decrease in SAA levels which suggests a reduction in inflammation. This is supported by a slight decrease in the prevalence of lameness and high CMT-scores as well as a significant decrease in prevalence of hock swelling. The change in plasma fibrinogen levels between the first and the second examination was not significant. However, the mean level of plasma fibrinogen was above the reference interval of 3-7 g/L at both examinations.

Overall, the effects of the foster cow system appear to be manifold but often not statistically significant. Further studies are still needed to conclusively determine which changes in clinical condition are caused by the CCC-systems.

6. Perspectives

This study is among the first to focus on the general clinical condition of the foster cow, instead of the calves nursed by foster cows, so the scientific evidence on the subject is limited. Therefore, there is still a need for further studies especially studies with control groups that make it possible to examine whether the observed changes are caused by the foster cow system or are related to other risk factors or confounders.

The farms in this study primarily used cull cows as foster cows. This might affect the development of the foster cows in the system and might complicate the research into the health of the foster cows because of confounding variables and preexisting conditions. Further research is needed to examine the effect of the foster cow system if only clinically healthy cows are used.

In this study, we only focused on the clinical condition of the foster cow. However, if foster cow systems with prolonged CCC are to be implemented on more farms, it is also important to consider the psychological impact on the foster cows (e.g. when separating the foster cow and its calves). While the absence of sickness and pain is important that alone does not equal good animal welfare. Furthermore, it is important to consider the health and welfare of the calves in the foster cow systems.

Many studies focus on either the calves or the cows in CCC-systems. However, it is also important to look at the system as a whole and include both the calves and the cows. Foster cow systems include all calves (or all heifer calves) but not all cows, while other CCC-systems (without separation of the calves from their biological mother) could include all cows. However, other CCC-systems might be harder to implement for practical reasons (barn structure, milking routine etc.) and so foster cow systems could be a compromise on the road towards better animal welfare.

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8. Appendix

8.1 Appendix 1

Interview of the Farmers

Questions about the Design of the Foster Cow System

- How long have you used foster cows?
- Why did you choose a foster cow system?
- How is the system designed on your farm?
  - Is it for all calves or only heifers?
  - How many calves does each foster cow nurse?
  - How do you decide how many calves a foster cow should nurse?
  - When do you wean the calves?
  - How are the cows selected?

- How do you get the foster cow to accept the calves? Do you do anything at all?
- What do you feed the foster cows?

8.2 Appendix 2

Clinical examination protocol

General condition

The general condition of the cows is assessed by inspecting the cow with minimal interaction. The cows are visually evaluated on a scale from 0 to 3 based on the following chart:

Score	**Definition**
Score 0	The cow is interested in its surroundings. It is alert and has clear eyes. There is nose licking and ear movement, and possibly rumination.
Score 1	The cow is less interested in its surroundings. There is a lack of nose licking and ear movement.
Score 2	The cow shows clear clinical signs of illness, including an arched back and teeth grinding.
Score 3	The cow does not rise with mild interaction. It is depressed, possibly apathetic, and shows clinical signs of severe illness. It is not aware of its surroundings.

Table 1. Scoring chart for general condition developed by these authors and their supervisors.

All cows are assessed while standing. If the cow is laying down during the initial inspection, she must voluntarily rise upon interaction with us when we enter the pen.

Body Condition Score (BCS)

The BCS of the foster cows is assessed using palpation and visual inspection. The cows are given a score from 1 to 5 with quarter points based on the system developed by Ferguson et al. (1994). Pictures by Elanco Animal Health were used as a reference on the farms (Elanco Animal Health, 1997).

Temperature

The temperature is measured rectally with a digital thermometer.
The temperature is considered normal if it is between 38.0-39.0^{o}C (Smith *et al.,* 2020).

Skin and hair coat

The hair coat is assessed by visual inspection.
Any deviations from normal are written down, and otherwise it is noted that the coat is normal. The hair coat is considered normal if it is dense, shiny and not falling off (Eriksen, 1991).

The skin is assessed by visual inspection. The skin is considered normal if it is intact, is of normal thickness and elasticity, and if no itching is observed (Eriksen, 1991). For any abnormal findings the location, size and type of lesion (tumour, vesicle, erosion, ulceration, hyperkeratosis or other) is written down. Otherwise, it is noted that the skin is normal.

Respiration

Auscultation of the lungs

The whole lung field is auscultated bilaterally and given a score of 1-3 based on the following chart:

Score	**Definition**
0	Normal vesicular respiration bilaterally over the entire lung field. Can be heard as a soft f-sound during the inspiration.
1	Rough respiration over parts of or the entire lung field. Can be heard as vesicular respiration (soft f-sound) during either inspiration or expiration and then a bronchial respiration (k-sound) opposite.
2	Bronchial respiration over parts of or the entire lung field. Can be heard as a k-sound during both the inspiration and the expiration.

Table 2. Scoring chart for auscultation of the lungs. Based on Eriksen (1991).

Type of respiration

The type of respiration is assessed visually, and each cow is given a score of 0-1 based on table 3. A thoracoabdominal respiration is considered normal (Eriksen, 1991).

Score	Definition
0	Thoracoabdominal respiration
1	Abdominal respiration

Table 3. Scoring chart for type of respiration.

Coughing

It is noted if the cow coughs during the examination. The cow is then given a score based on the following chart:

Score	Definition
0	No coughs observed
1	1-2 coughs observed
2	More than 2 coughs observed

Table 4. Scoring chart for coughing developed by these authors and their supervisors.

Respiratory rate

The respiratory rate is counted during auscultation of the lung field. We auscultate for 15 seconds and then multiply the counted rate by 4. Normal respiratory rate is considered 12-36 breaths/min (Smith *et al.,* 2020).

Circulatory system

Auscultation of the heart

The heart is auscultated on both sides. It is considered normal if the heart works rhythmically and with normal rate and strength. You should be able to hear two clear and distinctive heart sounds over the mitral ostium on the left side and over the tricuspidal ostium on the right side. There should not be any murmurs (Eriksen, 1991). Cows with abnormal findings are given a score of 1, while cows with normal findings are given a score of 0.

Heart rate

The heart rate is counted during auscultation of the heart. We auscultate for 15 seconds and then multiply the counted rate by 4. Normal heart rate is considered 40-80 beats per minute (Smith *et al.,* 2020).

Rumen fill

Rumen fill is evaluated by visual inspection and palpation of the rumen directly behind the most caudal ribs. The cow is given a score of 1-3 based on the following chart:

Score	Definition
1	The rumen fill is less than one hands width
2	The rumen fill is equal to one hand width
3	The rumen fill is greater than one hands width

Table 5. Scoring chart for rumen fill developed by these authors and their supervisors.

Abdomen

The abdomen is auscultated on the left and right side. Percussion auscultation is performed bilaterally. The abdomen is considered normal if a minimum of one complete rumen contraction can be heard by auscultating for 1 minute. No steel band should be heard when doing percussion auscultation (Eriksen, 1991). Cows with abnormal findings are given a score of 1, while cows with normal findings are given a score of 0.

Udder

Indicator paper (pH)

Milk from each quarter is milked onto the indicator paper. It is written down for each quarter if the pH in the milk is normal or chanced (increased). A quarter with normal pH is given a score of 0, while a quarter with increased pH is given a score of 1.

The normal pH of milk is 6.5-6.7. At this pH-level the milk leaves yellow/light green markings on the indicator paper. If the cow has mastitis (subclinical or clinical) the pH in the milk increases towards that of the blood (7.4). This can be seen as dark green/blue markings on the indicator paper (Eriksen, 1991).

California Mastitis Test (CMT)

A CMT is performed at quarter level. Approximately 2 mL of milk is mixed with 2 mL of CMT-reactant in each well. The results are read within 15 seconds.

A score of 1-5 is given to each quarter based on the scoring system from SEGES Innovation (2018):

Score	Definition
1	0-150,000 cells/mL. The mixture of milk and reactant becomes uniform and does not create "clouds" when the tray is tipped back and forth.
2	150,000-400,000 cells/mL. The mixture becomes slightly grainy/cloudy. There is formation of "clouds" that move quickly with the movements of the tray.
3	400,000-1,200,000 cells/mL. The mixture becomes slimier and reacts with a slight delay compared to the movements of the tray. The "clouds" are more distinct and move slower. There is no attachment to the tray during stirring.
4	1,200,000-5,000,000 cells/mL. The slimy texture of the mixture increases, and the surface becomes more irregular. There is slight attachment to the tray during stirring.
5	> 5,000,000 cells/mL. The mixture is gel-like and forms a lump when the tray is stirred.

Table 6. Scoring chart for CMT-score based on SEGES Innovation (2018).

Udder hygiene score

The cleanliness of the udder is assessed on a scale from 1 to 4 through visual inspection of the udder from behind.

Score	Definition
Score 1	Clean, little or no evidence of manure
Score 2	Clean, only slight manure splashing
Score 3	Dirty, distinct demarcated plaques of manure
Score 4	Filthy, confluent plaques of manure

Table 7. Scoring chart for udder hygiene based on Figure 1 and 3 in Cook and Reinemann (2007).

Hyperkeratosis of the teat ends

The condition of the teat ends is assessed on a scale from 1 to 4 using the following chart:

Score	**Definition**
Score 1/N	No ring. The teat end is smooth with small, even orifice.
Score 2/S	Smooth or slightly rough ring. The surface of the rings is smooth, or it may feel slightly rough, but no fronds or old keratin are evident.
Score 3/R	Rough ring. A raised, roughened ring with isolated fronds or mounds of old keratin extending 1-3 mm from the orifice.
Score 4/VR	Very rough ring. A raised ring with rough fronds or mounds of old keratin extending 4 mm or more from the orifice. The rim of the ring is rough and cracked. Often giving the teat-end a ''flowered'' appearance.

Table 8. Scoring chart for hyperkeratosis of the teat end. Based on Mein et al. (2001).

Wounds

The udder and the teats are each scored separately

Wounds on the udder

The udder (not the teats) is assessed through visual inspection and palpation and is scored on a scale from 0 to 1.

Score	**Definition**
Score 0	No wounds or tears on the udder
score 1	Wounds or tears on the udder

Table 9. Scoring chart for wounds on the udder. Developed by these authors and their supervisors.

Wounds on the teats

The teats are assessed through visual inspection and palpation and are scored on a scale from 0 to 6. Each teat is scored individually.

Score	Definition
Score 0	No change in skin thickness, no change in skin colour, no wounds or tears.
Score 1	Wear, change in skin colour (redness), no wounds or tears.
Score 2	One or more tears on the teat
Score 3	One small wound on the teat, max 0.5 cm in diameter. Possible also tears
Score 4	More than one small wound on the teat, max 0.5 cm in diameter. Possible also tears
Score 5	One larger wound on the teat, > 0.5 cm in diameter. Possible also tears
Score 6	More than one larger wound on the teat, > 0.5 cm in diameter. Possible also tears

Table 10. Scoring chart for wounds on the teats. Developed by these authors and their supervisors.

Leg hygiene score

The cleanliness of the hind leg is assessed on a scale from 1 to 4 through visual inspection of the legs distally from the hocks, both medially and laterally.

Score	Definition
Score 1	Clean, little or no evidence of manure
Score 2	Clean, only slight manure splashing
Score 3	Dirty, distinct demarcated plaques of manure
Score 4	Filthy, confluent plaques of manure

Table 11. Scoring chart for leg hygiene. Based on Figure 3 in Cook and Reinemann (2007).

Hock swelling

Swelling of the hocks is scored from 0 to 4 based on visual inspection

Score	Definition
Score 0	No swelling
Score 1	Slight swelling (1-2.5 cm) on the lateral side of the hock and/or hock tip
Score 2	Significant swelling (>2.5 cm) on the outer side of the hock and/or hock tip
Score 3	Slight swelling (1-2.5 cm) on the medial side of the hock and possibly swelling on the lateral side
Score 4	Significant swelling (>2.5 cm) on the medial side of the hock and possibly swelling on the lateral side

Table 12. Scoring chart for swelling of the hocks. Developed by these authors and their supervisors.

Wounds on the hocks are assessed under "Skin and hair".

Lameness Assessment

The cows' lameness score is evaluated on a scale from 1 to 5 based on Table 1 in Sprecher et al. (1997). The cows are assessed from the side or from behind while they walk on a firm surface.

Score	Definition
Score 1	Normal. The cow stands and walk with a level-back posture. Her gait is normal.
Score 2	Mildly lame. The cow stands with a level-back posture but develops an arched-back posture while walking. Her gait remains normal.
Score 3	Moderately lame. An arched-back posture is evident both while standing and walking. Her gait is affected and is best described as short striding with one or more limbs.
Score 4	Lame. An arched-back posture is always evident, and gait is best described as one deliberate step at time. The cow favours one or more limbs/feet.
Score 5	Severely lame. The cow additionally demonstrates an inability or extreme reluctance to bear weight on one or more of her limbs/feet.

Table 13. Scoring chart for lameness. Based on Table 1 in Sprecher et al. (1997).

8.3 Appendix 3

Clinical examination form

Examination no.: 1 / 2	
Date	/ 2024
Herd	
CKR number	
Blood sample number	
Breed	
Cows date of birth	
Date of last calving	
Parity	
Date of becoming a foster cow	
Reason for being selected as foster cow	
Used as foster cow before?	
How many calves?	

General condition (0-3)	
BCS (1-5)	
Temperature	
Skin and hair	

Respiration (0-2)	
Respiration type (0-1)	
Cough (0-2)	
Respiration frequency	
Heart (0-1)	
Heart rate	
Rumen fill (1-3)	
Abdomen (0-1)	

Indicator paper (pH)	HF:	VF:	VB:	HB:
CMT (1-5)	HF:	VF:	VB:	HB:
Udder hygiene score (1-4)				
Hyperkeratosis (1-4)	HF:	VF:	VB:	HB:
Udder score (0-1)				
Teat score (0-6)	HF:	VF:	VB:	HB:

Leg hygiene score (1-4)	
Hock score (0-4)	
Lameness score (1-5)	