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Effects of gradual adaptation to separation for calves on growth, feed intake and rumination in cow-calf contact system

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Acknowledgments

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Ås, 15. May 2022

Rannveig Øverland

Sammendrag

Interessen for dyrevelferden øker blant forbrukere, interessen for ku-kalv kontakt (CCC) systemer øker også. Dette er systemer hvor ku og kalv går sammen over lengre perioder i melkeku produksjoner. I melkeku produksjoner er det normalt å separere kalven fra kua få timer etter kalvingen. Produsenter som praktiserer CCC, opplever lavere melkemengde, men ser en høy tilvekst på kalvene. I denne studien ble to strategier for tilvenning til seperasjon av ku og kalv i et ku-drevet system utforsket. Begge strategiene har fire faser med ulike intervaller: 24 t tilgang (fase 1), 12 t (fase 2), 6 t (fase 3) og 0 t (fase 4) ved 8 ukers alder, men med kontakt gjennom et gjerde og totalt avvent ved 9 ukers alder. Den lange tilvenningen til seperasjon starter ved 4 ukers alder og den korte starter ved 6.5 ukes alder. Tilvenningen foregår i et spesialdesigna område som er delt inn i tre mindre områder: ku-område, kalvegjømme og møteareal. I kalvegjømmet har kalvene tilgang til kraftfôr, vann og grovfôr (høy og silo), samt melk fra automat etter at fase 2 har begynt.

Kalvene ble veid to ganger i uka etter at de ble flyttet til det spesialdesigna området. Måling av grovfôrinntak ble gjort to ganger i uka over et 24 t intervall, mens inntaket av kraftfôr og melk fra melkeautomat ble målt hver gang kalven besøkte automaten. Drøvtygging ble målt ved bruk av et Nedap halsbånd som ble plassert på kalven i forbindelse med avhorning.

I studien var det ingen signifikant mellom tilvenningsstrategiene, selv om det kan være et potensial for forskjell. Den daglige tilveksten var på 1.2 kg/d, som er høyrer en mange nåværende anbefalinger, og klavene endte på gjennomsnittlig 100 kg ved 9 ukers alder. Inntaket av grovfôr, kraftfôr og vann, samt drøvtyggings frekvensen var ikke signifikant forskjellig mellom strategiene. Ad libitum tilgang på melk påvirket opptaket av fast fôr negativt, opptaket var lavere enn kalver fôrt restriktivt.

Abstract

As animal welfare concerns are increasing, so is the interest in cow-calf contact (CCC). In CCC, the cow and calf go together for an extended period in dairy production. Compared to normal practice were the calf are separated from the cow within a few hours after birth. Producers practicing CCC have seen lower milk yields but also higher calf growth. In this study, two separation strategies for adaptation to the separation of cow and calf were explored in a cow-driven system. Both strategies had four phases at different intervals: 24 hours of accessibility (phase 1), 12 hours (phase 2), 6 hours (phase 3), and 0 hours (phase 4) at the age of 8 weeks, but fence line contact, at the age of 9 weeks they were totally weaned. The long adaptation started at the age of 4 weeks and comprised of 28 days and the short starts at the age of 6.5 weeks and comprised of 10 days. The adaptation happened in a specially designed area that was divided into three different areas: cow area, calf creep, and meeting area. In the calf creep the calves had access to concentrate, water, and roughage, and after phase 2 started also a milk feeder.

The calves were weighed two times a week after the move into the special designed area. Roughage intake were measured two times a week over a 24 h interval, while the intake of concentrate and milk form the feeder were measured each time the calves visited the feeder. Rumination was measured by a Nedap neck collar device that were placed on the calf neck as they were dehorned.

In this study, there was no significant difference between the adaptation strategies, even though there is a potential. The daily growth was 1.2 kg/d which is higher than current recommendations and the calves weighed on average 100 kg at 9 weeks of age. Intake of roughage, concentrate and water, as well as rumination were not significantly different between the strategies. Ad libitum access to milk did influence the intake of solid feeds, which were lower than for calves fed restricted.

Contents

1. Introduction

As animal welfare concerns are growing worldwide, and consumers place increasing demands on products they consume, the interest in cow-calf contact (CCC) systems increases (Ferneborg et al., 2020; Johnsen et al., 2021c). Animal productions are feeling pressure from consumers. In dairy production, it is normal to separate the cow and calf within a few hours after birth, contrary to beef cattle that are separated around the age of 6 months (Jensen, 2017). This has started to get the attention of the consumers (Busch et al., 2019; Sirovnik et al., 2020). Systems where cows and calves stay in contact for an extended period, are receiving increased interest from consumers and producers (Agenäs, 2020; Busch et al., 2019). A concern from the producers is the decrease in saleable milk yield due to the calf feeding from the dam. Producers with CCC systems have experienced a decrease in milk yield, but they have seen a higher calf growth (Johanssen & Sørheim, 2021). Meagher et al. (2019) found that multiple studies saw an increase in growth in calves that suckled the dam. CCC systems are systems that allow the cow and calf to have contact for different time periods (Johanssen, 2022; Johnsen et al., 2021c; Kiserud, 2019). These systems are allowing different behaviors such as suckling, licking, playing, and sniffing (Sirovnik et al., 2020).

This master thesis aims to investigate if the separation strategy influences calf performance. Hypotheses used were under the categories: growth, feed intake and rumination. The calves that have a long adaptation to separation will have a steadier growth, higher intake of concentrate, higher milk and water intake and higher rumination. Short adaptation will give a lower roughage intake.

2. Theory

2.1. Growth

Growth is a complex interaction between many different factors. The main factors influencing the growth are dietary, environmental, and genetic factors (Coverdale et al., 2004; Lundquist & Phillips, 1943; McDonald et al., 2011). Growth for all animals follows exponential functions, a sigmoid curve (Figure 2.1), where the daily weight gain increases until a maximum is reached (Sjaastad et al., 2016). Feed scarcity can cause the growth to slow down or cause the animal to lose weight, and feed abundance will allow more rapid growth (McDonald et al., 2011). Environmental factors, in which animals are reared, such as light, wind, temperature, and humidity as well as herd dominance can have a significant influence on growth rate (Alemneh & Getabalew, 2019).

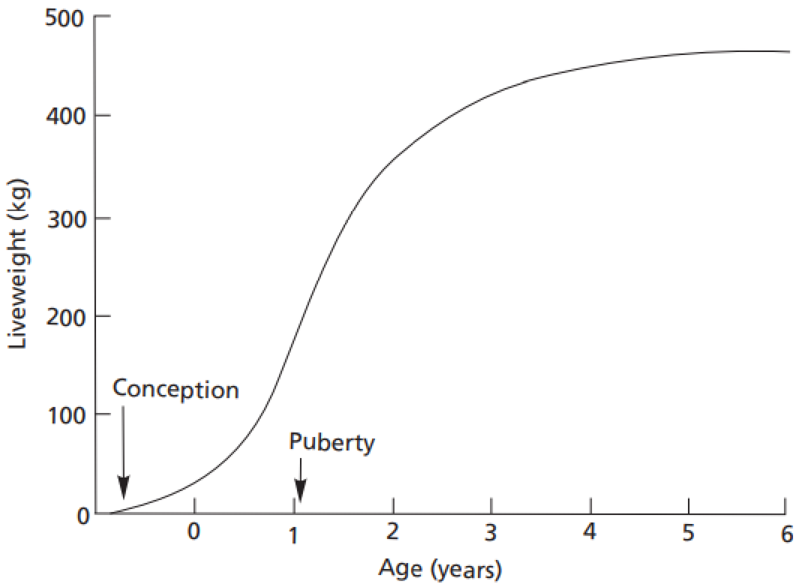

Figure 2.1: The typical sigmoid growth curve of a dairy cow (McDonald et al., 2011)

Groupe housing of calves is associated with higher body weight compared to individually housing, likely due to higher dry matter intake, and earlier sampling of solid feed (Costa et al., 2016). Calves in CCC are found to have a higher growth per day (1.3 kg/day and 1.2 kg/day) (Grøndahl et al., 2007; Johnsen et al., 2021a) From birth to weaning the calf should double its weight, which requires a growth rate of 0.8 kg/day (Agriland Team, 2018). The current Norwegian recommendation for calves is a growth per day of 600-800 grams for the age of 2-6 weeks, for calves that are fed for slaughter (Nortura, 2020). A growth rate of 950-

1000 g/d have shown to produce healthier calves and higher milk production in first lactation (Overrein et al., 2021). Calves feed milk replacer at moderate to high rates, had a daily weight gain of 0.64 kg/d (Hu et al., 2019). Frieten et al. (2017) found that calves fed on ad libitum milk allowance had a average daily weight gain of 1000 g/d.

2.2. Housing

On most modern dairy farms, calves are housed in individual pens (Grøndahl et.al 2007; Lorenz, 2021; Whalin et al.,2018). The separation at birth is done to prevent disease and easier monitor the health (Lorenz, 2021), as the calf is born without immunity (Sjaastad et al., 2016). In Europe, it is compulsory to house calves older than 8 weeks in groups (Council of the European Union, 1997). In Norway, most calves are moved over in group pens before they are three weeks of age. The housing of calves in groups requires higher skill and more management, even though housing in pairs has few disadvantages (Lorenz, 2021). Farms practice CCC differently, housing in tie stalls or lose housing, calving all year or concentrated to spring or fall, and different time spans with CCC (Johanssen, 2022).

2.3. Feed intake, commercial VS. CCC

2.3.1 Milk intake

Newborn calves depend on receiving colostrum within the first 6 hours of life. A calf that weighs around 40 kg needs 3-5 liter of colostrum (Sehested et. al, 2003; Sommerseth, n.d.). The calf relies on antibodies from colostrum, before it can synthesize its own (Sjaastad et al., 2016). The amount of immunoglobulin (Ig) from colostrum reaches a peak at 36 hours after birth and the half-life is normally around 16-17 days (Sehested et al., 2003). The calf's own immunity reaches a normal level around the age of 4-6 weeks (see Figure 2.2) (Sjaastad et al., 2016; Whist, 2015). In a CCC system the calf will suckle the dam for colostrum (Johnsen et al., 2021). There have been different recommendations for feeding during the milk feeding period over the years. For many decades it has been recommended to give the calves an amount of milk corresponding to 10% of body weight per day for about six weeks, to get the calves quickly over to roughage and concentrate (Grøndahl et al., 2011). The recommendation for milk intake was 6 liters per day and is now increased to 11 liters per day (Mejdell et al., 2021; Overvein et al., 2021). Dairy calves are usually weaned at the age of 5-12 weeks depending on the system (Jensen, 2017). Manual feeding frequency corresponds to minimum feeding (two feedings), and higher milk feeding frequency can accommodate higher milk allowances (Johnsen et al., 2021b). In Norway, the average feeding is 6-8 l/d of 3 weeks old calves (Johnsen et al., 2021b). In Canada, the average feeding is 4 l per day for the first week, 5.5 l per day in the time between the first week and the week before weaning, and 3 l the last week before weaning (Vasseur et al., 2010). Suckling the dam gives higher milk intake compared with bucket feeding the calves (Grøndahl et al., 2007), due to more frequent suckling from the dam (four to eight times daily) (Hammon et al., 2002).

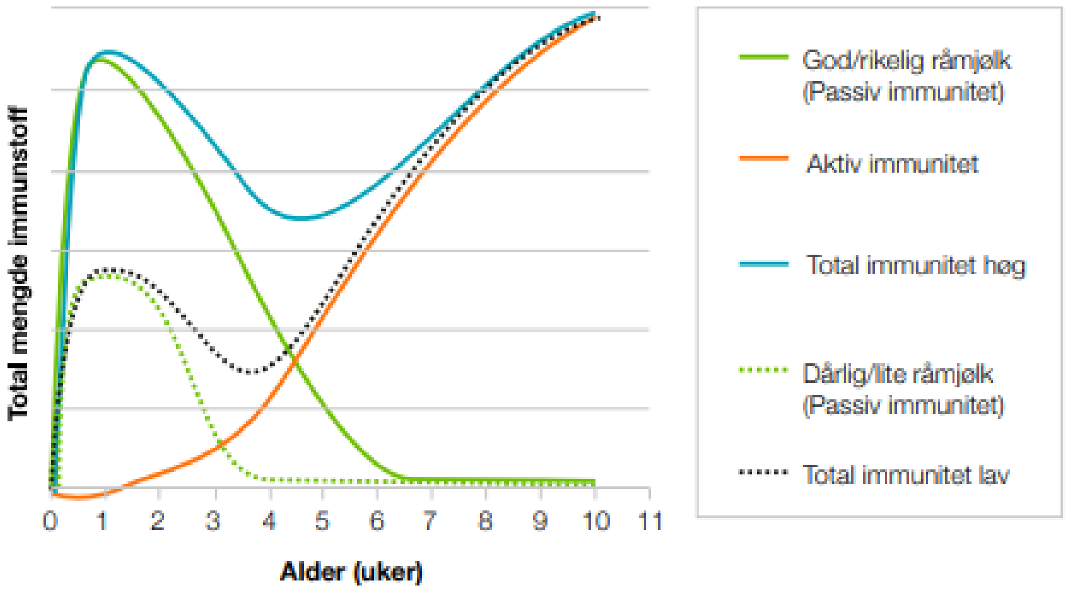

Figure 2.2: Development of good passive immunity (green line), active immunity (red line), total immunity high (blue line), bad passive immunity (green dotted line), and total immunity low (black dotted line) based on age in weeks (Whist, 2015)

2.3.2 Concentrate, roughage, and water

In commercial calf management restricted milk feeding to increase the intake of solid feeds earlier is practiced (Sehested et al., 2003). Intake of structured feeds like concentrate and roughage is important for the development of the forestomachs (see chapter 2.4). It is recommended to give calves access to both concentrate and roughage from the first week (Overrein et al., 2015; Sehested et al., 2003). Even though water is essential to body functions (Strudsholm, 2003), calves in the United States and Europe are provided water on average day 17, where as in Norway 84% of calves as free access to water at the age of 3 weeks (Johnsen et al., 2021b; Vasseur et al., 2012; Wickramasinghe et al., 2019).

In CCC systems the calves often have ad libitum access to concentrate, hay/silage and water (Grøndahl et al., 2007; Johnsen et al., 2021c; Kiserud, 2019). The recommendations in commercial production are to provide ad libitum amounts of concentrate until the consumption reaches 1,5-2 kg/d (Nortura, 2020; Overrein et al., 2015). Ad libitum access to fine hay in early age and later fine silage is recommended (Overrein et al., 2015) In Canada, the calves have access to concentrate at 7 d after birth, and hay is provided at age of 3 d, and in the United States access to concentrate and roughage at age of 8.5 d and 24.5 d (Vasseur et al., 2010). In central Europe, concentrate access is given at the average age of 14.8 d and hay at the age of 9.9 weeks (Vasseur et al., 2012).

2.4. Development of the forestomachs

The calf functions as a monogastric animal for the first weeks of its life. At birth, the forestomachs are to little use for the calf, while the abomasum is well developed (Sjaastad et al., 2016). Development of the forestomachs is a complex interaction between genetics, hormones, and the feed's chemical and structural composition (Sehested et al., 2003). In the first weeks when a major part of the feed is liquids (colostrum, whole milk, and milk replacer), it bypasses the rumen, reticulum, and omasum through the esophageal groove to the abomasum (Diao et al., 2019). Growth of the forestomachs is stimulated by fermentation products in the rumen (Sjaastad et al., 2016). Rumen development are stimulated of the presents and absorption of volatile fatty acids (VFA) which is the key to rumen epithelial development (Govil et al., 2017). Solid feeds and fermentation products stimulate the growth of the forestomachs (Sjaastad et al., 2016). The development of the rumen is an important physiological change for ruminants, establishing an anaerobic microbial ecosystem (Govil et al., 2017). Figure 2.3 shows the rumen development when feed ether only milk, milk and grain, and milk and hay.

Figure 2.3: Rumen development of 6 weeks old calves feed only milk, milk and grain, and milk and hay (Heinrichs & Jones, 2016)

Adult cows spend 6-10 h/day on rumination and can reach a maximum of 10-12 h/day (Beauchemin, 2018; Nørgaard, 2003). Rumination starts around the age of two weeks and periods/day and time/period increase as the forestomachs develop (Swanson & Harris, 1958). Feeding roughage increases calves' rumination time (Phillips, 2004). Reticulorumen is almost totally developed at the age of 8 weeks (Diao et al., 2019). As the development of the forestomachs increases the saliva flow, the amount of lipase in saliva decrease as the pH of the abomasum decreases (Sehested et al., 2003).

2.5. Separation in CCC systems

The separation of cow and calf is either an abrupt action or a continuous action, with or without weaning, depending on the system and age of the calf. Abrupt separation without weaning requires the calf to understand how to drink milk from a bucket or artificial teat, which can give some complications and extra work (Kiserud, 2019). Providing milk when separating from the cow as a continuous action has a positive effect on performance at separation and weaning (Johnsen et al., 2015) Continuous separation, where the calves are weaned by either a nose flap or with fence contact, has proven to have the same amount of stress (Johanssen et al., 2019). The process is practiced differently with different systems, some producers separate at day 30, and others separate and wean at the age of 10-12 weeks (Ingdal, 2019; Kiserud, 2019).

3. Method

This study was preformed from October 2020 to March 2022, at The Livestock Production Research Centre at Norwegian University of Life Sciences.

3.1. Animals

The cowherd is a part of The Livestock Production Research Center's Norwegian Red (NRF) research livestock. All cows in the herd calving in relevant periods were eligible for inclusion. Exclusion criteria were calving difficulties, failure of colostrum intake, ignorance of calf, calving outside of calving pen, aggression towards the calf or personnel, signs of health problems, and the cow's earlier participation in other batches or similar studies. Thirty-two pairs of cow and calf were divided into four batch. A maximum of 4 male calves per batch were set. Table 3.1 shows an overview of the animals in each batch, with the date of birth and sex.

Table 3.1: Overview of animals used in the study, with the birthdate of the calves and sex

Batch 1				Batch 2			
Cow	Calf	Birthdate	Sex	Cow	Calf	Birthdate	Sex
6811	7076	13.10.2020	Female	6825	7161	11.01.2021	Male
6609	7081	15.10.2020	Female	6735	7162	15.01.2021	Female
6436	7082	16.10.2020	Female	6691	7163	16.01.2021	Female
6497	7084	17.10.2020	Female	6728	7164	19.01.2021	Male
6564	7085	17.10.2020	Female	6738	7166	22.01.2021	Female
6374	7089	21.10.2020	Female	6714	7167	22.01.2021	Male
6804	7095	24.10.2020	Female	6585	7168	23.01.2021	Male
6769	7096	26.10.2020	Male	6576	7174	28.01.2021	Female
Batch 3				Batch 4			
Cow	Calf	Birthdate	Sex	Cow	Calf	Birthdate	Sex
6884	7218*	03.09.2021	Male	6682	7314	02.01.2022	Female
6920	7219**	04.09.2021	Female	6983	7315	02.01.2022	Male
6515	7221	06.09.2021	Female	7014	7317	03.01.2022	Female
6663	7224	09.09.2021	Female	6915	7318	03.01.2022	Male
6599	7225	09.09.2021	Female	7022	7320	04.01.2022	Female
6476	7227	10.09.2021	Female	6756	7321	06.01.2022	Male
6772	7229	10.09.2021	Male	7033	7324	08.01.2022	Male
6519	7233	13.09.2021	Male	6478	7326	14.01.2022	Female

*Excluded at age of 26 days due to sickness of cow, **excluded at age of 49 days due to sickness of cow

3.2. Batch overview and Separation strategy

Table 3.2 shows the distribution of cow-calf pairs for the batches and separation strategy. The study was performed over 2 years due to the distribution of calving's in the herd, concentrated in long spring and fall. To define the days of the trial, the birth date of the median calf where considered the start of the trial. Separation started on the same day for all the calves in a batch, thus calf age varied at separation. The study was designed so that calves were gradually adapted to separation by reducing CCC was reduced over time, with four different periods: the suckling period, the separation periods, and the weaning period. In the first period, cows had 24 h access to calves, second with 12 h access (11:00 am - 11:00 pm), third with 6 h (11:00 am - 5:00 pm), and fourth with 0 h access. Fence line access was available throughout the trial (see chapter 3.3). The fourth period was also used to wean the calves. Smart gates were used to restrict the availability of the meeting area (see chapter 2.2) for the cow and therefore restrict the CCC. Figure 3.1 shows the distribution of days for the four phases in the two strategies. The total of days for the long adaptation and short adaptation to solid feed is 65 and 64 days.

Table 3.2: An overview of the trial rounds; the number of pairs and separation strategy

	Round 1	Round 2	Round 3	Round 4
Time	Fall (2020)	Spring (2021)	Fall (2021)	Spring (2022)
Pairs of animals	8	8	8	8
Adaptation start (age)	Long (4 weeks)	Short (6,5 weeks)	Short (6,5 weeks)	Long (4 weeks)

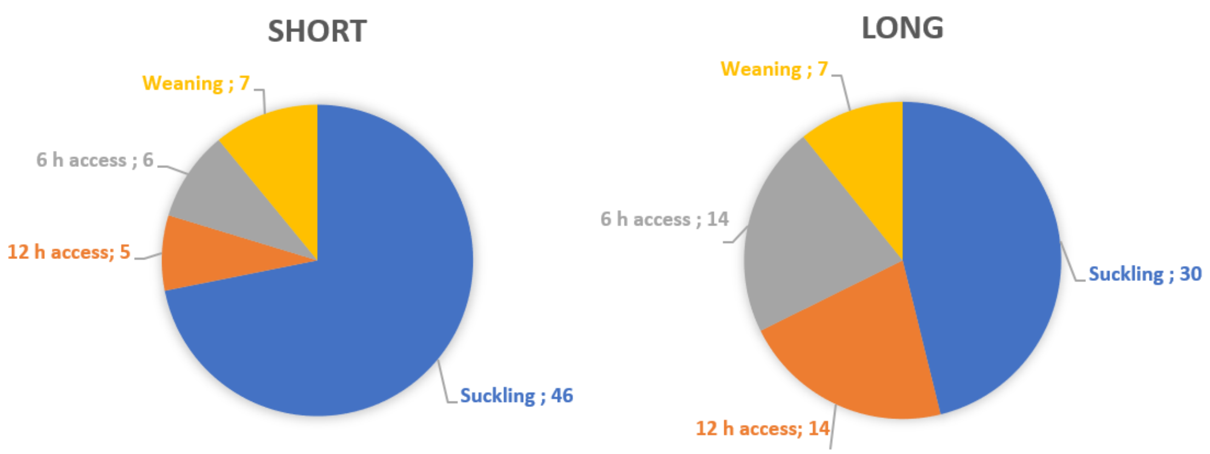

Figure 3.1: Distribution of days for each phase in the two strategies

3.3. Housing

At signs of imminent calving, cows were moved to individual calving pens (2.9 x 3.2 m) with deep straw bedding. The bedding was changed between cows to keep best possible hygienic housing for calving, and straw was added several times.

Three days after calving the cow-calf pair was moved to a separate specially designed CCC area. Cow-calf pairs were not moved on weekends, therefore, some pairs had up to five days in the individual calving pens. Figure 3.2 shows the special designed area in this study. The special designed area holds a calf creep, cow area and meeting area. Smart gates control the cows’ access to and from the meeting area and were modified as described by Johnsen et al., (2021c). The gates were and used to restrict the cows access in the separation period. Two openings in the concrete wall allows the calves access to the calf creep.

In the meeting area, there were slatted rubber mats on top of the concrete slatted floor to get the right spacing for calves, opening 25-30 mm and tread width of 80-100 mm (Mattilsynet, 2010). In the cow area, the cows had access to an automatic milking system (AMS), concentrate, ad Libitum access to roughage and resting stalls. The meeting area provide no other resources than CCC. A fence between the smart gates and between the resting stalls provided minimal CCC between the cow area and meeting area. The calf creep consists of a deep straw bedding, where they always had access to concentrate, hay, and water.

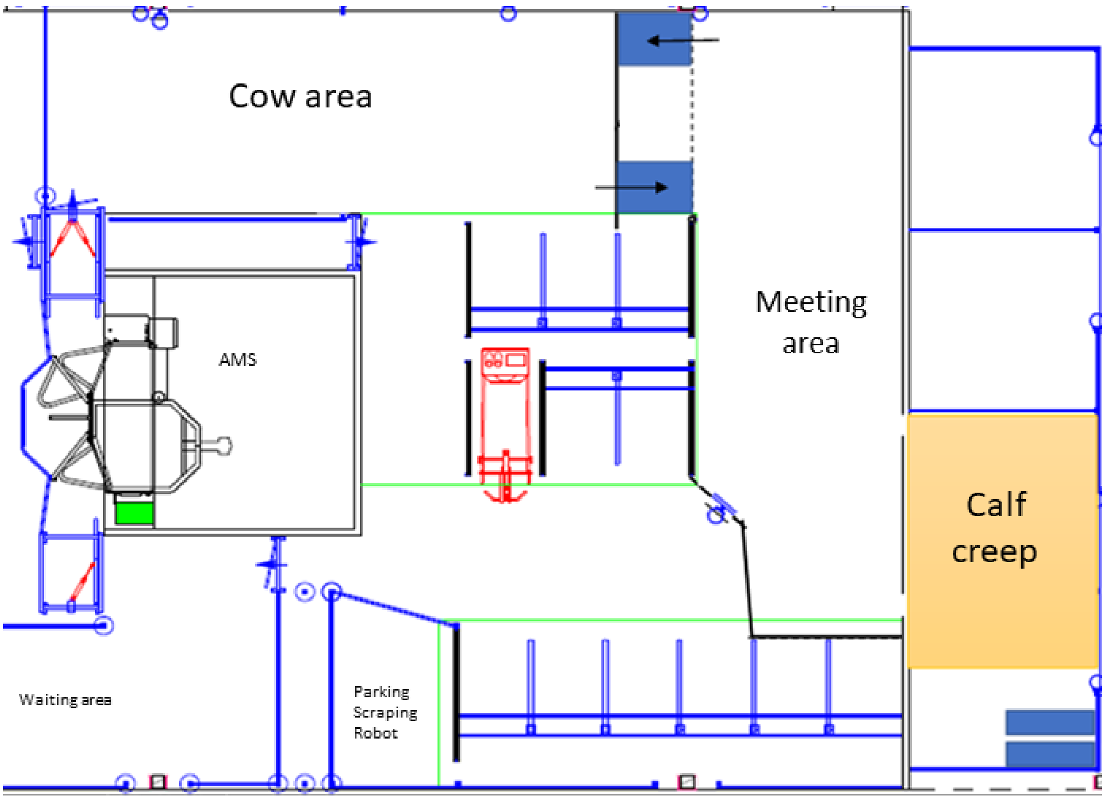

Figure 3.2: Special designed CCC area for the cow-calf pairs.

3.4. Growth measurements

The calves were weighed directly after birth and then twice a week throughout the trial, with a whole-body weight scale (Biocontrol AS, Rakkestad, Norway). They were weighed at approximately the same time, to minimize the variation through the day. Table 3.3 show the average birth weight of the calves in each batch.

Table 3.3: Average birth weight in each batch (kg)

	Batch 1	Batch 2	Batch 3	Batch 4
Average	38.16	38.72	40.22	39.04
SD	6.08	4.69	4.54	5.32

3.5. Feed intake measurements

Roughage consumption was measured in 24-hours intervals twice a week on group level. Calf hay were the main roughage provided and at age 57 d, they were provided added silage. Samples of roughage were taken twice a week and combined to one sample per week for dry matter analyses. Dry matter was found by drying at 60 degrees overnight and calculated by:

$$DM = \frac{dry\ weight}{fresh\ weight} \times 1000$$

Where DM is dry matter (g/kg); dry weight is the sample weight after drying (g); and fresh weight is the sample weight before drying (g). Volatiles lost during drying (Volden, 2011) is not correct for because of unknown chemical composition of the roughage. Water intake was measured on a group basis. The intake was measured twice a week with a stationary water meter on the pipe that led to the drinking bowl.

The concentrate intake was measured on an individual level, with a transponder in the ear ID mark. The concentrate feeder was calibrated once a week, to check quantity for feedings and variation. After separation start the calves got access to an automatic milk feeder (Delaval CF10005). The milk feeder measures milk intake individually and communicates with Delaval's Delpro system. Maximum feed rations per day were set to 12 l of whole milk. All measurements <0.5 l were categorized as failure to drink and set to 0 l.

3.6. Rumination measurements

Rumination was measured by Nedap' CowControll neck collar devise. The collars were fitted and adjusted to the calf neck during dehorning, when they were sedated, at approximately 3 weeks of age. Nedap gives a percent of time used on rumination throughout the day. Figure 3.3 shows a calf with the neck collar and Nedap devise.

Figure 3.3: Calf with the collar and CowControll devise

3.7. Statistic

Basic data handling was performed in Microsoft excel (Version 2201, Microsoft 365) Descriptive statistics were calculated using Rstudio (2021.09.1+372). All statistical figures are made in excel.

3.7.1 Statistical analyses

Data collected over the sampling days were analyzed using mixed models in Rstudio (2009-2021 Rstudio, PBC, Boston, USA) using the "lme4" and "lmerTest" package. Data on individual calves over different days (e.g., concentrate intake, milk intake, rumination) were assumed to be correlated, hence modeled with restricted maximum likelihood estimation as described by (Dean et al., 2017). In addition, multiple comparison analyses were obtained using the "lemeans" package with Tukey`s procedure. For milk intake, concentrate intake and rumination there were used log transformation of the intercept (e.g. rumination).

$$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$$

Where Y_{ij}=response variable (e.g. rumination); μ = overall mean; α_i = the effect of strategy (i=1,2); and β_j = the age (days or weeks) of the calves at sampling day (j=3,…,70 or 1,…,9).

4. Results

4.1. Growth

Figure 4.1 shows that the calves follow the same growth pattern until approximately seven weeks old, here the short adaptation flattens out and long continues to go down and do not reach the potential growth per day. The strategies end with a difference of 1.0 kg in growth (see Table 4.1) and are not significantly different (p=0.525). Looking at the growth per day, long adaptation grew slightly less per day (p=0.428). Figure 4.2 shows the distribution of observations of growth (kg/day) for the two strategies. Long has a higher variation through the whole study and short have a decrease in variation through the study.

Table 4.1: Average total growth from birth to weaned and average daily growth from birth to weaned.

Total growth (kg)	Average	SD	p-value
Long	60.1	7.5	0.525
Short	59.1	14.1	
Average daily growth (kg)			
Long	1.16	0.24	0.428
Short	1.21	0.28	

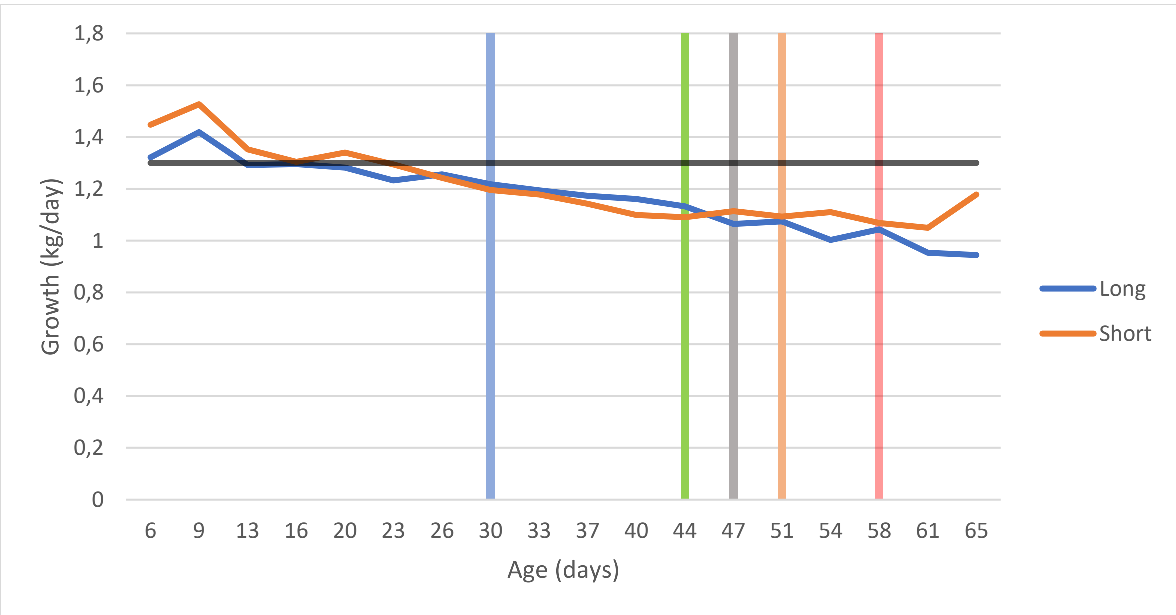

Figure 4.1: Average growth kg per day for the two strategies. The black line shows the potential daily growth in a CCC system (Grøndahl et al., 2007). The blue bar is the start of 12 h access for long, green start of 6 h access for long, grey the start of 12 h access for short, orange the start of 6 h access for short and red start of weaning for both strategies.

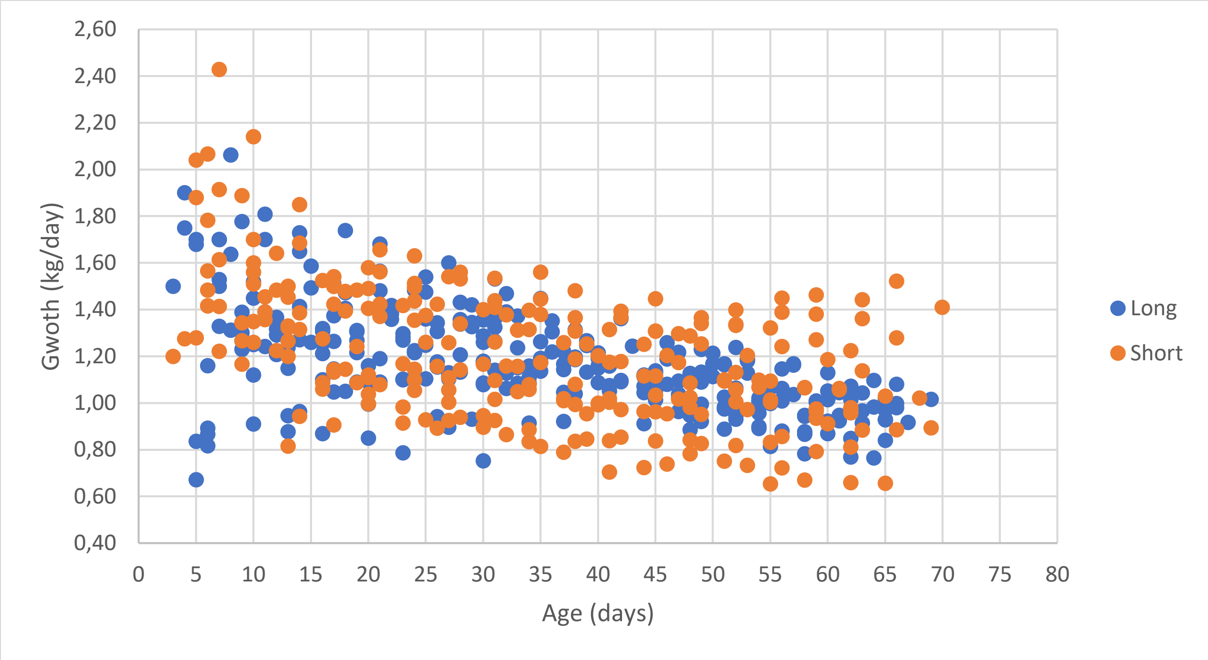

Figure 4.2: Distributions of observations for growth (kg/day)

4.2. Feed intake

Table 4.2 shows the average feed intake for the strategies. There is not any significant difference between the strategies for feed intake, water intake and rumination.

Table 4.2: Average intake per calf for hay, silage, concentrate, water, and milk.

Hay (kg DM/ group)	Average	SD	p-value
Long	0.28	0.23	0.243
Short	0.32	0.34	
Silage (kg DM/ group)			
Long	2.55	0.82	0.081
Short	1.45	0.40	
Concentrate (kg feed/calf)			
Long	0.09	0.09	0.735
Short	0.09	0.12	
Water (liter/calf)			
Long	1.73	1.28	0.491
Short	1.87	1.56	
Milk (liter/calf)			
Long	2.27	3.82	0.735
Short	4.33	4.62	

Figure 4.3 and Figure 4.4 show the development of average roughage intake. Both strategies had a steady development of hay intake, with long adaptation overall a little higher than short.

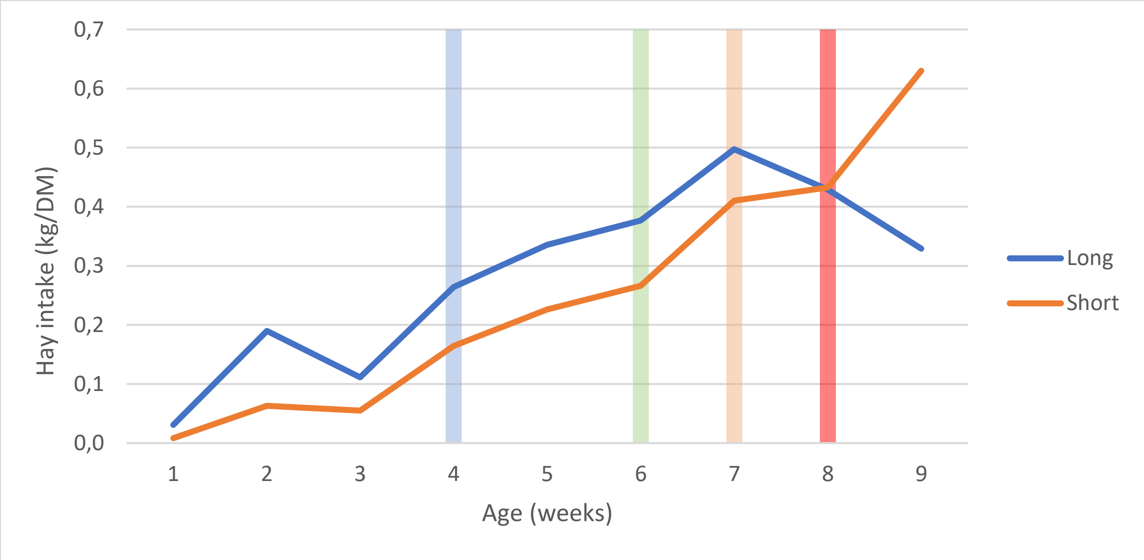

Figure 4.3: Average weekly intake of hay for the strategies. The blue bar is the start of 12 h access for long, the green bar the start of 6 h access for long and from 12 h access for short, the orange bar represents the start of 12 h access for short, and the red the start of weaning for both strategies.

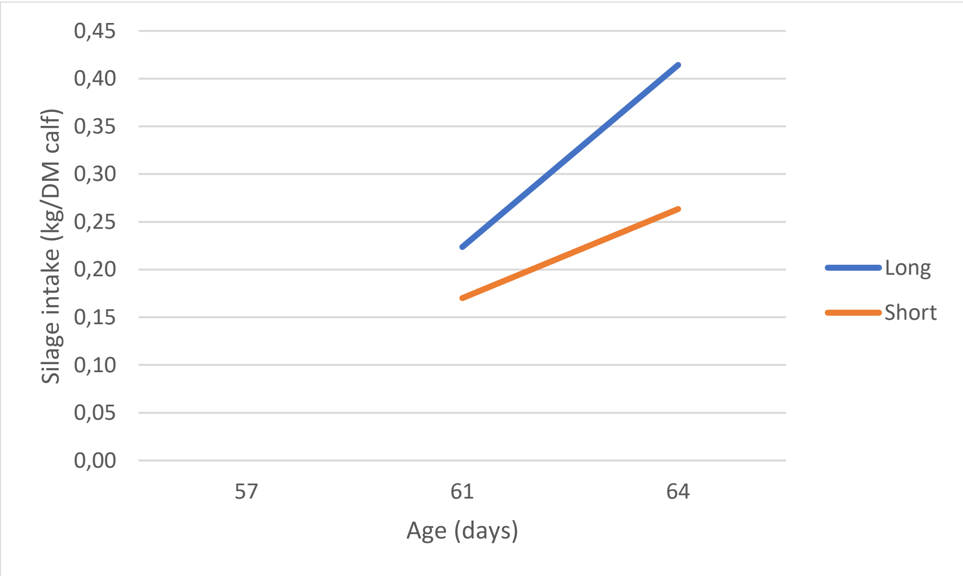

Figure 4.4: Average intake of silage for the strategies after total separation from the cow.

Figure 4.5 shows the average increase in concentrate intake on the two strategies. Both strategies had a steady increase in intake, the long adaptation strategy ends with the highest intake.

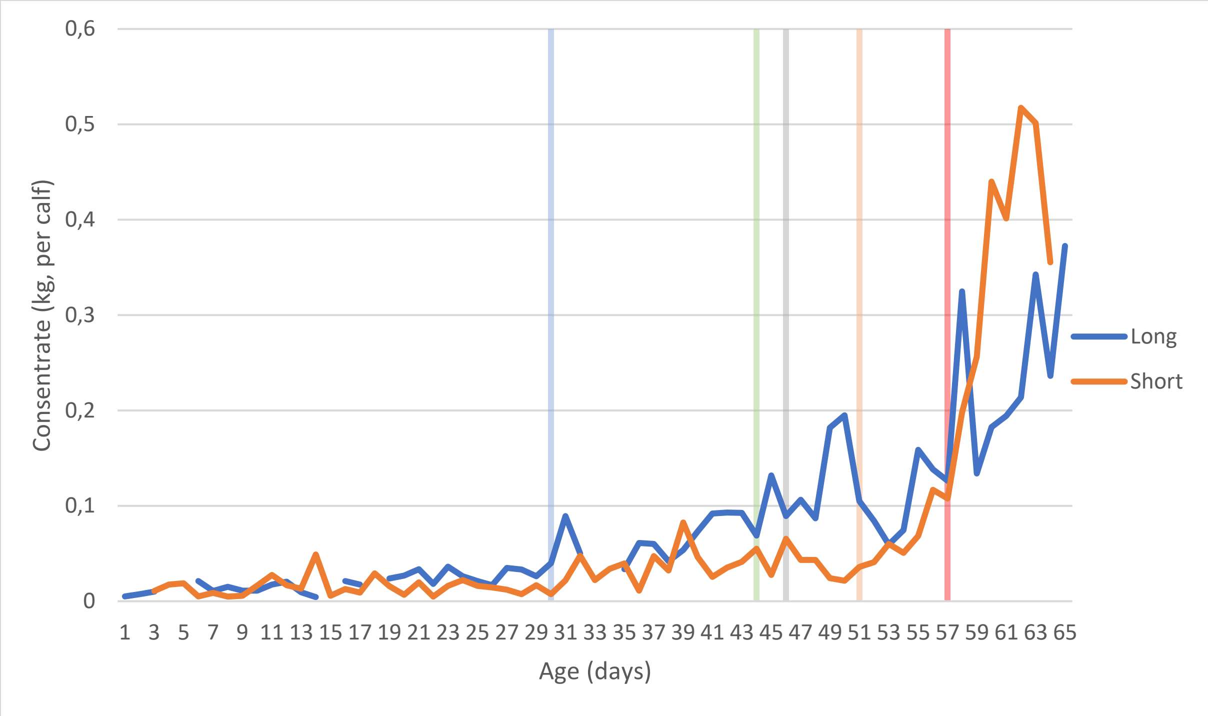

Figure 4.5: Average concentrate intake for the strategies (kg, per calf). The blue bar represents the start of 12 h access for long, the green bar the start of 6 h access for long, grey bar the start of 12 h access for short, orange bar the start of 6h for short, and red represent the start of weaning for both strategies.

Figure 4.6 shows the development of average milk intake from the milk feeder. The short adaptation has a higher milk intake after separation. Before weening, the long adaptation had the highest milk intake.

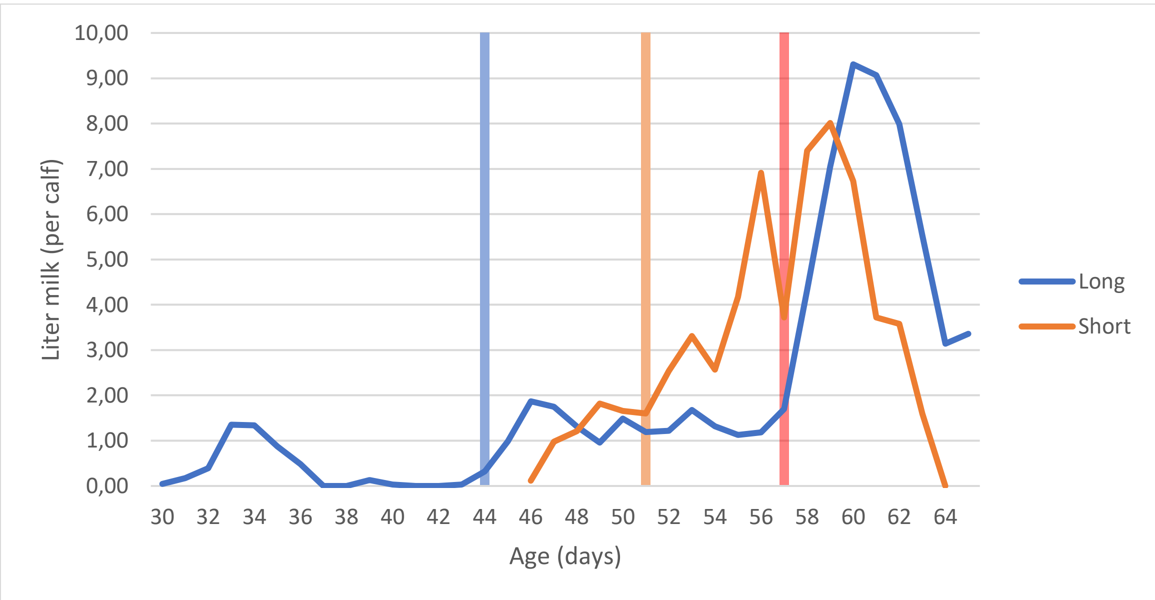

Figure 4.6: Average milk intake from automat for the strategies. The blue and orange represent the start of 6h access, for long and short respectively. The red bar is the start of weaning for both strategies.

Figure 4.7 shows the development of water intake for the two strategies. Water intake increased steadily over time, but no difference was seen between strategies.

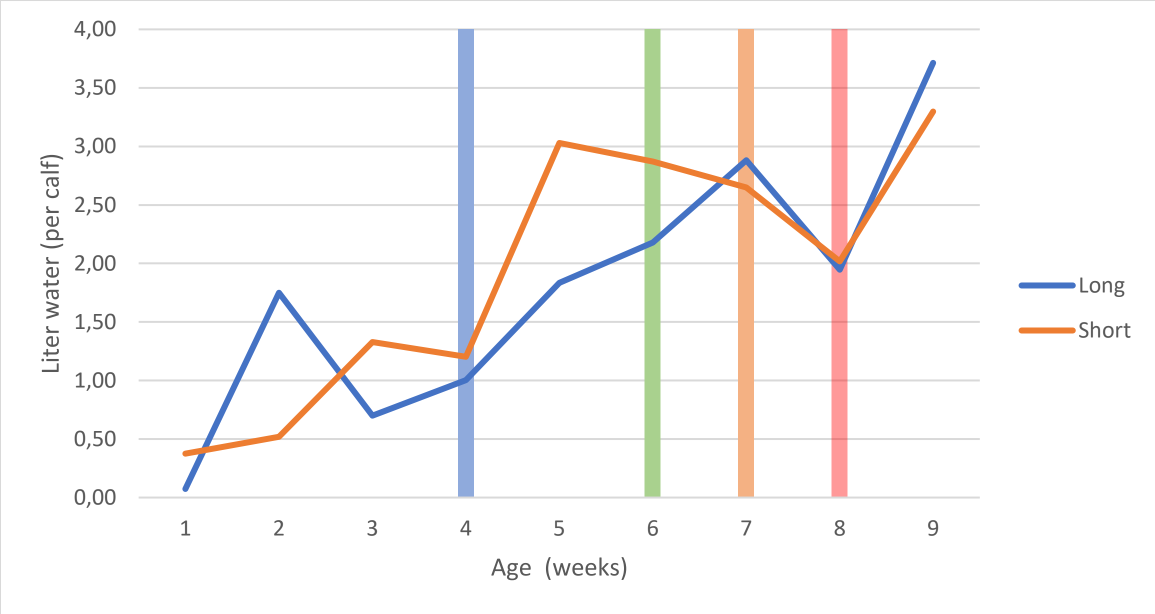

Figure 4.7: Average water intake per calf thought the experiment. The blue bar is the start of 12 h access for long, the green bar the start of 6 h access for long and from 12 h access for short, the orange bar represents the start of 12 h access for short, and the red the start of weaning for both strategies.

4.3. Rumination

Table 4.3 shows that short had higher average rumination and higher standard derivation. Figure 4.7 shows how short was a little higher than long and that they started the increase at the same time around the age of 52 days. Short had a higher increase than long.

Table 4.3: Average rumination per calf

Rumination	Average	SD	p-value
Long	3.50	4.05	0.094
Short	4.91	4.91	

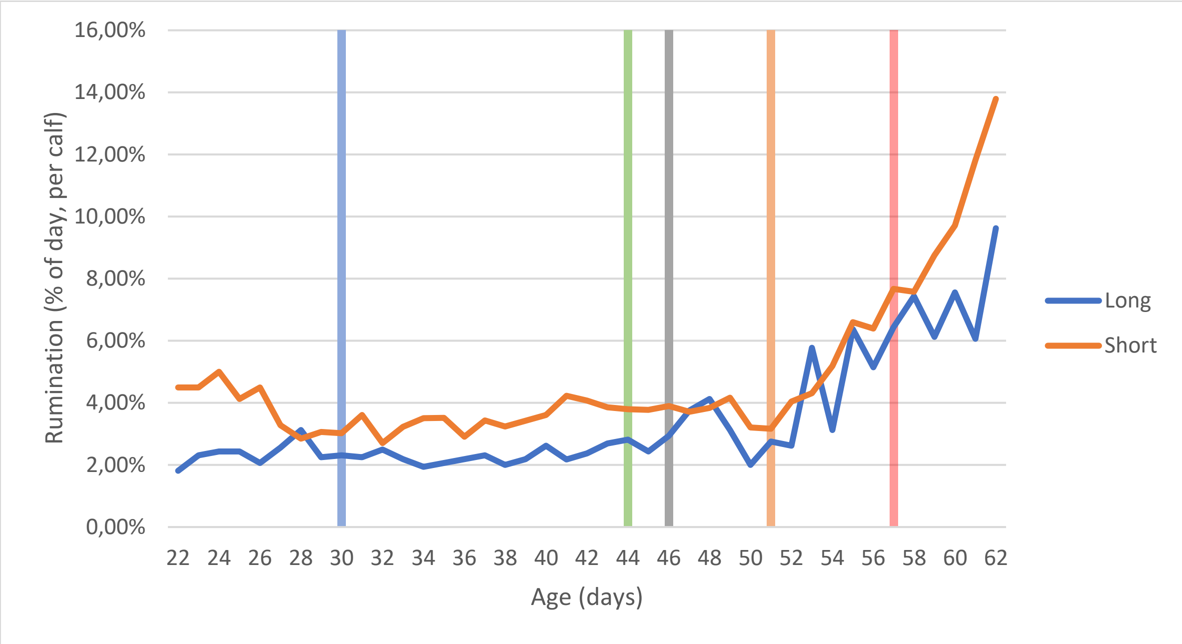

Figure 4.3: Average rumination for the strategies (% per day, per calf). The blue bar is the start of 12 h access for long, green start of 6 h access for long, grey the start of 12 h access for short, orange the start of 6 h access for short and red start of weaning for both strategies.

5. Discussion

This study aimed to see if separation strategy influenced growth, feed intake and rumination on calves in a CCC system. Findings in the present study suggest that separation strategy influences growth per day and intake of milk from feeder. The results are discussed hereunder.

5.1. Growth

In both strategies, the calves had an average total growth of approximately 60 kg, and weighed around 100 kg at 9 weeks of age, which are approximately 10 kg heavier than the recommended weight of 90 kg at 9 weeks (Overrein et al., 2015). In this study, the average daily growth was 0.3-0.4 kg higher than most Norwegian recommendations (Nortura, 2020; Overrein et al., 2021; Agriland Team, 2018), equal to a study done by Johnsen et al. (2021c) and comparable to a study by Grøndahl et al. (2007) and Asheim et al., (2016). The short adaptation had a 0.5 kg higher average daily weight gain than the long, this may be because of the prolonged access to suckling the cow. As shown in Figure 4.1 the two strategies follow each other until the age of 51 d, where short stabilizes around 1.1 kg/d and long continues to fall. Day 51 is in the middle of 6h access for the long adaptation, while it is the start of 12h access for the short. Figure 4.2 shows that the short separation has a higher variance between the individual observations than the long. A possible explanation to the variation can be the milk intake from the cow, as there are no estimates on this. The increase in daily weight gain at the end of the age of 61 d for short can be caused by rumen filling as the calves must compensate for the loss of energy from the milk to the energy from roughage (The Vet Group, 2019). If the study population had been larger, it would be easier to determine a mean and standard deviation for the strategies and probably find that short adaptation difference between the strategies.

Although the calves were weighed at approximately the same time for each observation it may vary due to variation in time since last feed/milk intake, water intake and urination/defecation. For more correct observations, the calves could have been weighed each day or there could be some sort of continuous weighing, however this was not practically feasible. Cases of mild diarrhea occurred in all the batches, which could have affected the results on growth (Donovan et al., 1998). Figure 5.1 shows a calf with diarrhea and feces covering the tail and the behind of the calf. Diarrhea is a costly disease both for economics and the performance of the calf and may have caused lower weight gain (Hessman et al., 2009). High-stress levels are associated with diarrhea (Cho & Yoon, 2014), part of the separation may have caused the stress levels to elevate. Diarrhea can also be because of large meals when the gates open after adaptation has started (Sjaastad et al., 2016).

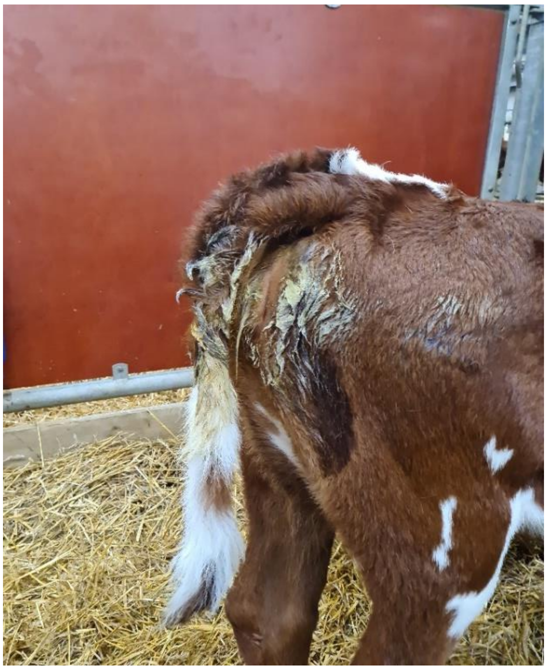

Figure 5.1: A calf with diarrhea, feces on its tail and behind

5.2. Feed intake

5.2.1 Milk

The results of this study have shown that the separation strategy has an impact on the intake of milk from the milk feeder (Figure 4.6 and Table 4.2). This is comparable to a study by Johnsen et al. (2015) where the milk intake from feeder increased at partial separation for combined (milk from cow and feeder) and nursing (milk only from cow) calves and increase with total separation. A study by Jasper and Weary (2002) show that calves feed on ad libitum amount of milk consume average 8.8 kg/d, comparable are the highest average level in this study was 8.01 l/d and 9.31 l/d for short adaptation and long adaptation respectively.

1 of 16 calves with long adaptation did not learn to use the feeder and 3 of 14 calves with short adaptation did not learn the feeder. The approach for learning the use of the milk feeder was changed for batch 3 and 4 to a gentler approach and molasses on the artificial teat. Problems with transitioning the calf from suckling the cow to suckling an artificial teat have been proven to be difficult (Johnsen et al., 2021a; Kiserud, 2019). Difference between the artificial teat and the cow teat as well as the bond to with the cow can be part of the problem. Suckling on a cow has shown to increase weight gain compared to suckling on a artificial teat, even when suckling the cow for a short period (10 days) has given higher weight gain at 2 month of age (Lidfors et al., 2009). The problem may be minimized with introduction to a milk feeder earlier in the process. Johnsen et al. (2015) found that calves in a combination of CCC and artificial rearing did use the milk feeder when apart from the cow. Due to miscommunication between the feeder and DelPro, some calves that did not use the whole daily rations had the remaining ration transferred to the next day's ration, and resulted in that eight calves did consume more than the daily ration of 12 l in phase with 0 h access, the highest being 14.05 l. The automatic weaning process did not function as it should, therefore, weaning was done by manually decreasing milk allowance each day. feeder. That is the probable reason behind why the long adaptation was not totally weaned at the age of 65 days.

5.2.2 Concentrate and roughage

In this study, concentrate intake steadily increased though the whole study, with no significant difference between strategies, which can be supported by a study by Jasper and Weary (2002) that did not find a difference between restricted milk feeding and ad libitum on concentrate intake. The intake increases most after the total separation and is comparable with a study done by Frieten et al. (2017), how found that calves with ad libitum milk intake had a concentrate intake of ≈ 0.5 kg at 8 weeks of age and then increased to 2 kg at the age of 11 weeks, and that calves feed restricted rations of milk had a concentrate intake of ≈0.9 kg at 8 weeks of age then increased to 2.5 kg at the age of 11 weeks. Other studies have found that ad libitum intake of milk decreases the intake of concentrate (Frieten et al., 2017; Hepola et al., 2007). The increase in intake after total separation can be explained by the loss of energy from the milk and the need to find other sources of energy (Johnsen et al., 2015). Delaying time of weaning until 12-13 weeks of age has shown to reduce signs of hunger for calves feed 6 l/d and 12 l/d, where high milk feed calves consumed less concentrate a weaning than low milk feed calves (de Passillé et al., 2011). Some recommendations state that the calves are ready for weaning when the calf consumes 1 kg of concentrate daily (Sehested et al., 2003). In this study, the calves have not reached that amount at the age of 9 weeks and if we followed the recommendation, they should not be weaned as both strategies had an intake of ≈0,4 kg/day. With continuous increase in concentrate intake as after weaning the calves would approximately be ready for weaning at the age of 11 weeks. From Figure 4.5 there is a tendency that short has the highest intake of concentrate but long starts the increase earlier. Long adaptation may start the increase earlier due to feeling hungry due to a low and uneven milk intake both from cow and milk feeder and short adaptation may have a hunger feeling later due to the extended access to the cow. Restricted feeding of milk have been shown to give the calves a hunger feeling (Khan et al., 2011). The increase for long can be compared to feeding the calves restrictively to promote solid feed intake (Grøndahl et al., 2011).

The hay intake was not significantly different between the strategies. It increases steadily for both strategies throughout the period. When silage was offered, the intake of hay declined. The calves preferred silage over hay, the explanation can be the taste and feel of something new. The difference in silage intake can have something to do with the composition of the silage as it changes from year to year. A diet of straw mixture compared to hay stimulate growth (Phillips, 2004). Asheim et al. (2016) assumed that the roughage intake was equal for calves suckling for 0 days, 3 days and 7 days and lower for long suckling (suckling for 7 weeks) calves. The calves preferred silage over hay, even though hay is recommended because of fiber structure (Asheim et al., 2016; Sehested et al., 2003). The total intake of solid feed was not high, this may be because of a high milk intake. Calves have a lower intake of solid feeds when they are on a higher level of milk intake than 8-10% of body weight (H. Hepola et al., 2007). From estimates for feed intake from the dam by Lehmann et al., (2021), the calves in this study´ may have had a milk intake of 15-20% of body weight.

5.2.3 Water

The water intake increased steadily in both strategies. Calves use water to regulate temperature and will drink more when it is warm (Amaral-Phillips, n.d.). Wickramasinghe et al. (2019) found that calves drank 0.75 kg/d during the first 16 days and that when calves got water on day 17 had a higher water intake through the preweaning period. In this study, the water intake was around 0.33 l/d at the age of 2 ½ week and on average 1.7-1.8 l/d for the whole period for long and short adaptation respectively. Weight gain and intake of concentrate have been found to decrease if the calves are deprived of water (Kertz et al., 1984).

In this study, calves learned that water was a good thing to play with. They spilled some water, and this is registered as water drunk. How much it amounted to are difficult to estimate but this can maybe explain parts of the variation seen in Figure 4.7. A water nipple to replace the water bowl can remove part of the problem with spilling. Hepola et al. (2008) found no difference between providing water from a bucket or nipple on water intake. Increase in water intake has been found to increase the intake of concentrate in multiple studies (Beiranvand et al., 2016; Kertz et al., 1984; Wickramasinghe et al., 2019).

The intake of water increased steadily with a slight peak at the end when they were totally weaned, and the intake of concentrate and roughage increased. Organs of the body needs fluids around them to function properly, therefore are the intake for fluids important (Sjaastad et al., 2016). The chemical composition of milk are about 87% water and 13% dry matter (Sjaastad et al., 2016), therefor it do not meet the calves' requirement for water even when feed on ad libitum milk allowance (Jensen & Vestergaard, 2021) Calves fed restricted milk allowance have higher water requirements, compared to calves on ad libitum milk allowance. An unbalanced milk intake, like when the cow's access is restricted, may influence the requirement for water. The intake of milk from the milk feeder do affect the intake of water as the intake goes down right before the total separation and then increases with the increased intake of solid feeds and weaning. Wickramasinghe et al. (2019) found that water intake did not affect the health of calves feed high amounts of milk. Compared to Jenny et al., (1978) how found that a fluid intake of 6% of body weight with 20% dry matter increased diarrhea occurrence and increased the water intake compared with calves with a fluid intake of 6% body weight with 10% dry matter. The water intake does not seem to be affected by the occurrence of diarrhea in this study as it did in the study by Jenny et al. (1978).

5.2.4 General feed intake

From the numbers in this study, it can look like the calves only starts drinking from the milk feeder when the separation is almost completed (Figure 4.6). Long adaptation waits until the total separation before rapidly increasing the milk intake from the feeder. The same tendency is to be seen in short adaptation, where the rapid increase starts in the middle of phase 3. The motivation for suckling the cow is higher than the motivation for drinking from the milk feeder, Johnsen et al. (2015) had comparable results for the nursing calves. This can be seen in the concentrate intake that also are increasing rapidly after the total separation. When the separation from the cow is complete, the calves are feeling hunger and satisfy the feeling by increasing the intake of concentrate, roughage, and milk from the feeder (Khan et al., 2011). A higher feed milk intake will decrease the feeling of hunger and improve calf growth, health, welfare, and future productivity (Johnsen et al., 2021b). Sometimes the calves were weighed before and after opening of the gate when the separation had started. There was a large difference in weight, that can indicate that the calves waited until the gates open and then consumed large meals. The impact can be notable on growth, the use of registered weight before or after, and the impact can be serious for the potential intake of solid feed.

5.3. Rumination

The development a calf undergoes from a monogastric to a ruminant increases the intake of roughage and the frequency of rumination (Sjaastad et al., 2016). The short adaptation had a higher rumination frequency than long even though long had a higher roughage intake and the concentrate intake was not different between the strategies. Separation start does not influence the rumination frequency, rather the age and weaning influence the frequency. The high variation within the strategies is comparable to a study done by Swanson and Harris (1958). Swanson and Harris (1958) found that the calves had a steady increase for rumination up to the age of 33-42 d, where it flattens out and that weaning did not influence the rumination time. Meale et al. (2016) found that the readiness of the rumen at the age of 48 d was the same regardless of weaning method. At the end of the period the average rumination time was 9.6% and 13,7% for long and short adaptation respectively, which is a 2.3 hours and 3.2 hours compared to an average of 5 hours for Jersey and Holstein calves (Swanson & Harris, 1958). Swanson & Harris used a milk allowance of 10-15% of body weight and 4 lb. (equal to 1.8 kg) of concentrate, compared with this study where the milk intake was 15-20% of body weight and ad libitum access to concentrate. The difference in rumination time per day is probably a difference in solid feed intake, and therefore the need to ruminate is different. A study with different milk feedings levels found that the rumination was unaffected (Ferreira et al., 2020), the results of this study can be compared to this with the intake of milk from the feeder. There is a risk of error in the measurements as the Nedap device is calibrated for adult cows and not for calves, and results on rumination should therefore be interpreted with caution. In adult cows, there is a strong correlation (≥0.92) between the observed reading and the registered reading from the Nedap (Borcher et al., 2021).

5.4. Further and future perspectives

From this study we found that rearing in a CCC system works for small groups of animals, with larger groups of animals there would maybe be a bigger difference between the strategies resulting in a higher difference in growth per day, milk intake and intake of silage. Even though there was no difference between the strategies on silage intake, with a larger group of animals and following them further could show a difference. As the intake of milk decreases the intake of solid feeds and water increases, it shows how the calf transition from milk to solid feeds, which was evident in both strategies. Based on the feed intake in this study the long adaptation appears to be the best separation method in this CCC system, even though the calves have the lower growth per day.

Studies on long term effects of suckling on calf and cow production parameters such as Johnsen et al. (2016) discuss is lacking. Questions have been raised on how calves reared in a CCC system function in a cow herd along with production parameters. Agenäs (2020) points out that there are several research projects on cow-calf together planed and running now, meaning that in the next years several articles will be published on the subject. Future studies should follow the calves until first or second calving to better conclude something regarding production parameters. Following the calves for a longer time will give a perspective on behavior, fertility, health, and economics for the producer. Also, larger studies involving farms across the country to determine how these systems work not only in special designed systems, but also out in the field, should be conducted.

6. Conclusion

This thesis aimed to see if there is a difference between separation strategies on growth, feed intake, and rumination. It is confirmed that there is a potential effect of separation strategy on growth and milk intake in a CCC system when the separation period differs. However, the separation strategy did not affect the production parameters focused in this study. This study recognizes the potential practical challenges with separation over time in the CCC system. Emphasizing the need for further investigating possible prolonged effects of separation strategies out over the weaning age, as the attention should be directed towards the production effects of heifers.

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