



ESTONIAN UNIVERSITY OF LIFE SCIENCES
Institute of Veterinary Medicine and Animal Sciences

Kia Emilia Moisander

**FEEDING INTERVAL AFFECTING CALVES' BIRTH TIME
AND WEIGHT IN SPRING-CALVING BEEF CATTLE**

**SÖÖTMISE INTERVALLI MÕJU VASIKATE SÜNNIAJALE JA
SÜNNIKAALULE KEVADEL POEGIVATEL LIHAVEISTEL**

Final Thesis

Curriculum in Veterinary Medicine

Supervisor: Professor Toomas Orro

Tartu 2019

Estonian University of Life Sciences Kreutzwaldi 1, Tartu 51014		Abstract of Final Thesis	
Author: Kia Emilia Moisander		Curriculum: Veterinary Medicine	
Title: Feeding interval affecting calves' birth time and weight in spring-calving beef cattle			
Pages: 37	Figures: 2	Tables: 2	Appendixes: 1
Chair: Chair of Clinical Veterinary Medicine Field of research and (CERC S) code: 3.2 Veterinary Medicine B750 Veterinary medicine, surgery, physiology, pathology, clinical studies Supervisor: Toomas Orro Place and date: Tartu 2019			
<p>The lack of assistance in parturition during the night time and the calves' high birth weight causes increased incidence of dystocia and can result in mortality of the cow, the calf or both parties. As a calf is largely the sole output in the beef cattle industry, these factors have an economically important matter. The aim of this study is to investigate the feeding interval affecting the time of birth, as well as the birth weight of beef calves born in spring time. The data of calving's was collected from one Hereford beef cattle farm situated in Southern Finland over the years 2003-2017. The data was statistically analysed with software STATA 14.2. When dams are fed only during the evenings, the odds of parturition to occur during the night hours was OR 1.10 (95% CI 0.43-2.86) when compared to feeding twice a day. This result was statistically insignificant ($p = 0.837$). The birth weight of calves was reduced by -2.77 kg when dams were fed only once a day during the late gestation period compared to feeding twice a day ($p = 0.001$). These results are corresponding to earlier conducted scientific studies. Further research is needed in order to fully understand the relationship between feeding intervals, the calving time and birth weight of calves.</p>			
Keywords: Beef cattle, late gestation time, feeding interval, new-born calves			

Eesti Maaülikool		Lõputöö lühikokkuvõte	
Kreutzwaldi 1, Tartu 51014			
Autor: Kia Emilia Moisander		Õppekava: Veterinaarmeditsiin	
Pealkiri: Söötmise intervalli mõju vasikate sünniajale ja sünnikaalule kevadel poegivatel lihaveistel			
Lehekülgi: 37	Jooniseid: 2	Tabeleid: 2	Lisasisid: 1
<p>Õppetool: Kliinilise veterinaarmeditsiini</p> <p>ETIS-e teadusvaldkond ja CERC S-i kood: 3.2 veterinaarmeditsiin B750</p> <p>Veterinaarmeditsiin, kirurgia, füsioloogia, patoloogia, kliinilised uuringud</p> <p>Juhendaja: Toomas Orro</p> <p>Kaitsmiskoht ja -aasta: Tartu 2019</p>			
<p>Öösel poegimine kui järelevalve on puudulik ja vasikate suur sünnikaal on lihakarja lehmadel sage raske poegimise põhjus ning tagajärjeks võib olla vasika ja/või lehma hukkumine. Kuna vasikas on peamine lihaveisekasvatuse toodang on see majanduslikult oluline probleem. Selle lõputöö eesmärk oli uurida lihaveise lehmade tiinuse viimase kolmandiku aegse söötmise intervalli mõju lehmade sünnitus ajale (öösel või päeval) ja vasikate sünnikaalule. Andmed poegimiste kohta koguti aastatel 2003-2017 ühest Lõuna-Soomes asuvast Herefordi tõugu lihaveiseid kasvatavast farmist. Kui lehmade söötmine tiinuse viimase kolmandiku ajal toimus ainult õhtuti, siis ei erinenud öösel toimunud poegimiste arv võrreldes ajaga kui lehmi söödeti kaks korda päevas (OR 1,10, 95% CI: 0,43-2,86; p = 0,837). Kui lehmi söödeti ainult õhtuti siis vasikate sünnikaal oli keskmiselt 2,77 kg väiksem võrreldes ajaga kui lehmi söödeti kaks korda päevas (p = 0,001). Need tulemused vastavad varasematele uuringutele. Täiendavaid uuringuid on vaja selleks, et paremini mõista lihatõugu lehmade söötmise intervalli, poegimisaja ja vasikate sünnikaalu seoseid.</p>			
Märksõnad: Lihaveised, tiinuse viimane kolmandik, söötmise intervall, vastsündinud vasikas			

THE TABLE OF CONTENTS

INTRODUCTION.....	6
ACKNOWLEDGEMENTS.....	7
1. LITERATURE VIEW.....	8
1.1 Feeding interval affecting the time of birth.....	8
1.2 Importance of optimal birth weight in beef calves.....	9
1.2.1 Cause of dystocia	9
1.2.2 Low birth weight affecting liveability.....	11
1.3 Factors affecting birth weight of calves.....	12
1.3.1 Parity of the dam.....	12
1.3.2 Maternal nutrition.....	13
1.3.3 Genetics.....	15
1.3.4 Other factors.....	17
2. AIMS OF THE STUDY.....	18
3. MATERIALS AND METHODS.....	19
3.1 Study design	19
3.1.1 Animals.....	19
3.1.2 Feeding during the late gestation.....	20
3.1.3 The logbook	21
3.2 Statistical analysis.....	22
4. RESULTS.....	23
4.1 Influence of the feeding to time of the parturition.....	23
4.2 Factors affecting the birth weight.....	25
5. DISCUSSION.....	27
5.1. Effects of the feeding intervals on the parturition.....	27

5.2. The relationship between once a day feeding of dams and decreasing the calves' birth weight	28
5.3. Other factors affecting the birth weight of the calves.....	29
6. CONCLUSIONS.....	31
REFERENCES	32
APPENDIX 1. Non-exclusive license for depositing the final thesis and opening it for the public and the supervisor's (supervisors') confirmation for allowing the thesis for the defence	36

INTRODUCTION

All over the world, beef cattle have a unique role of converting low quality forage to high quality protein for human consumption (Diskin and Kenny, 2016). Unlike dairy cattle, the vast majority of beef cow herds have seasonal calving (Diskin and Kenny, 2016). Reproductive performance is the key for profitability and efficiency, and therefore the birth weight of calves has been having an economical importance for a long time in the beef cattle industry (Gutiérrez *et al.*, 2007). The calf is largely the sole output in the beef industry, thus reproductive efficiency is a key determinant of profitability (Diskin and Kenny, 2016).

High weaning weight is important in beef cattle, and therefore there is a desire for the selection towards a higher weaning weight (Chud *et al.*, 2014). This desire causes, due to genetic correlation, increased birth weight of calves (Ahlberg *et al.*, 2016). This therefore can affect calving difficulty (Chud *et al.*, 2014). Another important factor for beef cattle is the viability of calves. Small birth weight can cause reduced viability and increased occurrence of different neonatal diseases (Eriksson *et al.*, 2004; Vinet *et al.*, 2018). The goal in the beef cattle industry is to produce optimal size calves to maximise the productivity without compromising the health of the calf and the dam (Diskin and Kenny, 2016; Nelson *et al.*, 2016).

Although the high birth weight is one of the major reasons for the dystocia, and therefore calve mortality, the lack of assistance is a contributing factor on the mortality associated with parturition (Jaeger *et al.*, 2008; Purohit *et al.*, 2012). During the night-time there is reduced observation of the dams and thus a lack of assistance in difficult parturitions (Jaeger *et al.*, 2008). Naturally, the herdsman are eager to reduce the mortality associated with these problems and therefore they want to influence the time of the parturition and the birth weight of the beef calves.

ACKNOWLEDGEMENTS

I would like to use this opportunity to thank my family and friends for encouraging me throughout my studies and my final thesis. It has been a long journey with a lot of ups and downs. But through all of it, I have been so grateful to have these kinds of people around me. I especially want to thank my mother who has been spending countless hours listening to my happiness, frustration, joy and sadness. All those thousands of phone calls meant a lot to me!

I also want to thank my supervisor, Toomas Orro for helping me with the statistical analysis and formatting this paper. Your notes on the paper have been very helpful. I am also grateful for all the lectures you have given in the past 6 years and for keeping up the student's rights on the University.

I also want to thank my better half, my lovely husband Wouter. You have been my absolute everything during our journey in Estonia. You did not only hold my hand and listen to me in the difficult times but most importantly, you celebrated success with me in the past 6 years. I also want to express my gratefulness for proof-reading my thesis. I know it was not one of the easiest things to do! You and our lovely pets have been my absolute rock through the process of writing this thesis and most importantly over these years to become veterinarian.

1. LITERATURE VIEW

1.1. Feeding interval affecting the time of birth

In the beef cattle industry, calves are one of the main outputs and carry a big economical value (Diskin and Kenny, 2016; Vinet *et al.*, 2018). Therefore, many beef cattle producers are eager to be present during the parturition in order to assist where needed and to avoid dystocia and potential mortality associated with it (Jaeger *et al.*, 2008). Increasing the likelihood of parturition during the day time would reduce the mortality rate associated with a lack of assistance during nightly hours (Jaeger *et al.*, 2008). Herdsmen being present during calving time can reduce the distress on the cow and calf (Jaeger *et al.*, 2008). Feeding once a day decreases the workload of the herdsmen as well.

The common believe amongst beef cattle farmers in Finland and other countries is that when beef cattle are fed once a day during the evenings, the likelihood of calving during the night time is decreased. Jaeger *et al.* (2008) also implicated on their research study that when cattle is provided feed in the evening, it may result in a smaller number of calves being born during the night hours. Controversially, Pennington and Albright (1985) concluded in their 2 year research study that there weren't significant effects on the calving time when dams were fed once a day during the late gestation period. It could be concluded that the feeding time per se may not influence the time of the calving in cattle so significantly but there can be other management or varying factors that may alter the distribution of parturitions (Pennington and Albright, 1985, Jaeger *et al.*, 2008).

Although the feeding interval may affect the time of the parturition in beef cattle to some extent, there are also other aspects that may alter it, such as rhythmic hormonal secretion, physical activity, the amount of light and the ambient temperature (Jaeger *et al.*, 2008). Pennington and Albright, 1985 observed that the higher low temperature on the day of calving seemed to affect the parturition time in dairy cattle. Jaeger *et al.* (2008) also

concluded in their research that the heifers appear to pattern their parturition time from their dams, therefore the parturition time might have in some extent genetic background.

1.2. Importance of optimal birth weight in beef calves

1.2.1. Cause of dystocia

For the beef industry it is important to produce calves which have a high mature weight and thus will be more productive (Hickson *et al.*, 2006). The issue is that the mature weight and the birth weight of calves are positively correlated and this desire produces high birth weights in calves (Eriksson *et al.*, 2004; Hickson *et al.*, 2006). When the birth weight increases remarkably over a certain level, it causes the incidence of difficult calvings to be higher (Eriksson *et al.*, 2004). The level of this threshold is dependent of the parity and the breed of the dam (Eriksson *et al.*, 2004).

Dystocia is a difficult or delayed parturition (Lombard *et al.*, 2007) which can result in the mortality of the calf, cow or both parties (De Amicis *et al.*, 2018). Dystocia can happen due to maternal or fetal reasons, but in 65.62% of the cases the dystocia is caused by a fetal origin (Purohit *et al.*, 2012). When dystocia is due to a fetal origin, the most common reason for dystocia is the increased size of the fetus (Purohit *et al.*, 2012). Fetal oversize can be caused by fetal death, emphysema and sex of the calf, but most importantly by an increased weight (Purohit *et al.*, 2012). Research has shown that the likelihood of dystocia increases with 13% for every additional kilogram of birth weight (Johanson and Berger, 2003) when weight was measured above the threshold. Nix *et al.* (1998) in contrast got result that calving difficulty score increase 0.23% for each increased birth weight kilogram. Due to this the birth weight can be used as an indicator trait for the avoidance of difficult calving's (Eriksson *et al.*, 2004).

Prevalence of dystocia in beef cattle is measured to be 4.4% (De Amicis *et al.*, 2018). Primiparous and second parity cows have significantly higher prevalence of dystocia when compared to multiparous cows (Purohit *et al.*, 2012; De Amicis *et al.*, 2018). Primiparous beef and dairy cows have an average of 11.0% prevalence in dystocia, while mature cows have a prevalence of only 3.5% (De Amicis *et al.*, 2018). Eriksson *et al.* (2004) got quite similar results, as they concluded that the first parity Hereford cows have 6.2% incidence of calving difficulty and the later parities only 1.2%. Heifers often have a smaller pelvic size and the fetus can be oversized compared to the birth canal, which can cause fetopelvic disproportion (Purohit *et al.*, 2012). This feto-maternal disproportion is a predominant reason for dystocia in first parity dams (Hickson *et al.*, 2006).

Difficult birth may cause trauma to the calf and the cow and in severe cases it can cause mortality of either or both parties (Johanson and Berger, 2003). The probability of death of the calf within 48 hours after the birth, with birth weights of 29, 35, 40, 46, and 52kg were 2.1, 2.5, 3.4, 5.1, and 9.6% respectively in Holstein cattle (Johanson and Berger, 2003). De Amicis *et al.* (2018) got results that the mortality rate for calves and cows in case of dystocia can be as high as 19.8% and 6.0% respectively. Therefore the birth weight is often lower with normal birth and mild traction, and higher in those births associated with heavy traction and Caesarean section (Nix *et al.*, 1998). Nix *et al.* (1998) instead got result that the mean birth weight of dead calves would be 36 ± 8 kg, while calves which were alive at 24 h after birth are 36 ± 6 kg. The optimal birth weight depends although on the breed (Nelson *et al.*, 2016). An oversized fetus doesn't only cause dystocia, but it can also cause uterine infection, reduce milk production, decrease fertility and can lead to additional veterinary costs (Johanson and Berger, 2003). Therefore the birth weight of the calves is not associated solely with dystocia but it can also be responsible for the increased production costs, and therefore it has an economical importance (Gutiérrez *et al.*, 2007; Chud *et al.*, 2014).

1.2.2. Low birth weight affecting liveability

The calf's birth weight needs to be properly balanced (Nelson *et al.*, 2016). When a calf is too big there is an increased risk of dystocia, and when the calf is too small it might not be healthy (Nelson *et al.*, 2016), as small calves may have reduced viability (Eriksson *et al.*, 2004). These calves can be the result of the shorter gestation length (Martinez *et al.*, 1983). Salehi *et al.* (2016) concluded that there is an increased risk of dystocia when the gestation length is short, <265 days. With this decreased gestation length the calf can be still slightly premature which causes them to be small and weak after the parturition (Martinez *et al.*, 1983). Therefore the mortality rate can be higher for the premature calves as well (Martinez *et al.*, 1983). In dairy cattle the low birth weight calves are more likely to be from primiparous dams or older dams with higher milk yields (Wathes *et al.*, 2008). A possible explanation for this is that the maternal growth or milk production is limiting the available nutrients for the fetal growth (Wathes *et al.*, 2008).

A low birth weight can be associated with poor vitality, increased occurrence of diseases and therefore higher mortality (Tudor, 1972; Vinet *et al.*, 2018). Low birth weight calves can also have a higher occurrence of early life diarrhoea (Vinet *et al.*, 2018). In mice it has been investigated that the offspring of undernourished dams have 27% lower birth weight than in the control group (Beauchamp *et al.*, 2015). This fetal undernourishment can cause decreased glucose tolerance and increased adiposity later in life (Beauchamp *et al.*, 2015). The study concluded that the undernutrition in utero is connected with metabolic diseases in the adulthood of mice (Beauchamp *et al.*, 2015). Calves with low birth weight are not able to produce high weaning weights compared to average weight calves (Eriksson *et al.*, 2004; Chud *et al.*, 2014). Calf liveability is therefore improving farm productivity (Vinet *et al.*, 2018).

1.3. Factors affecting birth weight of calves

1.3.1. Parity of the dam

Many researches have discussed the influence of dam's parity in calves birth weight. The age of the dam and birth weight of the calf doesn't only vary greatly between the breeds but also by analysis (Rumph and Van Vleck, 2004). Some study researches have shown that the birth weight of calves from primiparous cows were higher than in a case of multiparous cows calves (Nelson *et al.*, 2016). Nelson *et al.* (2016) concluded in their research that multiparous cows had 0.3-0.6 kg decrease in offspring's birth weight when compared to the heifers. They also discovered that if a dam at its first calving was older or 2.5 years old, the calf was estimated to be 0.5 kg lighter than the calf from heifers younger than 2.5 years (Nelson *et al.*, 2016).

However, some other researches have been getting reverse results. Heifers are not fully mature yet during their gestation period, and thus they require energy not just for gestation, maintenance and lactation but also for their own growth (Rumph and Van Vleck, 2004). Due to this the calves from primiparous cows are generally smaller at birth and during the weaning than calves from multiparous cows (Rumph and Van Vleck, 2004). Female calves born from second or third parity cows have 7-8% higher birth weight than calves born from heifers (Kertz *et al.*, 1997). Male calves have a similar pattern of increased birth weight with increased parity, but the increase is not that high in percentage compared to female calves (Kertz *et al.*, 1997). Other factors that can cause a smaller birth weight in calves from first-parity cows is that they usually have a shorter gestation length (Johanson and Berger, 2003). Although gestation length varies by the breed (Casas *et al.* 2012), in Holstein heifers gestation is measured to be 1.3 days shorter than in multiparous cows (Johanson and Berger, 2003). Belgium Blue primiparous cows also have 10 days shorter gestation length compared to cows with three or more parturitions (Fiems and Ampe, 2015). In the same research it was concluded that heifers generally have a shorter gestation period than multiparous cows (Fiems and Ampe, 2015). Birth weight increases on average 0.15-0.38 kg per each gestation day, and as a result the calves with longer gestation also have increased weight (Crews, 2006; Hickson *et al.*, 2006).

1.3.2. Maternal nutrition

Maternal nutrition is not only important for the cow's maintenance of the energy balance during gestation but it also has a critical role in the fetal growth and development (Radunz *et al.*, 2012). It has been proven that late gestation diets of dams can alter the fetal growth and birth weight, and may even affect a long-term body composition of calves (Radunz *et al.*, 2012). It would be beneficial to regulate and restrict the dam's feed intake during a late pregnancy to decrease the average birth weight of calves, without impairing postnatal growth of the calf or affecting the rebreeding performances of the dam (Prior and Laster, 1979). Many studies have been performed to investigate a different diet's impact to the calves' birth weight and dam's performance.

Nutrient demand grows rapidly during gestation due to the growing fetus, mammary gland regeneration and colostrumogenesis for lactation (Diskin and Kenny, 2016). Fetal growth is altered by glucose supply to the fetus which is determined by placental blood flow and maternal glucose concentration (Baumann *et al.*, 2002), thus birth weight is greater for calves born from cows fed excessive dietary energy (Wilson, 2015). Glucose levels in maternal blood are regulated by insulin which can be stimulated by propionate, glucose and amino acids in ruminants (Harmon, 1992). Different feeding is expected to alter insulin levels in cattle and therefore effecting the fetal growth and calf's birth weight (Kawashima *et al.*, 2016). Insulin resistance has been recorded to happen in dairy cattle (Kawashima *et al.*, 2016) but has not been well documented in beef cattle (Radunz *et al.*, 2012). Cows with insulin resistance have a lower body condition and glucose concentration before calving, and after parturition they have lower milk yield and earlier resumption of luteal activity (Kawashima *et al.*, 2016). Cows suffering from insulin resistance produce calves with lower birth weight, decreased plasma insulin-like growth factor 1 concentration and higher plasma insulin concentration (Kawashima *et al.*, 2016) which can result into a compromised glucose regulation at the calf's early life (Maresca *et al.*, 2018). Controversially, in some other researches it has been concluded that the dam's nutrition during gestation doesn't affect calf's serum insulin concentration after the birth (Radunz *et al.*, 2012; Maresca *et al.*, 2018).

Many studies have been conducted to find out how the difference in prepartum protein levels affect the dam and the calf. When dams are fed high protein diet during gestation their

progeny tends to be heavier at birth than the calves from dams with low protein diet ($p = 0.06$) (Maresca *et al.*, 2018). This could be explained with calves from high protein dams having increased insulin-like growth factor 1 concentration which may be associated with increased body mass index at birth (Maresca *et al.*, 2018). High amounts of amino acids from high crude protein diets in dams may be one of the factors causing greater plasma insulin concentration in dams when given certain diet such as dried distiller grains (Radunz *et al.*, 2010; Radunz *et al.*, 2012). This high insulin level in dams can cause calves to have higher birth weight (Radunz *et al.*, 2012). High protein level during prepartum time tends to increase the body weight and body condition score of the dam, without having negative consequences on the reproductive performance, milk yield and quality (López Valiente *et al.*, 2018). Controversial results have been obtained in this subject. Some of the studies have concluded that the higher protein intake in prepartum time doesn't affect serum insulin concentration in dams when compared to cows with lower protein intake (López Valiente *et al.*, 2018). In the same research it was found out that cows with low and high protein intake didn't have changed serum insulin-like growth factor 1 concentration (López Valiente *et al.*, 2018). Besides of the controversy results of the different studies, Radunz *et al.* (2010) concluded that excess crude protein intake is not the only plausible explanation for the differences in calves birth weights, but can explain the differences in certain dietaries.

Cows can be supplemented with for example oilseed or sunflower to increase the fat content of the diet during their last trimester of gestation with the aim to improve the dam's ovarian function and reproductive performance after the parturition (Bellows *et al.*, 2001; Salehi *et al.*, 2016). Salehi *et al.* (2016) concluded in their research that when dams were given supplemental oilseed during gestation, their progeny were heavier at birth and the gestation lasted longer than without the supplementation. In their study the gestation lasted 3 to 4 days longer than the average length, which they concluded to be controversial compared to other studies performed in the veterinary medicine field (Salehi *et al.*, 2016). Calf birth weight was also significantly influenced ($p = 0.02$) by the interaction between sex and the oilseed supplementation diet, as female calves were 5 kg heavier in cows that received supplement during prepartum period (Salehi *et al.*, 2016). Controversially, other studies have concluded that supplemental fat during gestation does not affect the calves' birth weight significantly (Bellows *et al.*, 2001; Petit and Berthiaume, 2006). In conclusion, prepartum fat supplementation causes decreased milk yield, decreased dry matter intake, increased or no

affect in calves birth weight without significantly improving ovarian function or reproductive performance of the dam (Bellows *et al.*, 2001; Salehi *et al.*, 2016).

When cows are given more energy by feeding high-concentrate diets, they also have more energy to be shared with the fetus instead of only maintaining the maternal tissues (Radunz *et al.*, 2012), and thus the birth weight of the calves is higher (Wilson, 2015). When underfeeding cows in attempt to limit birth weight it also results in compromised performance of the dam in early lactation (Hickson *et al.*, 2006). Underfeeding cows in attempt to avoid dystocia is not beneficial as the incidence of dystocia doesn't decrease and thus it is indicated to use alternative methods to reduce occurrence of dystocia (Hickson *et al.*, 2006). Cows can be fed as little as 70% of their total feed intake during gestation, without affecting the calf's birth weight (Shell *et al.*, 1995). If the calves are having prenatal undernutrition, it can cause inappropriate pancreas development which can lead to decreased insulin-like growth factor 1 concentration in early life (Maresca *et al.*, 2018). Because not all nutritional parameters affecting calves' birth weight are absolutely determined, it can be concluded that the changes in maternal metabolism affects the energy portioning of nutrients to the fetus and fetal growth (Radunz *et al.*, 2010).

1.3.3. Genetics

Birth weight of calves is to some extent inheritable (Purohit *et al.*, 2012). Selecting a bull with a low birth weight is a good way to decrease the calves' birth weight (Purohit *et al.*, 2012). However, it can affect the subsequent growth rates at weaning age as a birth weight is positively correlated to the growth rate (Eriksson *et al.*, 2004). Effects of the sire breed and their different genes for the birth weight is significant (Casas *et al.*, 2012). This can be illustrated as a variation of average birth weights of calves born from different breed sires, for example Angus calves are on average heavier (37.9 kg) than Wagyu calves (31.0 kg) (Casas *et al.*, 2012). Based on the heterosis, crossbred calves are on average heavier than purebred ones (Casas *et al.*, 2012). There is a genetic correlation between birth weight and gestation length, even up to 0.52 (Crews, 2006). The gestation length affects the birth weight

as the birth weight increases 0.15-0.38 kg by each gestation day (Crews, 2006) which can cause increased incidence of dystocia (Nix *et al.*, 1998).

Direct heritability of birth weight varies from moderate to high (Eriksson *et al.*, 2004). In Herefords and Charolais direct heritability varies for birth weight from 0.44 to 0.51 (Eriksson *et al.*, 2004). These results are similar for the first and later parities (Eriksson *et al.*, 2004). Other research studies have been getting similar results. Gutiérrez *et al.* (2007) discovered in their research about beef cattle that the direct heritability for the birth weight would be 0.390 ± 0.030 . Chud *et al.* (2014) got a lower value of 0.25 ± 0.02 whereas Mujibi and Crews (2009) got a higher value of 0.46 ± 0.03 . The genetic correlation between birth weight and calving difficulty is positive and moderate to high in magnitude (Ahlberg *et al.*, 2016). This means that when the birth weight of the calf increases, the calving difficulty score also increases (Ahlberg *et al.*, 2016). Birth weight can only explain approximately 41% of the genetic variation of calving difficulties, suggesting that the birth weight is only an indicator trait, and doesn't explain all the relevant genetic variations (Ahlberg *et al.*, 2016). Due to this, selecting bulls to reduce the dystocia in their calves will only have a small effect on the calving difficulties which their daughters may experience in the future (Ahlberg *et al.*, 2016).

Maternal heritability varies quite a bit in a different research. One of the researches discovered that the maternal heritability of birth weight in Herefords and Charolais is 0.06 to 0.15 for the first and later parities (Eriksson *et al.*, 2004). Similar values have been found from the other studies, ranging from 0.05 until 0.21 (Gutiérrez *et al.*, 2007; Chud *et al.*, 2014; Vinet *et al.*, 2018). These maternal effects are less heritable (Ahlberg *et al.*, 2016). Maternal effects are factors that are regulated by the genotype and the permanent environment of the dam that affect the fetus (Hickson *et al.*, 2006). The variance of permanent environmental effects on dams is 5% or more of the total birth weight variance (Eriksson *et al.*, 2004). In case of dystocia these effects are for example the dam's genetic potential for pelvic area or the likelihood of feto-maternal disproportion (Hickson *et al.*, 2006).

1.3.4. Other factors

Sex of the calve is clearly one of the factors affecting the birth weight of the calf. Male calves tend to be in average 2.3-3 kg heavier in birth than female calves (Echternkamp, 1993; Eriksson *et al.*, 2004; Nelson *et al.*, 2016; Vinet *et al.*, 2018). Kertz *et al.* (1997) also discovered in their research that male calves mean birth weight was 8.5% more than that of female calves. This can be due to longer gestation time of a male calves, which is measured to be 1 to 1.26 days longer than in female calves (Crews, 2006; Purohit *et al.*, 2012). The higher birth weight causes the survival of male calves to be 95% when female calves have an average rate of 97% (Vinet *et al.*, 2018). Due to the increased birth weight of bull calves, they are also more likely ($p < 0.001$) to require assistance at birth which increases their risk of dystocia (Lombard *et al.*, 2007).

As previously discussed, the gestation length affects the calves' birth weight (Tudor, 1972). Male calves tend to be carried a few days longer regardless of parity of dam (Martinez *et al.*, 1983), and the first parity cows have 1 day shorter mean gestation length than multiparous cows (Martinez *et al.*, 1983). Therefore heifers' calves can have decreased birth weight (Fiems and Ampe, 2015). Tudor (1972) discovered that a 1 day increase in the gestation period results into approximately 0.2 kg increase in the birth weight. Reynolds *et al.* (1980) instead showed that each 1 day increase in gestation length increases the birth weight by an average 0.25-0.30 kg per day.

2. AIMS OF THE STUDY

This study was made to investigate the effects of feeding intervals in beef cattle during the late gestation period on calving and new-born calves. The specific aims of this study were:

1. To estimate the effects of feeding once or twice a day on the parturition time of spring calving beef cattle.
2. To evaluate the effects of feeding once a day, compared to feeding twice per day, on the calves' birth weight in spring calving beef cattle.

3. MATERIALS AND METHODS

3.1. Study design

3.1.1. Animals

This study was conducted based on the data collected from one farm over the years 2003 - 2017. The farm is in Southern Finland and has been breeding purebred Hereford beef cattle over 30 years. During the data collection, the number of dams in gestation have been increasing over the years. In 2003 the data was collected from 21 dams while in 2017 the number of participating dams was 65. Data available for the study depended on different years, based on how well the data was collected in each year. Most of the parturitions in this farm occurred during the spring time, on average starting on the March and lasting until end of the May. During the data collection the time of the birth was recorded. In this study the night time was considered to be 07:00 – 22:00. On the *Table 1*. it is demonstrated the number of parturitions which occurred during the years 2003 – 2017. The table illustrates the number of parturitions which occurred during each particular month and the number of parturitions during the day or night time.

Table 1. Illustrates the number of parturitions which occurred during each particular year. In the table, all of the parturitions are divided based on the month of the parturition and if the parturition occurred during the night time, 20:00 – 07:00, or during the day time, 07:00 – 20:00.

Year	No. of parturitions	Month of parturition					Time of parturition	
		January, February	March	April	May	Summer	20:00 - 07:00	07:00 - 22:00
2003	21	0	16	4	1	0	8	13
2004	23	0	14	7	1	1	6	17
2005	24	0	5	6	10	3	3	21
2006	20	0	2	8	10	0	6	14
2007	23	1	12	6	2	2	6	17
2008	30	0	20	7	1	2	11	19
2009	38	1	24	10	2	1	12	26
2010	47	0	29	16	2	0	16	31
2011	52	0	37	12	3	0	19	33
2012	57	1	47	6	2	1	19	38
2013	52	0	34	11	5	2	18	34
2014	57	1	36	16	3	1	15	42
2015	56	4	38	9	4	1	25	31
2016	64	3	42	19	0	0	18	46
2017	65	4	49	11	1	0	21	44

3.1.2. Feeding during the late gestation

During the years 2003 and 2011 the dams were fed twice a day dry hay with a good nutritional value. The feeding happened twice a day, usually around 09:00 and 16:00. Additionally, dams received selenium and vitamin additives 2 to 3 times weekly. No carbohydrate or fatty acid substitutes were added to the diet. The amount of feed given was estimated based on the amount of feed left on the feeding table, aiming to have an empty table by the next feeding time. During these years, the dams were able to walk freely in the

paddock. Since 2010, and during the day time, the dams have been outside on the pasture during the late gestation. High quality straw has been used as a bedding material during the gestation and calving period.

During the years 2012-2017 the feeding interval during the late gestation was changed. At the start of each year the feeding is changed from twice daily to once a day. The dams then receive high quality dry hay which is distributed in the evenings around 19:00-20:00 o'clock. The amount of feed distributed is estimated with the idea that it will all be consumed by the next morning. Timothy-grass straw is available throughout the day from circular feeder. As previously stated, dams only receive additionally selenium and vitamin additive 2-3 times a week. The bedding material used is straw.

The farm changed gradually to organic feeding in 2016-2017.

3.1.3. The logbook

The study material was collected from the farm's own logbook. No scientific study settings were done on the farm. The feeding changes has been performed by the farmers with their own views and visions.

The farm owners have collected information of the calving's in their own logbook. Information gathered included; dam, sire, calving date, calving time, weight of the calf, sex of the calf and details of the calving process. In the case parturition was not seen, a calf was dead upon the birth or died within the first week of life, this observation was written down in the logbook.

The recordings from the logbook were transferred into a Microsoft Excel table. By using the Finnish online database of the farm, www.minunmaatilani.fi, the dam and sire names were able to be changed to their identification number. In case the dam was inseminated, the sire was marked with identification number of 0001. If the calf was the result of an embryo transfer, the sire identification was marked as 0002. With the same program, the dam's offspring number could be marked for each year. The birth weight of the calves was measured within 24 hours after the birth.

The following observations were marked;

1. Birth date of calve
2. The time of calves' birth
3. Dam's identification number
4. The dam's number of offspring
5. Sire's identification number
6. The sex of the calve: 0 = female, 1 = male
7. Calves birth weight in kilograms
8. Liveness of the calve: 0 = alive, 1 = death within 24 hours, 2 = death during the first week of life
9. Assistance on calving: 0 = Easy, no help needed, 1 = a little assistance given, 2 = Difficult birth, assistance needed
10. Number of offspring: 0 = single calf, 1 = twin calf

3.2. Statistical analysis

The effect of feeding once or twice a day to the birth time of calves was analysed using a random logistic regression model. The calves' birth time during the day time (07:00-22:00) or during the night time (22:00-7:00) was the outcome variable and the dam was included as a random factor. The feeding schedule (once or twice a day), the categorized month of birth (January-February, March, April, May and summer months), the calves' gender (male or female), the number of siblings (single or twin) and the cows parturition category (1., 2., 3.-5. and ≥ 6 . parturition) were included as categorical explanatory variables and the calves birth weight was included as a continuous explanatory variable.

To compare the feeding interval (once or twice a day) with the birth weight of the calves, random regression model was used. The calves' birth weight was used as outcome variable and the dam was included as a random factor. The feeding schedule, the categorized month of birth, the calves' gender, the number of siblings, the cow's parturition category and the sire of the calf were included as categorical explanatory variables.

A stepwise backwards elimination procedure was used for the final models. Statistically significant level $p \leq 0.050$ was used.

For the statistical analysis, statistical software STATA 14.2 (Stata Corporation, TX, USA) was used. The table was created by Microsoft Word and the bar charts were created with software Meta-Chart.

4. RESULTS

The sample size for the statistical analysis was 629 parturitions. From these, 278 calving's occurred between the years 2003 and 2011, and 351 calving's occurred between the years 2012 and 2017. Not all of parturitions had all recordings stated above available and therefore the sample size varied for different analyses performed. The number of observations for which all the data were available was 542.

4.1. Influence of the feeding to time of the parturition

The relationship between feeding once a day during the evening hours and the calving time was evaluated. The hypothesis was that when the spring calving beef cattle were fed only once a day during the evening hours, it would be less likely for them to calf during the night time.

When dams are fed once a day in evening, the odds of giving birth during the night hours is OR 1.10 (95% CI 0.43-2.86) when compared with feeding twice a day ($p = 0.837$). The two different feedings were compared in the bar charts (Figure 1 and 2). In both feeding intervals, the parturitions are quite evenly distributed over the day without a clear division related to the feeding intervals.

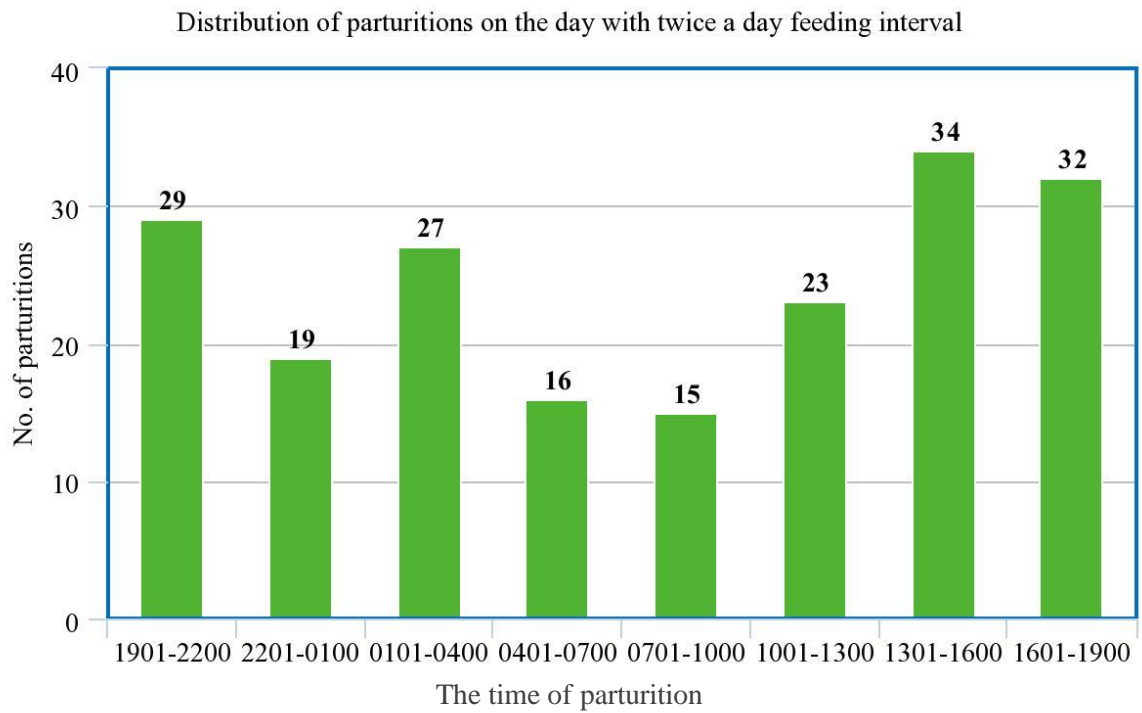


Figure 1. Distribution of the parturitions during the years 2003-2011 with feeding twice a day

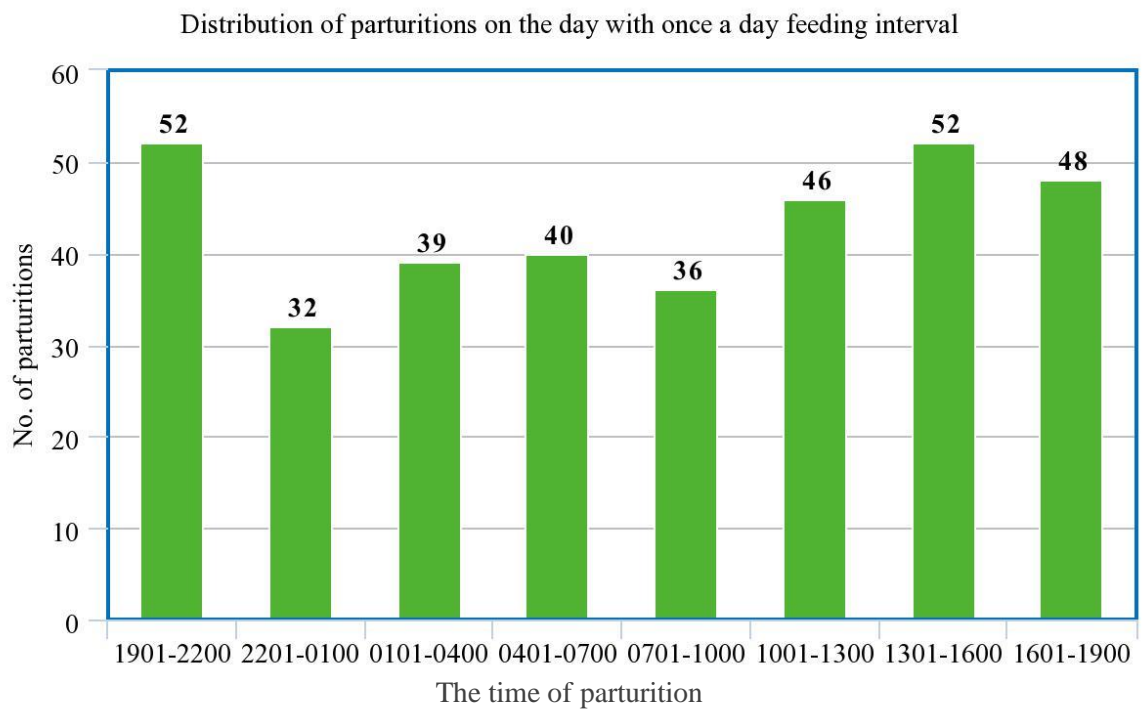


Figure 2. Distribution of the parturitions during the years 2012-2017 with feeding once a day

4.2. Factors affecting the birth weight

Different factors that can affect the birth weight of the calf were evaluated in the study. Once and twice a day feeding during the end of gestation period was evaluated on its influence on the birth weight. When dams received feed once a day their calves birth weight was smaller -2.77 kg compared to twice a day feeding ($p = 0.001$). Other factors affecting calves' birth weight were noticed as well, such as the parity of the dam and sex of the calf. The parameters were compared in Wald chi square test. In the statistical analysis the overall effects of the sires were considered ($p = 0.01$) but aren't displayed in the table (Table 1.).

Table 2. The results of random regression model to investigate factors associated with birth weight of calves. The data included 170 cows and 542 calves (1-10 calves per cow, mean 3.2 calves). The dam was included as random factor and the sire (n = 68) as fixed variable (data not shown). Wald-test p-value for overall sire effect was 0.009.

Variable	n	Coef.	SE	p-value	Wald test p-value
Feeding:					
Twice a day	198	0			
Once a day	344	-2.77	0.81	0.001	
Cow's parturition category:					<0.001
1. parturition	138	0			
2. parturition	101	3.97	0.79	<0.001	
3-5. parturition	196	5.40	0.74	<0.001	
≥6. parturition	107	5.11	0.87	<0.001	
Siblings:					
Single	519	0			
Twin	23	-10.89	1.38	<0.001	
Month of birth:					0.006
January-February	14	0			
March	368	2.79	1.49	0.061	
April	125	2.60	1.57	0.097	
May	27	1.39	1.83	0.447	
Summer	8	9.43	2.72	0.001	
Gender:					
Female	267	0			
Male	275	2.38	0.46	<0.001	
Intercept		37.40	1.71	<0.001	

5. DISCUSSION

5.1. Effects of the feeding intervals on the parturition

One of the aims of this study was to evaluate if feeding beef cattle during their late gestation time would affect the time of their calving. The hypothesis was that if dams are fed only once a day during the evening hours, they would spend more time eating, ruminating and being active during the night time rather than giving birth. This result would decrease the workload of the farmer and possibly decrease the mortality associated with dystocia due to better calving assistance during the day time (Jaeger *et al.*, 2008).

In the statistical analysis, it was concluded that the feeding interval affecting the time of birth was statistically insignificant. ($p = 0.837$). Other research studies had controversial results. Jaeger *et al.* (2008) concluded in their research that the number of calves born during the night may be smaller when dams are fed only during the evening. Pennington and Albright (1985) in other hand summarised the effect of the dams feeding on the parturition time to be insignificant. They also found a difference on the activity parameters of the cows on different feeding patterns. Cows which were fed during the night time were more active and lying less during the night time than the control group (Pennington and Albright, 1985). These results are in controversy on the earlier hypothesis stated above.

From the literature there is little indication about the feeding time affecting the time of the birth. The time of calving is not only dependent on the feeding interval of the dams but is effected by many other factors as well, such as temperature of the day, hormonal secretions, physical activity and the amount of light (Pennington and Albright, 1985, Jaeger *et al.*, 2008). Due to this, evaluating the effects of dams feeding habits on the parturition time is more challenging. Our study was conducted from data collected over a several years, comparing once a day during evening fed dams with control group from different years. Therefore, our study is more likely to have some biases such as different weather conditions during calving seasons. Another factor possibly affecting the results is the management

factors of the feeding. Evening fed dams received also a lower nutritional value feed throughout the day which could affect the amount of feed ingested during the evening feeding. More research would be needed to evaluate the significance of once a day feeding during the evening hours to the time of the parturition.

5.2. The relationship between once a day feeding of dams and decreasing the calves' birth weight

Another aim of this research study was to compare the effects of twice a day to once a day feeding of dams on the birth weight of the calf. Once a day feeding reduced the birth weight of the calves significantly. When dams were fed once a day during the late pregnancy, the birth weight of the calves was reduced. This decreased weight during the birth is important as dystocia due to high birth weight is one of the major factors causing mortality of the new born calves (Johanson and Berger, 2003). The weight of the calves in this study was not reduced so excessively that the mortality due to decreased liveability would have occurred.

Cows are mandatory ruminants and therefore they use on average 7 hours per day for rumination (Beauchemin, 2018). Lactating cows can use 2.4 to even up to 8.5 hours a day for eating (Beauchemin, 2018). When cows are fed twice a day they, they consume feed 10 minutes longer than when compared to once a day feeding intervals (Devries *et al.*, 2005). They also tend to spend more time eating after the delivery of the feed (Devries *et al.*, 2005). Although the feed is distributed only once a day, cows still tend to eat throughout the day (Devries *et al.*, 2005). As the cows feed many hours during the day and the feeding is distributed throughout, they require a longer access to the feed. Therefore, on this specific farm, from which the research study was conducted, they offered a lower-quality feed from the circular feeder for the dams throughout the day.

The heifers require energy during gestation more than multiparous cows as they need it for the fetal growth as well as for their own growth (Rumph and Van Vleck, 2004). Multiparous cows don't require as much energy, and therefore the birth weight will be greater for these calves born from cows fed excessive dietary energy (Wilson, 2015). In our research study the dams were fed a good quality feed once a day, and the feed offered during the other hours

was nutritionally lower, on purpose to avoid excessive dietary energy conducted by the dams. The purpose of this lower-quality feed was more for the mechanical fill of the rumen than for the nutritional value. In some other scientific researches cattle were not offered additional feed besides the single feeding during the evenings (Pennington and Albright, 1985, Jaeger *et al.*, 2008). Some of the reasons why this was not conducted in this specific farm is that the farmers wanted the dams to be able to fill their species-specific need of feeding and ruminating throughout the day. As mentioned above, cows tend to eat throughout the day and they can use even up to 19 hours a day for feeding and ruminating (Devries *et al.*, 2005, Beauchemin, 2018).

The birth weight of the calves is to some extent inheritable (Purohit *et al.*, 2012). In the beef cattle industry, breeding has been going towards the smaller birth weight and higher weaning weight (Eriksson *et al.*, 2004, Chud *et al.*, 2014). Similarly, on this farm the breeding selection has been favouring these characteristics of the dams and sires. In the statistical analysis the genetic effects of the sires and the dams on the birth weight of the calves were considered and therefore they should not influence our final results.

In the analysis we are comparing once a day to twice a day feeding of the cattle which occurred during different time periods. The data analysed in the study was collected between the years 2003 and 2011. During this time period there may be other changes next to the feeding that could affect the birth weight results. As we are comparing different years, there are possibilities that the quality of the feed has been changing over time. More research studies, in which feeding intervals are compared during the same time period and the same external factors, would be required.

5.3. Other factors affecting the birth weight of the calves

The effect of the dam's parity to the birth weight of the calf has controversial results in researches. Nelson *et al.* (2016) concluded that primiparous cows have higher birth weight calves than multiparous cows. Rumph and Van Vleck, (2004) instead concluded in their research that primiparous cows generally have smaller birth weight calves than multiparous cows. One of the reasons for this is that the heifers are not fully mature during their gestation

period and they might have a shorter gestation length when compared to multiparous cows (Johanson and Berger, 2003; Rumph and Van Vleck, 2004). Our analysis gave similar results to this. Dams on their second or higher parturition have higher birth weight calves than dams on their first parturition.

Male calves tend to be heavier at birth than female calves, on average 2.3-3 kilograms more than female calves (Echternkamp, 1993; Eriksson *et al.*, 2004; Nelson *et al.*, 2016; Vinet *et al.*, 2018). In our study the male calves were on average 2.38 kilograms heavier than the female calves.

6. CONCLUSIONS

These results suggest that feeding dams once a day during the evenings might not significantly alter the time of the calves' birth. Feedings dams once a day with their main feeding material may decrease the birth weight of the calves. To better understand the effects of the feeding interval on the time of birth and birth weight of the calves, more research is required.

REFERENCES

- Ahlberg, C. ., Kuehn, L. ., Thallman, R. ., Kachman, S. ., Snelling, W. . and Spangler, M. . (2016). Genetic Parameter Estimates and Breed Effects for Calving Difficulty and Birth Weight in a Multibreed Population. *American Society of Animal Science* 94, 1857–1864. doi: 10.2527/jas2015-0161.
- Baumann, M. U., Deborde, S. and Illsley, N. P. (2002). Placental glucose transfer and fetal growth. *Endocrine* 19, 13–22. doi: 10.1385/ENDO:19:1:13.
- Beauchamp, B., Ghosh, S., Dysart, M. W., Kanaan, G. N., Chu, A., Blais, A., Rajamanickam, K., Tsai, E. C., Patti, M. E. and Harper, M. E. (2015). Low birth weight is associated with adiposity, impaired skeletal muscle energetics and weight loss resistance in mice. *International Journal of Obesity* 39, 702–711. doi: 10.1038/ijo.2014.120.
- Beauchemin, K. A. (2018). Invited review : Current perspectives on eating and rumination activity in dairy cows 1. *Journal of Dairy Science* 1–23. doi: 10.3168/jds.2017-13706.
- Bellows, R. A., Grings, E. E., Simms, D. D., Geary, T. W. and Bergman, J. W. (2001). Effects of Feeding Supplemental Fat During Gestation to First-Calf Beef Heifers. *The Professional Animal Scientist* 17, 81–89. doi: 10.15232/S1080-7446(15)31602-8.
- Casas, E., Thallman, R. M. and Cundiff, L. V. (2012). Birth and weaning traits in crossbred cattle from Hereford, Angus, Norwegian red, Swedish red and white, Wagyu, and Friesian sires. *Journal of Animal Science* 90, 2916–2920. doi: 10.2527/jas.2011-4694.
- Chud, T. C. S., Caetano, S. L., Buzanskas, M. E., Grossi, D. A., Guidolin, D. G. F., Nascimento, G. B., Rosa, J. O., Lôbo, R. B. and Munari, D. P. (2014). Genetic analysis for gestation length, birth weight, weaning weight, and accumulated productivity in Nelore beef cattle. *Livestock Science* 170, 16–21. doi: 10.1016/j.livsci.2014.09.024.
- Crews, D. H. (2006). Age of dam and sex of calf adjustments and genetic parameters for gestation length in Charolais cattle. *Journal of Animal Science* 84, 25–31.
- De Amicis, I., Veronesi, M. C., Robbe, D., Gloria, A. and Carluccio, A. (2018). Prevalence, causes, resolution and consequences of bovine dystocia in Italy. *Theriogenology* 107, 104–108. doi: 10.1016/j.theriogenology.2017.11.001.

- Devries, T. J., Keyserlingk, M. A. G. Von and Beauchemin, K. A. (2005). Frequency of Feed Delivery Affects the Behavior of Lactating Dairy Cows. *Journal of Dairy Science* 88, 3553–3562. doi: 10.3168/jds.S0022-0302(05)73040-X.
- Diskin, M. G. and Kenny, D. A. (2016). Managing the reproductive performance of beef cows. *Theriogenology* 86, 379–387. doi: 10.1016/j.theriogenology.2016.04.052.
- Echternkamp, S. E. (1993). Relationship between placental development and calf birth weight in beef cattle. *Animal Reproduction Science* 32, 1–13. doi: 10.1016/0378-4320(93)90053-T.
- Eriksson, S., Näsholm, A., Johansson, K. and Philipsson, J. (2004). Genetic parameters for calving difficulty, stillbirth, and birth weight for Hereford and Charolais at first and later parities. *Journal of Animal Science* 82, 375–383. doi: 10.2527/2004.822375x.
- Fiems, L. O. and Ampe, B. (2015). Importance of dam BW change and calf birth weight in double-muscled Belgian Blue cattle and its relationship with parity and calving interval. *Animal* 9, 94–103. doi: 10.1017/S1751731114001864.
- Gutiérrez, J. P., Goyache, F., Fernández, I., Alvarez, I. and Royo, L. J. (2007). Genetic relationships among calving ease, calving interval, birth weight and weaning weight in the Asturiana de los Valles beef cattle breed. *Journal of Animal Science* 85, 69–75. doi: 10.2527/jas.2006-168.
- Harmon, D. L. (1992). Impact of nutrition on pancreatic exocrine and endocrine secretion in ruminants: a review. *Journal of animal science* 70, 1290–1301. doi: 10.2527/1992.7041290x.
- Hickson, Morris, Kenyon and Lopez-Villalobos (2006). Dystocia in beef heifers: A review of genetic and nutritional influences. *New Zealand Veterinary Journal* 54, 256–264. doi: 10.1080/00480169.2006.36708.
- Jaeger, J. R., Olson, K. C., DelCurto, T. and Qu, A. (2008). Case study: Pattern of Parturition as Affected by Time of Feeding and Prediction of the Time of Day that Parturition Will Occur in Spring-Calving Beef Cows. *The Professional Animal Scientist* 24, 247–253. doi: 10.1532/S1080-7446(15)30847-0.
- Johanson, J. M. and Berger, P. J. (2003). Birth Weight as a Predictor of Calving Ease and Perinatal Mortality in Holstein Cattle. *Journal of Dairy Science* 86, 3745–3755. doi: 10.3168/jds.S0022-0302(03)73981-2.
- Kawashima, C., Munakata, M., Shimizu, T., Miyamoto, A., Kida, K. and Matsui, M. (2016). Relationship between the degree of insulin resistance during late gestation and postpartum performance in dairy cows and factors that affect growth and metabolic status of their calves. *Journal of Veterinary Medical Science* 78, 739–745. doi: 10.1292/jvms.15-0583.

- Kertz, A. F., Reutzel, L. F., Barton, B. A. and Ely, R. L. (1997). Body Weight, Body Condition Score, and Wither Height of Prepartum Holstein Cows and Birth Weight and Sex of Calves by Parity: A Database and Summary. *Journal of Dairy Science* 80, 525–529. doi: 10.11622/smedj.2013080.
- Lombard, J. E., Garry, F. B., Tomlinson, S. M. and Garber, L. P. (2007). Impacts of Dystocia on Health and Survival of Dairy Calves. *Journal of Dairy Science* 90, 1751–1760. doi: 10.3168/jds.2006-295.
- López Valiente, S., Maresca, S., Rodríguez, A. M., Palladino, R. A., Lacau-Mengido, I. M., Long, N. M. and Quintans, G. (2018). Effect of protein restriction of Angus cows during late gestation: Subsequent reproductive performance and milk yield. *The Professional Animal Scientist* 34, 261–268. doi: 10.15232/pas.2017-01701.
- Maresca, S., Lopez Valiente, S., Rodriguez, A. M., Long, N. M., Pavan, E. and Quintans, G. (2018). Effect of protein restriction of bovine dams during late gestation on offspring postnatal growth, glucose-insulin metabolism and IGF-1 concentration. *Livestock Science* 212, 120–126. doi: 10.1016/j.livsci.2018.04.009.
- Martinez, M., Freeman, A. . and Berger, P. J. (1983). Factors Affecting Calf Livability for Holsteins. *Journal of Dairy Science* 66, 2400–2407. doi: 10.3168/jds.S0022-0302(83)82098-0.
- Nelson, S. T., Martin, A. D., Holmøy, I. H., Karlberg, K. and Nødtvedt, A. (2016). A cross-sectional study of factors associated with birth weights of Norwegian beef calves. *Preventive Veterinary Medicine* 125, 59–65. doi: 10.1016/j.prevetmed.2016.01.011.
- Nix, J. M., Spitzer, J. C., Grimes, L. W., Burns, G. L. and Plyler, B. B. (1998). A retrospective analysis of factors contributing to calf mortality and dystocia in beef cattle. *Theriogenology* 49, 1515–1523. doi: 10.1016/S0093-691X(98)00097-1.
- Pennington, J. A. and Albright, J. L. (1985). Effect of Feeding Time, Behavior, and Environmental Factors on the Time of Calving in Dairy Cattle. *Journal of Dairy Science* 68, 2746–2750. doi: 10.3168/jds.S0022-0302(85)81161-9.
- Petit, H. V. and Berthiaume, R. (2006). Effect of feeding different sources of fat during gestation and lactation on reproduction of beef cows and calf performance. *Canadian Journal of Animal Science* 86, 235–243. doi: 10.4141/A05-086.
- Prior, R. L. and Laster, D. B. (1979). Development of the bovine fetus. *Journal of Animal Science* 48, 1546–1553.
- Purohit, G. N., Kumar, P., Solanki, K., Shekher, C. and Yadav, S. P. (2012). Perspectives of fetal

- dystocia in cattle and buffalo. *Veterinary Science Development* 2, 31–42.
- Radunz, A. E., Fluharty, F. L., Day, M. L., Zerby, H. N. and Loerch, S. C. (2010). Prepartum dietary energy source fed to beef cows: I. Effects on pre- and postpartum cow performance. *Journal of Animal Science* 88, 2717–2728. doi: 10.2527/jas.2009-2744.
- Radunz, A. E., Fluharty, F. L., Relling, A. E., Felix, T. L., Shoup, L. M., Zerby, H. N. and Loerch, S. C. (2012). Prepartum dietary energy source fed to beef cows: Ii. effects on progeny postnatal growth, glucose tolerance, and carcass composition. *Journal of Animal Science* 90, 4962–4974. doi: 10.2527/jas.2012-5098.
- Reynolds, W. L., Derouen, T. M., Moin, S. and Koonce, K. L. (1980). Factors Influencing Gestation Length, Birth Weight and Calf Survival of Angus, Zebu and Zebu cross Beef Cattle. *Journal of animal science* 51, 860–867.
- Rumph, J. M. and Van Vleck, L. D. (2004). Age-of-dam adjustment factors for birth and weaning weight records of beef cattle: A review. *Genetics and Molecular Research* 3, 1–17.
- Salehi, R., Colazo, M. G., Oba, M. and Ambrose, D. J. (2016). Effects of prepartum diets supplemented with rolled oilseeds on calf birth weight, postpartum health, feed intake, milk yield, and reproductive performance of dairy cows. *Journal of Dairy Science* 99, 3584–3597. doi: 10.3168/jds.2015-10186.
- Shell, T. M., Early, R. J., Carpenter, J. R., Vincent, D. L. and Buckley, B. A. (1995). Prepartum nutrition and solar radiation in beef cattle: I. Relationships of body fluid compartments, packed cell volume, plasma urea nitrogen, and estrogens to prenatal development. *Journal of animal science* 73, 1289–1302. doi: 10.2527/1995.7351289x.
- Tudor, G. D. (1972). The effect of pre- and post-natal nutrition on the growth of beef cattle I. The effect of nutrition and parity of the dam on calf birth weight. *Australian Journal of Agricultural Research* 23, 389–395. doi: 10.1071/AR9720389.
- Vinet, A., Leclerc, H., Marquis, F. and Phocas, F. (2018). Genetic analysis of calf health in charolais beef cattle. *Journal of Animal Science* 96, 1246–1258. doi: 10.1093/jas/sky043.
- Wathes, D. C., Brickell, J. S., Bourne, N. E., Swali, A. and Cheng, Z. (2008). Factors influencing heifer survival and fertility on commercial dairy farms. *Animal* 2, 1135–1143. doi: 10.1017/S1751731108002322.
- Wilson, T. B. (2015). Influence of prepartum nutrition on cow performance and subsequent calf performance, glucose tolerance, carcass characteristics, efficiency, and gene expression. *The degree of doctor of philosophy in Animal Sciences in the Graduate Collage, University of Illinois* 1–246.

Appendix 1. Non-exclusive licence for depositing the final thesis and opening it for the public and the supervisor's (supervisors') confirmation for allowing the thesis for the defence

Hereby I, **Kia Emilia Moisander**
08/09/93

1. grant Eesti Maaülikool, the Estonian University of Life Sciences, a free-of-charge non-exclusive licence to store the final thesis titled **Feeding interval affecting calves' birth time and weight in spring-calving beef cattle**, supervised by Toomas Orro for
 - 1.1.preservation;
 - 1.2.depositing a digital copy of the thesis in the archive of DSpace and
 - 1.3.opening it for the public on the Webuntil the validity of the term of protection of copyright.
2. I am aware that the author retains the same rights as listed in point 1;
3. I confirm that by being issued the CC licence no rights deriving from the Personal Data Protection Act and the Intellectual Property Rights Act have been infringed.


Author of the final thesis

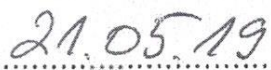

signature

In Tartu, **21.05.2019**

The core supervisor's approval for the final thesis to be allowed for defence

This is to confirm that the final thesis is allowed for defence.


Supervisor's name and signature


Date