UNIVERSITY OF COPENHAGEN
FACULTY OF HEALTH AND MEDICAL SCIENCE
DEPARTMENT OF VETERINARY AND ANIMALSCIENCE

Master Thesis

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Cow-calf-contact systems, identification of behavioural indicators of calf health and welfare.

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Submitted on: 14th June 2024

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Project type:	Veterinary Master's Thesis
Title and subtitle:	Cow-calf-contact systems, identification of behavioural indicators of calf health and welfare.
Topic description:	A behavioural study to identify behavioural indicators of health status in calves raised in cow-calf-contact systems. The study focuses on the calves' behaviour in the home-pen as well as latency to reunite with the cow after separation.
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Submitted on:	14th June 2024
Grade:	30 ETCS
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Preface

This paper is a 30 ECTS master thesis written by Monica Møller at the University of Copenhagen, as a conclusion of my master's degree in veterinary medicine. The thesis is based on behavioural observations and clinical assessments that seeks to identify behavioural indicators of health status in calves raised in cow-calf contact systems.

I would like to thank my academic advisors, Kirstin Dahl-Pedersen and Mette Bisgaard Petersen for their support and guidance during the process of writing this thesis. A special thanks to my company supervisor, Maja Bertelsen, for her support and teaching in regard to behavioural studies and working in the field.

I would like to also extend a thanks to the owner of the participating farm and the personnel there, for their help in contributing to the study, and their patience for my presence in the farm.

At last, a big thank you to those who read my thesis and offered up advice and input to better my work.

Monica Møller

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Abstract

Prolonged cow and calf contact (CCC) is gaining more attention in the dairy industry, as a response to the increase in demands from consumers regarding welfare and natural living for production animals. There is no set way of practicing CCC, as the practice is diverse, and variances in setup, duration and management is made according to the farm's wants and possibilities. There have been many studies made, and both benefits and disadvantages has been confirmed from the extended contact between cow and calf. However, a lot is yet unknown and a range of health concerns have been identified, especially in young calves.

This thesis aims to identify behavioural patterns that can help identify the sick calves when they are housed and raised in CCC pens. By doing this it aims to highlight behavioural indicators that can work as tools for farmers to use when monitoring their calves.

During the study 21 calves at an organic dairy herd were given a clinical assessment each week for four consecutive weeks. After this they were observed for a behavioural study of 1.5-2 hours duration, as well measuring their latency to reunite with the dam after separation. Additionally, a blood sample was taken from each calf at their first assessment, to evaluate their immunisation.

The results of this study showed that the sick calves spent on average 81% of the observed time resting, compared to the healthy calves spending 72,5% of the observed time resting. This difference was found to be statistically significant with the health status of the calves being a significant predictor to how the calf divided their time between resting and active. Additionally, it was found that the health status of the calves affected the amount of play behaviour observed, with the healthy calves performing play behaviour more than twice as many times as the sick calves (1,2 times per observation vs. 0,5 times per observation, respectively). No significant correlation between health status and the time it took for the calf to reunite with the dam after separation was found. Nor was a correlation between the immunisation level of the calf and the health status during the clinical assessments found.

To conclude, the health status of the calf statistically significantly affected the time it spent either resting or active, as well as how much the calf would play, with the sick calves being less active and less prone to play. The health status had no significant impact on latency time to reunite with the cow after separation. The immunisation of the calves had no significant impact on the health status nor the behaviour of the calves during the observational weeks. Further studies are needed to identify a more detailed description of time distribution of healthy and sick calves, as well as comparison between different types of CCC.

Resume

Forlænget ko- og kalv samvær (CCC) får mere og mere opmærksomhed fra mælkeindustrien som respons på offentlighedens øgede interesser for dyrevelfærd og dyrenes mulighed for at udleve naturlig adfærd. CCC er en alsidig praksis, der kan variere i opbygning, varighed og management, alt efter hvad der er ønsket af og mulighed for hos besætningen. En lang række studier har været gennemført og både fordele og ulemper er blevet påvist ved at udøve CCC. Der er dog stadig områder i praksissen der ikke er klarlagt og meget er endnu uvist omkring kalvenes sundhed og velfærd i systemerne.

Denne opgave har til formål at identificerer adfærdsmønstre der kan identificere syge kalve når de bliver holdt i CCC systemer. Ud fra dette er formålet at påpege adfærdsindikatorer der kan fungere som værktøj for landmanden når han/hun passer sine dyr.

Studiet har inkluderet 21 kalve fra en økologisk malkekvægsbesætning. Der blev udført klinisk undersøgelse og adfærdsobservationer en gang ugentligt i fire på hinanden følgende uger, foruden måling af latenstiden for hvor længe det tog hver kalv at genforenes med koen efter adskillelse. Derudover blev der taget blodprøve fra kalvene ved første kliniske undersøgelse for at måle niveauet af immunisering.

Det blev fundet at syge kalve brugte i gennemsnit 81% af den observerede tid på at ligge og hvile sig, i sammenligning brugte raske kalve 72,5%. Forskellen mellem de to værdier blev fundet at være statistisk signifikant og kalvenes sundhedsstatus blev fundet at have en signifikant effekt på hvordan kalvene fordelte deres tid mellem aktiv og hvile. Desuden blev det fundet at raske kalve udviste legeadfærd mere end dobbelt så mange gange per observation end de syge kalve (1,2 gange vs. 0,5 gang). Der blev ikke fundet nogen signifikant sammenhæng mellem kalvenes sundhedsstatus og den tid det tog dem at genforenes med koen efter adskillelse. Det blev heller ikke påvist at der var en sammenhæng mellem kalvenes immunstatus ved første besøg og dennes efterfølgende sundhedsstatus i de følgende uger.

Som konklusion blev det fundet at kalvenes sundhedsstatus havde en signifikant effekt på hvordan kalvene fordelte deres tid mellem aktiv og hvile, samt det havde en signifikant effekt på hvor meget legeadfærd blev observeret. Sundhedsstatus havde ingen signifikant effekt på latens tid for genforening efter separation, og kalvenes immunstatus blev ikke fundet at have effekt på deres sundhedsstatus i de observerede uger. Yderligere studier er nødvendige for at kortlægge mere specifikke adfærdsmønstre og bedre afbilde forskellene i adfærds- og tidsfordeling hos syge og raske kalve.

Abbreviations

BF	Bonding Foster (pen)
CCC	Cow-calf contact
FTPI	Failure of Transfer of Passive Immunity
GLM	General Linear Model
HSD	(Tukey) Honest Significant Difference
PF	Primary Foster (pen)
SD	Starter Dam (pen)
THS	Total Health Score
TPI	Transfer of Passive Immunity

1. Introduction

1.1 Cow-calf contact systems

For many the topic of animal welfare is an important one, and it's gaining more attention both from farmers and consumers (Meagher et al., 2019; Weary & Von Keyserlingk, 2017). The freedom to perform natural behaviour is an important welfare parameter, first described as part of the five freedoms in 1965 by Britain's Farm Animal Welfare Council (*Animal Humane Society*, 2024; Mills et al., 2010). Under natural conditions a calf would be able to nurse with the dam until between 7 to 14 months of age and would still be cared for after the dams next calf was born (Veissier et al.,1990). It is well described in literature that separation of calf and dam leads to stress and causes reactions such as vocalisation and restlessness in both calf and dam (Weary et al., 2008), additionally it can cause negative judgement bias in the calves (Daros et al., 2014). Despite this, it is common practice to separate the calf and dam shortly after parturition, and raise the calf with either bottle, bucket or automatic milkfeeders, a practice referred to in literature as artificial rearing (Sirovnik et al., 2020). Under Danish law (BEK 1743 of 30/11/2020 § 89) it is required that the dam and calf are kept together for a minimum of 12 hours after parturition. For organic herds this requirement is extended, by the industry, to a minimum of 24 hours (Okologi.dk, 2024). The term of prolonged Cow-Calf Contact (CCC) is used when the cow and calf stay together for longer than what is required by either law or industry (Sirovnik et al., 2020). The practice is diverse, and many varieties can be seen used in practice, both with the calf's own dam or with a fostercow (Johnsen et al., 2016). The practice also differs in how many hours a day, the calf has contact to the cow. This can be either full day contact, half day contact or restricted contact (Sirovnik et al., 2020). Studies have shown that consumers, both with and without prior relation to the dairy industry would prefer that the calf stay with the cow for a longer period, to have more natural conditions in the dairy production (Meagher et al., 2019), leading back to the welfare parameter of being free to perform natural behaviour. A qualitative study done by Bertelsen & Vaarst (2023) found that ethical considerations as well as the public opinion were big motivators for farmers when choosing to switch to a CCC system.

Benefits found from practicing CCC include significantly higher weight at weaning (Wagenaar & Langhout, 2007), a lower age for onset of puberty and higher fat-corrected milk yield at first lactation (Shamay et al., 2005) as well as better social behaviour that may enhance the calves coping abilities later in life (Stěhulová et al., 2008). Contrary, disadvantages from practicing

CCC include an aggravation of the acute stress response in relation to separation (Meagher et al., 2019; Stěhulová et al., 2008), a decrease in amount of saleable milk from the nursing cow (Alvåsen et al., 2023; Barth, 2020) and a bigger stagnation in weight gain following weaning, due the motherfed calves eating less dry-feed before weaning compared to bottlefed calves (Johnsen et al., 2016).

Studies have indicated that a possible other disadvantage from practicing CCC, especially fulltime contact, is an increase in morbidity in the calves. A study conducted by Roth et al. (2009) showed that motherfed calves had poorer health scores when compared to calves raised with automatic milk feeders. This finding is supported by Wenker et al. (2022) who found that calves raised with full-day contact to the dam had poorer healthscores and a tendency for higher antibiotics usage, compared with both no-contact and half-day contact calves. The health problems reported from Roth et al. (2009) was mainly diarrhoea and it is speculated that the reason for the increase in morbidity is due to elevated pathogen exposure, from being in proximity to a range of adult cows. Calves raised with full-day contact to the dam has been found to have a greater abundance of faecal bacteria, than calves raised with half-day contact or no contact to the dam (Wenker et al., 2022). The morbidity for calves in CCC systems has been found to be predominantly in calves aged 5 to 15 days (Dahl-Pedersen et al., 2024).

As listed above, some benefits and disadvantages have been found from practicing CCC in both conventional and organic herds. Despite this a lot is yet unknown, and it is difficult to say for sure if CCC is better, compared to artificial rearing, when it comes to the welfare of the animals. Illness and mortality in calves represents an important issue for the farmer, both economically and in relation to welfare. Identifying sick calves at an early stage may increase effectiveness of treatment and could limit the need for antibiotics and improve welfare (Belaid et al., 2020).

1.2 Immunisation and health in young calves

All calves are born agammaglobulinemic, meaning that they are born without immunoglobulins (Ig) (Morrill et al., 2015; Pakkanen & Aalto, 1997). This is due to the placenta of the cow being syndesmochorial. It consists of three maternal layers and three foetal layers (Nokes et al., 2001). There is a complete separation of the blood supplies of the calf and cow, and therefore no transfer of maternal immunoglobulins during gestation. Transfer of maternal immunoglobulins happens after parturition, by ingestion of an adequate amount and quality of colostrum shortly after parturition (within 24 hours). By ingesting colostrum, the calf gains maternal immunoglobulins, in particular IgG (Pakkanen & Aalto, 1997). The process of transferring the maternal immunoglobulins is referred to as transfer of passive immunity (TPI).

Assessing the level of passive immunity of the calf following TPI, can be done be measuring the levels of serum IgG (Lombard et al., 2020). Earlier, an adequate TPI was deemed as a serum IgG level of 10g/L when the calf is between 1-7 days old ((Lombard et al., 2020). New standards presented in 2020, has divided levels of serum IgG in groups of Excellent (>25g/L), Good (18-24,9 g/L), Fair (10,0-17,9 g/L) and Poor (<10,0 g/L). A failure of transfer of passive immunity (FTPI) is defined as a serum IgG level of less than 10 g/L. FTPI has been found to be associated with increased calf morbidity and neonatal mortality (Faber et al., 2005; Lora et al., 2018; Weaver et al., 2000).

The level of serum IgG can be tested in several ways, though a quick and easy way is by use of a refractometer or Brix digital refractometer. This equipment measures the concentration of total serum protein (Lombard et al., 2020; Wilm et al., 2018). The value for serum brix% for each of the categories by Lombard et al. (2020) is as follows Excellent: >9,4%, Good: 8,9-9,3%, Fair:8,1-8,8% and Poor: <8,1%.

1.3 Calf behaviour

From birth most calves are active and display investigative behaviour as well as social- and play-behaviour. It is suggested that play behaviour can an indicator of good welfare in calves (Jensen et al., 1998).Vitale et al. (1986) found that in semi-wild cattle species, the most dominant behaviour from the calves was lying down/resting. It was found during 24h observation that calves with whole-day contact to the dam spent on average 17,7 hours lying (Bertelsen & Jensen, 2023). In free-range conditions calves would spend most of the day in groups of young calves, and the dam-calf-contact mostly consist of regular visits for nursing and maternal care (Sirovnik et al., 2020). The time spent away from the cow, was always greater than the time spent close to the cow (Vitale et al., 1986). Nursing bouts are usually 10-15 minutes long and range in frequency of about 5-8 times a day for a newborn calf, and then drops to 3-5 times a day when the calf gets a bit older (P. Jensen, 2002; Vitale et al., 1986). Bertelsen & Jensen (2023) found that calves raised with whole-day contact to the dam spent on average 37 minutes a day on suckling. It has been shown that full-day-contact calves spend more time suckling than half-day-contact calves. Half-day-contact calves are also more likely to suckle cows, which are not their own dam. They are quicker to reunite with their dam when they return from milking, indicating that they are hungrier than their full day contact counterparts (Bertelsen & Jensen, 2023)

1.4 Behavioural changes in the sick animal

A sick animal will often change its usual distribution of time, spending more time inactive and less time on self-maintenance such as eating, drinking and grooming. (Mills et al., 2010). As quoted by Hart (1988) “The most commonly recognised behavioural patterns of animals at the onset of infectious febrile disease are lethargy, depression, anorexia, and reduction in grooming” Both anorexia and a reduced intake of water can stem from the animal simply not feeling hungry or thirsty, or lacking the motivation to move in search of sustenance. Calves fed ad libitum milk, will decrease their intake when sick (Borderas et al., 2009) In addition to the decrease in sustenance intake, an animal will usually stay in one spot and engage in as little movement as possible. This reduces the muscular activity and can then save energy that is needed due to the extra metabolic cost of fever. Also staying in one spot is preferable in relation to avoid heatloss. A calf laying deep in the bedding of the pen is much less vulnerable to heatloss than a calf up and moving, due to the limited exposure of body surface (Hart, 1988). Key behavioural parameters, such as physical activity, proximity to food and water as well as social behaviour, have been associated with the health status of an animal (White et al., 2023). Earlier studies have shown that sick calves can be identified from a model based on the frequency of visits to feed supply, number of steps and lying time (Belaid et al., 2020). This is reiterated in studies, such as Quimby et al. (2001) who found that using feeding behaviour, in this case frequency of visits to feedbunks, could be used to detect onset of sickness up to four days earlier than visual detection from trained farm personnel.

There is however a lack in the literature when studies that indicate increased illness in the CCC calves, such as Roth et al. (2009) and Wenker et al. (2022), usually examine and evaluate calves that are still with the dam or a fostercow and is not yet weaned. While the studies concerning behavioural indicators and predictive models, such as Quimby et al. (2001) and Belaid et al. (2020), usually work with calves that have been weaned from the dam and is being raised in feedlots.

1.5 Methods of planning a behavioural study

When planning a behavioural study, one must first ask a question, make predictions, and then choose appropriate measures of behaviour to answer the question and test the predictions (Martin

& Bateson, n.d.). The question and predictions usually require a basic knowledge about the animal in question and its surroundings. When preparing a study of animal behaviour, it is fundamental to describe and define the behaviour types which are being observed and recorded. This is done using an ethogram. An ethogram is originally considered to be a complete list of all behaviours of a species (Mills et al., 2010). However, when making an ethogram for a study, it is essential to also consider which behaviours are possible for the animal in the given situation, considering age and environment, as well as which behaviours are relevant for the study's question. It is necessary to classify the behaviour as either a behavioural state or a behavioural event. A behavioural state has a measurable duration of time and include behaviours such as resting or walking. A behavioural event has a very short duration and is ordinarily recorded as frequency of occurrence, rather than duration. Behavioural events include behaviours such as yawns, coughs, and jumps. (Mills et al., 2010). For the purpose of analysing data, it is most practical to make each category of behaviour mutually exclusive, meaning that each category of behaviour is defined precisely and with care, so that two different categories of behaviour cannot occur at once. This however may not be the case when working with behaviour events, as an animal may cough while resting, and this behavioural event does not disrupt the behavioural state of resting. When measuring a behaviour, it is necessary to choose what to measure precisely, this can either be latency, frequency, duration, or intensity. Latency refers to the time from a specified event to the occurrence of the observed behaviour, an example being the time from a gate being opened to the animal passing through. Frequency and duration are the number of occurrences of a specified behaviour and the length of time each occurrence lasts, respectively. Intensity is defined according to behaviour and can refer to for example the loudness of a call or intensity of fight between individuals.

After having defined and categorised each behaviour in an ethogram, it is time to define the observations and how they are made. Starting with specifying a method of sampling and rules of recording. The methods of sampling can be either watching one singular individual and recording all their behaviours (Focal sampling), watching several individuals at regular intervals (Scan sampling), watching for the display of a specific behaviour, and recording the individual after (Behaviour sampling) or simply recording all the behaviours the observer sees and deems relevant (Ad lib. Sampling). The rules of recording are related to time, in that it defines when to make the observations. This can be either a continuous recording or timed samplings. Continuous recording is where all behaviours are recorded, as well as duration and time of occurrence. Timed samplings can be split into two sub-categories: Instantaneous or One-Zero samplings. With instantaneous the recordings are divided into time intervals by sample points, and at each time-point the observer will record behaviours occurring at that moment. In One-zero samplings the recordings are again divided into intervals, however with this method the observer will record all behaviours that has occurred in the last interval. (Martin & Bateson, n.d.)

From all these considerations, definitions, and rules, it is possible to build a behavioural study. This thesis for example uses two different ethograms, as will later be described, which includes both behavioural states and events. One of the ethograms is made for observations meant to measure frequency and duration of the described behaviours, and the other is for a study of latency. The observations made are all live-continuous observations using focal animal sampling of the animals included.

1.6 Aims and objectives.

Considering that a lot is yet unknown about the health and welfare of calves raised in CCC systems, many farmers face new challenges in keeping their cows and calves healthy. This study has three objectives, that aids in giving farmers guidance that can help them identify the calves potentially at the onset of illness. The first is to identify an average time-budget for the calves when they are in the CCC-pens. The second objective is to identify variances in these time-budgets associated with onset of illness. The final objective is to evaluate if the sick calves are slower to seek out the dam after separation.
The necessary data was collected from behavioural observations and clinical assessments including blood samples.

Hypothesis:
A sick calf will display less active behaviour than the healthy calf. A sick calf will also spend less time seeking out food and drink. From these assumptions, measuring the amount of time the calves spent on resting, activity/play and eating can allow for early identification of calves in risk of being sick. Additionally, a sick calf will have a longer latency to reunite with the dam after separation.

2. Materials and Methods

2.1 Literary search

The databases primarily used in the literary search was Web of Science, Research Gate and Pubmed. The keywords used were variations of cow-calf contact, dam rearing, foster cow, behavioural study, cow, bovine, calf, health score, immunoglobulin, suckling, welfare, and animal behaviour. The keywords were combined with OR or AND. The languages were limited to Danish and English.
In addition, the snowballing method was used using Medline and Web of Science.

2.2 Ethical approval

The laboratory animal permit (2023-15-0201-01520) was issued on 02.10.2023. The Local ethical approval (2023-012) was issued on 04.09.2023.

2.3 Housing and management

This study was conducted in one organic herd with approx. 380 cows. The participating herd was already participating in a study conducted by Innovationscenter for økologisk Landbrug (ICOEL), working with behavioural observation. In the present thesis 21 calves were observed in the period from February to May 2024. The farm has been practicing prolonged CCC since 2019. They practice a mixture of half-day contact with the calf's own dam and full-day contact with a fostercow. For clarity the calf's own mother is hereafter always mentioned as the dam, and the fostercow will be referred to as either the fostercow or the cow.
After calving, the dam-calf pair is kept together in an individual calving pen until suckling is established, average estimated by personnel to be around 48 hours. After this they are typically moved to the starter dam (SD) pen, in which the dam-calf pair are housed along with 20-25 other dam-calf pairs (Table 1). From the SD pen the dams are moved to milking at 05.15am every morning and return around 06.30-07.00am. They are then separated from the calves around 09.45-10.00 am, and housed in the separation pen of the milking herd until the afternoon milking and are then returned to the SD pen at approximately 02.45-03.00 pm. The dam-calf pairs are housed in the SD pen until the calves reach an age of approximately 3 weeks. At which point the calf is separated from the dam and paired with a foster cow, along with 2-3 other calves in a bonding pen (BF). The foster cow and the calves are then kept together for 24-150 hours (average about 100 hours), to ensure a bond and that suckling is established, before they are

moved to a group pen (primary foster – PF) with 3-4 other foster cows and their 3-4 calves (Table 1). Dairy heifer calves are weaned from the foster cows at around 5 months of age and meat calves are weaned and sold at around 3,5 months of age.

Pen	*Type of CCC*	*Time spent apart*	*Number of cows/calves*	*Age of calves*	*Time spent in the pen*
Starter dam pen (SD)	Half day contact with own dam	5 hours (approx.)	20-25 dams with their own calf/calves	2 days – 3 weeks	3 weeks
Bonding foster (BF)	Full day contact w. foster cow	None	1-2 cows with each 3-4 calves	3 weeks	24-150 hours
Primary foster (PF)	Full day contact w. foster cow	None	3-4 cows with each 3-4 calves	3-6 weeks	2-3 weeks

Table 1: Overview of pens included in the observations

2.4 Data

In the spring of 2024, the writer of this thesis collected blood samples, clinical assessments, and behavioural observations during a 10-week sampling period at the participating farm. All collections and processing of data were performed by this writer. Before the first sampling visit, the farm was visited and information about management was gathered. Further information was later gathered through email correspondence.

The calves were supposed to be randomly chosen for the study, however due to the limited number of calves born in the period, convenience sampling was used and all calves which were between 3-7 days old on the first day of sampling were included. Each calf was included when they were 3-7 days old and followed for 4 consecutive weeks. At the first visit a blood sample was taken, and the calf was given a clinical assessment as well as observed for 1.5-2 hours. In week 2, the calves were aged 10-14 days, and they were each given clinical assessment and observed for 1.5-2 hours. This was repeated for week 3 and 4, where the calves were aged 17-21 days and 24-30 respectively.

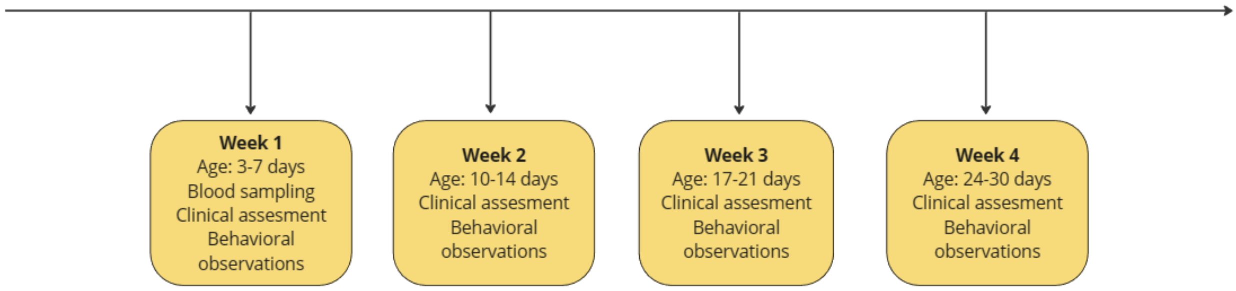

Figure 1: Description of observational weeks

2.5 Blood sampling

Blood samples were collected from vena jugularis from all 21 calves, when they were between 3 to 7 days old. Before sampling, the area was sanitized using 70% alcohol. One blood sample was taken from each calf and filled in one Serum tube (8.5 ml) with stable gel (BD vacutainer SST). All blood samples were kept at a maximum of 5 degrees ℃ by use of cooling box with a freezer block. All samples were analysed within 36 hours of collection. Each blood sample was centrifuged at 1800 G for 10 minutes on "Eickemeyer Standard Centrifuge PLC-02". The samples were then examined by use of Brix refractometer (KRUUSE Digitalt refractometer). The Brix refractometer was recalibrated before each round of testing, as per the instruction manual. Each sample were then tested using 2-3 drops of serum, applied using single-use pipette. Between each sample the refractometer was cleaned using paper towel and ionized water.

2.6 Clinical assessment

Each calf was given a clinical assessment once a week for 4 consecutive weeks, starting from age 3-7 days. The clinical assessment included hydration score, respiratory score, gastric score, umbilical score, and general attitude, as well as rectal temperature. Each of these scores could be 0-2 depending on severity of the clinical signs of that score. The assessment was done following Appendix 1, which was inspired by O'Reilly & Kirkegaard (2023). The category concerning respiratory score has been inspired by a scoring system developed by McGuirk & Peek (2014).

2.7 Behavioural study

As mentioned in section 2.3, the calves were in one of three places in the time range in which they were monitored in this study (Table 1). Most calves started in the SD pen. This was not the case for calves 8, 15, 16 and 17, all of which were started directly in the bonding foster (BF) pen, due to lameness and metritis in the dam that required treatment. Also, calves number 19 and 20 had their first clinical exam and behavioural observations while still in the calving pen, they were the correct age to be included, but were kept in the calving pen for more than the usual 2 days, to insure suckling.

The placement of the calves affected which observations were performed. The behaviour of the calves in the SD pen was recorded during live observations, using focal animal sampling during continuous observations of 1.5-2 hours duration when the calves were alone in the pen, i.e. when the cows were away in separation pen in the other barn. The ethogram is presented in table 2.

Immediately following these observations, a latency study was performed when the cows returned to the pen, as will be described in following sections. The behaviour of the calves in the BF and PF pens were recorded during live observation of 1.5-2 hours duration, following the ethogram in table 2. During these observations the foster cows were present as they were housed with the fostercow fulltime. The behaviour was recorded using the BORIS software (v. 8.24 2024-02-05) (Friard & Gamba, 2016). Two different datasets were collected from the live observations, as will be further described.

2.7.1 Dataset 1: Calf behaviour in home pen

For all the calves, independent of pen, the same ethogram (table 2) was used. The only difference being that the calves in the SD pen did not have the opportunity to suckle during the time span of the observation.

Behaviour	*Type*	*Description*
Resting	Behavioural state	The calf is lying either sternally or laterally. The legs may be extended or bent, and the head may be raised or rested on the bedding. A break of less than 5 seconds does not interrupt this behaviour. The behaviour switches from active to resting when the calf is fully laying down after standing.
Active	Behavioural state	Walking, standing stationary, looking around, exploring material within reach, using muzzle, tongue, or teeth to rub on the skin of own body. A break of less than 5 seconds does not interrupt this behaviour. The behaviour switches from resting to active when the calf is taking full support on all four legs.
Play	Behavioural event	Locomotor play (gallop, leap, jump and bucking), Social play, object play and straw play, as defined by Jensen et al. (1998). A new event was only recorded after 10 seconds.
Eating	Behavioural state	The calf's muzzle is placed in feeding bucket, over feeding bucket or next to hay rack while the calf is chewing. A break less than 5 seconds does not interrupt this behaviour.
Suckling	Behavioural state	The calf's head is positioned under the cow/dam's abdomen in the udder area, accessed either from between the front and hind leg (from the side) or from behind the cow/dam between the hind legs. A break of less than 10 seconds does not interrupt this behaviour.
Drinking	Behavioural state	The calf's muzzle is placed in the water bucket, over the water bucket or in the cows' drinking fountain. A break less than 5 seconds does not interrupt this behaviour.
Coughing	Behavioural event	Forceful expiration of breath. Either singular or multiple. A new event was only recorded after 10 seconds.
Out of view	Behavioural state	The calf is not visible to the observer in the environment.
Not observed	Behavioural state	The calf is not being observed.

Table 2: Ethogram for behavioural observations of calves in home pen

All behavioural states were mutually exclusive.

The point event of "Coughing" was excluded from the study after the first week of observations, as it was deemed too difficult to accurately assess which calf was coughing.

The observations ran for 1.5 to 2 hours and was ended either when the two hours was done or, in case of the calves being in the SD pen, when the latency study was started, see following.

2.7.2 Dataset 2: Calf behaviour when cows return – Latency study

Live-continuous observations focused on latency to suckle during the first 30 minutes after the dams return to the pen after the afternoon milking. The latency study was only performed on the calves in the SD pen and was performed when the dams returned from the milking parlour in the afternoon after a separation of approximately 4.5-5 hours.

The latency study is started, as soon as the first dam has both front legs in the SD pen when arriving back from the milking parlour. The calves are then observed, and the latency time ends for each calf when that individual has found its dam and started suckling. The latency study is ended when all observed calves has latched, or after a maximum of 30 minutes. Each calf that has not latched within the 30 minutes will be given the maximum number of seconds (1800 seconds).

Behaviour	*Type*	*Description*
Cows return	Behavioural event	Timepoint for when the dams return to the joint pen from the milking parlour. This is noted when the first dam has both front legs inside the pen.
Latency	Behavioural state	Started for all calves observed, when the first dam step inside the pen when returning from the milking parlor.
Suckling	Behavioural state	The calf's head is positioned under the dam's abdomen in the udder area, accessed either from between the front and hind leg (from the side) or from behind the dam between the hind legs.

Table 3: Ethogram for latency study of calves in home pen

2.8 Statistical analysis

All clinical data was transcribed in Microsoft Excel (Version 2405). All behavioural data was transformed using BORIS synthetic-timebudget analysis (Friard & Gamba, 2016) and extracted to Excel. The data was then analysed using Microsoft Excel and the statistical programme R studio(2020) (R version 4.3.3 (2024-02-29 ucrt)). The state events of "Out of view" and "Not observed" was excluded from the time-budget and statistical analysis.

2.8.1 Clinical data

The scores noted from each clinical assessment were evaluated individually, but also summarised to a Total Health Score (THS), which was used to define the categories of sick or healthy calves in this study. Based on the THS and the rectal temperature, the calves were divided into one of two Health groups: Healthy (Health group = 0) or Sick (Health group = 1). The calves which had either a THS of 2 or higher, or a rectal temperature of 39,7 ℃ or higher were categorised as sick. The calves with a THS lower than 2 and temperature lower than 39,7 were categorised as healthy. After calculating the THS of the calves, a mean of THS per observational week was calculated, after which first an ANOVA analysis and then a Tukey HSD (Honest Significance Difference) analysis was performed to compare the means of THS in the observational weeks. To compare the effect of the immunisation of the calves on their health status in the observations, a T-test- was applied to the calves categorised as Healthy or Sick, comparing the means of Serumbrix% in the two Health groups.

2.8.2 Behavioural data

Due to the observations being varying lengths (between 1.5 to 2 hours), it was decided to calculate and use the proportion of time spent on the individual behaviours in the statistical analysis. The first objective was as mentioned to identify an average time-budget for the healthy calf, meaning to calculate a mean of time the calves spent on each observed behaviour. This was done by calculating the mean proportion of time the calves in the Healthy group spent on each of the observed behaviours. It was decided to add a behavioural group consisting of the summed proportions of "Active", "Drinking", "Eating" and "Suckling" in one group called "Total active". From here when referring to a calf being active, it is considered to be in the group of Total active, meaning performing any behavioural state other than resting.

A general linear regression model (GLM) was made using the Total active proportion of time as outcome and with both the Health group and age measured in days as predictor variables. A similar model was made but with Total resting proportion of time as the outcome.

Play behaviour was recorded as a point event, meaning it wasn't measured in duration of time as "active" or "resting", but by how many occurrences of "play" is performed during the observations. From these observations a mean of occurrences of play per observation were made for both the Health groups. Additionally, a Poisson regression model was applied since the response variable, number of occurrences of play, is a count of events occurring in a fixed interval of time. This model was made to predict the outcome (number of occurrences of play) from predictor variables being Health group and age in days.

3. Results

3.1 Clinical observations

A total of 21 calves were included in the study. The calves were all, except 4, included in four consecutive weeks of clinical assessment and behavioural observations. Calves number 12 and 17 died or was euthanized after week 2 due to illness and calves number 15 and 16 were moved out of the PF pen, and into an older group after week 3, thus exiting the pens included in the study. This results in 21 calves being included in week one and two, 19 calves in week three and 17 calves in week four (Table 4).

Observational week	*One*	*Two*	*Three*	*Four*
Age of calves	3-7 days	10-14 days	17-21 days	24-30 days
Number of calves	21	21	19	17

Table 4: Overview of calf number and calf age for each observational week

In total 78 paired clinical assessment and behavioural observations were made. Of these, 45 observations were categorised as healthy and 33 were categorised as sick.
38 latency times were measured, of these 21 was from healthy calves and 17 from sick calves.

In their first week of assessment, it was found that 46% (n=10) had an umbilical score of 1, consistent with either swelling or pain around the umbilical area. In addition to this, 14% (n=3) had an umbilical score of 2, consistent with both swelling and pain (Table 6).

In week one 28,5% (n=6) had a gastric score of 1, consistent with loose faeces and soiling of the hindlegs. In week two, with the calves aged 10-14 days, this increased, to 47,6% (n=10) of the calves having a gastric score of 1, and 28,5% (n=6) having a gastric score of 2, consistent with watery or bloody faeces. In week two as well, 42,8% (n=9) of the calves had a hydration score of 1, consistent with a skinfold remaining 1-3 seconds, indicating slight dehydration. The umbilical scores of the calves are similar albeit a bit decreased from week 1, with 46% (n=10) having an umbilical score of 1 and 9,5% (n=2) having an umbilical score of 2. In week three there were a decrease in observed gastric clinical signs, with 10,5% (n=2) having a gastric score of 1 and 10,5% getting a gastric score of 2. There is also a slight decrease in calves with clinical signs of umbilical disease, with 11 calves (57,9%) having a score of 1, and none with a score of 2. In week four only 2 calves (11%) had any gastric clinical signs, both scoring 1 in gastric. Four calves had an umbilical score of 1. No other clinical signs were observed in week four (Table 6).

Category of immunisation	*Excellent*	*Good*	*Fair*	*Poor*
(Lombard et al., 2020)	*>9,4%*	*8,9-9,4%*	*8,1-8,8%*	*<8,1%*
Count (n=21)	6	3	8	4

Table 5: Distribution of calves between the four categories of Lombard et al.

There was no statistically significant difference between means of serumbrix% in the two Health group, with P-value of 0.29. It was found that the calves who died, had very different serumbrix%. Both calf number 12 and number 17 were euthanised as a result of being critically ill with respiratory clinical signs (calf 17) and/or gastric clinical signs (both calf number 12 and 17). Calf number 12 who had mainly a very watery diarrhoea had serumbrix of 7,8%, which indicates failure of transfer of passive immunity (FTPI) from the colostrum. Calf number 17 had both respiratory and gastric clinical signs and had a serumbrix of 9%.

	Observation 1 (Age: 3-7 days)							Observation 2 (Age: 10-14 days)							Observation 3 (Age: 17-21 days)							Observation 4 (Age: 24-30 days)						
Calf ID	Gen. con.	Hydr.	Umb.	Gastric	Resp.	Limbs	Temp.	Gen. con.	Hydr.	Umb.	Gastric	Resp.	Limbs	Temp.	Gen. con.	Hydr.	Umb.	Gastric	Resp.	Limbs	Temp.	Gen. con.	Hydr.	Umb.	Gastric	Resp.	Limbs	Temp.
1	0	1	1	1	0	0	39,4	0	0	1	1	0	0	38,5	0	1	1	0	0	0	38,2	0	0	0	0	0	0	38,7
2	0	0	0	0	0	0	39,2	0	0	1	1	0	0	40	0	0	0	0	0	0	38,4	0	0	0	0	0	0	38,3
3	0	0	0	0	0	0	39,3	0	0	0	1	0	0	39	0	0	0	0	0	0	39,3	0	0	0	0	0	0	37,8
4	0	0	0	1	0	0	39,7	0	1	0	1	0	0	39	0	1	0	1	0	0	39,4	0	0	0	0	0	0	38,3
5	0	0	0	0	0	0	38	0	0	1	1	0	0	38,6	0	0	1	0	1	0	38,6	0	0	0	0	0	0	38,8
6	0	0	0	0	0	0	39,1	0	0	0	2	0	0	38,9	0	0	0	0	0	0	39,3	0	0	0	0	0	0	38,6
7	0	1	1	0	0	0	38,9	0	1	1	1	0	0	38,6	0	0	1	0	0	0	39,3	0	0	1	0	0	0	38,7
8	0	0	1	1	0	0	38,2	1	0	0	2	0	0	39,7	0	0	0	0	0	0	39,1	0	0	0	0	0	0	40,4
9	0	1	2	1	0	0	39,8	0	1	2	1	0	0	39,7	0	0	1	0	0	0	39	0	0	1	0	0	0	38,8
10	0	0	0	1	0	0	39,1	1	1	0	0	1	0	39,2	0	0	1	0	0	0	39,1	0	0	1	0	0	0	38,6
11	0	0	1	0	0	0	39	0	0	0	2	0	0	39	0	0	0	0	0	0	38,5	0	0	0	0	0	0	38,9
12	0	0	1	0	0	0	39,2	0	1	0	1	0	0	37,6														
13	0	0	1	0	0	0	39,5	0	1	1	2	0	0	39,1	0	0	1	0	0	0	39,1	0	0	0	0	0	0	39,3
14	0	0	1	1	0	0	39	0	0	0	1	0	0	38,5	0	0	1	0	0	0	39,3	0	0	0	1	0	0	38,9
15	0	0	1	0	0	0	39	0	0	1	1	0	0	39,2	0	0	0	2	0	0	39,2							
16	0	0	2	0	0	0	38,8	0	0	1	0	0	0	39,6	0	0	1	2	0	0	39							
17	1	1	1	0	0	1	38,3	1	1	1	2	2	1	39,2														
18	0	0	0	0	0	0	39,7	0	0	1	0	0	0	39,3	0	0	1	0	0	0	39,3	0	0	0	0	0	0	39,1
19	0	0	2	0	0	0	39,4	0	1	1	0	0	0	39,2	0	0	1	0	0	0	39,3	0	0	0	1	0	0	39,7
20	0	0	0	0	0	0	39,1	0	1	0	0	0	0	39,2	0	1	0	1	0	0	38,1	0	0	0	0	0	0	38,4
21	0	0	1	0	0	0	39,5	0	0	2	2	0	0	38,6	0	0	1	0	0	0	39,3	0	0	1	0	0	0	38,9
Score 0	20	18	8	15	21	20		18	12	9	5	19	20		19	16	8	15	18	19		17	17	13	15	17	17	
Score 1	1	3	10	6	0	1		3	9	10	10	1	1		0	3	11	2	1	0		0	0	4	2	0	0	
Score 2	0	0	3	0	0	0		0	0	2	6	1	0		0	0	0	2	0	0		0	0	0	0	0	0	
Mean	0,05	0,19	0,76	0,29	0,00	0,05	39,10	0,14	0,43	0,67	1,05	0,14	0,05	39,03	0,00	0,16	0,58	0,32	0,05	0,00	38,99	0,00	0,00	0,24	0,12	0,00	0,00	38,84

Table 6: Clinical scores from the calves across the observational weeks.

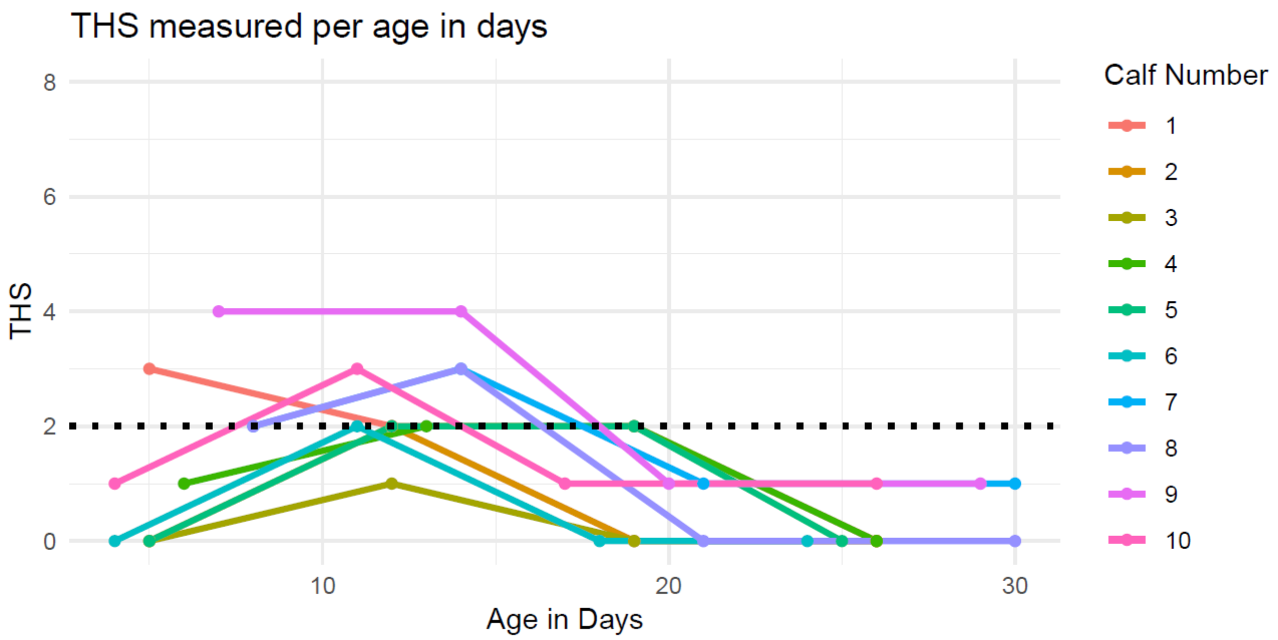

Figure 2: Total health score per age in days, calves number 1-10. Dotted line indicates THS=2.

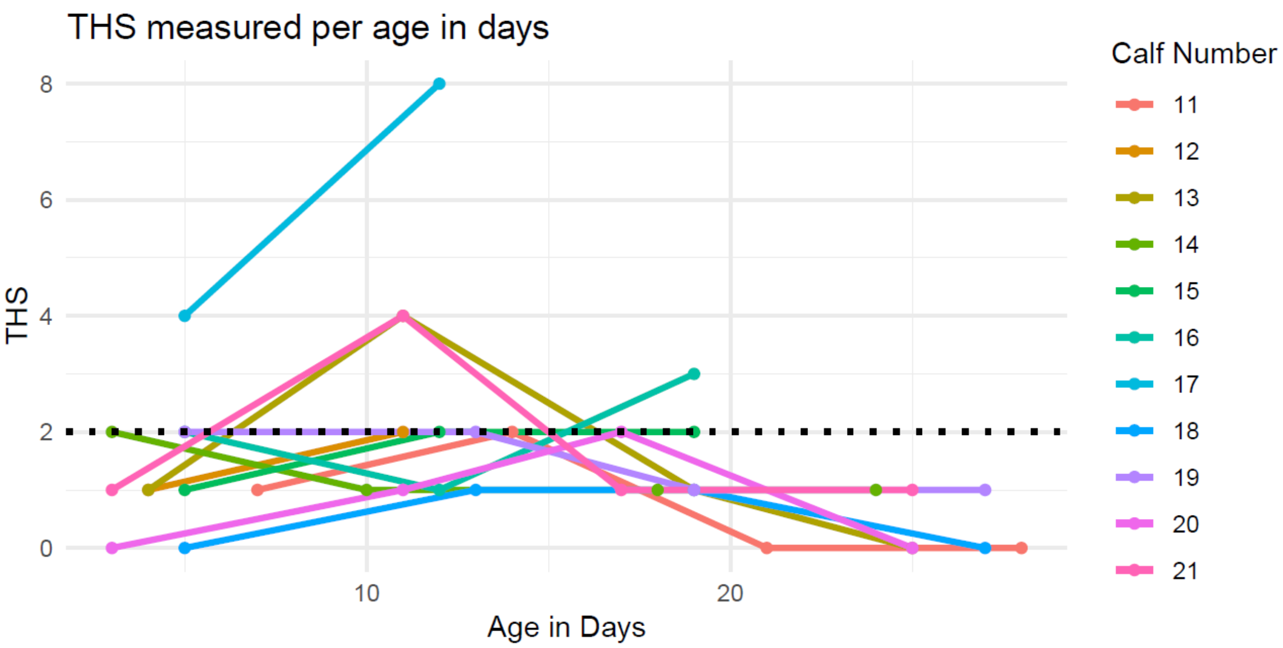

Figure 3: Total healthscore per age in days, calves number 11-21. Dotted line indicates THS=2.

THS is a sum of the scores given in the clinical assessment (Table 6) and is used in the definition of Health groups in this study. A THS of more than 2, indicates that the calf is experiencing clinical signs of disease. Each line in figure 2 and 3, represents a calf and its THS on each assessment. The dotted line indicates THS=2, meaning that all points above this indicates a calf categorised as sick.

The means of THS was 1,33, 2,48, 1,11 and 0,35 in observational week 1, 2, 3, and 4 respectively. An ANOVA analysis found statistically significant variance between the THS in the observational weeks (p value <0,001). Following this a Tukey HSD test found that the mean of THS was significantly higher in week 2 than week 1, week 3 and week 4, with p-values of 0,01, 0,002 and <0,001 respectively (Table 7). This means that the age in which the calves had the highest total health scores was between age 10-14 days.

Pairwise comparisons	*Difference in means*	*Lower bound of 95% confidence interval*	*Upper bound of 95% confidence interval*	*P adjusted*
2-1	1.14	0.20	2.08	0.011
3-1	-0.22	-1.19	0.73	0.925
4-1	-0.98	-1.97	0.01	0.054
3-2	-1.37	-2.33	-0.41	0.002
4-2	-2.12	-3.11	-1.12	<0.001
4-3	-0.75	-1.77	0.27	0.219

Table 7: Tukey Multiple Comparisons of means, 95% family-wise confidence level. Pair wise comparison between observational weeks.

3.2 Dataset 1: Calf behaviour in home pen

By calculating the mean proportion of time, the healthy calves spent on each behavioural category, an estimated timebudget was made (Table 8).

Behavioural category	*Active*	*Drinking*	*Eating*	*Suckling*	***Total active***	***Total Resting***
Healthy (n=45)	*23,7%*	*0,6%*	*0,2%*	*0,5%*	**27%**	**72,4%**
-With cow (n=24)	*21,9%*	*0,7%*	*0,1%*	*0,5%*	*22,5%*	*76,1%*
-Without cow (n=21)	*22%*	*0,6%*	*2,1%*	*-*	*23,7%*	*76,1%*

Table 8: Proportions of time spent on behavioural categories - Healthy calves

The healthy calves were found to spend approximately 27% of the observed time being active and 72,4% of the observed time resting.

By establishing a time-budget similar to the one just described, but for the calves categorised as sick. The sick calves were found to spent approximately 18% of the observed time being active and 81% of the observed time resting.

Behavioural category	*Active*	*Drinking*	*Eating*	*Suckling*	***Total active***	***Total Resting***
Sick (n=33)	*17,2%*	*0,7%*	*0,04%*	*0,06%*	**18%**	**81%**
-With cow (n=14)	*18,1%*	*0,8%*	*0,9%*	*0,6%*	*19,7%*	*79,8%*
-Without cow (n=19)	*25,5%*	*0,6%*	*0,1%*	-	*27,4%*	*71,5%*

Table 9: Proportions of time spent on behavioural categories - Sick calves

From a linear regression model, it was found that the Health group has a significant effect on the proportion of time spent active, with Health group 1 (sick) being associated with a decrease in Total active proportion of time (p=0,031). It was however found that the age in days did not have any statistically significant effect on the proportion of time spent active (p=0,88)(Table 10). The same was true when a similar model was built for the proportion of time spent resting. Here the Health group had a statistically significant effect on the time spent resting with a p-value of 0,05 while the age still didn't have a significant effect (Table 11).

	Estimate	*Std. error*	*Z value*	*P value*
Intercept (Healthy)	0,27	0,04	5.9	<0,001
Sick	-0,08	0,04	-2.15	0,0347
Age in days	-0,001	0,002	-1,41	0,888

Table 10: Results from general linear model for prediction Total active proportion of time

	Estimate	*Std. error*	*Z value*	*P value*
Intercept (Healthy)	0,726	0,046	15.613	<0,001
Sick	0,075	0,038	1.983	0,050
Age in days	-0,0001	0,002	-0,047	0,962

Table 11: Results from general linear model for prediction Total resting proportion of time

It was found that a healthy calf performed play behaviour, as defined in the ethogram (Table 2), on average 1,2 times per observation. Comparatively a sick calf performed play behaviour less than 0,5 times per observation. The Poisson regression model showed that being sick, statistically significantly decreased the log count of play occurrence, with a p-value <0,001. Additionally, the age in days also affected the number of play occurrences, with each additional day in age was found to be associated with a decrease in in log count of play by 0,08 units (Table 12).

	Estimate	*Std. error*	*Z value*	*P value*
Intercept (Healthy)	1,33	0,21	6,23	<0,001
Sick	-1,12	0,28	-3,96	<0,001
Age in days	-0,08	0,02	-5,20	<0,001

Table 12: Results from Poisson regression model for prediction of number of play occurrence

3.3 Dataset 2: Calf behaviour when cows return – Latency study

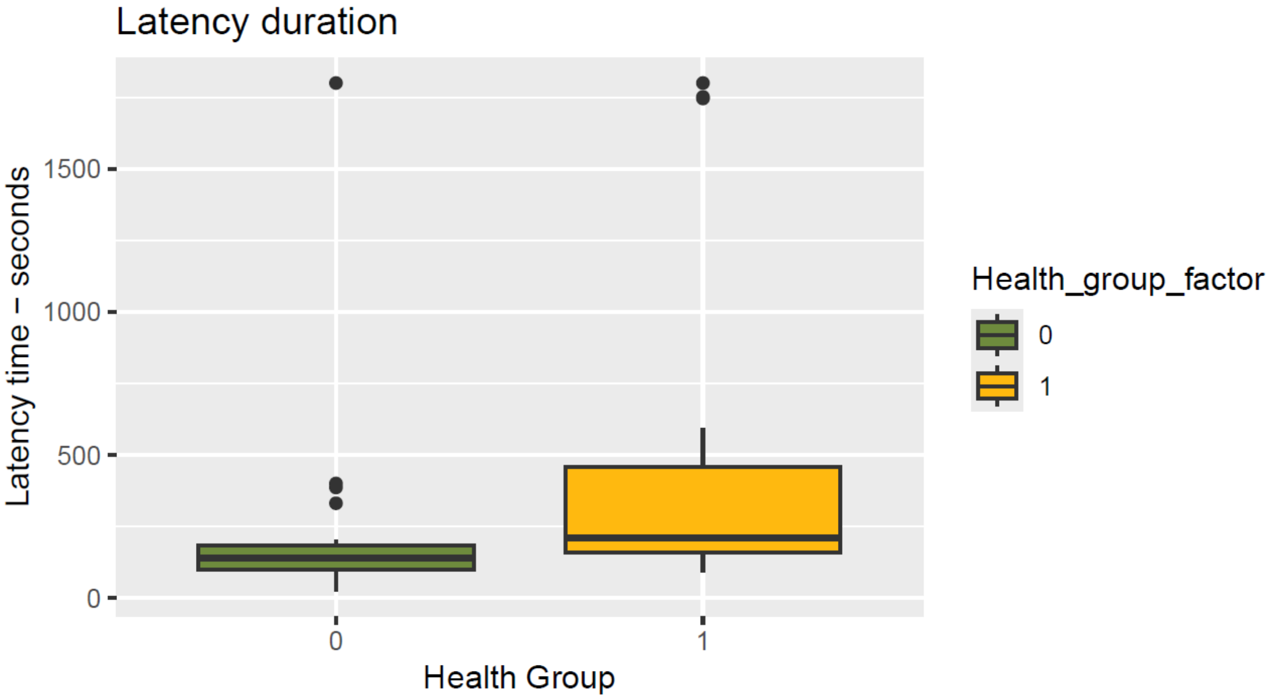

Figure 4: Boxplot visualising the latency time in seconds for both Health groups

In total 38 latency times were measured. (17 from sick calves, 21 from healthy calves).
The mean latency time for a healthy calf was calculated to be 234 seconds, in comparison to the mean latency time for a sick calf being 501 seconds. A general linear model was applied to the latency data, with latency time in seconds as outcome, using Health group as well as age in days

as predictor variables. There was no statistically significant effect on the latency time from neither the health group (p=0,118) nor the age (p=0,96).

4. Discussion

The behavioural observations and clinical assessments in this thesis, were carried out in an attempt to determine behavioural indicators of the health status of calves raised in CCC systems. These were to be presented as tools and pointers for the farmers to use when assessing their animals. Earlier studies and literature have already described in older calves that the key behavioural parameters indicative of health status include activity, lying time, frequency of visits to feed/ proximity to food and water, and social behaviour. (Belaid et al., 2020; Quimby et al., 2001; White et al., 2023).
As discussed by Lora et al. (2018) and Lombard et al. (2020), the immunisation of the calves by TPI from ingesting colostrum shortly after parturition, has been shown to affect the long-term health of the calves. In this study however the immunisation levels of the calves showed no predictive effect of the health status of the calves during the observational weeks. In addition to this, the two calves who died due to illness had two very different levels of immunisation, with one being in the "good" category and one being in the "poor" category. Calf number 12 who had a serumbrix% of 7,8% had a low enough level of serum IgG to be deemed having had FTPI. This does not necessarily imply that the immunisation has no effect on the health status at all, only that during this study it was not big enough to be significant.

4.1 Eating, drinking and suckling

After the behavioural observations, a decision was made to include the proportions of time spent on eating, drinking and suckling under the category of Total Active. This was done for two reasons: one being due to the suckling behaviour only being possible during the time they were observed, for the calves in the BF and PF pens. It wasn't possible for the calves in the SD pen during observations, as the dams were in the separation pen during observations. The other being the range in age of 3 to 30 days. It was witnessed and deemed from the writer that there was a difference in how the calves spend their active time, depending on their age. An example of this being the calves only really starting to eat and drink from the buckets in weeks 2-3. It was decided that by pooling all "non-resting" behaviours in a "Total active" category, it would be possible to assess the time the calves spent being active or resting, while still being comparable across pens and ages. From the data it is found that both groups (sick or healthy) spent less than

1% of the time observed on either eating, drinking or suckling (table 6 and table 7). With sick calves spending as little as 0,04% of the observed time on eating. From earlier studies, such as Quimby et al. and White et al., it has been shown that especially feeding behaviour is a good indicator for the health of calves. It is however uncertain if any significant results could have been made from the observations in this thesis due to the limited duration. From Belaid et al. it is shown that a healthy calf (age 30 days or older) will have approximately 10 ± 1 visits to feedbunks a day, spending 185 ± 32 minutes eating a day. This is not necessarily comparable to the calves observed in this thesis, due to them being a maximum of 30 days old. It can be assumed that the calves in this study, being younger, will spend less time eating since their gastrointestinal system is still developing and they are yet to be weaned during the time of observations. It can be assumed, at least, that they will not spend more time than the 185 minutes a day eating. Similarly, from literature it is known that calves housed with the cow suckle 5-8 times a day when young, with a duration of suckling being 10-15 minutes (P. Jensen, 2002; Vitale et al., 1986). This amounts to a maximum of 120 minutes of suckling spread out on the day. And it is not necessarily evenly spread, Vitale et al. describes peaks in suckling bouts in mornings and afternoons. It is therefore very possible to simply not have any suckling or eating behaviours during two hours of observation, without it being an indication of poor health in the calf.

4.2 Activity and resting times

It was found that there is a statistically significant difference in time spent active or resting between the groups of sick or healthy animals. In general, the healthy calves were shown to spent around 72% of the observed time resting, whereas the sick calves would spend around 81%. This is a similar, albeit not as drastic, difference as the one described by Belaid et al. (2020), who found that the sick calves will have a reduction in steps of up to 17% when sick, compared to the healthy calf. The reduction in activity stems from a need to limit energy consumption to be able to devote as much energy as possible to immune defence mechanisms (Hart, 1988). With the play behaviour it was shown that the healthy calves played significantly more than the sick calves. Additionally, it seemed that the older the calves became, they would play less. However, a reason for this could be the actual build of the pens in which they are housed. As described earlier, the calves were housed in one of three pens during the study period, the SD, BF or PF pens. The SD pen is significantly larger than the fostercow pens (BF, PF), since it houses up to 25 pairs of dam and calf, whereas the fostercow pens house 2-4 cows with each 3-4 calves. The observations of calves in the SD were made when the dams were away in a separation pen, leaving the calves with a lot more room per calf, than what is possible for the calves in the BF and PF pens. This could affect how much play is observed since the extra room surely allows more running and playing. If such a finding should be reliable and significant, it would have to be repeated in a study where all ages of the observed calves have equal amounts of space.

4.3 Latency to suckle

One of the aspects in the hypothesis of this study was that a sick calf will be slower in reuniting with the cow after separation, when compared to a healthy calf. This assumption stems from both the literature citing less activity in the sick animal (Belaid et al., 2020; Hart, 1988) and the findings about calves having less visits to available feed when they are sick (Quimby et al., 2001). The findings from the latency study in this thesis was that sick calves used in average twice as long to seek out the cow than the healthy calves did (501 seconds and 234 seconds, respectively). This however was not found to be statistically significant, as the Health group did not prove to be a significant predictor variable for latency time. These results could be due to the small sample size of the study. Only 38 latency times were measured, with 17 sick and 21 healthy calves being included.

4.4 Practical uses and implementation

Due to the grouping of all non-resting behaviours in a common group of Total active, no conclusions were made on eating, suckling or drinking behaviour. This means that the objective of establishing a timebudget for calves was not met. The only true result of distribution of time was how much time the calves spent being active or resting. As stated above the healthy calves spent approximately 8% less time resting than the sick animals. However, when put into context, this difference can still be hard to put to practical use for the farmer. In general, the healthy calves were shown to spent around 72,5% of their time resting, whereas the sick calves would spend around 81%. This translates to, when observing them for 2 hours, the sick calves spending around 10 minutes longer resting, than the healthy calves (96 minutes and 86,4 minutes, respectively). When the personnel at the participating farm were asked, they estimated they used approximately 5-10 minutes twice a day (morning and evening) to check on the calves by standing outside the pen and monitoring them. This was in addition to quickly looking over them whenever they were actively working in the stables. Additionally, they would use 10-15 minutes a day physically in the box to evaluate the health of the calves. Being generous this time still amounts to less than an hour a day spent looking at the calves. In this time, they would have to be able to discriminate between a calf spending 16 minutes or 10 minutes being active, and that is without taking into consideration the standard deviation of ± 9 minutes for the healthy calves and ± 10 minutes for the sick. Meaning that, based on an hours observational period in this study, a healthy calf will spend 16 minutes active ± 9 minutes, and a sick calf will spend 10 minutes active ± 10 minutes. The time estimate found in this study is thus not necessarily useful in practice directly. However, as mentioned by Belaid et al. (2020) the occurrence of sickness can be predicted in advance, using models based on resting time, eating time and steps taken. This is partially reiterated in the present thesis, where it was shown there is a statistically significant difference in resting and active times depending on the health of the calf. It is possible that an automated system could be used to identify calves at risk of becoming sick and apply preventive treatment. This could be done through developing ear-tags or other sensors that can detect the calves' activity hourly. These tags or sensors should be programmed to estimate when the calf is expressing behaviours indicating onset of sickness. This could be based on a timebudget, similar to but preferably more detailed than what is being presented here. To be able to make a timebudget including eating, drinking and suckling, it would be necessary to include more animals, differentiate in age when calculating the budget and to make the observations over 24-hour duration to include all times of day. From this an estimate of how the calves spend their average 24 hours, can be used to identify calves that are deviating from this, for example, by spending less time eating/suckling and more time resting. The models can be adjusted on anindividual level, so that each calf is compared to its own timebudget from previous days.

Overall pointers that the farmer may be able to use in practice, is that the healthy calves will be more likely to display play behaviour as well as active behaviour in general. This means that it may not be directly possible to identify sick calves solely on their behaviour, but there is potential to use the findings to identify calves who are not sick.

4.5 Limitations

The main limitation of the data and results found from this study is that all behavioural observations were of a maximum of 120 minutes duration. The results from this provides a timebudget over a two-hour period and is not necessarily reflective of the "true" timebudget of how each calf would spend 24 hours. Additionally, the observations were not carried out at a certain time of day but was planned during each visit depending on the number of calves and the placement of them in the pens. The time interval was however usually between 10am and 3 pm, meaning that the observations were always during the daytime where the workers on the farm were active in and around the pens, which could lead to disturbance of the calves and affect their behaviour. Beside the workers, a confounding factor to the observations could be the disturbance effect of an observer in the farm and close to the pens for hours at a time. However, this factor is equal to all individuals observed so should be equal in disturbance.

For the statistical analysis, a decision was made to view each observation as an individual, meaning that each calf was included more than once. This was done due to the small number of individuals included, and also as a way to include the four individuals who did not participate for a full four weeks. This results in a falsely increased n-value when analysing the data. If a follow up study was made, or a similar one, it would be advantageous to either include a bigger group of individuals, and calculate the activity, play and resting for each observational week.

5. Conclusion

In conclusion as an answer to the hypothesis made in the beginning of the thesis, it could be possible to identify sick calves based on the amount of time they spent resting or active. This identification can be difficult to do directly in the farm due to the small though significant difference in time-budget. Also, the healthy calf will display more play behaviour, giving the farmers a tool to indicate that the calf is probably not sick. It was not possible to indicate that the sick calves had a longer latency to reunite with the dam after separation.

6. Perspectives

This study shows that behavioural observations could be a useful tool when assessing the health of calves raised in CCC systems. This, however, should not be used alone as a primary indicator of health, as the differences in behaviour from sick to healthy calves is small enough that it can be confusing to implement directly. However, it can be used as pointers, with the indication that the active and playful calves at least is less likely to be experiencing sickness. In addition to this, especially with small herds, it can be useful to know that when the calves increase resting time it could be a sign of morbidity.

The knowledge about the behaviour of calves in CCC systems is limited and it would be useful to carry out further studies to investigate the true time-budget of the calves. Knowing the true time-budget of the calves could be beneficial to calves housed in other systems as well, as the knowledge may lead to development of equipment that can accurately determine the activity of the calves and indicate whenever they deviate from a “healthy” time-budget.

Studies like the one carried out by Quimby et al. (2001) where they used trackers to indicate the location of the calves in their homepen, could be useful in the study of calves in CCC systems. This study used eartags with individual radiofrequences, and every 5.25 seconds the animal was recorded as either absent or present near the feedbunk. A similar technique could be used, with the calves being recorded as absent or present in calfcreeps, near waterbuckets or feedbunks while in their home-pens.

As present, the implementation of behavioural observation as a tool to monitor health in the calves is not yet sufficient on its own, and physical assessment of the health of the calves is still necessary.

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8. Appendix

8.1 Appendix 1

Category	Criteria
General condition - Based on Wisconsin-Madison Calf Health Scoring Criteria.	0: Interested in surroundings. Normal posture of the head and ears. Reacts when approached and handled. Displays good appetite. 1: Slightly depressed. Less interested in surroundings, less reactive when approached and handled. Unilateral eardrop. 2: Markedly depressed, lying down. Sunken eyes, bilaterally drooping ears, inappetence, dull fur. Possible comatose.
Hydration	0: Skinfold stands max. 1 second 1: Skinfold stands for 1-3 seconds 2: Skinfold stands for >3 seconds
Umbilical score	0: No swelling or signs of pain 1: Lightly swollen or dolent 2: Swollen and dolent
Gastric score - Based on Wisconsin-Madison Calf Health Scoring Criteria.	0: Normal faeces, no gastrointestinal symptoms 1: Mild gastrointestinal symptoms; loose faeces and soiling of the hindlegs

	2: Severe gastrointestinal symptoms; watery or bloody faeces. (treatment required)
Respiratory score: - Based on Wisconsin-Madison Calf Health Scoring Criteria.	0: Normal, no respiratory symptoms. 1: Mild respiratory symptoms; small amount of nasal discharge (serous, seromucusal), slight coughing (sporadic) 2: Severe respiratory symptoms; Forced breathing, mucopurulent/purulent, severe and/or continuous coughing. Ocular discharge. (treatment required).
Palpation of limbs (carpal and fetlock joints)	0: Normal, no swellings or warmth around joints. 1: Slightly swollen or warm over carpal or fetlock joint 2: Swollen and warm over carpal or fetlock joint.