Norwegian University of Life Sciences
Faculty of Biosciences
Department of Animal and Aquacultural Sciences

Philosophiae Doctor (PhD)
Thesis 2023:78

Cow-calf contact in dairy farming - Norwegian cow-calf contact (CCC) farmers' practice and perceptions, and effects of CCC on behavior and performance on pasture

Ku-kalv-kontakt i melkeproduksjon – Norske ku-kalv kontakt (CCC)-bønders praksis og oppfatninger, og effekter av CCC på atferd og ytelse på beite

Juni Rosann Engelien Johanssen

Cow-calf contact in dairy farming

- Norwegian cow-calf contact (CCC) farmers' practice and perceptions, and effects of CCC on behavior and performance on pasture

Ku-kalv-kontakt i melkeproduksjon

– Norske ku-kalv-kontakt (CCC)-bønders praksis og oppfatninger, og effekter av CCC på atferd og ytelse på beite

Philosophiae Doctor (PhD) Thesis

Juni Rosann Engelien Johanssen

Norwegian University of Life Sciences
Faculty of Biosciences
Department of Animal and Aquacultural Sciences

Ås 2023

Thesis number 2023:78
ISSN 1894-6402
ISBN 978-82-575-2110-3

Supervisors and Evaluation Committee

Supervisors:

Knut Egil Bøe
Department of Animal and Aquacultural Sciences
Norwegian University of Life Sciences
P.O. Box 5003, 1432 Ås, Norway

Julie Føske Johnsen
Department of Terrestrial Animal Health and Welfare
Norwegian Veterinary Institute
Pb 64, N-1431 Ås, Norway

Evaluation Committee:

Lena Lidfors
Department of Animal Environment and Health
Swedish University of Agricultural Sciences
P.O. Box 234, 53223, Skara, Sweden

Emma Matilda Ternman
Faculty of Biosciences and Aquaculture
Nord University
Postboks 2501, 7729 Steinkjer

Committee coordinator:

Inger Lise Andersen
Department of Animal and Aquacultural Sciences
Norwegian University of Life Sciences
P.O. Box 5003, 1432 Ås, Norway

Acknowledgements

The following projects funded and made this thesis's studies possible: The SUCCEED project (2020-2023), funded by the Agriculture and Food Industry Research Funds (FFL/JA) (project number 310728, Norwegian Research Council), the project "Kalvelykke" (Norw.: calf happiness) (2019-2022), funded by the Regional Research Fund Mid-Norway, and the project "Dairy cows and calves together on pasture" (2020-2021): Funded by the Norwegian Animal Protection Alliance's Research Fund.

First, I would like to thank my main supervisor Knut Egil Bøe, my co-supervisor Julie Føske Johnsen, and my "extra" supervisors Kristin Sørheim, Steffen Adler, and Mette Vaarst. Thank you for all the meetings, all your feedback, and all the support you have provided me throughout the whole process of the PhD. My sincere gratitude goes to Gunn-Turid Kvam and Brit Logstein, thank you so much for the collaboration. Then, a big thank you to all the 17 dairy farmers whom we had the honor of interviewing about their CCC systems. A special thank you to the farmers at Bergtun Gård, Julie and Christopher, who let us carry out the study with cows and calves on their farm and summer pasture, and helped us throughout the pasture study. I am so grateful to all of you farmers, this PhD would not have been anything without you. A big thanks to all the others who helped us carry out the pasture study, including family of the farmers: Jan Ivar and Håvard, colleagues from NORSØK: Peggy Haugnes, Martha Ebbesvik, Turid Strøm, Tor Kalseth, Sara Hansdotter, and Anne de Boer from NIBIO and Liliam Lambret who came all the way as a veterinary student from France to work in our study. Even though I have had four courses in statistics during my student years, including one during my PhD, I am still struggling with understanding statistics, and I would not have been able to analyze the results from the pasture study without all the valuable help I got from Torfinn Torp. Thank you so much, Torfinn, for always helping me with the statistics when I had questions. I also want to thank all the industry partners and research institutions in the SUCCEED project for your engagement in the project. Thanks to NORSØK and other colleagues at Tingvoll Farm, the ethology group at NMBU, and especially the other PhD students, and of course my family and friends for always being there, and last but not least, my two best friends; my Poodle Sonja and my Silken Windhound Eira.

Table of Contents

1 Definitions

Term	Definition
CCC	Cow-calf contact: *“Any physical contact and behavioral interaction between a dam and her own calf or a foster cow and her foster calf”* (Sirovnik et al., 2020)
CCC system	“*Any housing or management where calves have contact to either the dam or a foster cow; cow-calf pairs either bond with or tolerate each other; they may or may not be able to suckle/nurse*” (Sirovnik et al., 2020)
Full CCC	*“Unrestricted CCC between a cow and her calf/foster calves is allowed; i.e. both suckling/nursing and affiliative interactions without any hindrance”* (Sirovnik et al., 2020)
Partial CCC	“*Limited CCC between a cow and her calf/foster calves, for instance, fence-line contact and/or prevention of suckling with a nose-flap or an udder net; in terms of daily duration of contact it can be whole-day or part-time*” (Sirovnik et al., 2020)
Whole-day CCC	*“The cow and the calf are managed together with CCC for almost 24 hours daily with a possible exception of being temporarily separated during milking and feeding and with a possibility to retreat”* (Sirovnik et al., 2020)
Part-time CCC	*“The cow and the calf are managed with CCC during specific periods of the day only, that is when temporary cow-calf separation exceeds milking and feeding times”* (Sirovnik et al., 2020)
AMS	Automatic milking system
NRF	Norwegian Red (cattle breed)

Artificial rearing	*"Calves are separated from the dam in the first days after calving and have no physical contact to the dam or foster cow"* (Sirovnik et al., 2020)
Machine milk yield	Milk delivered from the cow at milking
Calf hide	In this study a calf hide on pasture consisted of a hutch with straw bedding and an outdoor area surrounded by a steel fence.
Udder net	Net covering the cows' teats to prevent the calf from suckling
Fence-line contact	Limited amount of physical contact is allowed through a fence-line
CC	The cow-calf contact treatment in this thesis's pasture study
ES	The early separation treatment in this thesis's pasture study

2 List of papers

The thesis is based on the papers listed below.

Paper I: **Juni Rosann Engelien Johanssen,** Gunn-Turid Kvam, Brit Logstein & Mette Vaarst, 2023. **Interrelationships between cow, calf, and human in cow-calf contact systems–An interview study among Norwegian dairy farmers**. *Journal of Dairy Science, https://doi.org/10.3168/jds.2022-22999*

Paper II: **Juni Rosann Engelien Johanssen,** Julie Føske Johnsen, Kristin Sørheim, Knut Egil Bøe, 2023**. A pilot study of the behavior of dairy calves with or without their dams on pasture.** *Resubmitted to Applied Animal Behavior Science* (September 2023)

Paper III: **Juni Rosann Engelien Johanssen,** Steffen Adler, Julie Føske Johnsen, Kristin Sørheim & Knut Egil Bøe, 2023. **Performance in dairy cows and calves with or without cow-calf contact on pasture – A pilot study**. *Submitted to Livestock Science* (November 2023).

3 Abstract

The separation of cow and calf within the first day after calving is common practice in dairy farming, but cow-calf contact (CCC) systems are receiving increased attention from different stakeholders. This interest is driven by consumers' increasing concerns about animal welfare, and their desire for more ethical and natural rearing of animals. Surveys have shown that many consumers prefer to see cows together with their calves, and that cattle have access to pasture.

At the outset of this PhD work in 2020, existing research on the experiences and perceptions of farmers regarding CCC systems was limited. Additionally, there was a lack of knowledge about keeping dairy cows and their calves together on pasture. The main aim of this thesis was to gain knowledge about how Norwegian dairy farmers practice and perceive their CCC systems and about the effects of CCC on calf behavior and cow-calf performance on pasture. To accomplish the study's main aim, three specific objectives were defined. The first objective involved exploring how Norwegian dairy farmers with CCC systems practice these systems, along with how they experience and perceive the interrelationships between cows and calves and humans within these systems (Paper I). This objective was achieved through interviews with 17 Norwegian farmers (from 12 dairy farms) who practiced CCC systems where the calves remained with their dams for at least four weeks.

The second objective aimed to compare the behavior of pastured dairy calves with or without their dams by examining their calf hide usage, lying behavior, grazing, playing, allogrooming between calves, and by describing their behavior in a food neophobia test. It also aimed to describe the calves suckling or sucking milk, allogrooming between cow and calf, and calf vocalizations post-weaning (Paper II). The third objective aimed to evaluate performance in pastured dairy cows and calves with or without CCC through cow machine milk yield and composition, and calf daily body weight gain. Additionally, it aimed to study cow body weight and condition, calf intake of concentrates, artificially reared calves' milk intake, and cow and calf health (Paper III). For the second and third objectives, a pasture study was conducted with 20 cow-calf pairs allocated to two treatments with two groups per treatment: Cow-calf contact (CC, n=10 pairs) and early separation (ES, n=10 pairs).

The interviewed farmers had diverse practices and perceptions regarding CCC systems. All of them practiced CCC in the indoor cow areas, and seven of the farms also practiced CCC on pasture. The duration of CCC ranged from 6-8 weeks to 4 months, and the duration of full CCC from 2 days to 3 months. On 10 of the farms, calves were allowed to suckle throughout the milk feeding period, whereas the remaining two farms continued to provide milk to calves after separation from their dams. Generally, the cows were perceived as being good mothers. When the farmers had developed good relationships with the cows so that cows and farmers felt safe around each other, they could develop good relationships with the calves as well. According to the farmers, the calves learned from the cows, e.g., feeding behavior and how to be a cow in their environment. Animal welfare was important to the interviewed farmers, and they enjoyed practicing these systems (Paper I).

In the pasture study, calf behavior was influenced by CCC. CC calves spent less time using a calf hide compared to ES calves (mean across weeks 3, 6 and 9: 12.8 vs 56.2 %), but the differences were dependent on age for the other behaviors (Paper II). The lower machine milk yield in CC cows compared to ES cows (weeks 0-6: 10.8 vs 34.5 kg/cow/day) persisted at least till weeks 10-11 postpartum when CC cows nursed until week 8 (weeks 10-11: 23.7 vs 32.0 kg/cow/day). Inhibited milk ejection was a challenge during milking of CC cows. The challenge was prominent with primiparous cows, as well as during weaning and separation from their calves. The mean fat content in machine milk was lower in CC cows compared to ES cows, although not significantly (week 5: 2.6 vs 3.3 %). Lactose content was significantly lower in machine milk from CC cows than ES cows (4.5 vs 4.9 %). Post-treatment, composition of machine milk became similar in both treatments (Paper III).

The interviewed farmers expressed that higher weight gain and improved health in their calves were among the main benefits of CCC systems. However, in the pasture study, artificially reared calves were fed milk close to ad libitum, and no difference was found between treatments in terms of calf weight gain during any of the examined periods (weeks 0-6, CC: 1.34 vs ES: 1.25 kg/calf/day, weeks 6-9: 1.05 vs 0.92 kg/calf/day, week 9 to 6-7 months: 1.06 vs 1.16 kg/calf/day). Similarly, there were no notable differences in calf health across treatments.

Further research is necessary to enhance milk ejection during milking of dairy cows rearing their calves on pasture and to minimize stress associated with weaning and separation of pastured cows and calves.

4 Norsk sammendrag

Det å skille ku og kalv innen første døgnet etter kalving er fortsatt vanlig praksis i melkeproduksjon, men det er økende interesse for ku-kalv-kontakt (CCC) systemer fra ulike aktører. Denne interessen påvirkes av at forbrukere er mer opptatt av dyrevelferd, og deres ønske om at dyra skal holdes på en måte som er mer etisk og naturlig. Undersøkelser viser at mange forbrukere ønsker at ku og kalv skal være sammen, og at storfe har tilgang til beite.

Da dette PhD-arbeidet startet i 2020 var forskningen angående bønders erfaringer og oppfatninger om CCC-systemer begrenset. I tillegg var det mangel på kunnskap om det å ha melkeku og kalv sammen på beite. Hovedmålet med denne studien var å få ny kunnskap om hvordan norske melkeprodusenter praktiserer og oppfatter sine CCC-systemer og om effektene av CCC på kalvers atferd, samt ytelse hos melkeku og kalv på beite. For å svare på hovedmålet, ble det definert tre delmål. Det første delmålet var å undersøke hvordan norske melkebønder med CCC-systemer praktiserte disse systemene og hvordan de erfarte og oppfattet forholdene mellom kyr og kalver og mennesker innen disse systemene (artikkel I). For å nå dette delmålet ble det gjennomført intervjuer med 17 norske bønder fra 12 gårder som hadde ku og kalv sammen hvor kalvene var sammen med sine egne mødre i minst fire uker.

Det andre delmålet var å sammenligne atferd hos kalver med eller uten mødrene sine på beite, ved deres bruk av kalvehytte, liggeatferd, beiting, lek, stell mellom kalver, og beskrive deres atferd i en test med ukjent fôr. Målet var også å beskrive kalvenes diing eller drikking av melk, stell mellom ku og kalv, og kalvens vokaliseringer etter avvenning (artikkel II). Det tredje delmålet var å sammenligne ytelse hos melkekyr og kalver med og uten CCC på beite gjennom maskinmelket ytelse og sammensetning, og kalvers daglige tilvekst. I tillegg var det tredje delmålet å beskrive kyrs kroppsvekt og hold, kalvers inntak av kraftfôr, inntak av melk hos ikke-diende kalver, samt helse hos ku og kalv (artikkel III). For det andre og tredje delmålet ble det gjennomført en beitestudie hvor 20 ku-kalv-par var delt i to behandlinger med to grupper per behandling: Ku-kalv-kontakt (CC, n=10 par) og tidlig separasjon (ES, n=10 par).

De intervjuede bøndene praktiserte CCC forskjellig fra hverandre, og de hadde ulike, men også like oppfatninger om sine CCC-systemer. Alle praktiserte CCC på kyrnes områder i fjøset, og på 7 av disse gårdene praktiserte de også CCC på beite. Varigheten på CCC varierte fra 6-8 uker til 4 måneder, og varigheten på full CCC fra 2 dager til 3 måneder. På 10 av gårdene, fikk kalvene die hele melkefôringsperioden, mens på 2 gårder, fortsatte kalvene å få melk etter separasjon fra mødrene sine. Generelt ble kyrne ansett å være gode mødre. Etter at et godt bonde-ku-forhold var på plass, slik at de følte seg trygge rundt hverandre, kunne bøndene også utvikle gode forhold med kalvene. Ifølge bøndene lærte kalvene mye fra kyrne, dyrevelferd var viktig for de intervjuede bøndene, og de trivdes med å praktisere disse systemene (artikkel I).

I beitestudie ble kalvenes atferd påvirket av CCC. CC-kalver brukte mindre tid i kalvehytta sammenlignet med ES-kalver (gjennomsnitt over uke 3, 6 og 9: 12.8 vs 56.2%), men forskjellene var avhengig av alder for de andre atferdene (artikkel II). Den lavere maskinmelkede ytelsen hos CC-kyr sammenlignet med ES-kyr (uke 0-6: 10.8 vs 34.5 kg/ku/dag) vedvarte til minst uke 10-11 etter kalving (uke 10-11: 23.7 vs 32.0 kg/ku/dag), da CC-kyr ble diet til uke 8 (artikkel III). Dårlig nedgiing av melk var en utfordring ved melking av CC-kyr, og utfordringen var størst blant førstegangskalvere, samt under avvenning og separasjon fra kalvene. CC-kyr hadde i gjennomsnitt lavere fett-innhold i den leverte melka si sammenlignet med ES-kyr (uke 5: 2.6 vs 3.3%), men forskjellen var ikke signifikant. Innhold av laktose var signifikant lavere i maskinmelken til CC-kyr sammenlignet med ES-kyr (4.5 vs 4.9%). Etter behandlingene ble sammensetning av melka lik.

De intervjuede bøndene opplevde bedre tilvekst og helse hos kalvene sine blant de viktigste fordelene med CCC-systemer. Men i beitestudie ble kalvene holdt uten kyr fôret med nesten fri tilgang til melk, og det ble ikke funnet noen forskjell mellom behandlingene for kalvetilvekst i noen av de undersøkte periodene (uke 0-6, CC: 1.34 vs ES: 1.25 kg/kalv/dag, uke 6-9: 1.05 vs 0.92 kg/kalv/dag, uke 9 til 6-7 måneder: 1.06 vs 1.16 kg/kalv/dag). Det ble heller ikke funnet forskjeller i kalvehelse mellom behandlingene.

Videre forskning trengs for å forbedre nedgiing av melk ved melking av kyr som går med kalvene sine på beite, og for å minimere stress i forbindelse med avvenning og separasjon av kyr og kalver på beite.

5 Synopsis

5.1 Introduction

5.1.1 Separation of the dairy cow and calf – A contentious practice

5.1.1.1 Increased interest in animal welfare and cow-calf contact (CCC)

The practice of early cow-calf separation in dairy farming is a contentious practice (Ventura et al., 2013). Recently, increased attention has been given to CCC systems among different stakeholders, including consumers (Busch et al., 2017; Placzek et al., 2021) and farmers (Hansen et al., 2023; Vaarst et al., 2020). Consumers are becoming increasingly concerned with animal production practices (Boyle et al., 2022) and animal welfare (Bock and Buller, 2013). Animal welfare consists of three dimensions; namely, normal biological functioning, emotional state, and ability to express natural behavior (Fraser et al., 1997). When consumers think about what they perceive as the right practices related to animal welfare, they are particularly concerned about ensuring a natural environment for the animals (Clark et al., 2016; Prickett, 2008; Vanhonacker et al., 2008). Surveys from various countries show that many consumers are unaware of common animal husbandry practices, such as early separation of cow and calf after calving (review by Placzek et al., 2021). However, when informed about this practice, many consumers do not support early separation (Busch et al., 2017; Hötzel et al., 2017; Ventura et al., 2016, 2013). In a Canadian study, citizens did not perceive foster cow systems as better than rearing calves artificially, since they did not want calves to be separated from their dams (Sirovica et al., 2022). Moreover, many consumers favor systems that allow pasture access (Hötzel et al. 2017), and view pasture-based systems as more natural and beneficial for cattle welfare (Mee & Boyle 2020).

A recent survey by Hansen et al. (2023) showed that even though only 2.8 % of the surveyed Norwegian farmers (n=1038) practiced CCC, 15.3 % of the farmers wanted to have or planned to start implementing CCC. The increased interest generates need for more knowledge about CCC systems both indoors and on pasture.

5.1.1.2 Standard calf rearing practice

Standard calf rearing practice in the dairy industry after separation of cow and calf within the first day after calving is to place the calves in individual pens and feed them restricted milk amounts (reviews: Cantor et al., 2019; Costa et al., 2016, 2019; Miller-Cushon & Devries, 2015; Whalin et al., 2021). Not only the early cow-calf separation is a contentious practice, but also the individual housing and restricted milk feeding of calves. Individual housing is done to promote health by minimizing infection pressure (Cantor et al., 2019), and restricted milk amounts are applied, often in two-three meals per day (Costa et al., 2019), to encourage early consumption of solid feed and accelerate rumen development (Kertz et al., 2017; Khan et al., 2011). At the same time as interest and research in CCC systems are increasing, there has been a massive development of knowledge in artificial calf rearing practices. This includes comparisons of individual versus social rearing of young calves (as reviewed by Costa et al., 2016), as well as studies on varied milk feeding approaches for calves, examining different quantities and feeding methods such as using open buckets or artificial teats (reviews by Cantor et al., 2019; Miller-Cushon & Devries, 2015).

Social housing of calves has been associated with increased play behavior (Jensen et al., 2015; Tapki, 2007), the ability to perform allogrooming (Bøe and Færevik, 2003), enhanced social skills, cognitive development, and the calves' improved coping with novelty (Costa et al., 2016). Moreover, social housing leads to more time spent eating solid feed (De Paula Vieira et al., 2010; Overvest et al., 2018), and higher solid feed intakes, resulting in improved weight gains, compared to when calves are housed individually (Costa et al., 2015; De Paula Vieira et al., 2010; Tapki, 2007). Additionally, housing calves with older calves has been found to result in higher solid feed intakes and weight gains compared to housing them with calves of the same age (De Paula Vieira et al., 2012), which indicates that young calves learn more from being with older animals than with same-aged peers.

Calves given a large or ad libitum milk allowance have been observed to consume more milk and achieve higher weight gains compared to those on a restricted milk allowance (Appleby et al., 2001; De Paula Vieira et al., 2008; Jasper and Weary, 2002; Miller-Cushon et al., 2013; Shamay et al., 2005). However, increased milk intakes decrease intakes of solid feed (Rosenberger et al., 2017; Sweeney et al., 2010). While restrictively milk-fed calves consumed 4-6 L/calf/day, those fed large or ad libitum amounts were shown to consume 9-10 L/calf/day (Appleby et al., 2001; De Paula Vieira et al., 2010; Jasper and Weary, 2002), and in some studies, up to 14 L/calf/day (Miller-Cushon et al., 2013; Von Keyserlingk et al., 2004). A higher milk allowance has also been associated with increased play behavior (Duve et al., 2012; Jensen et al., 2015; Krachun et al., 2010), and allows calves to exhibit behavior more similar to natural suckling (Miller-Cushon and Devries, 2015). Providing more space for calves has also been linked to positive effects on play behavior (Jensen et al., 1998; Jensen and Kyhn, 2000; Mintline et al., 2012), and enables the expression of natural behaviors such as synchronized resting (Færevik et al., 2008). Additionally, gradual weaning has been found to reduce stress-related behaviors associated with weaning, such as vocalizations and increased activity (Budzynska and Weary, 2008).

From the mentioned research on calves, we thus know that it is beneficial for calves to be social, receive large amounts of milk, and have plenty of space. All these needs can be naturally met by allowing the calves to be together with and suckle their dams.

5.1.2 Dairy farming in Norway

Norwegian dairy cows are usually separated from their calves immediately or within a short time after calving (Hansen et al., 2023), as in other countries (Australia: Abuelo et al., 2019; Brazil: Hötzel et al., 2014; the US: Pempek et al., 2017). In Norway, the farms are typically small, and in 2023, dairy farms had an average of 31 dairy cows per farm (SSB, 2023). Of the total dairy cattle population, 91 % were Norwegian Red (NRF), a dual-purpose cattle bred to produce both meat and milk (Geno, 2020), 5 % were Holstein, 2 % were Jersey and 2 % were other dairy cattle breeds (Tine, 2023).

In 2022, half of the Norwegian dairy farmers used tiestall barns for their cows, while most others with freestall barns had automatic milking systems (AMS) (Tine, 2023). However, as freestall herds are generally larger, more than 70 % of all cows are housed in freestalls. Regulations state that all Norwegian dairy farms should have freestall barns by 2034, and that one should provide cattle with good opportunities for free movement, exercise, and natural behavior. Freestall cattle must spend at least 8 weeks on pasture during summer, whereas tiestall cattle must be pastured for at least 16 weeks. Keeping cows and calves together on pasture may be a viable option for dairy farmers in Norway, but more knowledge is needed on how CCC affects both cow and calf in this setting.

5.1.2.1 Calf management and feeding

Today's Norwegian regulations for keeping cattle, called "Forskrift om hold av storfe" (Lovdata FOR-2004-04-22-665, 2004), do not address CCC. It is allowed to keep calves in single pens for up to eight weeks postpartum. However, a Norwegian survey (508 farms) found that the median age for moving calves from single to group pens was two weeks (Johnsen et al., 2021). When it comes to milk feeding of calves, the regulations do not mention specific minimum milk amounts or weaning age, but state that: "*Calves should be given a sufficient amount of colostrum as soon as possible after birth and no later than within 6 hours*", and that "*Calves should be fed at least twice daily*" (Lovdata FOR-2004-04-22-665, 2004). In the survey by Johnsen et al. (2021), milk allowance for 3-week-old calves was found to range from 2 to 15 L/day, and 61 % of the farmers fed less than 8 L milk/day to young calves (Johnsen et al., 2021). For calf feeding in conventional farming, the Norwegian dairy cooperative Tine recommends as of 2021 7-11 L/milk/calf/day during the first weeks (Overrein et al., 2021). Additionally, it is recommended to provide milk through artificial teats to satisfy sucking needs and thus prevent abnormal sucking, and to wean calves after 7-9 weeks.

The organic regulations for cattle in Norway state that "*Calves should suckle for at least three days after birth", "With a shorter suckling period than one month, calves should drink from an artificial teat until they are one month old*" and that "*Calves should get natural milk for at least three months after birth*" (Mattilsynet, 2022). In the guidelines for organic agriculture, the Norwegian Food Safety Authority (Mattilsynet) has made special recommendations for how to minimize stress when cow and calf are separated after the suckling period. They suggest making the separation gradual through such methods as using an udder net, fence-lines, or a transition to part-time CCC, e.g., by suckling half day before separation (Mattilsynet, 2022). The organic regulations also state that the calves should be together with other calves, whenever possible, after the first week.

5.1.2.2 Animal welfare organizations' initiatives

Norwegian animal welfare organizations, such as the Norwegian Animal Protection Alliance promote CCC systems and use of pasture for cattle. Their Animal Protection Label states that dairy cattle should spend at least 16 weeks on pasture during the grazing season, and that cow and calf should stay together for at least half of the day for six weeks after calving (Dyrevernalliansen, 2019). As of 2023, only two dairy farms in Norway carry this label. No Norwegian milk is marketed as coming from

CCC systems, unlike in Denmark and Germany (Ayoub, 2022; Thise, 2023). Two other Norwegian welfare organizations called NOAH and Anima want to stop early separation of cow and calf after calving, a stance that is heightening consumer awareness on the issue (ANIMA, 2022; NOAH, 2023).

5.1.3 Calf and dam – Natural behavior

With the growing interest in promoting natural behaviors associated with keeping cows and calves together rather than early separation, it is essential to understand their behavior in a natural setting.

Cattle naturally live in herds (Bouissou et al., 2001), and a cow will typically leave the herd before calving (review by Rørvang et al., 2018). However, there is variation in whether they leave the herd or not and how far they go (Edwards, 1983; Edwards and Broom, 1982). Cattle have long been seen as a species whose calves are "hiders" (Lent, 1974). While cows graze, their calves lie still and hide in tall grass or bushes; this is mainly the way the calves are protected against predators during their first days (Lent, 1974). Some calves may choose to follow their dams earlier (Hall, 1989), depending on environmental circumstances and hiding opportunities (Vitale et al., 1986).

Immediately after calving, cow-calf communication begins through odor, vocalizations, and tactile stimulation as the dam sniffs and licks her newborn (Fleming et al., 1999; Okabe et al., 2012), establishing a bond within five minutes (Hudson and Mullord, 1977). The cow's calf-licking behaviour is most intense during the first 30 minutes (Lidfors & Jensen, 1988). Factors such as the cow's age (Le Neindre and D'Hour, 1989), breed, as well as the cow's own experience as a calf (Le Neindre, 1989) have been found to influence the variation of the dams licking of her calf. Lidfors & Jensen (1988) found that pastured calves attempted to stand after an average of 9.6 ± 6.5 (SD) minutes, successfully stood at 45.9 ± 38.2 minutes, and initiated their first suckling bout at 97.3 ± 44.2 minutes after birth.

Vitale et al. (1986) found calves' hiding behavior to be sustained until 3-4 days postpartum before the calves started following their dams, and gradually integrated with the herd. Cow-calf pairs spend progressively less time together as the calf becomes more independent (Hirata et al., 2003) and socializes more with other calves, where this socializing is peaking between 11-40 days of age (Vitale et al., 1986). Through social transmission from dams and other peers, calves are thought to learn feeding and grazing behavior (Cantor et al., 2019).

From birth until natural weaning, calves suckle between 4 and 10 times per day, with each bout lasting about 7 to 10 minutes (de Passillé, 2001). Suckling frequency decreases with age (Das et al., 2000; Reinhardt and Reinhardt, 1981). While one study found a tendency for the duration of suckling bouts to increase with age (Walker, 1962), another found similar durations regardless of age (Reinhardt and Reinhardt, 1981). During the first days when calves are hiding, cows usually initiate suckling (Lent, 1974). Afterwards, calves initiate most suckling (Vitale et al., 1986), while cows increasingly prevent or end suckling initiated by their calves (Lidfors et al., 1994). Natural weaning occurs between 7 and 14 months, often coinciding with the cow having a new calf (Reinhardt and Reinhardt, 1982).

5.1.4 CCC systems – Farmers' practices and perceptions

Previous surveys of on-farm calf management practice included data on the prevalence of CCC. In the US (n=727) and Brazil (n=242), surveys revealed that the majority of farmers separated cow and calf within 12 hours postpartum (Hötzel et al., 2014; Pempek et al., 2017). However, in the Brazilian survey, 11 % practiced CCC, including 8 % with foster cows and 3 % with dam-rearing systems (Hötzel et al., 2014). Two surveys targeting organic dairy farmers were conducted to assess compliance with organic regulations, which require calves to suckle for at least the first three days after birth. The first survey, involving 236 Norwegian farmers (Henriksen et al., 2009), and the second one, which included 133 Norwegian and Swedish farmers (Ellingsen-Dalskau et al., 2015), found that 25 % and 27 % of the farmers, respectively, practiced CCC beyond the initial three days. This practice was mainly used for the first 1-2 weeks, however a few farmers applied CCC throughout the entire 12-week milk feeding period, and some used foster cow systems. In a recent survey of 1038 Norwegian dairy farmers, according to which 2.8 % practiced CCC systems for at least two weeks, 213 farmers reported having tested but discontinued CCC (Hansen et al., 2023). Therefore, there is a compelling need to gain deeper insight into benefits, barriers, and challenges associated with CCC systems through qualitative studies.

Prior to the start of this PhD study, only a very limited number of interview studies had focused on CCC among farmers, though the number has increased in recent years. These interviews, conducted in various countries, reveal that CCC is practiced in a wealth of different systems by the farmers, including the use of foster cows or hybrid systems (Bertelsen and Vaarst, 2023; Eriksson et al., 2022; Lehmann et al., 2021), and that CCC durations can be as short as 7 days or 30 minutes per day (Eriksson et al., 2022). Farmers engaging in CCC have identified several benefits of this practice. On one hand these benefits are centered around the farmer: farmers enjoy practicing these systems (Hansen et al., 2023; Vaarst et al., 2020; Wagenaar and Langhout, 2006), some report reduced workload (Langhout, 2003), and some perceive CCC as a convenient method for milk feeding of calves (Henriksen, 2010). On the other hand, benefits for cow and calf are reported: the promotion of natural behavior (Bertelsen and Vaarst, 2023; Eriksson et al., 2022; Lehmann et al., 2021; Vaarst et al., 2020; Wagenaar and Langhout, 2006) that motivates a cow to be the mother of her calf (Lehmann et al., 2021). Farmers view CCC as being better for the animals than early separation (Henriksen, 2010), with increased activity for cows (Langhout, 2003). Farmers also experience calves learning from cows (Bertelsen and Vaarst, 2023; Lehmann et al., 2021; Vaarst et al., 2020, 2019; Wagenaar and Langhout, 2006), improved calf health (Eriksson et al., 2022; Hansen et al., 2023; Neave et al., 2022) and greater calf weight gain (Langhout, 2003; Wagenaar & Langhout, 2007), suggesting that CCC calves receive a good start and become more robust (Ellingsen-Dalskau et al., 2015).

Alongside the benefits, several barriers have been reported by farmers practicing early separation, and challenges have been perceived by CCC farmers themselves. Surveys show that an important reason to separate cow and calf early after birth, according to farmers practicing this system, is to reduce animal stress (Hötzel et al., 2014; Ventura et al., 2013). Similarly, both older (Ellingsen-Dalskau et al., 2015; Henriksen et al., 2009; Wagenaar & Langhout, 2006; Wagenaar & Langhout, 2007) and more recent studies (Berge & Langseth, 2022; Bertelsen & Vaarst, 2023; Churakov et al., 2023; Hansen et al., 2023; Lehmann et al., 2021; Neave et al., 2022; Vaarst et al., 2020) show that cow-calf stress after separation is perceived as one of the main challenges by the CCC farmers, irrespective of whether they practice CCC for a few days or for several weeks. Among the 213 farmers who had discontinued practicing CCC in the survey by Hansen et al. (2023), perceived animal stress was the most important reason for discontinuing. Other challenges with CCC include reduced machine milk yield (Hansen et al., 2023; Wagenaar and Langhout, 2007), inhibited milk ejection (Bertelsen and Vaarst, 2023; Ellingsen-Dalskau et al., 2015; Henriksen et al., 2009; Lehmann et al., 2021; Wagenaar and Langhout, 2006) and lower fat content in machine milk (Ellingsen-Dalskau et al., 2015).

Farmers practicing early separation might have concerns regarding dam-rearing that might not necessarily be perceived as challenging by CCC farmers. One such concern about CCC systems among farmers practicing early separation of cow and calf is the cows' aggressive behavior to protect their calves (Berge and Langseth, 2022; Neave et al., 2022), thus creating a more dangerous working environment, especially for employees (Neave et al., 2022). Another concern is that modern dairy breeds may not be suitable for taking good care of their calves, and that this can have detrimental effects on the calves if they do not get to suckle milk from their dams (Neave et al., 2022). Furthermore, if CCC calves have less human contact since they are not milk-fed by humans, they may become wilder and more difficult to handle (Lehmann et al., 2021; Neave et al., 2022; Vaarst et al., 2020), potentially leading to wilder heifers later on (Lehmann et al., 2021; Vaarst et al., 2019). While several CCC farmers have pointed out the importance of handling CCC calves so that they do not become "wild" (Bertelsen and Vaarst, 2023; Lehmann et al., 2021; Vaarst et al., 2020), others have not experienced any problems with this issue (Vaarst et al., 2019).

Most research and practice of CCC seems to occur indoors. However, building constraints, such as space allowance, might be perceived as a barrier and challenge with dam-rearing (Bertelsen & Vaarst, 2023; Hansen et al., 2023; Neave et al., 2022). Contrarily, some CCC farmers believe that pasture-based CCC allows cows and calves to exhibit more natural behavior and thus enhances the calves' learning process, including learning how to graze and respect fences (Vaarst et al., 2019). Yet, practicing CCC on pasture might be associated with challenges such as a need for additional fencing (Bertelsen and Vaarst, 2023) and calf shelters (Neave et al., 2022), increased labor (Vaarst et al., 2020) and more difficulties in taming calves (Vaarst et al., 2019).

In summary, CCC is practiced in a wide range of systems, and while some farmers see benefits with CCC, several barriers and challenges have also been reported. These include stress at later separation, building constraints, inhibited milk ejection, cows not being suitable mothers or wanting to protect their calves, handling of CCC calves when they are not milk-fed by the farmer, as well as specific challenges regarding CCC on pasture. Given these challenges, gaining deeper insights into how farmers practice and perceive CCC both indoors and on pasture becomes valuable. Despite this, there have been relatively few qualitative interview studies of CCC farmers. Earlier studies have not focused on farmers' experiences and perceptions of the interrelationships between cows, calves and humans within CCC systems, which is an important aspect when considering the above-mentioned challenges.

5.1.5 Behavior of dairy calves in CCC systems

Most research examining the impact of CCC on dairy calf behavior has been conducted indoors. Therefore, it is important to consider studies that have investigated calf behavior both indoors and on pasture, even though this thesis focuses on the pasture setting.

Recent indoor studies have found that suckling, grooming and time spent by cow and calf close to each other vary with the type of CCC system (full CCC vs part-time or partial CCC: Bertelsen, 2023; Johnsen et al., 2015; Wenker et al., 2021). Another indoor study observed a decline in suckling bouts (Fröberg and Lidfors, 2009) with increasing calf age. Similarly, older pasture studies also found that suckling bouts decreased with calf age (Hutchison et al., 1962; Lidfors & Jensen, 1988; Vitale et al., 1986). While Walker (1962) found a peak in suckling during morning, Vitale et al. (1986) found suckling peaks both during morning and evening. Recent research by Mac et al. (2023) supports these findings, showing the most suckling and cow-calf proximity in the first two weeks, followed by a decrease.

Research indicates that pastured cattle prefer to seek shelter or remain indoors under specific environmental conditions, like notably low (Sawalhah et al., 2016) or high (Van Laer et al., 2015) ambient temperatures, as well as during windy weather, particularly when combined with precipitation (Smid et al., 2019). However, the impact of CCC on the calves' utilization of a calf shelter remains unclear.

Indoor studies have shown differences in behaviors like lying and moving between CCC calves and artificially reared calves (Fröberg et al., 2007; Fröberg and Lidfors, 2009). Fröberg & Lidfors (2009) reported full CCC calves to be lying more than artificially reared calves, while artificially reared calves were more active. In another study, Fröberg et al. (2007) found increased activity in part-time CCC calves compared to their artificially reared counterparts. Indoors, artificially milk-fed calves usually spend most of their time lying, about 17-18 hours per day (Bonk et al., 2013; Duthie et al., 2021). Pastured Zebu calves with their dams showed less lying time, around 14-15 hours daily (Hutchison et al., 1962). These calves were lying less than their dams, but the time spent "moving" was similar between the calves and their dams during the first few months. Both with (Mac et al., 2023) and without

(Roy et al., 1955) their dams on pasture, calves begin grazing in their first week of life. Grazing behavior in CCC calves has been observed to be determined by their dams after the first month of life (Hutchison et al., 1962). Studies by Vitale et al. (1986) and Walker (1962) found cows and calves to be grazing together mostly during mornings and evenings. This social facilitation may lead to pastured calves spending less time lying down. Generally, calves reduce lying time (Kerr and Wood-Gush, 1987; Webster et al., 1985) and increase grazing with age (Chambers, 1959; Hutchison et al., 1962; Roy et al., 1955). Sinnott (2023) reported an increase in lying time with age across calves reared with full CCC, part-time CCC or no CCC, with no significant differences in lying time despite CCC calves being more active. Notably, in this study, only full CCC calves were on pasture. A recent study by Nicolao et al. (2020) focusing on grazing post-weaning, found calves with full CCC on pasture until weaning to show different grazing behavior compared to both CCC calves and artificially reared calves without previous pasture experience. The previous research indicates that calf behavior varies, depending on the type of rearing and environmental conditions. Given the scarcity of studies conducted on pasture, it is essential to observe behavior in dairy calves both with and without CCC under similar pasture conditions.

Food neophobia, i.e., the reluctance to taste unfamiliar foods (Cooke et al., 2006), can be an issue in animal husbandry if animals refuse novel feeds provided by the farmers (Villalba et al., 2010). If cattle are too cautious about eating novel feed, it can decrease feed intake and productivity (Launchbaugh et al., 1997). Costa et al. (2014) discovered that calves housed with other calves and cows indoors exhibited less food neophobia compared to those housed individually. Considering that dairy calf management involves transitions through various feeding, housing and social groups, we need knowledge of how CCC affects food neophobia when comparing calves with or without their dams on pasture.

Play behavior in dairy calves has also primarily been studied indoors, with factors like available space (Jensen and Kyhn, 2000), social circumstances (Jensen et al., 2015; Lv et al., 2021), and hunger (Krachun et al., 2010) influencing it. The presence of the dam also seems to affect play. For instance, Waiblinger et al. (2020a) observed more solitary play in CCC calves compared to artificially reared calves, while Wenker et al. (2022a) found the opposite during a novel object test. Løver (2022) reported a decrease in play behavior in calves as their dams' access to visit their calves in a CCC pen was reduced. However, Webster et al. (1985) and Sinnott

(2023) found no significant differences in amount of play between CCC calves kept on pasture versus artificially reared calves kept indoors. Sinnott (2023) also found no difference between full CCC calves kept on pasture versus part-time CCC calves kept indoors. Older studies examining calves' behavior with their dams on pasture indicate that calves' play increases until 6 months (Das et al., 1999) and then decreases (Reinhardt et al., 1978), with play occurring in short durations and sporadically throughout the day (Duve et al., 2012). Play has been found to happen mainly after suckling in pastured CCC calves (Das et al., 2000), and while Reinhardt et al. (1978) found calves to play most during evening, Vitale et al. (1986) found play peaks both during morning and evening. Given that play indicates positive emotions (Boissy et al., 2007; Špinka et al., 2001), it is relevant to understanding more about how CCC affects calves' play on pasture.

Allogrooming is a crucial behavior in cattle that facilitates several functions (Reinhardt et al., 1986; Sato et al., 1991), including the bonding between calf and dam postpartum (Jensen, 2011), and the formation and maintenance of social bonds, typically among closely-aged pairs or relatives (Sato et al., 1993). Calves reared artificially and indoors rarely groom each other (Horvath and Miller-Cushon, 2019), compared to calves and their dams on pasture (Reinhardt et al., 1978). Cow-calf allogrooming decreases with calf age both indoors (Jensen, 2011) and on pasture (Kerr and Wood-Gush, 1987), similar to the decline in suckling bouts (Fröberg and Lidfors, 2009; Lidfors and Jensen, 1988). In contrast, allogrooming among calves on pasture seems to increase with age (Kerr and Wood-Gush, 1987). Considering the importance of allogrooming for cattle, it is valuable to investigate whether pastured CCC calves experience more allogrooming than artificially reared calves due to calf-dam interaction. Additionally, it would be insightful to explore if artificially reared calves exhibit more allogrooming between themselves to compensate for the absence of dam-calf grooming.

As mentioned regarding farmers' perceptions, reducing animal stress is one main reason for the regular practice of early cow-calf separation, and stress after separation is perceived as one main challenge of CCC systems. Indoor studies have shown more stress in calves when separated from their dams after two weeks than after one day (Flower and Weary, 2001), and more stress after weaning from suckling compared to artificial rearing (Fröberg et al., 2011). Similarly, Sinnott (2023) observed that CCC calves, whether with full CCC on pasture or part-time CCC indoors, vocalized more than artificially reared calves after weaning. However, weaning and the transition from milk to solid feed can be a major stressor for both CCC and artificially reared calves (Weary et al., 2008). At the same time, gradual weaning has been shown to mitigate stress-related behaviors, like vocalizations and activity, in both artificially reared (Budzynska and Weary, 2008) and CCC calves (Johnsen et al., 2015b). Nicolao (2022) found both cows and calves to be stressed after weaning, regardless of the time they spent together before weaning. Nevertheless, there is a lack of comparative studies on pastured dairy calves' behavior during weaning from suckling versus artificial milk feeding.

Most research on dairy calf behavior both with and without CCC has been conducted indoors, and there are few studies examining dairy calf behavior with CCC on pasture. There are some recent studies with CCC dairy cows and calves on pasture (Mac et al., 2023; Nicolao, 2022; Sinnott, 2023), however these studies did not compare the CCC calves with artificially reared calves also reared on pasture. Furthermore, artificially reared calves typically do not receive a milk allowance close to ad libitum as full CCC calves do, which might influence their behavior. To gain a comprehensive understanding of dairy calf behavior on pasture, further research is needed. This research should compare pastured dairy calves both with and without their dams on pasture and should ensure that artificially reared calves receive as high milk allowances as the CCC calves.

5.1.6 Performance of dairy cows in CCC systems

From what we know about farmers' perceptions, concerns about lower income due to reduced machine milk yield in CCC cows is one of the barriers for farmers to practice these systems (Hansen et al., 2023). Several studies, both with CCC cows indoors (Flower and Weary, 2001; Jannerman, 2022; Kišac et al., 2011; Langhout, 2003; Metz, 1987; Tufvesson, 2021; Wenker et al., 2022b; Zaralis and Leach, 2015; Zipp, 2018) and on pasture (Nicolao et al., 2022; Sinnott et al., 2022) show that full CCC decreases cows' machine milk yields during the nursing period. A review by Meagher et al. (2019) indicated no consistent evidence of reduced machine milk yields over a longer period after nursing. However, most of the studies reviewed by Meagher et al. (2019) were old studies and with part-time CCC. Among them, two studies with full CCC for up to 14 days (Flower and Weary, 2001) and 10 days (Metz, 1987) reported that machine milk yields matched those of non-nursing cows soon after cow-calf separation. However, Kisac et al. (2011) found cows nursing for 21 days to have lower machine milk yields in their second month of lactation than those nursing for just 7 days. Similarly, more recent research exploring extended full

CCC around two (Sinnott, 2023) or three months (Barth, 2020; Jannerman, 2022) indicated that nursing cows had lower machine milk yields after cow-calf separation. Barth's (2020) indoor study showed significantly lower yields throughout lactation for both full CCC and part-time CCC with nursing 15 minutes twice per day, compared to night-time CCC or no CCC. In Sinnott's (2023) study, where full CCC cows were with their calves on pasture while part-time CCC cows were with their calves indoors, cows from both CCC treatments persisted having lower machine milk yields than non-CCC cows after separation from their calves and throughout their lactations. However, in Jannerman's (2022) indoor study, the difference was not significant. The recent study by Nicolao et al. (2022) got contradictory results, as cows that were with their calves part-time indoors (20 minutes before morning milking/day) persisted in having lower machine milk yields after separation from their calves compared to non-CCC cows, while the cows that were with their calves part-time on pasture (9 h/day) got the same machine milk yield as the non-CCC cows within one week after cow-calf separation.

Some studies have examined factors influencing machine milk yield in CCC cows. Mutua & Haskell (2022) found cows' machine milk yields to vary greatly due to lactation number and calf sex when calves suckled for 5-6 months. In a farm study where CCC was practiced for two months, Hanssen (2020) reported large variations in machine milk yields from CCC cows before and after separation from their calves. He also noted that multiparous cows increased their yields faster after separation than primiparous cows.

Practicing CCC might result in a lower content of solids in machine milk, as several indoor studies have reported lower fat content in machine milk from CCC cows (Barth, 2020; Carbonneau et al., 2012; Mendoza et al., 2010; Tufvesson, 2021; Wenker et al., 2022b; Zipp, 2018; Zipp et al., 2013). The composition of machine milk might also be affected by CCC on pasture, as seen in a recent study by Nicolao et al. (2022). Boden & Leaver (1994) reported that CCC dairy cows, grazing with their dairy-beef cross calves for 7-8 hours daily, had lower fat contents but higher protein and lactose contents than non-CCC cows. Contrary to what Boden & Leaver (1994) found on pasture, others reported a lower (Tufvesson, 2021), a tendency for lower (Wenker et al., 2022b) or no difference in lactose content (Carbonneau et al., 2012) in machine milk from CCC cows compared to milk from non-CCC cows. While Barth (2020) found a higher protein content similar to Boden & Leaver (1994), others found no difference in protein content of machine milk from CCC cows compared to non-CCC cows (Carbonneau et al., 2012; Tufvesson, 2021; Wenker et al., 2022b). After separation from the calves, the composition of machine milk has been shown to become similar for CCC cows and cows separated early from their calves (Mendoza et al., 2010). While the reduction in machine milk fat content during CCC seems evident, the effects of CCC on protein and lactose are less clear, highlighting the need for more research comparing cows with and without their calves on pasture.

In CCC systems, challenges include not only lower machine milk yields and altered machine milk composition, but inhibited milk ejection might be a challenge during milking of CCC cows (Kälber & Barth, 2014; Krohn, 2001; Zipp, 2018; Zipp et al., 2013, 2016). High-yielding dairy breeds like Holstein have been shown to release more oxytocin, crucial for milk ejection, during nursing compared to when being milked (Bar-Peled et al., 1995; de Passillé et al., 2008; Lupoli et al., 2001). For Bos indicus cattle such as Zebu or crosses, it is common practice to allow calves to suckle, often in conjunction with twice-daily milking, as these cows generally need calf stimulation for adequate milk ejection (Ryle and Orskov, 1990). In studies of performance in these types of cattle, the cows are often on pasture, or cows and calves are on separate pastures. However, when they practice part-time CCC, cows and calves are typically not together on pasture. Studies involving performance in dairy cows and calves grazing together are limited.

5.1.7 Performance of dairy calves in CCC systems

Implementing CCC has been shown to affect calf weight gain, as review articles claim that full-CCC calves have higher weight gains than artificially reared calves (Kälber and Barth, 2014; Krohn, 2001; Meagher et al., 2019). Most studies with full CCC indoors reported higher weight gains in suckled calves compared to artificially reared calves (Bar-Peled et al., 1997; Fröberg et al., 2011; Grøndahl et al., 2007; Jannerman, 2022; Kišac et al., 2011; Langhout, 2003; Metz, 1987; Valníčková et al., 2015; Wenker et al., 2022b; Zaralis and Leach, 2015). However, in most of these studies, artificially reared calves were provided a restricted milk allowance (e.g., Bar-Peled et al., 1997; Flower & Weary, 2001; Roth et al., 2009). In some other studies, where CCC was practiced for short periods of up to 4 or 7 days, no differences in calf weight gains were found between CCC calves and calves separated early from their dams (Stěhulová et al., 2008; Weary and Chua, 2000). Milk allowance has been shown to determine calves' weight gain, especially during the first weeks when their underdeveloped rumen function prevents digestion of solid feed (Khan et al., 2011). However, Krohn et al. (1999) observed that calves suckling for the first four days postpartum had higher weight gains than non-suckling calves, despite similar milk intakes. Johnsen et al. (2015b) found CCC calves to have similar weight gains regardless of suckling or not when the dams were without or with udder nets. In a study on beef cattle, Sato (1984) found that calves that received more grooming from their dams showed higher weight gains. These findings suggests that not only milk allowance, but also maternal care provided by the dam can positively influence calf weight gain. The recent studies by Sinnott (2023) and Bertelsen (2023) present contrasting findings: Sinnott (2023) found higher weight gains in CCC calves, both with full CCC on pasture and with part-time (half-day) CCC indoors, compared to artificially reared calves, while Bertelsen (2023) observed similar weight gains among full CCC, part-time (half day) CCC and artificially reared calves, all kept indoors. Milk allowances for artificially reared calves were up to 9.5 L/calf/day in Sinnott's (2023) study and ad libitum twice per day in Bertelsen's (2023) study. Both studies found CCC calves to have lower weight gains than the artificially reared calves after weaning. Although it is established that pre-weaning calf weight gain is largely affected by milk allowance, there are no studies comparing ad libitum-fed artificially reared calves with CCC calves on pasture.

5.1.8 Health of dairy cows and calves in CCC systems

While farmers practicing early cow-calf separation might be concerned about cow-calf health in CCC systems, CCC farmers experience health benefits with CCC (Neave et al., 2022). Beaver's et al. (2019) review revealed improved or unchanged udder health in CCC cows compared to early-separated cows. Similarly, in a recent indoor study, cow health was not negatively affected by CCC (Wenker et al., 2022b). In terms of calf health, an argument in favor of early separation has been the minimization of infection pressure for calves (Grøndahl, 2011; Relić et al., 2020). However, Beaver et al. (2019) did not find support for a recommendation of early dairy cow-calf separation, on the basis of either cow or calf health, and Krohn (2001) reported that calves allowed to suckle are in general typically healthy. In contrast, Wenker et al. (2022b) found the health of CCC calves to be negatively affected compared to artificially reared calves, attributing the difference to suboptimal housing conditions for the CCC calves. Sinnott (2023) also reported more health issues in CCC calves compared to artificially reared calves, and the whole-day CCC calves on pasture required more antibiotic treatments compared to the part-time CCC calves kept indoors. Sinnott (2023) suggested that the results could have been influenced by varying weather conditions on pasture. Neave et al. (2022) pointed out that most of the CCC studies in the Beaver et al. (2019) review about health were conducted indoors, and that there might be differences in mastitis or other udder health issues for pasture-based nursing cows that were not detected. Calf health should also be compared for calves kept on pasture both with and without their dams.

Most earlier studies on performance in dairy cows and calves with CCC have been conducted indoors, similar to the studies on calf behavior. The recent studies examining dairy calf behavior with CCC on pasture (Mac et al., 2023; Nicolao, 2022; Sinnott et al., 2022) also examined performance in dairy cows and calves kept with CCC on pasture. None of the mentioned studies compared the performance of both CCC and early separated cows and calves when they are all kept on pasture. Additionally, distinguishing the effects of CCC versus milk allowance on calf performance can be achieved by comparing CCC calves with artificially reared calves given a milk allowance close to ad libitum.

5.1.9 Aim of the thesis

From the identified need for more qualitative research involving CCC farmers and research on pasture with comparisons of cows and calves with and without CCC, the objectives for this thesis were formulated.

The main aim of this thesis was to gain knowledge about how Norwegian dairy farmers practice and perceive their CCC systems and about the effects of CCC on calf behavior and cow-calf performance on pasture.

To reach the main aim, three specific objectives were defined:

The first objective was to explore how Norwegian dairy farmers with CCC systems practice these systems and how they experience and perceive the interrelationships between cows, calves and humans within these systems.

The second objective was to compare behavior in dairy calves pastured with or without their dams by their use of calf hides, lying, grazing, playing, and allogrooming between calves. This also included describing their behavior in a food neophobia test, as well as describing their behavior of suckling or sucking milk, allogrooming between cow and calf, and the calves’ vocalizations after weaning.

The third objective was to compare performance in dairy cows and calves with or without CCC on pasture through machine milk yield and composition and calf daily weight gain. Additionally, it aimed to describe cow body weight and condition, calf intake of concentrates, artificially reared calves' milk intake, and cow and calf health.

For the second objective, it was hypothesized that the presence of the dam on pasture may lead to less use of a calf hide, less lying, more grazing, more play, and less allogrooming between calves, but that the effects may be modulated by calf age and weaning.

For the third objective, it was hypothesized that the lowered machine milk yields due to suckling would increase to levels similar to non-nursing cows after separation and weaning was completed. Likewise, it was hypothesized that the nursing cows' milk fat content would be lowered, but that it, too, would increase and become similar to the milk fat contents in non-nursing cows after separation and weaning. It was also hypothesized that calves with their dams on pasture would have higher weight gains than artificially reared calves during the milk feeding period, but that this difference would disappear at weaning and separation.

These objectives were achieved by a semi-structured qualitative interview study and a quantitative pasture study with cows and calves in two different treatments.

5.2 Materials and Methods

5.2.1 Interview study

5.2.1.1 Selection and invitation of interviewees

Before conducting the interviews, we set some criteria for selecting the farmers we wanted to interview. The criteria were to have variation in sex, age, and geographical location. We also wanted to only include farmers with at least one year of experience of practicing CCC, and who have kept calves together with their dams for at least four weeks. Furthermore, we had criteria for variation in farm size, and number of cows. Included should be farmers having freestalls with AMS, freestalls with milking parlors, and at least two having tiestalls. At least four of the farmers should also be practicing CCC on pasture, and there should be variation regarding calving time. Lastly, we wanted at least three organic farms to be included. Five farms were recruited by farmers contacting us after a post about the interview study on a Facebook group called "*Samvær ku og kalv—forum for melkebønder*" (Cow-calf togetherness—a forum for dairy farmers). Farmers from five more farms were contacted and recruited after being identified through social media, as they were likely to match the criteria. The last two farms were recruited through a small survey conducted in another part of the SUCCEED project.

The Norwegian Centre for Research Data (a part of Sikt-Norwegian Agency for Shared Services in Education and Research from January 1, 2022) determined that the processing of personal data in this interview study was in accordance with privacy regulations. All the interviewees received an information letter with a statement of consent to be signed before the interviews. The letter contained information including the aim of the project and why the interviewees were being asked to participate. It also stated that participation was voluntary and explained our privacy policy and their rights.

5.2.1.2 The interviews

An interview guide was constructed in 2020 with several different themes, and a short version of it is shown in Table 1. Twelve semi-structured qualitative interviews with 17 farmers were carried out from October 2020 to March 2021. During interviews on five of the farms, two farmers per farm were interviewed together, while the other interviews were with one farmer per interview. As little was known about how farmers experience CCC systems and especially how they perceived the interrelationship between cows, calves, and humans in such systems, a qualitative approach with semi-structured interviews was suitable for our study (Ferneborg et al., 2020; Vaarst and Sørensen, 2009). The first three interviews were carried out by me together with one of the co-authors (BL, GTK). The remaining interviews were led by one researcher, either by me (seven interviews) or by co-authors (two interviews). Seven of the interviews were conducted during visits to the farms, including a tour in the barn, while the other five interviews had to be conducted online because of COVID-19 restrictions.

Table 1. Themes from the interview guide that were used for interviews with Norwegian farmers with cow-calf contact systems in the SUCCEED (sustainable systems with cow-calf-contact for higher welfare in dairy production) project

Short version of the interview guide
About the farmer, the farm, the housing, and the animals
Practice with cow-calf contact from before, the beginning, and until today
The change/why they started with cow-calf contact
Economy questions
Benefits and challenges with cow-calf contact
If they want any changes, what is important for cow-calf contact, advice for other farmers
Obstacles and benefits for more farmers to have cow-calf contact

5.2.1.3 Editing and analysis

The interviews were audio-recorded, and each lasted between 51 and 130 minutes, with an average duration of 101 min. The transcription of the interviews was done verbatim on Microsoft Word, and there were between approximately 8 500 and 23 000 transcribed words per interview. The interviews were analyzed on NVivo version 12 Plus software (QSR International: https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home/). The analysis was conducted using an inductive approach, inspired by the methodological framework of grounded theory (Corbin and Strauss, 2015). All contents from the transcribed interviews were used in the analysis, with sequences of statements being given a heading in line with the content through open coding before axial coding was performed to identify themes across the interviews.

5.2.1.4 Norwegian report from the interviews

A Norwegian report called "*Ku og kalv sammen i melkeproduksjon – Intervjuer med melkeprodusenter*» (Cow and calf together in dairy farming – Interviews with dairy farmers) was also published from the interviews (Johanssen and Sørheim, 2021). The report included 10 of the farms and was about the farmers' practical solutions for their CCC systems. It included photos and descriptions of how the farmers perceived the benefits and challenges of having these systems. Additional interview results, which were included in the Norwegian report but not in Paper I, are included in Chapter 5.3.1.4. Also, the pasture study in this thesis was mentioned in the same report, and a small interview with the farmers from the study farm was conducted. The interview was about their experiences from the study and their perceptions of CCC and was summarized in the report. Some of this material is added to the thesis Chapter 5.3.1.6.

5.2.2 Pasture study

The pasture study complied with the Norwegian Regulation on Animal Experimentation (Forsøksdyrforskriften, 2015) under the Norwegian Animal Welfare Act (Dyrevelferdsloven, 2009). It was conducted on a commercial dairy farm (220 meters above sea level (MASL)) in Mid-Norway with a herd of 80 dairy cows of the breed NRF, but also some Holstein crosses, and with a freestall barn and AMS. The cows were usually on summer pasture (summer farm, 580 MASL), which was located 17 km from the main farm, and had a milking parlor. Calving was concentrated in three periods, including one period in May/June. The pasture study farm was not one of the 12 interview study farms.

In a parallel-group-designed controlled study, 20 cow-calf pairs were allocated to two treatments: Cow-calf contact (CC) and early separation (ES). Ten cow-calf pairs were enrolled into two groups per treatment (CC: CC1, CC2, and ES: ES1, ES2) with five pairs per group. The pairs were 17 NRF pairs and three NRF x Holstein crossbred pairs. One of the crossbred pairs was in the CC treatment and two crossbred pairs were in the ES treatment, but one multiparous ES Holstein cross cow was excluded from the study due to illness. The cows calved between 7 May and 14 June. The pairs were distributed to their groups by calving date to get as little age variation among the calves in each group as possible, thus the age variation per group was 6-8 days. Because of a restricted number of calvings, it was not possible to divide the groups evenly according to cows' parity and calves' sex, and thus, the CC cows were 4 primiparous and 6 multiparous cows, and the ES cows were 1 primiparous cow and 8 multiparous cows. The CC calves were 2 bull and 8 heifer calves, while the ES calves were 6 bull and 4 heifer calves.

The first calving pairs were designated as the ES groups so that the ES calves could be let out on the on-farm pasture in May, because the cows and calves could not be let out on the summer pasture before early June. It was not possible to let cows out on pasture near the farm, and it was important to have the calves in the different groups on pasture at the same age to enable behavioral observations of them on their first day on pasture. Thus, the ES cows were let out later postpartum than the CC cows (Table 1).

Table 1. Weeks in which the various events and recordings occurred during the study.

Event	Week
Calvings	Week 0
CC pairs and ES calves let on pasture	Week 1
ES2 cows let on pasture	Week 3
ES1 cows let on pasture	Week 4
Full CCC/High milk allowance	Weeks 1-6
Gradual weaning	Weeks 7-8
Fully weaned and separated	Week 9
Calf behavior observations	Weeks 1, 3, 6 and 9
Calf food neophobia test	Week 8
Cow machine milk yield	Weeks 0-11
Cow machine milk composition	Weeks 5, 9, and weeks 14-16 (16 Sep)
Cow teat samples (mastitis bacteria)	Weeks 5 and 9
Cow breast girth	Week 0, pasture day 1 and week 9
Cow weighing	Pasture day 1 and week 9
Cow condition scoring	Pasture day 1 and week 9
Calf weighing	Weeks 0, 6, 9, and 6-7 months (3 Dec)
ES calf milk intake	Weeks 0-8
Calf concentrate intake	Weeks 0-9
Cow health assessment	Pasture day 1 and week 9
Cow and calf daily health checks	Weeks 0-9

5.2.2.1 The treatments: CC and ES

Each of the CC pairs was alone in a calving pen for the first three days (Figures 1a, b & c). Week 0 was defined as the average calf birth week for each group, and each group was let out on pasture in week 1 when the youngest calf in the group was 3-4 days old. The other pairs (except for the pair with the youngest calf in each group) were in the freestall between being in the calving pen and being let out on pasture (Figures 2a, b & c). The CC pairs had full CCC except during morning and evening milking (about one hour per day on the summer pasture) until week 6. In weeks 7 and 8 they were gradually weaned by having physical contact through fence-line (Figure 6), without suckling except for two hours after morning and evening milking in week 7, and one hour together after morning and evening milking in week 8 (Figure 7). After week 8, the cows were moved to another pasture 120 meters away from the calves so that they got fully weaned and separated, but they could still hear each other and maybe see each other as well.

Figure 1. CC pairs in calving pens indoors, photos taken on their calving days.

Figure 2a, b & c. a) Calf lying in the calf creep with saw dust bedding in two lying cubicles, b) Calf suckling dam in the freestall, c) Calf lying between lying cubicles on each side.

The ES pairs were separated within 1-3 hours after calving, whereupon the calf was placed in an individual calf pen for three days (Figure 3a), before being placed into a group pen (Figure 3c) or directly out on pasture, since each calf group was let out on pasture when the youngest calf was 3 days old. These calves were fed natural milk (Figure 3b) in four meals per day until week 6. They had a milk allowance of on average 12 L/calf/day during weeks 0-3 and 14 L/calf/day during weeks 4-6. In weeks 7-8, the ES calves were gradually weaned by getting a milk allowance of 8 L/calf/day in week 7 and 4 L/calf/day in week 8. After week 8 they were fully weaned from milk.

Figure 3a, b & c. a) ES calf in an individual calf pen with a milk bar, b) Heating of whole milk for ES calves, and c) ES calves in a group pen with a bigger milk bar.

5.2.2.2 Pasture management

All the groups were let out on pasture areas on the summer pasture according to Table 1. The ES cows and calves were kept with a distance of at least 130 meters between them, and did not have any contact with each other. The CC pairs and ES calves had electric sheep net fences, while the ES cows had electric polywires around their pastures (Figure 8). The cows were milked in the milking parlor at 06.30 AM and 05.30 PM each day. All animals had ad libitum access to pasture and water. The cows received on average (± SD): 9.5 ± 2.1 kg of concentrates per day, and the calves had ad libitum access to concentrates in calf hides. Each calf group had access to a calf hide, and the ES calves also got their milk there, from milk bars with one artificial teat per calf (Figure 4a). Each calf hide (10.9 m^2) consisted of a hutch with straw bedding (5.8 m^2) and an area surrounded by a steel fence (5.1 m^2). The gate to the calf hide was open for the calves, but the CC cows were not able to enter (Figure 5).

Figure 4a & b. a) The ES1 calves sucking milk from the milk bar and b) A CC calf suckling while being licked by its dam.

Figure 5. CC pairs with the CC calves' calf hide on pasture.

Figure 6. CC pairs suckling after milking (week 7-8). The calves usually suckled from their own dams.

Figure 7. Physical contact between cows and calves (without suckling, except for periods after milking) through fence-line weeks 7-8

Figure 8. Cow grazing between an ES cow pasture with a fence of two electric polywires and a CC pair pasture with an electric net fence.

5.2.2.3 Calf behavior

The calves were observed directly on pasture. All calves in a group were observed at the same time, while the behavior of each calf was registered individually on pasture day 1 (week 1) and on one day per week per group in weeks 3, 6 and 9. In these weeks, one person observed the calves, while on pasture day 1, the calves were observed by two persons to register more behavior. For one group on day 1, one observer could not participate, and another stepped in, but the registrations could not be used due to a lack of inter-observer reliability. On the observation days in weeks 3, 6, and 9, each group was observed for 8 hours, divided between one period from 06.00 to 10.00 AM and one period from 04.00 to 08.00 PM. During the observations, each calf was identified by a colored neck collar. Different behaviors were registered by different methods: Being in the calf hide, grazing, lying, and standing/moving by instantaneous sampling every second minute. Playing, suckling/sucking milk, allogrooming between calves, and allogrooming between cow and calf were registered by one-zero sampling for 30-second periods (i.e., if the behavior happened or not during each period) for 1.5 minutes followed by a 30-second break for the instantaneous sampling and then continued. Additionally, both low and high-pitched vocalizations were registered, but only on the observation day in week 9, in the same periods as one-zero sampling but as the number of vocalizations per 30-second period.

The times of when the CC cows left for and returned from milking (weeks 3 and 6) were noted in the scoring sheets. On average, each group was away for 30 minutes per milking.

Vocalizations in CC cows were registered as number of vocalizations per cow per 30-second period in a total of three hours, divided into one hour in the morning, one hour in the middle of the day, and one hour in the evening. The results from group CC1 days 1, 2, and 3 in week 9 are shown descriptively in Chapter 5.4.2.1.

In week 8 for each group, a food neophobia test was conducted, inspired by Costa et al. (2014). Each test was done as a group test with the whole group together, since the calves were not used to being alone. Each test was done for three consecutive days, with 30-minute observation periods per day. The calves were let out on a 6 x 6 m area outside the calf hide, which was surrounded by a net fence. Four 90 L black plastic buckets were placed within the enclosure. Two buckets contained novel feed: carrots and hay (Figures 9a & b), one bucket contained familiar feed: concentrates (Figure 9c), and one bucket was empty. The buckets were placed one at each rectangle side and far enough from the fence so that all five calves in each group could eat from one bucket simultaneously (Figure 10a). The feed in each bucket was weighed before and after each test to register feed intakes at group level. The tests were video-recorded by two cameras, and observed and registered by a research technician later, via the recordings. Individual registrations were made each time a calf put its head in a bucket, and when it removed its head from the bucket again. Thus, we also calculated individual calf latencies from test start to head was put in each of the buckets.

Figure 9a, b & c. Buckets for the food neophobia test with a) carrots (5 kg), b) hay (1,5 kg) and c) concentrates (5 kg) before a test.

Figure 10a & b. Test area for the food neophobia test a) before and b) at the end of a test.

5.2.2.4 Cow performance

Table 1 shows in which weeks different registrations were done for both cows and calves. Each cow's machine milk yield was recorded at each milking during the study and until week 11 after calving. Milk samples for analysis of milk composition were taken from individual cows' morning and evening one day in week 5 and one day in week 9 for each group. The samples were preserved with Bronopol (2-Bromo-2-nitropane-1,3 diol, Broad Spectrum 231 Microtabs® II), stored at 4 °C and then analyzed for fat, protein, lactose, urea, free fatty acids (FFA), and somatic cell count (SCC) using Fourier Transform Spectrometry (Bentley FCM and IBC, Chaska, US).

There were challenges with inhibited milk ejection in CC cows during the study. The greatest challenge was with three of the primiparous cows, most prominent during weaning and after separation of the CC calves. A veterinarian and the farmers were worried about mastitis and the farmers were also worried about potentially lower long-term milk yields in the CC cows. Because of these concerns, injections of oxytocin in doses of 2 ml were given to CC cows, a total of 38 injections to the cows in group CC1 (12 in weeks 0-6 and 26 in weeks 7-9) and 28 injections to the cows in group CC2 (2 in weeks 0-6 and 26 in weeks 7-9). For days with oxytocin injections, data were excluded from the results. This included data from days on which cows were injected and the following day, and if a cow was injected more than one day consecutively, the two following days after the last injection were excluded. The milk samples from week 9 were also excluded since most CC cows were injected on the sampling day of that week. Instead, data on machine milk composition from September 2021 were included. This was after the study, when the cows were back in the barn, corresponding to weeks 14-18, depending on the group. These data included 8 cows per treatment. In addition to milk data, each cow was breast-measured once after calving, once on the day they were let out on pasture, and once in week 9. Cows were also weighed, and their body condition scored once on the first day of pasture and once in week 9.

5.2.2.5 Calf performance

Each calf was weighed once after birth, and each calf group was weighed in weeks 6, 9, and once when they were 6-7 months (all on the same day in December 2021, exact age dependent on the group). This was to calculate their weight gains per day from birth till before weaning, from before weaning to after weaning, and after weaning till they were some months older after the treatments. Intakes of concentrates were registered by weighing concentrates in the morning on four days per week until week 9. It was not possible to measure the CC calves' milk intake, but the ES calves' milk intakes were registered by measuring milk amounts before and after each meal on four days per week until weaning.

5.2.2.6 Cow and calf health

Health assessments were done by a veterinarian for each calf after birth, and for each group, both cows and calves, when they were let out on pasture, and once in week 9. Health assessments of the calves were also done once in week 6. Additionally, daily health checks were carried out by staff for both cows and calves during the study.

Figure 11a & b. a) Cows in the milking parlor (by the summer pasture), and b) A cow in the enclosure where the weighing, breast measurement, body condition scoring, and health examination were done.

5.2.2.7 Statistical analysis

Statistical analyses were conducted in Minitab 21 Statistical Software. Each response variable was analyzed separately by using the Mixed Effects Model. For Paper II the response variables were the behaviors: "In calf hide", "Lying", "Grazing", "Play" and "Allogrooming calf-calf", and for Paper III they were: "Milk per day" (daily machine milk yield/cow in kg), and for the composition of machine milk in week 5 and post-study (weeks 14-18) they were in %: "Fat", "Protein", "Lactose", "Total solids", in kg: "Energy corrected milk (ECM)", and in mEq/L: "FFA", mmol/l: "Urea" and 10^3/mL: "SCC". The calf response variable for statistical analysis was: "Weight gain" (daily gain per calf in grams calculated from the weighing). For the models for each response variable, the residual plot from the model fit was visually checked for normality and homogeneity of variance. Additionally, normality tests called Anderson Darling and Ryan-Joiner were performed, and suggestions for transformation were made by using Box-Cox transformation methods.

In the models, treatment was the main effect of treatment (fixed factor with two levels: CC, ES). Group(treatment) was the effect of the group within treatment (random factor), calf(treatment; group) was the effect of calf within group within treatment (random factor). The other fixed factors were parity (two levels: primiparous and multiparous cows), and sex (two levels: bull and heifer calves). For the behaviors, we used period (two levels: morning and evening) and week (three levels, weeks 3, 6, and 9) as fixed factors. Period was also a fixed factor for "Milk per day" (three levels: weeks 7-8 (weaning), week 9 (full separation), and weeks 10-11 (after separation)), and for “Weight gain” (three levels: weeks 0-6, weeks 6-9 and week 9 till 6-7 months). In the models, interactions were first included, and then the models were reduced for each response variable by removing clearly non-significant higher-order interactions, to arrive at the final model we used for analysis for each response variable. Thereafter, post hoc analyses were run with Tukey pairwise comparison tests to examine the differences between each level for the factors and interactions having p-values less than 0.10. Significance was declared at $P < 0.05$; a tendency was declared at $P < 0.10$.

5.3 Results

5.3.1 Interview study

5.3.1.1 About the CCC farms

The farmers interviewed were from 8 conventional and 4 organic farms. Two of the farms (one organic and one conventional) were approved to use the welfare label from the Animal Protection Alliance. Six of the farms had freestalls and AMS, two had freestalls and milking parlors and four had tiestalls. The farms had between 14 and 60 dairy cows. The milk quotas were between 75 and 420 tons, and on two of the farms, they also used own milk to produce cheese products. Three of the farms started practicing CCC in the 1990s and the other 9 farms started with CCC between 2015 and 2019. Some of the farmers also tested CCC with a few cows and/or foster cows before they started keeping basically all calves with their dams. Seven farms had spread calving, one had spring calving, two autumn calving, one had calving in two periods, and one had spread calving over half the year.

5.3.1.2 The CCC farmers’ practices

On two of the farms having calving in spring or autumn they preferred the cows to calve outside, and another farm with spread calving also let cows calve outside in the grazing season. Most of the other farmers let the cows calve in indoor calving pens. The farmers had different practices to ensure colostrum access for the calves. Half of them bottle-fed colostrum to most calves, while the other half were more focused on observing and maybe helping the calves to suckle from their dams. The latter group bottle-fed only when they considered it necessary for different reasons. On all farms, the farmers kept the calves together with their dams in the cow areas, and on 7 of the farms, they also practiced CCC on pasture (Table 2). All the farmers who had cows and calves together in freestall areas had calf creeps for the calves, but they experienced calves also lying in the cows' cubicles, between the cubicles, and in front of cubicles near the wall. The CCC period varied from 6-8 weeks till 4 months and full CCC varied from two days till 3 months. On 10 of the farms, cows and calves were kept together during the whole milk feeding period, and on two farms they continued giving milk to the calves after separation from the cows. Weaning and separation were done by different methods, either abruptly, with nose-flaps, or gradually with fence-line and/or less time together.

Table 2. How the cow-calf contact system is applied at the 12 Norwegian farms participating in the interview study.

Farm no.	Full time together (how long, where)	Less time together, weaning, and separation
1	3 mo, mostly on pasture, some in the freestall.	Gradually less time together till weaning at 4 mo. Calves in own pen when not with cows and after weaning.
2	2–3 wk in an area with 3 lying cubicles. Cows are tied, calves are loose; then cows are moved to the other side of the feeding area and the calves to their own pen.	Cows are tied, calves are let out to be with cows for several hours 2 periods per day until wk 4. Then a period around milking morning and evening until just before wk 8, and 1 period per day till weaning at 8 wk.
3	9–10.5 wk. Cows are in the welfare area often for around 2–3 wk before they are moved to the freestall area. The calves use the whole barn after 1 wk.	Nose flap for the last 1.5–2 wk they are together, then calves are moved to their own pen.
4	9.5 wk in the freestall area after calving pen. Access to pasture during grazing season.	Nose flap for the last week they are together, then calves are moved to their own pen.
5	1 mo, with cows (dams) in the freestall; after, calving pen; then 2 mo with foster cows in own pens with 1 cow and 2–4 calves.	Fence-line contact with dam for a few days after 1 mo. Moved from foster cows after 3 mo.
6	4 wk on pasture or in the tiestall, where cows are tied and calves are loose before calves are moved to their own pen.	Cows are tied. Calves are let out to be with cows for a period after milking morning and evening until wk 8, then for 1 period per day until 9 wk.
7	6–9 wk. Cows are in the welfare area for at least 1 wk, then moved to the freestall area; calves can move around the whole barn.	Cows and calves are moved to the welfare area, where they have fence-line contact for 3 d before being moved again. Calves get milk until weaning at 12 wk or more.

8	3 mo (6 mo before). Cows are in the welfare area as long as space is available, then moved to the freestall area. Calves can move around the whole barn and have access to pasture in the grazing season.	Abrupt moving of calves to their own pen.
9	2 mo together in the freestall area after calving pen. Access to pasture in the grazing season.	Abrupt by moving calves to their own pen, but some (if strong bonds or a lot of vocalizations) are together for some more days when the farmer is in the barn.
10	8 wk together, in the freestall area after calving pen. Access to pasture/go outside almost all year round.	Calves are moved to a pen where they have fence-line contact with the cows for at least 5 d before being moved again. Heifer calves get milk until 4 mo, and bull calves until 6 mo.
11	Most of the calves are with the cows full time for the first 2 d, lying on hay beside the cow. Then the calves are moved to their own pen.	Calves are let out in the tiestall area for periods morning and evening until 3 mo. In the beginning, they get more hours together and before milking, then gradually less time and after milking instead.
12	2–4 wk together inside where cows are tied and calves are loose, outside on pasture before calves are moved to their own pen, or both.	Calves are let out from their pen for half the day until between 70 and 100 d.

Figure 12a & b. Farm no. 2. a) Dairy cows in a tiestall where bigger calves were let out in periods during the day. By the wall on the far side is a calving pen made of two cubicles. b) An own enclosed area where tied cows were with smaller calves having whole-day CCC.

Figure 13a, b & c. Farm no. 6 with dairy cows in a tiestall where small calves had whole-day CCC. a) Calf suckling its dam. b) & c) The calves had an area in a corner behind the cows on one side and an own open room behind the cows on the other side where they could lie on straw bedding.

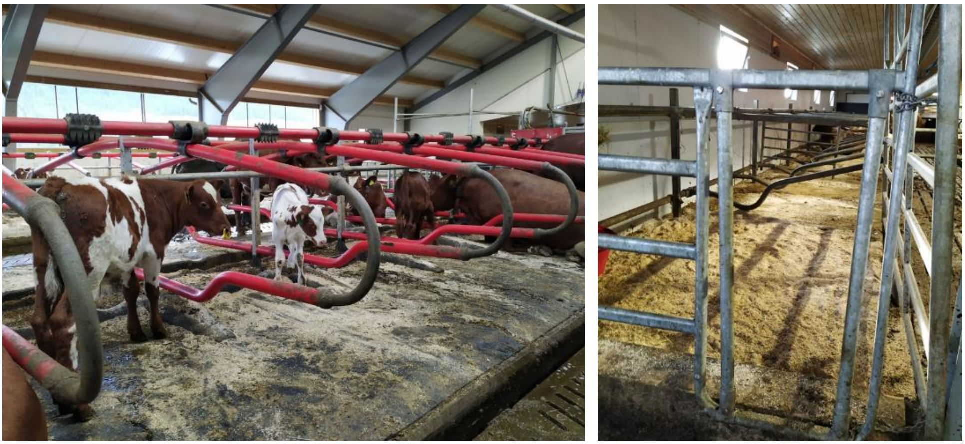


Figure 14a, b, c & d. Farm no. 3. a) The calves were weaned with nose flaps. c) This barn had some large calving pens. b) & d) A calf creep in the freestall's welfare area.

Figure 15a, b, c & d. Farm no. 4. a) Cow and calf in a calving pen. b) A freestall with a calf creep with straw bedding. c) & d) Cows and calves in the lying cubicles where the calves could be lying in front of the cows.

Figure 16a, b, c & d. Farm no. 5. a) & b) Calves with their dams in the freestall area the first four weeks. c) & d) Calves with foster cows (2-4 calves per cow) in own pens from four weeks till 3 months.

5.3.1.3 Interrelationships between cows, calves and humans

From the qualitative analysis, several themes related to practice and interrelationships between cows, calves, and humans in CCC systems were identified, like e.g., ensuring that dam and calf establish a strong bond and farmers establishing their own relationships with cow and calf. The farmers had different perceptions, but there were also similarities, e.g., regarding colostrum management. Despite differing strategies to ensure colostrum intake for newborn calves, none considered this as a challenge. A good relationship between a dam and her calf was important, and most of the farmers let cow and calf stay alone during the first days to help establish a strong bond between them. The cows were generally perceived as being good mothers, but there were also some cows that seemed to not care about the calf or could seem stressed and aggressive towards it. The farmers had different solutions for such challenges. While some farmers had felt forced to practice early separation of calf and dam in such cases, others meant that these cows just needed some help and time to calm down and understand the situation.

Among the farmers almost all reported witnessing one or a few cows showing aggressive behavior towards humans to protect their calves after calving. The farmers perceived such behaviour as an exhibition of the cows' natural protective instinct. Several of the farmers also discussed possible differences between primiparous and multiparous cows, regarding how they behaved towards their calves and humans after calving. However, the farmers built good relationships with the cows so that cow and farmer knew each other and felt safe around each other. Then, the farmers could handle the calves and build good relationships with them as well. At the same time, there could be a bigger risk for cows to show aggressive behavior to protect their calves if strangers were present. Some farmers perceived suckling calves to behave differently from artificially reared calves, while others said they were just as tame now as before when they were separated early from their dams. Some also mentioned individual differences in personalities among cows and calves, for example, a shy cow that could transfer her shy behavior to her calf. Most of the farmers also talked about how much the calves learned from being with the cows, like different feeding behaviors and how to be a cow in their environment.

The farmers, with their different housing and milking systems, generally experienced that dairy cow areas were not designed to accommodate CCC and therefore were not adapted to the needs of small calves. The CCC systems could require spending more time on observing the animals. Adjustments in the cow areas, like putting up extra gates and wooden planks could also be required to accommodate CCC in existing barns. Although most of our interviewees practiced CCC in older barns without large investments, they agreed that CCC systems require sufficient space. The cows, especially primiparous cows, would also need some extra attention during milking, especially in the beginning after calving. Some of the farmers practicing CCC on pasture thought that their system was the best and most natural for the animals, while some of the farmers who grazed their cows in forest or mountain areas did not want to have small calves with the cows 'out there'. Some also preferred allowing cows calve on pasture, despite that it could sometimes be hard to locate newborn calves outside. While some farmers spent time on searching for these new-born calves, farmers from one farm had stopped spending time on this, as they consistently found that the calves would show up within a few days. Farmers practicing CCC on pasture experienced calves escaping under the fences. However, this was not considered a problem, as the calves would never go far away. Farmers considered that the calves would return upon hearing their dams call or when their dams were walking back inside.

The farmers had different perceptions of their cows' and calves' stress behavior related to weaning and separation. Generally, there could be some challenges with stress, but several farmers had found methods to minimize stress among their cows and calves. It seemed that stress could also vary considerably between individual cows and calves. The farmers had different opinions about workload, where half of the farmers thought they spent less time working when using CCC systems, while the other half thought they spent as much or even more time working. At the same time, they agreed on that they spend less time on calf feeding, and farmers having AMS experienced the work being more flexible, as they did not have to go to the barn at certain times to feed calves. Additionally, some of the farmers expressed how they really enjoyed spending time in the barns with their animals every day. We found that the farmers enjoyed having these systems, where they all described positive emotions when seeing cows and calves together. Most of the farmers talked about how a cow and her calf being together was natural, and they generally saw this as good animal welfare.

5.3.1.4 Cow and calf performance and health

The Norwegian report from the interview study (Johanssen and Sørheim, 2021) included more comprehensive information and citations about how the farmers perceived performance and health in their cows and calves when practicing CCC systems. In the following, text in italics denotes direct quotes by farmers.

Several of the interviewed farmers reported lower machine milk yields when the calves were suckling their dams. One farmer said: "*You get less milk delivered per cow, so you need to have more cows to fill the milk quota, and/or you need to increase the yield on the cows."* Another farmer was worried about some of the cows' entire lactation curve being affected, he said*: "It may be that some dams do not utilize their milk potential because they are together with their calves, I am afraid that they get a much lower lactation curve, especially the primiparous cows*." The farmers also talked about benefits regarding the cows' milk yields: *"The calves stimulate milk production", "A big advantage is that the (milking) robot knows which glands are* *empty and empties the others without any problem", "When the cow is used to the teats being suckled, it can in many cases make it easier to milk the cow", "The goal is that the dairy cows that grow up now are much better than the ones I have today because their wellbeing was better while growing up",* and *"We get big nice heifers, more robust, they give more milk in their first lactation, they can be inseminated earlier, and they get easier pregnant again after their first calving*". Some of the farmers mentioned challenges regarding the composition of machine milk: "*The quality of the delivered milk decreases", "There is a lower fat content in the delivered milk",* and *"I do not understand how the calves are able to drink the fatty milk regardless of if you let them be together with the cow before milking, after milking or in the middle of the day, that I do not understand".*

The farmers used several positive words about the calves' weight gain: Good, much better, really good, insanely, huge weight gain, and that the suckling calves were robust, powerful, large, vigorous, better calves, very nice calves, that they had smooth coats and that *"They get a good start in life*".

Some of the farmers talked about challenges regarding cow and calf health: "*There can be a high infection pressure indoors when you have many animals and small areas" "Diseases spread faster with cows and calves together", "There is a risk of infection if a calf suckles several cows", "The cows are slightly more susceptible to mastitis", "When the calf is with the cow you lose a bit of control over the udder health".* Especially one farmer experienced several challenges with calf health in her CCC system: "*It can be a challenge with wounds and abscesses on calves that run and play and hurt themselves on the slatted floor in the freestall", "The calves get infections easier", "I have a higher use of medication and wound care"* and *"There are more injuries from cows stepping on the calf, or lying on the calf*". Farmers talked about stress in relation to the separation of cow and calf as mentioned in Paper I, additionally, some of them talked about other challenges regarding the calf related to this: *"The calves might get diarrhea after separation", "There can be lower feed intakes in calves for some days after separation"* and *"The calves may have a drop in their growth after separation*".

The farmers also mentioned several benefits regarding health, like better udder health, less udder inflammation, and about the calves emptying the udder as being positive for udder health. Other comments about health were: "*We generally have healthier animals now", "We do not use antibiotics and have not used antibiotics for* *over 20 years against mastitis", "We do not experience cows having retained placenta", "If cows have milk fever, they have a milder degree, it is easier to get them going again",* and *"It is positive for cow health after calving, she has something to get up for, something to do, a meaning in her life*". Farmers also talked more about benefits and said, for example, that when practicing CCC they had very good calf health, better calf health, no calf disease, and made comments like: *"We have more equal and healthier calves", "We have not had a vet on a calf except for dehorning or if someone is injured", "If there is anything with a calf, the mother takes care of it, and the calf recovers faster", "We no longer have calves with diarrhea, if you have calves with diarrhea, you lose hundreds of liters of milk in the first lactation and lose growth which is difficult to catch up again*" and *"The calves can get diarrhea from too much nourishment, but the general condition is good, they do not get sick from it".*

5.3.1.5 CCC systems and reputation

Several of the farmers talked about benefits regarding social sustainability of dairy production. This included such aspects as practicing CCC being positive for dairy farming reputation. Words as branding, storytelling and "added value" were mentioned in relation to sales. Collectively, these statements indicate a belief that higher prices may potentially be charged for milk, meat, cheese etc. from CCC farms. Comments included: *"CCC makes good external advertising for agriculture", "It makes a good image of dairy farming for the consumers", "With CCC we are in front regarding consumer demands", "Consumers more or less demand that the calf should be with the cow", "Animal welfare is more and more important to people", "The cow and the calf thing is something that touches everyone's hearts, even guys are touched in their hearts by that", "We get increased knowledge and exchange of experience when more people do it* (CCC systems)*", "When more people have cow and calf together, more will understand that this is the right way, where we are going", "Others are also proud* (e.g. neighbors)*", "Employees think that it is gratifying working in CCC systems",* and *"Visitors and advisors who are in the barn say: "Oh, those are some nice calves!".*

5.3.1.6 Interview with the pasture study farmers

The farmers from the pasture study farm said they did not experience problems with letting the small calves be together with the cows in the freestall area in the barn before they were transported to the summer pasture (Johanssen and Sørheim, 2021). However, they saw challenges with having the cows together with the calves on the summer pasture, and the biggest challenge was inhibited milk ejection in CC cows during milking, throughout the study. They said that several of the CC cows continued having low machine milk yields after the study was completed (after week 9). They also said they had never experienced cows kicking that much during milking in the milking parlor as some of the CC cows did in the study. They clearly saw CC cows being stressed, but pointed out that several of them were primiparous cows.

Father and daughter on the pasture study farm discussed CCC, and the father did not believe that having calves with their dams would work out well practically, he believed more in having foster cows with the calves. He also pointed out that an important reason for those who have calf and dam together is the well-being the farmers feel themselves by having this system. The daughter, however, meant that part of the point of having dairy CCC was lost by practicing foster cow systems instead of dam-rearing, and that the foster cow would be more like an automatic milk feeder if the cow did not really want to foster the calves, and the calves did not get the care that they would otherwise have gotten from their dams. She argued that there must be other benefits of having dam-rearing systems in addition to the farmers' own well-being; otherwise, the farmers practicing the system would not do so. She was sure that the calf and dam had better well-being and life quality during the time they spent together, but she was not sure if it was worth it when she saw the stress that especially the cows experienced during weaning and separation. The farmers saw that the calves' weight gains were high, but that CCC systems (with dam-rearing) cannot work out if the cows do not deliver sufficient amounts of milk during machine milking. In their opinion, cows used in CCC systems must be able to let down their milk during milking and continue to have a high milk production after separation from their calves.

5.3.2 Pasture study

5.3.2.1 Calf behavior

The calves' behavior of suckling or sucking milk could not be compared between the treatments, but both treatments were observed to spend up to around 13 minutes in one suckling or sucking bout. The CC calves had numerically more but shorter suckling bouts in week 3 compared to week 6 with 3.1 vs 1.7 suckling bouts (from total 8 h/day) of 4.2 vs 6.7 minutes per calf for week 3 and week 6, respectively. This indicates that number of suckling bouts decreased while time per suckling bouts increased with calf age.

Of the statistically analyzed behaviors, all had a treatment*week interaction with $P < 0.001$, and the means presented are in % of total sample points per period (4 hours). Use of calf hide was the only behavior with a significant difference between the treatments independently of week. The CC calves used the calf hide less than the ES calves throughout the study but more with increased age (week 3: 0.4 vs 64.1 %, week 6: 11.0 vs 45.7 % and week 9: 27.0 vs 58.8 %). Before weaning, the CC calves were lying less (45.1 vs 61.5 %) and playing more (5.4 vs 1.5 %) than the ES calves in week 3, but with no difference in week 6 (lying: 66.8 %, playing: 1.3 %). The CC calves were also lying less and playing more in week 3 than in week 6, while the ES calves showed no difference in lying or playing between weeks 3 and 6. Referring to the comments about the CC cows' absence during milking, we could see that the CC calves played more and were lying less during these absences in week 3 than in week 6. The CC calves tended to be grazing more in week 3 versus week 6 (6.8 vs 2.9 %), while the ES calves grazed more in week 6 compared to week 3 (9.3 vs 4.7 %), and in week 6 they grazed more than the CC calves. Allogrooming between cow and calf was numerically similar in weeks 3 and 6 for the CC calves (2.8 %). Allogrooming between calves was more frequent in week 9 compared to week 3 for the CC calves (3.1 vs 1.4 %) and in week 6 compared to weeks 3 and 9 for the ES calves (4.1 vs 0.7 and 2.0 %). After weaning, in week 9, calves from both treatments were lying less and grazing more than before. The CC calves were lying less than the ES calves (34.8 vs 50.2 %), but there was no difference in grazing (18.2 %). There was no difference in playing between the CC and the ES calves in week 9 (1.1 %). While the CC calves showed no difference in playing between their weeks 6 and 9, the ES calves were playing less in week 9 than in week 6. Low-pitched vocalizations in week 9 were low for both treatments (1.9/calf/hour), but high-pitched vocalizations were numerically higher for the CC calves than the ES calves after weaning and separation from their dams (61.7 vs 6.3/calf/hour).

In the food neophobia test, CC calves showed numerically shorter latencies to approach both novel and familiar feed buckets on day one compared to ES calves (median latencies per calf in seconds for hay, CC: 124 vs ES: 789, carrots: 291 vs 389, concentrates: 173 vs 596, and empty bucket: 272 vs 322). On days 2 and 3, latency differences between CC and ES calves decreased, showing more similarity, especially on day 3. Although the time spent with each bucket and feed consumption were less different, CC calves spent notably more time with hay (time spent in median per calf in % of 30 minutes per day for hay: 26.8 vs 17.9, carrots: 16.3 vs 14.2, concentrates: 3.7 vs 7.9, empty: 5.1 vs 2.6).

5.3.2.2 Calves' standing and moving

Regarding results from the pasture study, the data from registrations of standing/moving was removed from paper II. There was an interaction between treatment and week (P < 0.001) for calves standing/moving, as can be seen in Figure 17. The post hoc test showed that the CC calves tended to be standing/moving more than the ES calves in week 3. There were no differences between the CC and the ES calves in weeks 6 or 9, but the CC calves were standing/moving more in week 3 than in week 6 and more in week 3 than the ES calves in weeks 6 and 9. The CC calves were also standing/moving more in week 9 than in week 6. Anecdotally, according to comments made during the registrations of when the CC cows were brought to milking and back, the CC calves were standing/moving more around these times in week 3 compared to week 6.

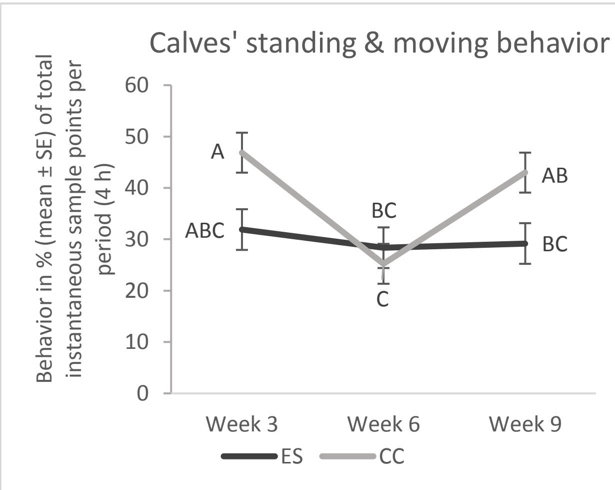


Figure 17. Calves standing/moving behavior for the two treatments: Cow-calf contact (CC, n=10) and early separation (ES, n=10) in weeks 3 and 6 before and week 9 post-weaning. The behavior is shown in % (mean ± SE) of total instantaneous sample points per period (4 h). Means that do not share a letter are significantly different interactions between treatment and week (P < 0.005).

5.3.2.3 CC cows vocalizations after separation from their calves

Some registrations on vocalizations were not included in paper II. Registered vocalizations for the CC cows in group CC1 on days 1, 2, and 3 in week 9 (the first full separation week) showed large individual variations in the numbers of vocalizations among the cows (Figure 18). They had numerically a high number of high-pitched vocalizations on day 1 after separation from the calves. The vocalizations decreased on day 2, where the number also became more similar between high and low-pitched vocalizations, and on day 3 the number of vocalizations decreased even more.

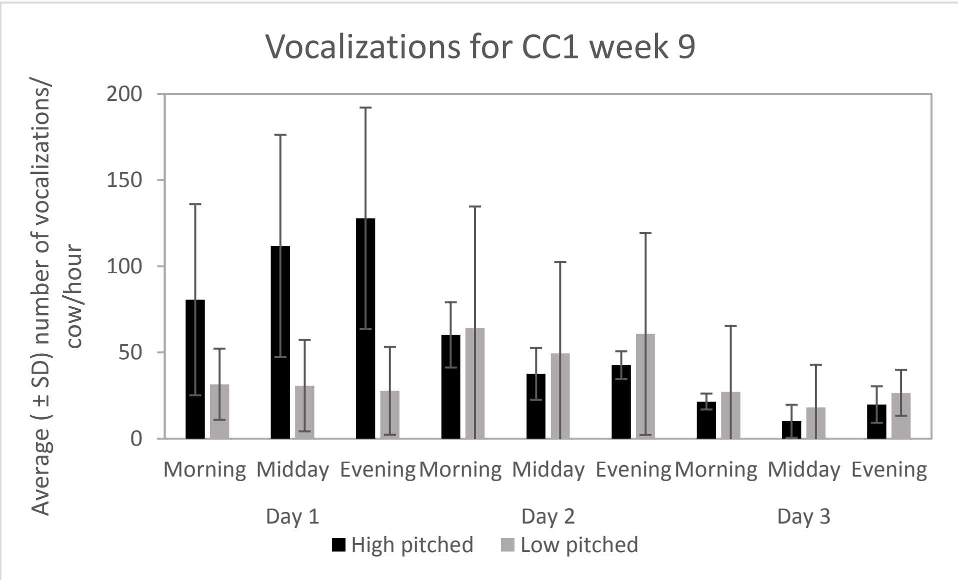


Figure 18. Vocalizations in cow-calf contact cows from the CC1 group (n=5) from the first three days in the first week after separation, from one hour after morning milking, one hour in the middle of the day, and one hour before evening milking.

5.3.2.4 Cow performance

The cows' average machine milk yield during weeks 0-6 postpartum (full CCC period for the CC pairs) was 10.8 kg/cow/day for the CC cows and 34.5 kg/cow/day for the ES cows. The statistical analysis showed significantly lower machine milk yield in the CC cows compared to the ES cows both during weaning (weeks 7-8: 10.4 vs 33.1 kg/cow/day), the first week with full separation of the CC pairs (week 9: 18.2 vs 33.1 kg/cow/day) and afterwards (weeks 10-11: 23.7 vs 32.0 kg/cow/day) ($P < 0.001$). There were no significant differences in the composition of machine milk, except for lactose in week 5 postpartum (CC: 4.5 vs ES: 4.9 %, P=0.005), and the ECM was different (CC: 7.8 vs ES: 33.8 kg/cow/day, P=0.010). The mean machine milk fat content was numerically lower in the CC cows compared to the ES cows (2.6 vs 3.3 %, P=0.146), but it was low in both treatments, and the difference was not significant. There were no significant differences between the treatments in machine milk composition post-study (in weeks 14-18 postpartum, depending on the group), but the ECM was still numerically lower for the CC cows (23.4 vs 28.4 kg/cow/day, P=0.447).

Both the CC and the ES cows had a decrease in their body weight and body condition from when they were let out on pasture until week 9 postpartum, but the decrease was numerically higher in the ES cows. The average body weight decrease was 973 g/cow/day for the CC cows and 1647 g/cow/day for the ES cows from the day they were let out on pasture till week 9.

5.3.2.5 Calf performance

We could not measure the CC calves' milk intake, but the ES calves' milk intake during the period from birth till 6 weeks when they got a high milk allowance was on average 10.7 l/calf/day. The registrations on concentrate intake indicated that the ES calves started eating concentrates earlier than the CC calves, and the amounts were larger for the ES calves than the CC calves, especially during and after weaning (CC, week 0-6: 19 and week 7-9: 428 g/calf/day vs ES, week 0-6: 66 and week 7-9: 980 g/calf/day). The calves body weight gains were not significantly different between the treatments, neither in the period from birth till week 6 after birth (CC: 1.34 vs ES: 1.25 kg/calf/day), the period from week 6 till week 9 (CC: 1.05 vs ES: 0.92 kg/calf/day), or the period from week 9 till 6-7 months (CC: 1.06 vs ES: 1.16 kg/calf/day for the CC and the ES calves, respectively). Both treatments had a lower body weight gain in the period including weaning than the period before weaning.

5.3.2.6 Cow and calf health

Except for the challenge with inhibited milk ejection in the CC cows, there were no obvious differences in health between the CC and the ES cows. There were some challenges with mastitis, teat wounds, and udder injuries in cows from both treatments.

There were some diarrheas in both CC and ES calves, and some coughing in one ES group, but the calves' general conditions were not affected, and on the whole, all calves were perceived as being healthy throughout the study.

5.4 Discussion

The main aim of this thesis was to investigate practices and perceptions of Norwegian dairy farmers with CCC systems and to compare calf behavior and cow and calf performance when calves were with or without their dams on pasture. The aim was achieved by a semi-structured qualitative interview study and a quantitative pasture study with cows and calves in two different treatments. The interviewed farmers practiced their CCC systems differently regarding, e.g., durations of full relative to duration of part-time contact, and methods for weaning and separation (Paper I). They showed various perceptions regarding interrelationships between cows, calves and humans in their systems. Calf behavior was affected by CCC on pasture, but for all behaviors except calf hide use, the differences were dependent on calf age (Paper II). Pastured CC cows machine milk yields were consistently low during the suckling period, weaning and after separation (Paper III). The interviewed farmers perceived improved calf weight gain and healthy calves as primary benefits of practicing CCC. In the pasture study, however, both full CCC and artificially reared calves with high milk allowances were healthy and had comparable weight gains. The main challenge observed with the pasture study was inhibited milk ejection in CC cows.

5.4.1 How do farmers practice and perceive their CCC systems?

The farmers in our interview study practiced their CCC systems differently from each other (Paper I). There were variations in colostrum management, CCC duration after calving, duration of daily CCC and methods for weaning and separation. This complies with previous studies (Bertelsen and Vaarst, 2023; Eriksson et al., 2022; Vaarst et al., 2020, 2019). One similarity between our interviewees was that they all practiced CCC in the same indoor area as the other lactating cows, thus they had not designed and built a separate area for CCC in their barns. Research on conventional calf rearing has indicated that calf management differs between farms (Ellingsen-Dalskau et al., 2015; Johnsen et al., 2021). Our study indicates a comparable variation in the way CCC systems are implemented. All farms have different resources as space indoors or outdoors, access to bedding material, workforce, time etc. These resources may to different degrees accommodate CCC. Our study confirms that so far, there is no recommendation for CCC best practice, or in other words, there is no “one size fits all” CCC system. Additionally, interviewed farmers highlighted that the current housing systems were not suited for CCC systems, which also contributes to farmers developing individual and farm-specific solutions for their CCC systems.

5.4.1.1 Adjustments to facilitate CCC

Although our interviewees experienced that their housing systems were not built to accommodate CCC, most of them were able to change from artificial calf rearing to CCC by making minimal adjustments like adding wooden planks, gates and/or making calf creeps (Paper I). Minimal investment for CCC was also reported by most of the CCC farmers in the Norwegian survey by Hansen et al. (2023). In contrast, Danish farmers in Bertelsen and Vaarst's (2023) study believed that only deep-bedded areas were suitable for CCC, leading several to practice part-time CCC or foster cow systems. These farmers anticipated large investments and barn modifications for full CCC practice (Bertelsen and Vaarst, 2023). Similarly, building constraints have been reported as one of the main barriers to implementing CCC systems (Eriksson et al., 2022; Hansen et al., 2023). Swedish CCC farmers in Jonsson’s (2019) study also perceived the need for more space and redesigned buildings for CCC systems. Although most of our interviewees practiced CCC in older barns with minor investments, they agreed that CCC systems require sufficient space.

It appears that for farmers who are both motivated and possess sufficient space, the implementation of CCC systems can be successful. However, a notable consideration is the potential decrease in delivered milk when adopting CCC systems (Hansen et al., 2023). This may necessitate an increase in the number of cows to maintain the same amount of milk delivered (Berge and Langseth, 2022). Conversely, if the available space dictates maintaining or reducing the number of dairy cows, this may not be economically feasible. Additionally, the challenge intensifies if rebuilding or expanding the barns is required for CCC. Moreover, some existing barn solutions may be more suitable than others (Johanssen and Sørheim, 2021; Vaarst et al., 2019). The need for more space in CCC systems was one of the reasons why some farmers in our study preferred to practice CCC on pasture (Paper I). In our pasture study (Papers II and III), we did not focus on investment evaluation. However, our investments were electric net fences, calf hides, and solid fences for fence-line contact during weeks 7-8.

5.4.1.2 Farmers' perceptions of CCC on pasture

On 7 of the 12 farms in our interview study, farmers practiced CCC on pasture. While some farmers preferred pastured CCC, others opposed it (Paper I). In previous studies, farmers had concerns regarding CCC on pasture (Bertelsen and Vaarst, 2023; Neave et al., 2022; Vaarst et al., 2020; Vaarst and Christiansen, 2023). Bertelsen and Vaarst (2023) found that some farmers were reluctant to practice CCC on pasture due to concerns about the need for expensive "calf-proof" fencing, and the calves' inability to walk long distances for grazing with the cows. Conversely, our interviewees who had CCC on pasture did not invest in "calf-proof" fencing. They reasoned that if calves escaped under the fence, they would never go far from their dams. One farmer noted that pastured CCC reduced labor and fencing needs since calves could graze alongside cows without needing separate areas. In contrast, Vaarst et al. (2020) reported that some farmers found CCC on pasture to be more labor-intensive.

In the study by Lehmann et al. (2021), one farmer viewed calves hiding on pasture as a challenge. Some farmers in our study did report that they regularly were searching for newborn calves on pasture. However, farmers from one farm had quit searching for newborn calves on pasture, as they consistently found that the calves would show up within a few days. Differences in practice and perceptions regarding CCC on pasture may also be affected by the farmers different needs of "being in control", since the farmer may feel less control about the situation when having cow and calf together on pasture compared to indoors. Some farmers in the study by Vaarst et al. (2020) perceived that CCC farmers could be "too laid back", and in the study by Bertelsen and Vaarst (2023) some farmers with larger farms felt that larger farms required a different type of structure and control to be effectively managed compared to smaller farms.

In our pasture study, we could not fully replicate typical farm conditions regarding fencing since we needed to segregate cows and calves into different groups (Papers II and III). This required the use of electric net fences to prevent calves from mixing with other groups. However, gaining more knowledge about dairy CCC on pasture, as from our pasture study, might increase farmers' interest in trying out these systems. Nonetheless, managing CCC on larger pasture areas with larger herds, e.g., in Denmark (Bertelsen and Vaarst, 2023) and New Zealand (Neave et al., 2022), could be more challenging in terms of calf shelter, fencing and other concerns like calves becoming “wilder” on pasture than in rather small conditions of our Norwegian pasture study farm and the farms of our Norwegian interviewees.

5.4.2 Interrelationships between cows, calves, and humans

In contrast to Paper I, the study in Paper II and III did not primarily explore the interrelationships between animals and humans during the pasture study. However, we did record behavior related to the interrelationship between cow and calf, like suckling and allogrooming (Paper II). We considered conducting human interaction tests with the calves, like a human approach test, but decided against it because ES calves in our study, due to their artificial rearing, had more frequent human contact and were thus presumed to be less fearful of humans. This assumption aligns with findings from Bertelsen et al. (2023), who observed that artificially reared calves tended to approach humans more quickly, likely due to their increased exposure to human contact during milk feeding.

5.4.2.1 Dairy cows’ maternal abilities

Our interviewees generally perceived their dairy cows as “good mothers” (Paper I), contrasting the concerns from farmers who practice early cow-calf separation. These farmers worry that cows of modern dairy breeds might not be showing suitable maternal abilities for rearing calves (Neave et al., 2022). Additionally, they might be concerned that cows allowed to bond with their calves may show aggression towards humans to protect their calves (Neave et al., 2022; Vaarst et al., 2020). Almost all our interviewees reported witnessing one or a few cows showing aggressive behavior towards humans to protect their calves. When the farmers knew the cows well and the cows felt safe, this was not perceived a problem, but there seemed to be perceived as an increased safety risk when other people were involved, like employees who did not know the cows that well. In their survey, Hansen et al. (2023) reported that almost no farmers had experienced increased accidents or compromised work safety due to CCC. These findings might appear conflicting at first, but an explanation could be that when our interviewees had experienced cows showing aggression, this was within short time after calving before being early separated from their calves because of this. The finding that this aggression was only experienced within short time after calving might indicate that the risk of such aggressive behavior, might be similar, irrespective of whether early separation or CCC are normally practiced.

In our pasture study, we had inclusion criteria for the CC pairs, including the cows' not showing aggression towards their calves or humans (Papers II and III). The study involved 10 CC cows, all without former experience of CCC beyond a few hours postpartum. Nevertheless, every cow cared for its calf, and none were excluded for aggression or poor maternal behavior. Research indicated that various factors influence maternal behavior, including the cows' breed, age, and previous experience (Le Neindre, 1989; Le Neindre and D'Hour, 1989). Le Neindre and D'Hour (1989) found that primiparous cows more often exhibited aggressive behavior towards their calves and spent less time licking them compared to multiparous cows post-calving. Cows reared with their dams as calves tended to exhibit more "maternal" behavior towards their calves. Moreover, Rørvang et al. (2018) stated that: "*providing dairy cows with an environment where they can perform the maternal behavior they are motivated for, may aid a calm and secure calving and provide optimal surroundings for postpartum maternal behavior.*" Successful CCC practices may hinge on farmers proper facilitation, as well as breeding for appropriate maternal behavior in dairy cows.

5.4.2.2 Farmers handling CCC calves

For the farmers in our study, fostering trust between cow and farmer was deemed crucial as part of the process of facilitating relationships with the calves (Paper I). Handling calves seemed of high importance for most farmers though they varied in if they were most focused on handling calves shortly after calving, regularly during the CCC period or more after cow-calf separation. Other studies also indicate that CCC farmers emphasize the need for handling to tame calves (Bertelsen and Vaarst, 2023; Jonsson, 2019; Vaarst et al., 2020). Similar as the variation in calf handling in our study, the farmers also varied in if they experienced their calves to be less tame, similar or even more tame compared to when practicing early cow-calf separation. Farmers practicing early cow-calf separation might be concerned about calves in CCC systems becoming more difficult to handle when they are not milk-fed by the farmer (Neave et al., 2022), and potentially turning "wilder" on pasture with their dams (Vaarst et al., 2020). Some of the farmers in our study had experienced the calves being a bit "wild" or shy on pasture, but when they focused on handling them through this period or afterward, this was not a problem. However, these were small farms with few calves, and this might be more challenging with bigger herds. Some of our farmers also perceived that the calves would be like their dams through both learning and genetics. Similarly, farmers in Vaarst et al.'s (2020) study mentioned that they believed the calves reared in a CCC system would become calm and confident as adults, and farmers in Bertelsen and Vaarst's (2023) study believed that calves would become calmer with age, regardless of early handling. In our pasture study, we did not perceive handling of CC calves as challenging. Perhaps they were a bit "wilder" than the artificially reared calves, but these perceptions remain anecdotal as we did not record handleability of cows or calves (Papers II and III).

5.4.2.3 Calves learning from their dams

In our interviews, farmers generally viewed calves learning from their dams as an advantage of CCC systems (Paper I). It is known from previous research that calves reared individually have difficulties learning (Gaillard et al., 2014; Meagher et al., 2015), and that offspring learn from their mothers (Mogi et al., 2011; Newberry and Swanson, 2008). This perspective has also been discussed in other studies (Jonsson, 2019; Lehmann et al., 2021; Vaarst et al., 2020), highlighting the positive effects of calves learning from their dams how to "behave like a cow" in their housing and on pasture. However, in Bertelsen and Vaarst's (2023) study, Danish CCC farmers seemed to place less emphasis on this learning aspect. A possible reason could be that their CCC practices occurred in separate areas, part from where the calves would later live as dairy cows (Bertelsen and Vaarst, 2023).

In our pasture study's food neophobia test, the less cautious behavior shown by CC calves compared to ES calves on test day 1 (Paper II) might have been influenced by the CC calves being more confident and exploratory in this situation due to previous learning of feeding and social behavior from their dams (Marino and Allen, 2017). We also suggested that calves' grazing behavior on their first day on pasture might be influenced by their learning experiences, either with or without their dams present. However, due to insufficient inter-observer reliability, the results from this first day could not be used.

5.4.2.4 Stress around weaning and separation in CCC systems

Among the farmers we interviewed, some viewed separation stress as a challenge (Paper I). Farmers reported that especially cows could vocalize for several days. But unlike other studies, in which separation stress has been perceived as a main concern about CCC systems (Eriksson et al., 2022; Hansen et al., 2023; Neave et al., 2022), several of our interviewees used self-developed methods which they believed alleviated this stress. In our pasture study, we attempted gradual weaning and separation to lessen stress, but recorded peak levels of high-pitched vocalizations in both CC cows' and calves' post-separation (Figure 14 and Paper II). The farmers from the pasture study farm noted stress in CC cows, including an increased challenge of milk ejection inhibition during milking, likely influenced by the separation-stress. Some of the farmers in Bertelsen and Vaarst's (2023) study believed that gradual weaning could prolong stress compared to abrupt separation. However, a review by Enriquez et al. (2011) reported various outcomes in studies comparing gradual and abrupt weaning methods on separation stress in beef cattle. Our pasture study showed large individual variations in vocalizations, a finding that was also reported by some of the interviewed farmers who had experienced that some cows could vocalize a lot for several days, while others seemed not to be bothered as much by the separation (Paper I). It appears that there is no clear solution for optimally minimizing of separation stress, and perhaps the methods should be adapted on an individual level. Given that some farmers believe they have developed functional methods, researchers should collaborate with these farmers to further examine this important concern of CCC systems.

5.4.2.5 Being a farmer working in a CCC system

Opinions among farmers in our interview study varied on the labor intensity of CCC systems compared to early cow-calf separation (Paper I). They concurred that they spend less time on calf feeding, aligning with Asheim et al. (2016). Conversely, a common concern about CCC systems among farmers practicing early separation is in fact increased labor. This concern is reported by farmers with both small (Hötzel et al., 2014) and large farms (Neave et al., 2022). Farmers in Neave et al.'s (2022) study also expressed concerns about more complicated and stressful work. However, several studies indicate that many farmers practicing CCC experience reduced labor (Bertelsen and Vaarst, 2023; Eriksson et al., 2022; Hansen et al., 2023; Jonsson, 2019). Some farmers in our study found the work to be easier and more flexible without fixed calf-feeding schedules, similar to what was reported by Bertelsen and Vaarst (2023). The latter study reported that Danish CCC farmers favored CCC for its practicality, ease, and labor efficiency. Farmers with pastured CCC systems in the study by Neave et al. (2022), also reported the work being easier. We did not examine labor input in our pasture study (Papers II and III), as the setup was not realistic since the animals were kept in small groups on different pasture areas. The varying perceptions regarding workload with CCC systems are likely affected by several factors, such as the variation in CCC practice, type of housing, farm size, and whether the farmers have other work outside farming. Moreover, some of our interviewees highlighted their enjoyment of spending time in their barns with their animals, which may indicate some not being concerned about working very efficient. The farmers variation between the need for "being in control" and their trust in the animals' capabilities (Vaarst et al., 2020) also likely impacts their perceived workload.

Our interview study's farmers expressed enjoyment with their CCC systems, similar as found in other studies, in which farmers expressed satisfaction and joy as a motivation to continue using these systems (Vaarst et al., 2020), and increased well-being (Berge and Langseth, 2022; Wagenaar and Langhout, 2006). Other research indicates a direct correlation between farmers' well-being and the welfare of their animals (Hansen and Østerås, 2019; King et al., 2021), implying that farmers derive satisfaction of perceiving their animals enjoying themselves. In the interview with the pasture study farmers, one of them believed that one main reason for some farmers to practice CCC is the well-being the farmers feel themselves by practicing this system. This perspective aligns with findings from our interviews study and other research, highlighting the farmers personal well-being as an important motivation for practicing CCC systems.

5.4.3 Is dairy calf behavior affected by CCC on pasture?

Our expectation was that calves would use the calf hides to seek shelter, as cattle generally seek shelter under varying weather conditions (Sawalhah et al., 2016; Van Laer et al., 2015). We also hypothesized that CC calves would use calf hides less than ES calves and this was confirmed during all observations (Paper II). It could be that CC calves used the calf hides less due to social facilitation by their dams. Additionally, CC calves' calf hide usage increased with age, possibly because cow-calf proximity diminishes over time, as reported by other studies (Hirata et al., 2003; Vitale et al., 1986). The larger pasture areas for CC calves might also be a factor affecting calf hide use. Hutchison et al. (1962) noted that time spent moving was similar between calves and their dams on pasture, suggesting that CC calves accompanying their mothers, would naturally spend less time near or in calf hides. Furthermore, while CC calves suckled from their dams, ES calves were fed milk in the calf hide area, likely contributing to ES calves increased use of calf hides.

We hypothesized that CC calves would be lying less than ES calves due to social facilitation by their dams (Paper II). Additionally, we hypothesized that CC calves would show more play behavior if they got welfare benefits from being with their dams, as play is a sign of positive welfare (Held and Špinka, 2011). In week 3, this was evident with CC calves lying less and playing more than ES calves, but by week 6, these differences disappeared. Since CC calves in our study were lying less, standing/moving more, and playing more around the times the cows were being milked in week 3 than week 6, it seems that CC calf behavior was affected more by the dams milking in week 3 than week 6. While full-day observations would have been ideal, we focused on morning and evening due to practical constrains. Another reason for the chosen observation periods was that other studies showed peaks of grazing (Kilgour et al., 2012; Martins et al., 2017; Walker, 1962), playing (Day et al., 1987; Odde et al., 1985) and suckling in calves during these periods (Reinhardt et al., 1986). However, the twice-daily milking would likely influence calf behavior regardless of observation times. In the study by Mac et al. (2023), cows were also taken away for milking, and the authors found that cows' vocalizations and attempts to return to their calves decreased with calf age. This suggests that younger calves might be more affected by their dams' behavior, at a time when the dams show more interest in being with their calves. Sinnott (2023) found CCC calves to be standing less and moving more than artificially reared calves. This could possibly have been seen in our study as well, but we did not distinguish between standing and moving like in the mentioned study.

Sinnott (2023) found no difference in the amount of play among full CCC calves on pasture, part-time CCC calves indoors and artificially reared calves indoors. However, Waiblinger et al. (2020b) observed increased solitary play in CCC calves compared to artificially reared calves indoors. Distinguishing between various play behaviors would have been beneficial in our study, but direct observations on pasture limited this capability (Paper II). We included running as a part of play and noted that CCC calves ran to follow their dams. Bailly-Caumette et al. (2023) reported that milking of cows influenced calves play behavior indoors, with calves showing more intense locomotor play after the cows were taken away for milking. Exploring the use of mobile milking robots for CCC cows on pasture could be an intriguing aspect, potentially allowing calves to stay close during milking and thereby reducing the impact of milking on calf behavior.

We hypothesized that CC calves would graze more than ES calves (Paper II). However, we found no difference in grazing between treatments in week 3, and in week 6 ES calves grazed more than CC calves. Previous studies have indicated that restricted milk feeding increases solid feed intakes (Fröberg et al., 2011; Miller-Cushon et al., 2013). In our study, both treatments had ample milk access, so hunger was not expected. However, the milk feeding methods differed: ES calves had four meals daily, while CC calves suckled freely, except during cows' milking. This difference in milk feeding might have impacted CC calves to spend more time on milk ingestion which could have led to a have a higher milk intake, while ES calves spend more time on grazing (Paper II) and had a higher concentrate intake, since the weight gains were not different (Paper III). Since ES calves did not have opportunities to spend time on behavior with their dams, such as suckling and cow-calf allogrooming this could also have influenced them spending more time on other behaviors, such as grazing. If ES calves had ad libitum milk access from an automatic feeder, these differences might have been minimized. CC calves, potentially influenced by CCC, might have had a higher energy requirement than ES calves. This could be due to increased physical activity and more exposure to wind and precipitation by not using the calf hides as much as ES calves. CC calves could have met these nutritional needs by suckling more milk instead of increased grazing and concentrate consumption. The botanical composition and quality of the pasture might also have played a role in grazing behavior, as the pasture for ES calves was of somewhat lower quality.

Nicolao et al. (2020) found grazing behavior differences between CCC calves and artificially reared calves when released onto pasture post-weaning. In their study, CCC calves had the advantage of previous experience with both their dams and pasture, in contrast to the artificially reared calves who lacked such experience. In our study, observing the calves' grazing behavior for several days immediately after their first pasture access, could have been valuable when considering that all calves were put on pasture at the same age.

We hypothesized that CC calves would engage in less allogrooming with each other due to receiving allogrooming from their dams (Paper II), since Webster et al. (1985) found CCC calves on pasture to groom each other less than calves artificially reared indoors. However, we did not find differences in calf-calf allogrooming between CC and ES calves. This could be due to the limited number of animals and generally few recordings of this behavior. As it has been suggested that artificially reared calves will use an automated brush for grooming as a redirected behavior associated with maternal grooming (Zobel et al., 2017), the ES calves may have spent more time on self-grooming for the same reason. However, we did not record self-grooming. In our study, aside from calf-calf allogrooming, there was an effect of

CCC on calf behavior. However, for most behaviors the differences between CC and ES calves were dependent on calf age.

5.4.3.1 Behavior after weaning

The observed decrease in lying and increase in vocalizations among CC calves compared to ES calves post-weaning (week 9, Paper II) indicates higher stress levels, likely due to separation from their dams in addition to weaning. CC calves might also have had a more abrupt transition from milk to solid feed if they ingested more milk than ES calves in weeks 7-8, during which the CC calves could suckle the cows in periods after milking. Also, the challenges with inhibited milk ejection in CC cows were prominent in this period. However, the similar grazing levels in week 9 and the similar weight gains from weeks 6 to 9 (Paper III) might indicate that all calves coped well with the transition from liquid so solid feed (Khan et al., 2011). While both groups increased their concentrate intake during and after weaning, ES calves consumed more concentrates than CC calves (Paper III), possibly influenced by their greater use of calf hides where concentrates were located (Paper II). The difference in intakes of concentrates could also be linked to the possibility of CC calves consuming more milk in the suckling period, as suggested by the relation to ES calves' increased grazing in week 6.

Regarding vocalization as an indication of stress, we included recordings of the calves' vocalizations only on the observation day in week 9 (Paper II). Extended vocalization recordings post-separation and during weaning in weeks 7-8 could have been insightful. However, making such recordings was not feasible due to economical constraints and because we did not compare different weaning and separation methods between CC pairs. Our comparisons of CC and ES calves aligns with findings from an indoor study (Fröberg et al., 2011), which observed greater stress in suckling calves post-weaning and separation from their dams than in artificially reared calves. Although we attempted more gradual weaning, peaked levels of vocalizations were recorded from both CC calves (Paper II) and cows (Chapter 5.3.2.3) after weaning and separation, potentially exacerbated by their ability to hear each other.

5.4.3.2 Food neophobia test

Our food neophobia test indicated that CC calves were quicker to explore and eat from buckets, especially on the first test day (Paper II), indicating less food neophobia (Costa et al., 2014). However, this applied to buckets containing both novel and familiar feed, suggesting that ES calves were more cautious rather than neophobic. The time spent with buckets and intake of novel feed were similar across both treatments and the three test days. The variation in novel feed intake seemed more group-specific than treatment-specific, indicating that individual calf personalities and group dynamics played a role. Our findings, which aligned with Neave et al. (2018), indicate that calf personalities, including their level of exploration, affect feeding behavior. The more exploratory nature of CC calves might make them better adapted to environmental changes, possibly due to the benefits of being with their dams. Yet, seeing that latencies on days 2 and 3, and the other variables were similar between treatments, the slight caution of ES calves towards the buckets is unlikely to negatively affect their long-term feed intake or production, as food neophobia might do (Launchbaugh et al., 1997).

5.4.4 Is dairy cow performance and health affected by CCC on pasture?

5.4.4.1 Machine milk yield and inhibited milk ejection

In our pasture study, we hypothesized that machine milk yields from CC and ES cows would align post-separation (from week 9, Paper III). In contrary, CC cows showed consistently lower machine milk yields than ES cows until week 10-11 postpartum. Although Meagher et al. (2019), found no substantial long-term reduction in machine milk yield post-separation some recent studies found a prolonged lower machine milk yield in CCC cows compared to non-CCC cows (Barth, 2020; Sinnott et al., 2022).

Our pasture study revealed that CC cows, during full CCC had a machine milk yield that was on average -23.7 kg/d compared to ES cows (Paper III). Much of the milk was likely consumed by the calves, each having individual nutritional needs, as evidenced by the large variation in milk intake among calves reported in other studies (e.g., Appleby et al., 2001). However, this discrepancy was likely also influenced by the higher relative proportion of primiparous cows among CC cows and challenges with inhibited milk ejection, especially in these cows. The study farm farmers expressed concerns about persistently low milk yield. Similarly, a farmer from our interview study was worried that primiparous cows might have a lower lactation curve with CCC compared to early separation from their calves (Paper I). Most of our interviewed farmers, however, did not view inhibited milk ejection as a major issue in CCC. It seemed a transient problem, mainly in the initial days postpartum and predominantly with primiparous cows. Yet, one farmer suggested that this issue might be more widespread and underrecognized, potentially leading to farmers overestimating calves' milk intake during suckling. In a recent study by Vaarst and Christiansen (2023), farmers participating in a three-year project discussing CCC systems reported challenges related to inhibited milk ejection, which remained unresolved by the project's end.

Churakov et al. (2023) employed two methods to estimate salable milk loss in CCC systems and estimated lower machine milk yields in CCC cows both before and after calf separation. In our study, we could not calculate such losses due to the limited observation period (first 11 weeks postpartum, Paper III). Barth (2020) indicated that the prolonged yield reduction in CCC cows could be due to a negative feedback effect on milk secretion. Studies shows that dairy cows release more oxytocin during suckling than at milking (Bar-Peled et al., 1995; Lupoli et al., 2001), which may contribute to challenges in milk ejection when machine milking nursing cows (Kälber & Barth, 2014; Zipp, 2018). Additionally, incomplete milking combined with ongoing milk production can cause milk to return from the udder cistern to the alveoli (Caja et al., 2004), thus resulting in faster udder refilling between milkings and a decrease in overall milk secretion.

Stress from unfamiliar environments may also affect milk ejection (Wellnitz and Bruckmaier, 2001). In our study, primiparous cows were unfamiliar with being on the farm's summer pastures, and possibly the milking parlor and the associated routines impacting their milk ejection (Paper III). Udder hand massage, known to stimulate milk ejection (Kentjonowaty et al., 2021), was tried before and during milking without success. Bruckmaier (2013) suggested tactile vaginal or cervical stimulation to be more effective into improving milk ejection than udder massage, however, this was not practically doable in a farm study. Other methods to improve milk ejection could be training primiparous cows to milking routines before calving (Ujita et al., 2021) or allowing calves to suckle briefly before milking and/or having them present during milking, as is done with tropical cattle (Hernández et al., 2006; Junqueira et al., 2005). Moreover, the cows' stress due to separation from their calves (Newberry and Swanson, 2008), even when done gradually (Johnsen et al., 2015b), might have contributed to the inhibition of milk ejection being prominent during weaning and separation.

5.4.4.2 Fat content in machine milk

In our pasture study, we hypothesized that CC cows would have a lower fat content in their machine milk compared to ES cows while CC cows were nursing (Paper III), in line with findings from indoor studies (Barth, 2020; Wenker et al., 2022; Zipp, 2018). This hypothesis was supported by similar findings in recent studies with CCC on pasture (Nicolao et al., 2022; Ospina Rios et al., 2023). In our study, milk from CC cows had a 0.7 percentage points lower fat content than milk from ES cows, though both treatments showed lower fat content than the Norwegian average of 4.4% (Tine, 2023). This could be attributed to the influence of grazing, as indicated by Adler et al. (2013), who found a decrease in fat content in machine milk from Norwegian farms during pasture periods relative to indoor periods. The lack of a significant difference between CC and ES cows in our study may stem from large variations in fat content and the limited number of cows involved. Among the farmers we interviewed, some reported affected milk quality with lower fat content while cows were nursing, while others had not noticed this (Paper I). Similarly, in Ellingsen et al.'s (2015) survey, some farmers experienced milk quality being affected by nursing, while others did not. However, in our pasture study, composition of machine milk aligned between treatments post-separation, consistent with other studies (Barth, 2020; Ospina Rios et al., 2023). Given that milk fat content increases during milking and inhibited milk ejection can reduce fat content (Dymnicki et al., 2013), finding ways to enhance milk ejection in CCC cows could potentially increase the fat content in their machine milk during nursing.

5.4.4.3 Cow health

During our pasture study, we encountered challenges related to udder health and mastitis across the treatments both with and without CCC (Paper III). Most farmers in our interview study reported no difference or an improvement in overall cow health, including udder health, with CCC compared to when they practiced early separation (Paper I). This aligns with the findings in Beaver et al.'s (2019) review, although most studies in the review were conducted under indoor conditions. As in our pasture study, another recent pasture study by Ospina Rios et al. (2023) reported a similar occurrence of mastitis in both CCC and early separated cows. However, farmers in the study by Neave et al. (2022) practicing CCC on pasture, perceived an improvement in both cow and calf health in their systems. It is clear that factors other than CCC, such as genetics, different environmental factors (Cheng and Han, 2020) and nutrition (Erickson and Kalscheur, 2019), play a crucial role in cow health. Nevertheless, the challenge of inhibited milk ejection during milking of

CCC cows, as observed in our pasture study, warrants further investigation due to its potential negative effects on cows' health.

5.4.5 Is dairy calf performance and health affected by CCC on pasture?

5.4.5.1 Calf milk intake and weight gain

In our pasture study, the milk consumption of CC calves remains unknown, but ES calves exhibited an average intake of approximately 11 L/calf/day when they got four meals per day (Paper III). In another recent study with the same breed (NRF), which included calves with and without CCC indoors, it was found that artificially reared calves with close to ad libitum milk access (four meals, one hour per meal) consumed an average of 12 L/calf/day (Sløbraaten, 2023). Our interview study (Chapter 5.3.1.4), along with findings from other studies, indicates that farmers perceive higher weight gains and improved health in calves as a key advantage of practicing CCC compared to practicing early cow-calf separation (Eriksson et al., 2022; Hansen et al., 2023; Jonsson, 2019). Our hypothesis postulated that CC calves would have higher weight gains than ES calves during the milk feeding period in our pasture study, with the difference disappearing post-weaning. However, we found calf weight to be comparable between treatments. This aligns with other recent studies conducted indoors, where similar weight gains were observed in calves regardless of CCC when artificially reared calves received either ad libitum (Vagle, 2020) or substantial milk allowances (Bertelsen and Jensen, 2023). Additionally, in the second trial in the recent study by Nicolao et al. (2022), part-time CCC cows (9 h/day) on pasture and artificially reared calves indoors also had similar weight gains. Johnsen et al. (2015a) found consistent weight gains in CCC calves regardless of whether they suckled or not. In their study, in one treatment calves suckled, while in the other, calves were prevented from suckling by udder nets and received a daily allowance of 12 L of milk per calf. Our pasture study, along with other research, suggests that milk availability plays a more pivotal role than CCC itself in influencing calf weight gain during the milk feeding period, despite farmers attributing substantial weight gain as a primary benefit of CCC systems.

5.4.5.2 Calf health

The farmers we interviewed reported experiencing good calf health for calves kept in CCC systems (Paper I). This aligns with Vaarst et al. (2020), who reported that many farmers highlighted not only the physical but also the mental and emotional well-being of calves in CCC systems. In our pasture study, we also experienced calves being healthy (Paper III). However, while the interviewed farmers often perceived better health in CCC calves compared to early separated calves, our pasture study revealed no discernible health differences between the two treatments. In a similar vein, Ospina Rios et al. (2023) did not identify any health issues related to treatment, regardless of whether calves had CCC on pasture or were artificially reared indoors. A recent comprehensive study by Johnsen et al. (2022), involving 109 herds with a total of 1779 CCC calves and 2980 artificially reared calves, also found no difference in mortality or morbidity risk within the first 90 days of a calf's life. Contrarily, Sinnott (2023) observed a decline in health, with increased diarrhea, in calves with full CCC on pasture compared to artificially reared calves indoors. Wenker et al. (2022b) similarly reported poorer health in full CCC calves. However, in their study, all calves were kept indoors, and they attributed the CCC calves' poorer health to suboptimal hygiene and environmental conditions for the CCC calves in the cows' freestall housing. In our interview study, some of the farmers perceived infection pressure as being higher indoors. These farmers preferred practicing CCC on pasture, where the calves had access to more space, better hygiene conditions, and were thus exposed to a lower infection pressure (Paper I and Chapter 5.3.1.4). Additionally, some farmers favored pasture calving, driven by both their desire for natural behavior and health considerations. These varied findings regarding calf health in CCC systems, as compared to early separation, suggest that factors other than the CCC system itself are more important in affecting calf health.

5.4.6 Animal welfare and natural behavior

Most farmers in our interview study talked about how practicing CCC increased their animals' welfare and their animals' possibilities to perform natural behavior (Paper I). Similarly animal welfare and natural behavior was important to Norwegian and Swedish CCC farmers in the studies by Hansen et al. (2023) and Jonsson (2019), respectively. Like in Norway, the Swedish CCC farms were also relatively small. In contrast, only three out of 12 Danish farmers mentioned animal welfare and naturalness as motivators for CCC (Bertelsen and Vaarst, 2023), indicating relatively less emphasis on animal welfare among Danish farmers than among Norwegian and Swedish farmers. This disparity might be influenced by farm size, as Danish farms were larger. However, on the equally larger or even larger pasture-based dairy farms in New Zealand, studied by Neave et al. (2022), farmers also prioritized animal welfare. In New Zealand, Farmers practicing early separation were concerned about animal welfare in CCC systems, whereas CCC farmers perceived animal welfare as being improved by practicing CCC. Additionally, among the interviewed Danish farmers, some had quit practicing CCC, others practiced foster cow systems, while only four practiced dam-rearing for periods of at least two weeks.

Animal welfare is a concept with varied definitions (Weary and Robbins, 2019), and aspects perceived as being most important for animal welfare differs among individuals (Logstein and Bjørkhaug, 2023; Sumner et al., 2018; Vigors, 2019). Similar as for several of the CCC farmers in our interview study, consumers are especially focused on what is considered as being natural for the animals when they reflect on animal welfare (Vigors et al., 2021). However, the ability to perform natural behaviors, often included in welfare definitions, does not always equate to positive welfare (Browning, 2020). Enabling animals to live so-called naturally can sometimes lead to adverse experiences; for instance, animals on pastures face greater exposure to predators and risks compared to the safer environment of a barn. In my view, the essence of animal welfare should be centered on the animals' own experience and emotions, as eloquently described by Braastad (n.d.). "*Animal welfare is the subjective experience of the individual of its psychological and physical condition as a result of its attempts to master its environment*". This perspective shifts the focus to understanding welfare from the animal's point of view.

One CCC farmer we interviewed perceived calf welfare with CCC as comparable to calf welfare with artificial rearing, since calves received high milk allowances and good care when they were separated early as well (Paper I). In our pasture study, both CC and ES calves had access to large pastures, calf hides, straw bedding, ad libitum grazing, concentrates, water, other peers, and either free suckling or high milk allowance from milk bars (Papers II and III). The key distinction was that CC calves could naturally suckle from their dams, receiving maternal care and experiencing social behaviors and allogrooming not just with peers but also with their mothers. The presence of dams may have offered additional protection, comfort, a sense of safety, and unique learning opportunities from older animals. Yet, despite these potential benefits, we cannot conclusively assert that CC calves experienced better welfare than ES calves in our pasture study. Under natural conditions, calves typically suckle until weaning at 7-14 months (Reinhardt and Reinhardt, 1981), however, in our study, calves were separated after 8 weeks. The female farmer from the study farm pondered whether the perceived increased welfare for both cow and calf during their time together justified the stress, particularly for the cows, observed during their subsequent separation (Chapter 5.3.1.6).

5.4.7 Methodological considerations

To examine how CCC impacts calf behavior and cow-calf performance on pasture, an enhanced approach would involve a controlled experiment with variables except for the treatment, being more stable between the treatments than what was practically possible in out pasture study. Our pasture study was conducted on a Norwegian commercial dairy farm with 80 cows and e.g., that the farm had only a third of the cows calving in May-June made practical constraints (Papers II and III). Group sizes and replication numbers were pre-planned with a statistician to enable statistical analysis, but a larger sample size and more replicates would have enhanced the reliability of the behavior and performance results. The study's validity was further challenged by the uneven distribution of calf gender and cow parity, as well as other aspects considered below.

In the pasture study, the CC groups had more primiparous cows, known for lower milk yields (Hansen et al., 2006) and a higher likelihood of inhibited milk ejection (Bruckmaier, 2005) than multiparous cows. The cows calved between May 7 and June 14, but snow cover delayed release on the summer pasture (17 km from the farm) until June 7. While ES calves could graze on a farm pasture, there were no suitable cow pastures near the AMS barn. To maintain age consistency among calves for behavioral observations, early calving cows and their calves were assigned to ES groups. Consequently, ES calves experienced different conditions than the CC pairs, initially grazing on the main farm and later moving to the summer pasture at higher ages than CC calves. Despite these differences, conditions for ES calves were comparable across both pasture locations in terms of group composition, area size, calf hide access, and feed allowance. However, ES cows stayed indoors longer postpartum, leading to delayed pasture exposure compared to CC cows. Additionally, the need to have separate grazing areas for ES calves versus the ES cows and CC pairs resulted in varied botanical composition and slightly inferior pasture quality for ES calves.

In the pasture study, to account for the influence of individual animals within a group a Mixed Effects Model was used in the statistical analyses. The mixed model accounted for the hierarchical structure of the data with repeatedly measured animals within groups within treatments. However, due to the limited number of groups and animals, and some data being on group-level, certain results were presented descriptively without statistical analysis. Individual behavior data from the food neophobia test were also presented descriptively. The test should have ideally been done individually but was conducted in groups since the calves were not used to being alone.

Due to the limitations of the pasture study methodology, the study was called a "pilot study" in the papers (Papers II and III).

5.4.7.1 Calf behavior

Calf behavior was directly observed on pasture (Paper II), with limitations in this method. Although video recording allows for more precise behavior analysis through playback, pause and slow-motion options, as done in the food neophobia test conducted in a smaller area, it was impractical for observations on larger pasture areas. Direct observations, used in weeks 3, 6 and 9, faced challenges: the observer's presence potentially influenced the calves (mitigated by a quiet and calm observer), and only a limited range of behaviors could be recorded. For example, it was difficult to make distinctions between standing and moving, and different play behaviors. "Running" was included in "Play", and CC calves were observed running after their dams. It could also have been convenient to add abnormal sucking to the registrations. The larger pasture areas for CC calves compared to ES calves might have influenced their behavior. However, all calves appeared to have ample space for natural behaviors like grazing and playing, including running.

5.4.7.2 Cow and calf performance

Cows' machine milk yields in our pasture study were not followed throughout the cows' lactations (Paper III). This limitation prevented a thorough examination of whether the lower machine milk yields in CC cows persisted and thus an estimation of salable milk loss, as was estimated by two different methods in the recent study by Churakov et al. (2023). Our study faced challenges with inhibited milk ejection in CC cows, especially during weaning and separation, likely due to increased stress. Oxytocin injections were administered several times to mitigate this issue. Following advice from lactation biology experts, days around oxytocin injections for recorded machine milk yields and milk samples from week 9 were excluded from the analyses. Later, additional samples were obtained, when the cows were in different weeks after calving, and back in the barn. A predefined protocol for identifying and managing inhibited milk ejection could have enhanced the study's preparedness for addressing this issue.

To ensure that treatment rather than milk allowance affected calf performance in our pasture study, we aimed for ad libitum milk access for both CC and ES calves. While ES calves received high milk allowances in four daily meals, practical limitations prevented ad libitum milk feeding on pasture. The initial plan was to provide up to 16 liters of milk per ES calf per day, based on a previous study (Wormsbecher et al., 2017), but this was adjusted to reduce milk waste since there usually were left-overs of several liters after the calves' second and fourth meals. Ideally, if ES calves had been fed milk ad libitum from automatic milk feeders, we could have compared CC calves' suckling with ES calves sucking behavior. With automatic feeders for milk (ES) and concentrates (CC and ES), we could also have recorded feed intakes individually, but instead, intakes were recorded on group level. In any case, milk intakes for CC calves could not be measured. Weaning and separation were conducted using fence-lines, allowing suckling post-milking in weeks 7-8. More frequent weighing during this period could have offered more detailed insights into weight gain before, during and after weaning. CC calves seemed more stressed after weaning than ES calves, and consumed less concentrates, possibly affected by a more abrupt transition from milk to solid feed. However, mean weight gains between treatments were similar, also from between week 9 to 6-7 months.

5.4.8 Future perspectives

A study of Norwegian consumers' attitudes towards animal welfare (Bugge and Schjøll, 2021; Kjærnes et al., 2022) revealed high trust in Norway's animal health and animal welfare systems and in farmers, more so than in other countries. Focus group interviews conducted by Kvam & Logstein (2023) with 14 Norwegian consumers indicated trust in Norwegian agriculture regarding animal welfare. The results indicated that consumers felt that farmers probably have a good reason for the usual practice of early cow-calf separation. Several respondents thought that CCC could be positive for animal welfare and the animals' abilities to express natural behavior. However, participants expressed a need for more information before deciding on their preferred practice. Unlike more populous countries like Canada, the US, Brazil and Germany, Norway lacks extensive surveys on attitudes towards early separation in dairy farming, an area ripe for further research.

For future studies comparing behavior and performance in dairy calves with CCC and artificial rearing both indoors and on pasture, one should use automatic feeders for ad libitum feeding of milk and concentrates to ensure comparable feeding conditions and enable individual intake monitoring. This approach would also facilitate comparisons of natural suckling and artificial sucking behaviors, as well as abnormal sucking. Gradual weaning using automatic feeders could also be explored. However, it might be difficult to wean suckling calves in the same way as calves fed from automatic milk feeders, unless they switch to automatic milk feeders after separation from their dams for a period before weaning. However, encouraging CCC calves to adapt to artificial teats can be challenging (Johanssen and Sørheim, 2021), but this might be made easier by using molasses on the artificial teats (Sørby et al., 2023). Future studies should also focus on comparing various behaviors, including different types of play, as well as observing early grazing and ruminating on pasture.

The recent report "Welfare of calves" (Nielsen et al., 2023), by the EFSA panel of Animal Health and Welfare highlights the importance of CCC in calf welfare. The panel recommends keeping the calf with its dam for at least one day postpartum and gradually extending this contact for the welfare of both cow and calf. The authors emphasize the necessity for further research to guide the practical implementation of CCC systems. Future research might focus solely on CCC systems, reflecting potential consumer demand. However, considering that most dairy farmers favor early separation, the readiness of the dairy sector for this shift, remains questionable. Future research should not only focus on CCC systems in practice, but also examine more about how it influences calf behavior, both short-term and long-term. The key difference between CCC calves and artificially reared calves may lie in the learning, care and protection the CCC calf receive from its dam, if conditions such as environment and milk allowance are similar. In a review by Nawroth and Rørvang (2022) they stated that: "*Future studies should focus on elucidating what and how much calves learn from their dam during prolonged cow-calf contact in dairy cattle. Such information could constitute an important part of the discussion of whether to keep cows and calves together for a longer time after calving in the dairy industry."* Research methodologies could include comparing calves in different tests to study their neophobia and exploratory behavior, but also their social competence and cognitive intelligence in different tasks, both as calves and when they are adults.

To enhance milk ejection in pastured dairy cows with calves, research could explore mobile milking robots for CCC cows, bringing calves with cows to milking parlors, or training primiparous CCC cows to milking routines before calving. Stress minimization during weaning and separation is also crucial, possibly through methods like first having a period of part-time suckling before a period of only fence-line contact, and then completing separation by moving cows and calves far away from each other (no visible or audible contact). It could also be beneficial to continue milk feeding of CCC calves after cow-calf separation, as suggested by Johnsen et al. (2015).

5.5 Conclusion

The farmers in our interview study practiced their CCC systems differently regarding, e.g., durations of full relative to duration of part-time contact, and methods for weaning and separation. They showed various perceptions regarding interrelationships between cows, calves and humans in their systems. Some main findings were that they did not see intake of colostrum as a challenge despite of different practices. The cows were generally perceived as being "good mothers", though nearly all farmers had experienced one or a few cows showing aggressive behavior towards humans to protect their calves. The farmers found their farm buildings initially unsuitable for CCC, but most had made only small adjustments to make it work, and they agreed on the importance of adequate space. While some preferred practicing CCC on pasture, others were reluctant to practice CCC on pasture. The farmers noted the benefits of calves learning from their dams, like feeding behavior and learning "how to be a cow". Opinions on the workload with CCC compared to early cow-calf separation differed, but there was a consensus on reduced time spent on calf feeding. Overall, the farmers agreed that CCC encouraged natural behaviors and experienced enjoyment from observing what they perceived as good welfare in their cows and calves.

In the pasture study, calf behavior was affected by their dams on pasture. E.g., CCC calves used the calf hides less than artificially reared calves but more with increasing age. For the other behaviors, differences between treatments were dependent on calf age. CCC calves seemed to be more affected by their dams in week 3 than in week 6. Additionally, CCC calves showed behavior indicating more stress than artificially reared calves after weaning. On the first day of a food neophobia test, CCC calves showed behavior indicating that they were less cautious towards the buckets, regardless of feed content, compared to artificially reared calves.

Pastured CCC cows machine milk yields were consistently low during the suckling period, weaning and after separation. Of milk composition parameters, lactose content was transiently decreased for CCC cows. The interviewed farmers perceived improved calf weight gain and healthy calves as primary benefits of practicing CCC. In the pasture study, however, both full CCC and artificially reared calves with high milk allowances were healthy and had comparable weight gains. The main challenge observed with the pasture study was inhibited milk ejection in CCC cows.

This interview and pasture study offers valuable insights for farmers contemplating a shift to practicing CCC. By learning from the experiences of other farmers and drawing on research findings, these farmers can make more informed, knowledge-based decisions about managing CCC, both indoors and on pasture. Future studies should investigate how calf development may be affected through social facilitation by the cow. For CCC in pastured dairy cows and calves, further research is needed to improve milk ejection during milking of dairy cows, and to minimize stress around weaning and separation of pastured dairy cows and calves.

6 References

Abuelo, A., Havrlant, P., Wood, N., Hernandez-Jover, M., 2019. An investigation of dairy calf management practices, colostrum quality, failure of transfer of passive immunity, and occurrence of enteropathogens among Australian dairy farms. J Dairy Sci 102, 8352–8366. https://doi.org/10.3168/jds.2019-16578

Adler, S.A., Jensen, S.K., Govasmark, E., Steinshamn, H., 2013. Effect of short-term versus long-term grassland management and seasonal variation in organic and conventional dairy farming on the composition of bulk tank milk. J Dairy Sci 96, 5793–5810. https://doi.org/10.3168/jds.2012-5765

ANIMA, 2022. Skilt fra mor [WWW Document]. URL https://stoppdyremishandling.no/skilt-fra-mor

Appleby, M.C., Weary, D.M., Chua, B., 2001. Performance and feeding behaviour of calves on ad libitum milk from artificial teats. Appl Anim Behav Sci 74, 191–201. https://doi.org/10.1016/S0168-1591(01)00171-X

Asheim, L.J., Johnsen, J.F., Havrevoll, Ø., Mejdell, C.M., Grøndahl, A.M., 2016. The economic effects of suckling and milk feeding to calves in dual purpose dairy and beef farming. Review of Agricultural, Food and Environmental Studies 97, 225–236. https://doi.org/10.1007/s41130-016-0023-4

Ayoub, N., 2022. Elternzeit für Kühe: In diesem Betrieb dürfen Kälber bei ihren Müttern bleiben [WWW Document]. URL https://utopia.de/milch-elternzeit-muttergebundene-kaelberaufzucht-melkburen-69841/

Bailly-Caumette, E., Bertelsen, M., Jensen, M.B., 2023. Social and locomotor play behavior of dairy calves kept with the dam either full time or half time in straw-bedded pens. JDS Communications. https://doi.org/10.3168/jdsc.2022-0337

Bar-Peled, U., Maltz, E., Bruckental, I., Folman, Y., Kali, Y., Gacitua, H., Lehrer, A.R., Knight, C.H., Robinson, B., Voet, H., Tagari, H., 1995. Relationship Between Frequent Milking or Suckling in Early Lactation and Milk Production of High Producing Dairy Cows. J Dairy Sci 78, 2726–2736. https://doi.org/10.3168/jds.S0022-0302(95)76903-X

Bar-Peled, U., Robinzon, B., Maltz, E., Tagari, H., Folman, Y., Bruckental, I., Voet, H., Gacitua, H., Lehrer, A.R., 1997. Increased weight gain and effects on production parameters of Holstein heifer calves that were allowed to suckle from birth to six weeks of age. J Dairy Sci 80, 2523–2528.

Barth, K., 2020. Effects of suckling on milk yield and milk composition of dairy cows in cow-calf contact systems. Journal of Dairy Research 87, 133–137. https://doi.org/10.1017/S0022029920000515

Beaver, A., Meagher, R.K., von Keyserlingk, M.A.G., Weary, D.M., 2019. Invited review: A systematic review of the effects of early separation on dairy cow and calf health. J Dairy Sci 102, 5784–5810. https://doi.org/https://doi.org/10.3168/jds.2018-15603

Berge, C., Langseth, E., 2022. Animal Welfare and Economics in the Dairy Industry (Master thesis). Norwegian School of Economics, Bergen.

Bertelsen, M., 2023. Comparing cow-calf contact systems (PhD thesis). Aarhus University, Denmark.

Bertelsen, M., Jensen, M.B., 2023. Comparing weaning methods in dairy calves with different dam-contact levels [Submitted]. J Dairy Sci 10. https://doi.org/10.3168/jds.2023-23393

Bertelsen, M., Steinerová, K., Jensen, M.B., 2023. The effects of part-time dam-contact and stepwise weaning and separation on the voluntary human approach behaviour of dairy calves. Appl Anim Behav Sci 260. https://doi.org/10.1016/j.applanim.2023.105871

Bertelsen, M., Vaarst, M., 2023. Shaping cow-calf contact systems : Farmers ' motivations and considerations behind a range of different cow-calf contact systems. J Dairy Sci. https://doi.org/10.3168/jds.2022-23148

Bock, B., Buller, H., 2013. Healthy, happy and humane: Evidence in farm animal welfare policy. Sociol Ruralis 53, 390–411. https://doi.org/10.1111/soru.12011

Boden, R.F., Leaver, J.D., 1994. A dual purpose cattle system combining milk and beef production. Proceedings of the British Society of Animal Production (1972) 1994, 145.

Bøe, K.E., Færevik, G., 2003. Grouping and social preferences in calves, heifers and cows. Appl Anim Behav Sci 80, 175–190. https://doi.org/10.1016/S0168-1591(02)00217-4

Boissy, A., Manteuffel, G., Jensen, M.B., Moe, R.O., Spruijt, B., Keeling, L.J., Winckler, C., Forkman, B., Dimitrov, I., Langbein, J., Bakken, M., Veissier, I., Aubert, A., 2007. Assessment of positive emotions in animals to improve their welfare. Physiol Behav 92, 375–397. https://doi.org/10.1016/j.physbeh.2007.02.003

Bonk, S., Burfeind, O., Suthar, V.S., Heuwieser, W., 2013. Technical note: Evaluation of data loggers for measuring lying behavior in dairy calves. J Dairy Sci 96, 3265–3271. https://doi.org/10.3168/jds.2012-6003

Bouissou, M.F., Boissy, A., Le Neindre, P., Veissier, I., 2001. The social behaviour of cattle, in: Social Behaviour in Farm Animals. Wallingford UK: cabi Publishing., pp. 113–145.

Boyle, L., Conneely, M., Kennedy, E., O'Connell, N., O'Driscoll, K., Earley, B., 2022. Animal welfare research – progress to date and future prospects. Irish Journal of Agricultural and Food Research 1–22. https://doi.org/10.15212/ijafr-2020-0151

Braastad, B.O., n.d. Dyrevelferd - hva er det? [WWW Document]. braastad.info. URL https://www.braastad.info/dyrevelferd/

Browning, H., 2020. The Natural Behavior Debate : Two Conceptions of Animal Welfare The Natural Behavior Debate : Two Conceptions of Animal Welfare. Journal of Applied Animal Welfare Science 23, 325–337. https://doi.org/10.1080/10888705.2019.1672552

Bruckmaier, R.M., 2013. Oxytocin from the pituitary or from the syrine Importance and consequences for machine milking in dairy cows. NMC Annual Meeting Proceedings 4–11.

Bruckmaier, R.M., 2005. Normal and disturbed milk ejection in dairy cows. Domest Anim Endocrinol 29, 268–273. https://doi.org/10.1016/j.domaniend.2005.02.023

Budzynska, M., Weary, D.M., 2008. Weaning distress in dairy calves: Effects of alternative weaning procedures. Appl Anim Behav Sci 112, 33–39. https://doi.org/10.1016/j.applanim.2007.08.004

Bugge, A.B., Schjøll, A., 2021. Environmental and animal welfare issues related to production and consumption of fish and meat – what are consumers' considerations and concerns? Oslo, Norway.

Busch, G., Weary, D.M., Spiller, A., Von Keyserlingk, M.A.G., 2017. American and German attitudes towards cowcalf separation on dairy farms. PLoS One 12, 1–20. https://doi.org/10.1371/journal.pone.0174013

Caja, G., Ayadi, M., Knight, C.H., 2004. Changes in cisternal compartment based on stage of lactation and time since milk ejection in the udder of dairy cows. J Dairy Sci 87, 2409–2415. https://doi.org/10.3168/jds.S0022-0302(04)73363-9

Cantor, M.C., Neave, H.W., Costa, J.H.C., 2019. Current perspectives on the short- And long-term effects of conventional dairy calf raising systems: A comparison with the natural environment. Transl Anim Sci 3, 549–563. https://doi.org/10.1093/tas/txy144

Carbonneau, E., de Passillé, A.M., Rushen, J., Talbot, B.G., Lacasse, P., 2012. The effect of incomplete milking or nursing on milk production, blood metabolites, and immune functions of dairy cows. J Dairy Sci 95, 6503–6512. https://doi.org/10.3168/jds.2012-5643

Chambers, D.T., 1959. Grazing behaviour of calves reared at pasture. J Agric Sci 53, 417–424. https://doi.org/10.1017/S0021859600020840

Cheng, W.N., Han, S.G., 2020. Bovine mastitis: risk factors, therapeutic strategies, and alternative treatments — A review. Asian-Australas J Anim Sci 33, 1699–1713. https://doi.org/10.5713/ajas.20.0156

Churakov, M., Eriksson, H.K., Agenäs, S., 2023. Proposed methods for estimating loss of saleable milk in a cow-calf contact system with automatic milking. J Dairy Sci Article in. https://doi.org/10.3168/jds.2022-23099

Clark, B., Stewart, G.B., Panzone, L.A., Kyriazakis, I., Frewer, L.J., 2016. A Systematic Review of Public Attitudes, Perceptions and Behaviours Towards Production Diseases Associated with Farm Animal Welfare. J Agric Environ Ethics 29, 455–478. https://doi.org/10.1007/s10806-016-9615-x

Cooke, L., Carnell, S., Wardle, J., 2006. Food neophobia and mealtime food consumption in 4-5 year old children. International Journal of Behavioral Nutrition and Physical Activity 3, 1–6. https://doi.org/10.1186/1479-5868-3-14

Corbin, J., Strauss, A., 2015. Basics of Qualitative Research - Techniques and Procedures for Developing Grounded Theory, Fourth edi. ed. SAGE Publications, Inc, San Jose State University, USA.

Costa, J.H.C., Cantor, M.C., Adderley, N.A., Neave, H.W., 2019. Key animal welfare issues in commercially raised dairy calves: Social environment, nutrition, and painful procedures. Can J Anim Sci 99, 649–660. https://doi.org/10.1139/cjas-2019-0031

Costa, J.H.C., Daros, R.R., von Keyserlingk, M.A.G., Weary, D.M., 2014. Complex social housing reduces food neophobia in dairy calves. J Dairy Sci 97, 7804–7810. https://doi.org/10.3168/jds.2014-8392

Costa, J.H.C., Meagher, R.K., von Keyserlingk, M.A.G., Weary, D.M., 2015. Early pair housing increases solid feed intake and weight gains in dairy calves. J Dairy Sci 98, 6381–6386. https://doi.org/10.3168/jds.2015-9395

Costa, J.H.C., von Keyserlingk, M.A.G., Weary, D.M., 2016. Invited review: Effects of group housing of dairy calves on behavior, cognition, performance, and health. J Dairy Sci 99, 2453–2467. https://doi.org/10.3168/jds.2015-10144

Das, S.M., Forsberg, M., Wiktorsson, H., 1999. Influence of Restricted Suckling and Level of Feed Supplementation on Postpartum Reproductive Performance of Zebu and Crossbred Cattle in the Semi-Arid Tropics. Acta Vet Scand 40, 57–67. https://doi.org/10.1186/BF03547041

Das, S.M., Redbo, I., Wiktorsson, H., 2000. Effect of age of calf on suckling behaviour and other behavioural activities of Zebu and crossbred calves during restricted suckling periods. Appl Anim Behav Sci 67, 47–57. https://doi.org/10.1016/S0168-1591(99)00115-X

Day, M.L., Imkawa, K., Clutter, A.C., Wolfe, P.L., Zalesky, D.D., Nielsen, M.K., Kinder, J.E., 1987. Suckling behavior of calves with dams varying in milk production. J Anim Sci 65, 1207–1212. https://doi.org/https://doi.org/10.2527/jas1987.6551207x

de Passillé, A.M., 2001. Sucking motivation and related problems in calves. Appl Anim Behav Sci 72, 175–187. https://doi.org/10.1016/S0168-1591(01)00108-3

de Passillé, A.M., Marnet, P.-G., Lapierre, H., Rushen, J., 2008. Effects if twice-daily nursing on milk ejection and milk yield during nursing and milking in dairy cows. J Dairy Sci 91, 1416–1422. https://doi.org/https://doi.org/10.3168/jds.2007-0504

De Paula Vieira, A., Guesdon, V., de Passillé, A.M., von Keyserlingk, M.A.G., Weary, D.M., 2008. Behavioural indicators of hunger in dairy calves. Appl Anim Behav Sci 109, 180–189. https://doi.org/10.1016/j.applanim.2007.03.006

De Paula Vieira, A., von Keyserlingk, M.A.G., Weary, D.M., 2012. Presence of an older weaned companion influences feeding behavior and improves performance of dairy calves before and after weaning from milk. J Dairy Sci 95, 3218–3224. https://doi.org/10.3168/jds.2011-4821

De Paula Vieira, A., von Keyserlingk, M.A.G., Weary, D.M., 2010. Effects of pair versus single housing on performance and behavior of dairy calves before and after weaning from milk. J Dairy Sci 93, 3079–3085. https://doi.org/10.3168/jds.2009-2516

Duthie, C.A., Bowen, J.M., Bell, D.J., Miller, G.A., Mason, C., Haskell, M.J., 2021. Feeding behaviour and activity as early indicators of disease in pre-weaned dairy calves. Animal 15, 100150. https://doi.org/10.1016/j.animal.2020.100150

Duve, L.R., Weary, D.M., Halekoh, U., Jensen, M.B., 2012. The effects of social contact and milk allowance on responses to handling, play, and social behavior in young dairy calves. J Dairy Sci 95, 6571–6581. https://doi.org/10.3168/jds.2011-5170

Dymnicki, E., Sosin-Bzducha, E., Gołębiewski, M., 2013. Effects of calf separation and injection of oxytocin on milk performance and milk composition of the Polish Red cows. Arch Anim Breed 56, 882–891. https://doi.org/10.7482/0003-9438-56-088

Dyrevelferdsloven, 2009. Lov om dyrevelferd (LOV-2009-06-19-97) [WWW Document]. URL https://lovdata.no/dokument/NL/lov/2009-06-19-97

Dyrevernalliansen, 2019. Kriterier for dyrevernmerket melkekuproduksjon (melk og kjøtt) [WWW Document]. URL https://dyrevernmerket.no/wp-content/uploads/Melkekuproduksjon-kriterier-pdf-020919.pdf

Edwards, S.A., 1983. The behaviour of dairy cows and their newborn calves in individual or group housing. Applied Animal Ethology 10, 191–198. https://doi.org/10.1016/0304-3762(83)90140-2

Edwards, S.A., Broom, D.M., 1982. Behavioural interactions of dairy cows with their newborn calves and the effects of parity. Anim Behav 30, 525–535. https://doi.org/10.1016/S0003-3472(82)80065-1

Ellingsen-Dalskau, K., Grøndahl, A.M., Johnsen, J.F., Mejdell, C.M., 2015. Kalvestell blant produsenter av økologisk melk i Norge og Sverige. Resultater fra en spørreundersøkelse. Oslo. https://doi.org/10.13140/RG.2.1.5035.1445

Enríquez, D., Hötzel, M.J., Ungerfeld, R., 2011. Minimising the stress of weaning of beef calves: a review. Acta Vet Scand 53, 28. https://doi.org/10.1186/1751-0147-53-28

Erickson, P.S., Kalscheur, K.F., 2019. Nutrition and feeding of dairy cattle. Animal Agriculture: Sustainability, Challenges and Innovations 157–180. https://doi.org/10.1016/B978-0-12-817052-6.00009-4

Eriksson, H., Fall, N., Ivemeyer, S., Knierim, U., Simantke, C., Fuerst-Waltl, B., Winckler, C., Weissensteiner, R., Pomiès, D., Martin, B., Michaud, A., Priolo, A., Caccamo, M., Sakowski, T., Stachelek, M., Spengler Neff, A., Bieber, A., Schneider, C., Alvåsen, K., 2022. Strategies for keeping dairy cows and calves together – a cross-sectional survey study. Animal 16, 100624. https://doi.org/10.1016/j.animal.2022.100624

Færevik, G., Tjentland, K., Løvik, S., Andersen, I.L., Bøe, K.E., 2008. Resting pattern and social behaviour of dairy calves housed in pens with different sized lying areas. Appl Anim Behav Sci 114, 54–64. https://doi.org/10.1016/j.applanim.2008.01.002

Ferneborg, S., Napolitano, F., Vaarst, M., Mejdell, C.M., Waiblinger, S., De Oliveira, D., 2020. Methodology for studying human attitudes and behaviour to cow-calf

contact systems. Journal of Dairy Research 87, 122–127. https://doi.org/10.1017/S0022029920000448
Fleming, A.S., O'Day, D.H., Kraemer, G.W., 1999. Neurobiology of mother-infant interactions: central nervous system plasticity and inter-generational affiliation. Neurosci Biobehav Rev 23, 673–685.
Flower, F.C., Weary, D.M., 2001. Effects of early separation on the dairy cow and calf: 2. Separation at 1 day and 2 weeks after birth. Appl Anim Behav Sci 70, 275–284. https://doi.org/10.1016/S0168-1591(00)00164-7
Forsøksdyrforskriften, 2015. Forskrift om bruk av dyr i forsøk (FOR-2015–06-18–761) [WWW Document]. URL https://lovdata.no/dokument/SF/forskrift/2015-06-18-761
Fraser, D., Weary, D.M., Pajor, E.A., Milligan, B.N., 1997. A scientific conception of animal welfare that reflects ethical concerns. Animal Welfare 6, 187–205.
Fröberg, S., Aspegren-Güldorff, A., Olsson, I., Marin, B., Berg, C., Hernández, C., Galina, C.S., Lidfors, L., Svennersten-Sjaunja, K., 2007. Effect of restricted suckling on milk yield, milk composition and udder health in cows and behaviour and weight gain in calves, in dual-purpose cattle in the tropics. Trop Anim Health Prod 39, 71–81. https://doi.org/10.1007/s11250-006-4418-0
Fröberg, S., Lidfors, L., 2009. Behaviour of dairy calves suckling the dam in a barn with automatic milking or being fed milk substitute from an automatic feeder in a group pen. Appl Anim Behav Sci 117, 150–158. https://doi.org/10.1016/j.applanim.2008.12.015
Fröberg, S., Lidfors, L., Svennersten-Sjaunja, K., Olsson, I., 2011. Performance of free suckling dairy calves in an automatic milking system and their behaviour at weaning. Acta Agriculturae Scandinavica A: Animal Sciences 61, 145–156. https://doi.org/10.1080/09064702.2011.632433
Gaillard, C., Meagher, R.K., Von Keyserlingk, M.A.G., Weary, D.M., 2014. Social housing improves dairy calves' performance in two cognitive tests. PLoS One 9, e90205, 1–6. https://doi.org/10.1371/journal.pone.0090205
Geno, 2020. Historien om Geno og NRF [WWW Document]. URL https://www.geno.no/om-geno/om-norsk-rodt-fe/historien-om-geno-og-nrf/
Grøndahl, A., Skancke, E., Mejdell, C., Jansen, J., 2007. Growth rate, health and welfare in a dairy herd with natural suckling until 6–8 weeks of age: a case report. Acta Vet Scand 49, 16. https://doi.org/10.1186/1751-0147-49-16
Grøndahl, A.M., 2011. Overføring av smittestoffer fra ku til kalv i melkefôringsperioden – en litteraturstudie 211–219.

Hall, S.J.G., 1989. Chillingham cattle: social and maintenance behaviour in an ungulate that breeds all year round. Anim Behav 38, 215–225. https://doi.org/10.1016/S0003-3472(89)80084-3

Hansen, B.G., Langseth, E., Berge, C., 2023. Animal welfare and cow-calf contact-farmers' attitudes, experiences and adoption barriers. J Rural Stud 97, 34–46. https://doi.org/10.1016/j.jrurstud.2022.11.013

Hansen, B.G., Østerås, O., 2019. Farmer welfare and animal welfare- Exploring the relationship between farmer ' s occupational well-being and stress , farm expansion and animal welfare. Prev Vet Med 170, 104741. https://doi.org/10.1016/j.prevetmed.2019.104741

Hansen, J. V., Friggens, N.C., Højsgaard, S., 2006. The influence of breed and parity on milk yield, and milk yield acceleration curves. Livest Sci 104, 53–62. https://doi.org/10.1016/j.livsci.2006.03.007

Hanssen, H., 2020. Hvordan påvirkes melkeytelsen i AMS de første 100 dagene av laktasjonen når kalven dier kua? (Fordypningsoppgave). The Norwegian University of Life Sciences, Norway.

Held, S.D.E., Špinka, M., 2011. Animal play and animal welfare. Anim Behav 81, 891–899. https://doi.org/10.1016/j.anbehav.2011.01.007

Henriksen, B.I.F., 2010. Vurdering av regel om diing i tre dagar. Bioforsk Økologisk 1–8.

Henriksen, B.I.F., Johnsson, J., Ellingsen, K., 2009. Ku, kalv og diing - Økobonden sine erfaringar. Bioforsk 1432.

Hernández, C., Orihuela, A., Fröberg, S., Lidfors, L.M., 2006. Effect of restricted suckling on physiological and behavioural stress parameters in dual-purpose cattle in the tropics. Livest Sci 99, 21–27. https://doi.org/10.1016/j.livprodsci.2005.05.020

Hirata, M., Nakagawa, M., Funakoshi, H., 2003. Mother – young distance in Japanese Black cattle at pasture. J Ethol 161–168.

Horvath, K.C., Miller-Cushon, E.K., 2019. Characterizing grooming behavior patterns and the influence of brush access on the behavior of group-housed dairy calves. J Dairy Sci 102, 3421–3430. https://doi.org/10.3168/jds.2018-15460

Hötzel, M.J., Cardoso, C.S., Roslindo, A., von Keyserlingk, M.A.G., 2017. Citizens' views on the practices of zero-grazing and cow-calf separation in the dairy industry: Does providing information increase acceptability? J Dairy Sci 100, 4150–4160. https://doi.org/10.3168/jds.S0022-0302(02)74391-9

Hötzel, M.J., Longo, C., Balcão, L.F., Cardoso, C.S., Costa, J.H.C., 2014. A survey of management practices that influence performance and welfare of dairy calves reared in southern Brazil. PLoS One 9, 1–17. https://doi.org/10.1371/journal.pone.0114995

Hudson, S.J., Mullord, M.M., 1977. Investigations of maternal bonding in dairy cattle. Applied Animal Ethology 3, 271–276. https://doi.org/10.1016/0304-3762(77)90008-6

Hutchison, H.G., Woof, R., Mabon, R.M., Salehe, I., Robb, J.M., 1962. A study of the habits of zebu cattle in Tanganyika. J Agric Sci 59, 301–317. https://doi.org/10.1017/S0021859600015379

Jannerman, K., 2022. Ko och kalv tillsammans i mjölkproduktion – fältförsök på två ekologiska gårdar farms (Independent Project). Swedish University of Agricultural Science, Sweden.

Jasper, J., Weary, D.M., 2002. Effects of Ad Libitum Milk Intake on Dairy Calves. J Dairy Sci 85, 3054–3058. https://doi.org/https://doi.org/10.3168/jds.S0022-0302(02)74391-9

Jensen, M.B., 2011. The early behaviour of cow and calf in an individual calving pen. Appl Anim Behav Sci 134, 92–99. https://doi.org/10.1016/j.applanim.2011.06.017

Jensen, M.B., Duve, L.R., Weary, D.M., 2015. Pair housing and enhanced milk allowance increase play behavior and improve performance in dairy calves. J Dairy Sci 98, 2568–2575. https://doi.org/10.3168/jds.2014-8272

Jensen, M.B., Kyhn, R., 2000. Play behaviour in group-housed dairy calves, the effect of space allowance. Appl Anim Behav Sci 67, 35–46. https://doi.org/10.1016/S0168-1591(99)00113-6

Jensen, M.B., Vestergaard, K.S., Krohn, C.C., 1998. Play behaviour in dairy calves kept in pens: The effect of social contact and space allowance. Appl Anim Behav Sci 56, 97–108. https://doi.org/10.1016/S0168-1591(97)00106-8

Johanssen, J.R.E., Sørheim, K., 2021. Ku og kalv sammen i melkeproduksjon - Intervjuer med melkeprodusenter. Tingvoll.

Johnsen, J. F., Beaver, A., Mejdell, C.M., Rushen, J., de Passillé, A.M., 2015. Providing supplementary milk to suckling dairy calves improves performance at separation and weaning. J Dairy Sci 98, 4800–4810.

Johnsen, Julie Føske, de Passille, A.M., Mejdell, C.M., Bøe, K.E., Grøndahl, A.M., Beaver, A., Rushen, J., Weary, D.M., 2015a. The effect of nursing on the cow-calf bond. Appl Anim Behav Sci 163, 50–57. https://doi.org/10.1016/j.applanim.2014.12.003

Johnsen, Julie Føske, Ellingsen-Dalskau, K., Grøndahl, A.M., Bøe, K.E., Lidfors, L., Mejdell, C.M., 2015b. The effect of physical contact between dairy cows and

calves during separation on their post-separation behavioural response. Appl Anim Behav Sci 166, 11–19. https://doi.org/10.1016/j.applanim.2015.03.002
Johnsen, J.F., Garmo, R., Holmøy, I.H., 2022. Calf mortality, calf treatments and mastitis treatments in Norwegian dairy herds practicing cow-calf contact versus herds practicing artificial calf rearing. Proc. International Symposium of Veterinary Epidemiology and Economics, Halifax, Canada. 691.
Johnsen, J.F., Holmøy, I.H., Nødtvedt, A., Mejdell, C.M., 2021. A survey of pre-weaning calf management in Norwegian dairy herds. J Dairy Sci 63, 1–5. https://doi.org/10.1186/s13028-021-00587-x
Jonsson, K., 2019. Inventering av uppfödningssystem som tillåter ko-kalvkontakt i svenska mjölkbesättningar (Examensarbete i veterinärmedicin). Swedish University of Agricultural Sciences, Sweden.
Junqueira, F.S., Madalena, F.E., Reis, G.L., 2005. Production and economic comparison of milking F1Holstein X Gir cows with and without the stimulus of the calf. Livest Prod Sci 97, 241–252. https://doi.org/10.1016/j.livprodsci.2005.05.005
Kälber, T., Barth, K., 2014. Practical implications of suckling systems for dairy calves in organic production systems – a review. Landbauforsch 1, 45–58. https://doi.org/10.3220/LBF_2014_45-58
Kentjonowaty, I., Mardhotillah, A.B.A., Susilawati, T., Surjowardojo, P., 2021. Effects of mammae hand massages on oxytocin release, milk yield, and milk quality in dairy cows. Livestock and Animal Research 19, 311. https://doi.org/10.20961/lar.v19i3.49120
Kerr, S.G.C., Wood-Gush, D.G.M., 1987. A comparison of the early behaviour of intensively and extensively reared calves. Anim Prod 45, 181–190. https://doi.org/10.1017/S0003356100018778
Kertz, A.F., Hill, T.M., Quigley, J.D., Heinrichs, A.J., Linn, J.G., Drackley, J.K., 2017. A 100-Year Review: Calf nutrition and management. J Dairy Sci 100, 10151–10172. https://doi.org/10.3168/jds.2017-13062
Khan, M.A., Weary, D.M., von Keyserlingk, M.A.G., 2011. Invited review: Effects of milk ration on solid feed intake, weaning, and performance in dairy heifers. J Dairy Sci 94, 1071–1081. https://doi.org/10.3168/jds.2010-3733
Kilgour, R.J., Uetake, K., Ishiwata, T., Melville, G.J., 2012. The behaviour of beef cattle at pasture. Appl Anim Behav Sci 138, 12–17. https://doi.org/10.1016/j.applanim.2011.12.001

King, M.T.M., Matson, R.D., DeVries, T.J., 2021. Connecting farmer mental health with cow health and welfare on dairy farms using robotic milking systems. Animal Welfare 30, 25–38. https://doi.org/10.7120/09627286.30.1.025

Kišac, P., Brouček, J., Uhrinčať, M., Hanus, A., 2011. Effect of weaning calves from mother at different ages on their growth and milk yield of mothers. Czech Journal of Animal Science 56, 261–268.

Kjærnes, U., Borgen, S.O., Thorjussen, C.B.H., 2022. Behind a fluttering veil of trust: The dynamics of public concerns over farm animal welfare in Norway. Sociol Ruralis 62, 763–781. https://doi.org/10.1111/soru.12405

Krachun, C., Rushen, J., de Passillé, A.M., 2010. Play behaviour in dairy calves is reduced by weaning and by a low energy intake. Appl Anim Behav Sci 122, 71–76. https://doi.org/10.1016/j.applanim.2009.12.002

Krohn, C.C., 2001. Effects of different suckling systems on milk production, udder health, reproduction, calf growth and some behavioural aspects in high producing dairy cows - A review. Appl Anim Behav Sci 72, 271–280. https://doi.org/10.1016/S0168-1591(01)00117-4

Krohn, C.C., Foldager, J., Mogensen, L., 1999. Long-term effect of colostrum feeding methods on behaviour in female dairy calves. Acta Agriculturae Scandinavica A: Animal Sciences 49. https://doi.org/https://doi.org/10.1080/090647099421540

Kvam, G.-T., Logstein, B., 2023. Holdninger til økt samvær mellom ku og kalv blant norske forbrukere og meieri- og dagligvareaktører. Trondheim.

Langhout, J., 2003. Suckling as rearing method on dairy farms. Louis Bolk Instituut.

Launchbaugh, K.L., Provenza, F.D., Werkmeister, M.J., 1997. Overcoming food neophobia in domestic ruminants through addition of a familiar flavor and repeated exposure to novel foods. Appl Anim Behav Sci 54, 327–334. https://doi.org/10.1016/S0168-1591(96)01194-X

Le Neindre, P., 1989. Influence of cattle rearing conditions and breed on social relationships of mother and young. Appl Anim Behav Sci 23, 117–127. https://doi.org/10.1016/0168-1591(89)90012-9

Le Neindre, P., D'Hour, P., 1989. Effects of a postpartum separation on maternal responses in primiparous and multiparous cows. Anim Behav 37, 166–168. https://doi.org/10.1016/0003-3472(89)90023-7

Lehmann, J.O., Mogensen, L., Bertelsen, M., Vaarst, M., 2021. Dam-rearing of dairy calves: Lessons from practice for future research & development. Tjele, Denmark.

Lent, P.C., 1974. Mother-infant relationships in ungulates. The behaviour of ungulates and its relation to management 1, 14–55.
Lidfors, L., Jensen, P., 1988. Behaviour of free-ranging beef cows and calves. Appl Anim Behav Sci 20, 237–247. https://doi.org/10.1016/0168-1591(88)90049-4
Lidfors, L.M., Jensen, P., Algers, B., 1994. Suckling in Free-ranging Beef Cattle — Temporal Patterning of Suckling Bouts and Effects of Age and Sex. Ethology 98, 321–332. https://doi.org/10.1111/j.1439-0310.1994.tb01080.x
Logstein, B., Bjørkhaug, H., 2023. Good Animal Welfare in Norwegian Farmers' context. Can both industrial and natural conventions be achieved in the social license to farm? J Rural Stud 99, 107–120. https://doi.org/10.1016/j.jrurstud.2023.03.002
Lovdata FOR-2004-04-22-665, 2004. Forskrift om hold av storfe [WWW Document]. lovdata.no. URL https://lovdata.no/dokument/SF/forskrift/2004-04-22-665
Løver, T., 2022. Effect of access to dam on play behavior in dairy calves in a cow-calf contact system. (Master's Thesis). The Norwegian University of Life Sciences, Norway.
Lupoli, B., Johansson, B., Uvnäs-Moberg, K., Svennersten-Sjaunja, K., 2001. Effect of suckling on the release of oxytocin, prolactin, cortisol, gastrin, cholecystokinin, somatostatin and insulin in dairy cows and their calves. Journal of Dairy Research 68, 175–187. https://doi.org/10.1017/S0022029901004721
Lv, J., Zhao, X.W., Su, H., Wang, Z.P., Wang, C., Li, J.H., Li, X., Zhang, R.X., Bao, J., 2021. Effects of group size on the behaviour, heart rate, immunity, and growth of Holstein dairy calves. Appl Anim Behav Sci 241, 105378. https://doi.org/10.1016/j.applanim.2021.105378
Mac, S.E., Lomax, S., Clark, C.E.F., 2023. Dairy cow and calf behavior and productivity when maintained together on a pasture-based system. Anim Biosci 36, 322–332. https://doi.org/10.5713/ab.22.0135
Marino, L., Allen, K., 2017. The Psychology of Cows 4, 474–498.
Martins, L.S., Paulino, M.F., Rennó, L.N., Detmann, E., de Almeida, D.M., Ortega, R.M., Moreno, D.P.S., Cárdenas, J.E.G., 2017. Creep feeding effects on male Nellore calves influencing behavior and performance of their dams. Trop Anim Health Prod 49, 1669–1676. https://doi.org/10.1007/s11250-017-1375-8
Mattilsynet, 2022. Regelverksveileder - Økologisk landbruk [WWW Document]. URL https://www.mattilsynet.no/om_mattilsynet/gjeldende_regelverk/veiledere/veileder_for_okologisk_landbruk.2651/binary/Veileder for økologisk landbruk

Meagher, R.K., Beaver, A., Weary, D.M., von Keyserlingk, M.A.G., 2019. Invited review: A systematic review of the effects of prolonged cow–calf contact on behavior, welfare, and productivity. J Dairy Sci 102, 5765–5783. https://doi.org/10.3168/jds.2018-16021

Meagher, R.K., Daros, R.R., Costa, J.H.C., Von Keyserlingk, M.A.G., Hötzel, M.J., Weary, D.M., 2015. Effects of degree and timing of social housing on reversal learning and response to novel objects in dairy calves. PLoS One 10, 1–15.

Mendoza, A., Cavestany, D., Roig, G., Ariztia, J., Pereira, C., La Manna, A., Contreras, D.A., Galina, C.S., 2010. Effect of restricted suckling on milk yield, composition and flow, udder health, and postpartum anoestrus in grazing Holstein cows. Livest Sci 127, 60–66. https://doi.org/10.1016/j.livsci.2009.08.006

Metz, J., 1987. Productivity aspects of keeping dairy cow and calf together in the post-partum period. Livest Prod Sci 16, 385–394. https://doi.org/10.1016/0301-6226(87)90007-8

Miller-Cushon, E.K., Bergeron, R., Leslie, K.E., DeVries, T.J., 2013. Effect of milk feeding level on development of feeding behavior in dairy calves. J Dairy Sci 96, 551–564. https://doi.org/10.3168/jds.2012-5937

Miller-Cushon, E.K., Devries, T.J., 2015. Invited review: Development and expression of dairy calf feeding behaviour. Can J Anim Sci 95, 341–350. https://doi.org/10.4141/CJAS-2014-163

Mintline, E.M., Wood, S.L., de Passillé, A.M., Rushen, J., Tucker, C.B., 2012. Assessing calf play behavior in an arena test. Appl Anim Behav Sci 141, 101–107. https://doi.org/10.1016/j.applanim.2012.08.006

Mogi, K., Nagasawa, M., Kikusui, T., 2011. Developmental consequences and biological significance of mother-infant bonding. Prog Neuropsychopharmacol Biol Psychiatry 35, 1232–1241. https://doi.org/10.1016/j.pnpbp.2010.08.024

Mutua, E.K., Haskell, M.J., 2022. Factors contributing to milk yield variation among cows in a cow–calf contact system in early lactation. JDS Communications 3, 55–58. https://doi.org/10.3168/jdsc.2021-0143

Nawroth, C., Rørvang, M. V., 2022. Challenges and opportunities in cattle cognition research: Future research areas from an industry point of view. Appl Anim Behav Sci.

Neave, H.W., Costa, J.H.C., Weary, D.M., von Keyserlingk, M.A.G., 2018. Personality is associated with feeding behavior and performance in dairy calves. J Dairy Sci 101, 7437–7449. https://doi.org/10.3168/jds.2017-14248

Neave, H.W., Sumner, C.L., Henwood, R.J.T., Zobel, G., Saunders, K., Thoday, H., Watson, T., Webster, J.R., 2022. Dairy farmers' perspectives on providing cow-calf contact in the pasture-based systems of New Zealand. J Dairy Sci 105, 453–467. https://doi.org/10.3168/jds.2021-21047

Newberry, R.C., Swanson, J.C., 2008. Implications of breaking mother-young social bonds. Appl Anim Behav Sci 110, 3–23. https://doi.org/10.1016/j.applanim.2007.03.021

Nicolao, A., 2022. Suckling of dairy calves by their dams: consequences on performance, feeding behavior and animal welfare. University of Padova, Italy.

Nicolao, A., Coppa, M., Bouchon, M., Sturaro, E., 2020. Early-Life Dam-Calf Contact and Grazing Experience Influence Post-Weaning Behavior and Herbage Selection of Dairy Calves in the Short Term. https://doi.org/10.3389/fvets.2020.600949

Nicolao, A., Veissier, I., Bouchon, M., Sturaro, E., Martin, B., Pomiès, D., 2022. Animal performance and stress at weaning when dairy cows suckle their calves for short versus long daily durations. Animal 16, 100536. https://doi.org/10.1016/j.animal.2022.100536

Nielsen, S.S., Alvarez, J., Bicout, D.J., Calistri, P., Canali, E., Drewe, J.A., Garin-Bastuji, B., Gonzales Rojas, J.L., Gortazar Schmidt, C., Herskin, M., Michel, V., Miranda Chueca, M.A., Padalino, B., Pasquali, P., Roberts, H.C., Spoolder, H., Stahl, K., Velarde, A., Viltrop, A., Jensen, M.B., Waiblinger, S., Candiani, D., Lima, E., Mosbach-Schulz, O., Van der Stede, Y., Vitali, M., Winckler, C., 2023. Welfare of calves. EFSA Journal 21. https://doi.org/10.2903/j.efsa.2023.7896

NOAH, 2023. Ku, kalv og okse i melk- og kjøttindustri [WWW Document]. landbruksdyr.no. URL https://www.landbruksdyr.no/fakta/dyr-i-landbruk/kyr-og-kalver/ku-og-kalv-i-industrien/#easy-footnote-bottom-17-176

Odde, K.G., Kiracofe, G.H., Schalles, R.R., 1985. Suckling behaviour in range beef calves 61, 307–309.

Okabe, S., Nagasawa, M., Mogi, K., Kikusui, T., 2012. The importance of mother-infant communication for social bond formation in mammals. Animal Science Journal 83, 446–452. https://doi.org/10.1111/j.1740-0929.2012.01014.x

Ospina Rios, S.L., Lee, C., Andrewartha, S.L., Verdon, M., 2023. A Pilot Study on the Feasibility of an Extended Suckling System for Pasture-Based Dairies. Animals 13, 1–17. https://doi.org/10.3390/ani13162571

Overrein, H., Skjold, A. V., Kischel, S.G., 2021. Godt kalveoppdrett 0-3 mnd, TINE Rådgivning og Medlemsservice. Oslo.

Overvest, M.A., Crossley, R.E., Miller-Cushon, E.K., DeVries, T.J., 2018. Social housing influences the behavior and feed intake of dairy calves during weaning. J Dairy Sci 101, 8123–8134. https://doi.org/10.3168/jds.2018-14465

Pempek, J.A., Schuenemann, G.M., Holder, E., Habing, G.G., 2017. Dairy calf management—A comparison of practices and producer attitudes among conventional and organic herds. J Dairy Sci 100, 8310–8321. https://doi.org/10.3168/jds.2017-12565

Placzek, M., Christoph-Schulz, I., Barth, K., 2021. Public attitude towards cow-calf separation and other common practices of calf rearing in dairy farming—a review. Organic Agriculture 11, 41–50. https://doi.org/10.1007/s13165-020-00321-3

Prickett, R.W., 2008. Welfare : Results From a Telephone Survey.

Reinhardt, C., Reinhardt, A., Reinhardt, V., 1986. Social behaviour and reproductive performance in semi-wild Scottish Highland cattle. Appl Anim Behav Sci 15, 125–136. https://doi.org/10.1016/0168-1591(86)90058-4

Reinhardt, V., Mutiso, F.M., Reinhardt, A., 1978. Social behaviour and social relationships between female and male prepubertal bovine calves (Bos indicus). Applied Animal Ethology 4, 43–54. https://doi.org/10.1016/0304-3762(78)90092-5

Reinhardt, V., Reinhardt, A., 1982. Social behaviour and social bonds between juvenile and sub-adult Bos indicus calves. Appl Anim Behav Sci 9, 92–93. https://doi.org/https://doi.org/10.1016/0304-3762(82)90177-8

Reinhardt, V., Reinhardt, A., 1981. Natural suckling performance and age of weaning in zebu cattle (Bos indicus). J Agric Sci 96, 309–312. https://doi.org/https://doi.org/10.1017/S0021859600066089

Relić, R., Starič, J., Ježek, J., 2020. Management practices that influence the welfare of calves on small family farms. Journal of Dairy Research 87, 93–98. https://doi.org/10.1017/S0022029920000539

Rørvang, M.V., Nielsen, B.L., Herskin, M.S., Jensen, M.B., 2018. Prepartum maternal behavior of domesticated cattle: A comparison with managed, feral, and wild ungulates. Front Vet Sci 5. https://doi.org/10.3389/fvets.2018.00045

Rosenberger, K., Costa, J.H.C., Neave, H.W., von Keyserlingk, M.A.G., Weary, D.M., 2017. The effect of milk allowance on behavior and weight gains in dairy calves. J Dairy Sci 100, 504–512. https://doi.org/10.3168/jds.2016-11195

Roth, B.A., Barth, K., Gygax, L., Hillmann, E., 2009. Influence of artificial vs. mother-bonded rearing on sucking behaviour, health and weight gain in calves. Appl

Anim Behav Sci 119, 143–150. https://doi.org/10.1016/j.applanim.2009.03.004
Roy, J.H.B., Shillam, K.W.G., Palmer, J., 1955. 591. The outdoor rearing of calves on grass with special reference to growth rate and grazing behaviour. Journal of Dairy Research 22, 252–269. https://doi.org/10.1017/S0022029900007809
Ryle, M., Orskov, E.R., 1990. On milk yields and calf rearing. Livestock research for Rural Development 2.
Sato, S., 1984. Social licking pattern and its relationships to social dominance and live weight gain in weaned calves. Appl Anim Behav Sci 12, 25–32. https://doi.org/10.1016/0168-1591(84)90093-5
Sato, S., Sako, S., Maeda, A., 1991. Social licking patterns in cattle (Bos taurus): influence of environmental and social factors. Appl Anim Behav Sci 32, 3–12. https://doi.org/10.1016/S0168-1591(05)80158-3
Sato, S., Tarumizu, K., Hatae, K., 1993. The influence of social factors on allogrooming in cows. Appl Anim Behav Sci 38, 235–244. https://doi.org/10.1016/0168-1591(93)90022-H
Sawalhah, M.N., Cibils, A.F., Maladi, A., Cao, H., Vanleeuwen, D.M., Holechek, J.L., Rubio, C.M.B., Wesley, R.L., Endecott, R.L., Mulliniks, T.J., Petersen, M.K., 2016. Forage and Weather Influence Day versus Nighttime Cow Behavior and Calf Weaning Weights on Rangeland. Rangel Ecol Manag 69, 134–143. https://doi.org/10.1016/j.rama.2015.10.007
Shamay, A., Bruckental, I., Barash, H., Werner, D., Moallem, U., 2005. Effect of Nursing Management and Skeletal Size at Weaning on Puberty, Skeletal Growth Rate, and Milk Production During First Lactation of Dairy Heifers. American dairy science association 88, 1460–1469. https://doi.org/10.3168/jds.s0022-0302(05)72814-9
Sinnott, A.M., 2023. Finding the balance - Improving labour efficiency and animal welfare in calf rearing (PhD thesis). Wageningen University and Research, the Netherlands.
Sinnott, A.M., Kennedy, E., Mcpherson, S.E., Bokkers, E.A.M., 2022. Impact of prolonged cow-calf contact on dairy cow production in a pasture-based system. EAAP 2022 73rd Annual Meeting of the European Federation of Animal Science. 387.
Sirovica, L. v., Ritter, C., Hendricks, J., Weary, D.M., Gulati, S., von Keyserlingk, M.A.G., 2022. Public attitude toward and perceptions of dairy cattle welfare in cow-calf management systems differing in type of social and maternal contact. J Dairy Sci 105, 3248–3268. https://doi.org/10.3168/jds.2021-21344

Sirovnik, J., Barth, K., De Oliveira, D., Ferneborg, S., Haskell, M.J., Hillmann, E., Jensen, M.B., Mejdell, C.M., Napolitano, F., Vaarst, M., Verwer, C.M., Waiblinger, S., Zipp, K.A., Johnsen, J.F., 2020. Methodological terminology and definitions for research and discussion of cow-calf contact systems. Journal of Dairy Research 87, 108–114. https://doi.org/10.1017/S0022029920000564

Sløbraaten, L., 2023. Play behaviour in preweaned Norwegian Red calves housed in different social settings (Master's Thesis). The Norwegian University of Life Sciences, Norway.

Smid, A.M.C., Burgers, E.E.A., Weary, D.M., Bokkers, E.A.M., von Keyserlingk, M.A.G., 2019. Dairy cow preference for access to an outdoor pack in summer and winter. J Dairy Sci 102, 1551–1558. https://doi.org/10.3168/jds.2018-15007

Sørby, J., Ferneborg, S., Kischel, S.G., Johnsen, J.F., 2023. Two different training protocols to encourage dam-reared calves to drink supplemental milk, No. 29. ed, Book of Abstracts of the 74th Annual Meeting of the European Federation of Animal Science. Lyon, France.

Špinka, M., Newberry, R.C., Bekoff, M., 2001. Mammalian play: Training for the unexpected. Quarterly Review of Biology 76, 141–168. https://doi.org/10.1086/393866

SSB, 2023. Husdyrhald [WWW Document]. ssb.no. URL https://www.ssb.no/jord-skog-jakt-og-fiskeri/jordbruk/statistikk/husdyrhald

Stěhulová, I., Lidfors, L., Špinka, M., 2008. Response of dairy cows and calves to early separation: Effect of calf age and visual and auditory contact after separation. Appl Anim Behav Sci 110, 144–165. https://doi.org/10.1016/j.applanim.2007.03.028

Sumner, C.L., von Keyserlingk, M.A.G., Weary, D.M., 2018. Perspectives of farmers and veterinarians concerning dairy cattle welfare. Animal Frontiers 8, 8–13. https://doi.org/10.1093/af/vfx006

Sweeney, B.C., Rushen, J., Weary, D.M., de Passillé, A.M., 2010. Duration of weaning, starter intake, and weight gain of dairy calves fed large amounts of milk. J Dairy Sci 93, 148–152. https://doi.org/10.3168/jds.2009-2427

Tapki, I., 2007. Effects of individual or combined housing systems on behavioural and growth responses of dairy calves. Acta Agriculturae Scandinavica A: Animal Sciences 57, 55–60. https://doi.org/10.1080/09064700701464405

Thise, 2023. Mælk ad libitum [WWW Document]. URL https://thise.dk/produkter/maelk/maelk-ad-libitum

Tine, 2023. Statistikksamling for ku- og geitekontrollen for 2022 - Årsrapport fra Helsekortordningen 2022 [WWW Document]. medlem.tine.no. URL

https://medlem.tine.no/fag-og-forskning/statistikksamling-for-ku-og-geitekontrollen-for-2022
Tufvesson, C., 2021. Effects of Levels of Concentrates on Feed Intake and Milk Production of Dairy Cows in Early Lactation (Independent Project). Swedish University of Agricultural Science. https://doi.org/10.2508/chikusan.48.468
Ujita, A., El Faro, L., Vicentini, R.R., Pereira Lima, M.L., de Oliveira Fernandes, L., Oliveira, A.P., Veroneze, R., Negrão, J.A., 2021. Effect of positive tactile stimulation and prepartum milking routine training on behavior, cortisol and oxytocin in milking, milk composition, and milk yield in Gyr cows in early lactation. Appl Anim Behav Sci 234. https://doi.org/10.1016/j.applanim.2020.105205
Vaarst, M., Christiansen, I.A., 2023. Three years of situated social learning and development of diverse cow-calf contact systems in Danish organic dairy farms. J Dairy Sci. https://doi.org/10.3168/jds.2022-22755
Vaarst, M., Hellec, F., Verwer, C., Johanssen, J.R.E., Sørheim, K., 2020. Cow calf contact in dairy herds viewed from the perspectives of calves, cows, humans and the farming system. Farmers' perceptions and experiences related to dam-rearing systems. Landbauforschung (Braunschw) 70, 49–57. https://doi.org/10.3220/LBF1596195636000
Vaarst, M., Sørensen, J.T., 2009. Danish dairy farmers' perceptions and attitudes related to calf-management in situations of high versus no calf mortality. Prev Vet Med 89, 128–133. https://doi.org/10.1016/j.prevetmed.2009.02.015
Vaarst, M., Sørheim, K., Rosann Johanssen, J.E., Cynthia Verwer, N., 2019. Calves with their dams in dairy cow systems. Denmark, France, Norway & The Netherlands.
Vagle, I., 2020. Effekten av å holde ku og kalv sammen på vekst og fôrinntak hos kalv (Bachelor's Thesis). The Norwegian University of Life Sciences, Norway.
Valníčková, B., Stěhulová, I., Šárová, R., Špinka, M., 2015. The effect of age at separation from the dam and presence of social companions on play behavior and weight gain in dairy calves. J Dairy Sci 98, 5545–5556. https://doi.org/10.3168/jds.2014-9109
Van Laer, E., Moons, C.P.H., Ampe, B., Sonck, B., Vandaele, L., De Campeneere, S., Tuyttens, F.A.M., 2015. Effect of summer conditions and shade on behavioural indicators of thermal discomfort in Holstein dairy and Belgian Blue beef cattle on pasture. Animal 9, 1536–1546. https://doi.org/10.1017/S1751731115000804

Vanhonacker, F., Verbeke, W., Van Poucke, E., Tuyttens, F.A.M., 2008. Do citizens and farmers interpret the concept of farm animal welfare differently? Livest Sci 116, 126–136. https://doi.org/10.1016/j.livsci.2007.09.017

Ventura, B.A., von Keyserlingk, M.A.G., Schuppli, C.A., Weary, D.M., 2013. Views on contentious practices in dairy farming: The case of early cow-calf separation. J Dairy Sci 96, 6105–6116. https://doi.org/10.3168/jds.2012-6040

Ventura, B.A., Von Keyserlingk, M.A.G., Wittman, H., Weary, D.M., 2016. What difference does a visit make? Changes in animal welfare perceptions after interested citizens tour a dairy farm. PLoS One 11, 1–18. https://doi.org/10.1371/journal.pone.0154733

Vigors, B., 2019. Citizens' and farmers' framing of 'positive animal welfare' and the implications for framing positive welfare in communication. Animals 9, 1–22. https://doi.org/10.3390/ani9040147

Vigors, B., Ewing, D.A., Lawrence, A.B., 2021. Happy or healthy? How members of the public prioritise farm animal health and natural behaviours. PLoS One 16, 1–26. https://doi.org/10.1371/journal.pone.0247788

Villalba, J.J., Provenza, F.D., Manteca, X., 2010. Links between ruminants food preference and their welfare. Animal 4, 1240–1247. https://doi.org/10.1017/S1751731110000467

Vitale, A.F., Tenucci, M., Papini, M., Lovari, S., 1986. Social behaviour of the calves of semi-wild maremma cattle,. Appl Anim Behav Sci 16, 217–231. https://doi.org/10.1016/0168-1591(86)90115-2

Von Keyserlingk, M.A.G., Brusius, L., Weary, D.M., 2004. Competition for teats and feeding behavior by group-housed dairy calves. J Dairy Sci 87, 4190–4194. https://doi.org/10.3168/jds.S0022-0302(04)73563-8

Wagenaar, J.P., Langhout, J., 2006. Rearing calves with cows nature works! Bunnik.

Wagenaar, J.P.T.M., Langhout, J., 2007. Practical implications of increasing "natural living" through suckling systems in organic dairy calf rearing. NJAS - Wageningen Journal of Life Sciences 54, 375–386. https://doi.org/10.1016/S1573-5214(07)80010-8

Waiblinger, S., Wagner, K., Hillmann, E., Barth, K., 2020a. Play and social behaviour of calves with or without access to their dam and other cows. Journal of Dairy Research 87, 144–147. https://doi.org/10.1017/S0022029920000540

Waiblinger, S., Wagner, K., Hillmann, E., Barth, K., 2020b. Short-and long-term effects of rearing dairy calves with contact to their mother on their reactions towards humans. Journal of Dairy Research 87, 148–153. https://doi.org/10.1017/S0022029920000576

Walker, D.E., 1962. Suckling and grazing behaviour of beef heifers and calves. New Zealand Journal of Agricultural Research 5, 331–338. https://doi.org/10.1080/00288233.1962.10419963

Weary, D.M., Chua, B., 2000. Effects of early separation on the dairy cow and calf: 1. Separation at 6 h, 1 day and 4 days after birth. Appl Anim Behav Sci 69, 177–188. https://doi.org/10.1016/S0168-1591(00)00128-3

Weary, D.M., Jasper, J., Hötzel, M.J., 2008. Understanding weaning distress. Appl Anim Behav Sci 110, 24–41. https://doi.org/10.1016/j.applanim.2007.03.025

Weary, D.M., Robbins, J.A., 2019. Understanding the multiple conceptions of animal welfare. Animal Welfare 28, 33–40. https://doi.org/10.7120/09627286.28.1.033

Webster, A.J.F., Saville, C., Church, B.M., Gnanasakthy, A., Moss, R., 1985. The effect of different rearing systems on the development of calf behaviour. British Veterinary Journal 141, 249–264. https://doi.org/10.1016/0007-1935(85)90061-2

Wellnitz, O., Bruckmaier, R.M., 2001. Central and peripheral inhibition of milk ejection. Livest Prod Sci 70, 135–140. https://doi.org/10.1016/S0301-6226(01)00206-8

Wenker, M.L., van Reenen, C.G., Bokkers, E.A.M., McCrea, K., de Oliveira, D., Sorheim, K., Cao, Y., Bruckmaier, R.M., Gross, J.J., Gort, G., Verwer, C.M., 2022a. Comparing gradual debonding strategies after prolonged cow-calf contact: stress responses, performance, and health of dairy cow and calf 253. https://doi.org/10.1016/j.applanim.2022.105694

Wenker, M.L., van Reenen, C.G., de Oliveira, D., McCrea, K., Verwer, C.M., Bokkers, E.A.M., 2021. Calf-directed affiliative behaviour of dairy cows in two types of cow-calf contact systems. Appl Anim Behav Sci 243, 105461. https://doi.org/10.1016/j.applanim.2021.105461

Wenker, M.L., Verwer, C.M., Bokkers, E.A.M., te Beest, D.E., Gort, G., de Oliveira, D., Koets, A., Bruckmaier, R.M., Gross, J.J., van Reenen, C.G., 2022b. Effect of Type of Cow-Calf Contact on Health, Blood Parameters, and Performance of Dairy Cows and Calves. Front Vet Sci 9, 1–19. https://doi.org/10.3389/fvets.2022.855086

Whalin, L., Weary, D.M., von Keyserlingk, M.A.G., 2021. Understanding behavioural development of calves in natural settings to inform calf management. Animals 11. https://doi.org/10.3390/ani11082446

Wormsbecher, L., Bergeron, R., Haley, D., de Passillé, A.M., Rushen, J., Vasseur, E., 2017. A method of outdoor housing dairy calves in pairs using individual calf hutches. J Dairy Sci 100, 7493–7506. https://doi.org/10.3168/jds.2017-12559

Zaralis, A.K., Leach, K., 2015. SOLID participatory research from UK : A farm case study of rearing calves on milking cows. The Organic Research Centre.

Zipp, K., 2018. How to tackle alveolar milk ejection problems during milking in dam rearing? Influence of different stimuli in the parlour and effects of half-day compared to free contact (PhD thesis). University of Kassel, Germany.

Zipp, K.A., Barth, K., Knierim, U., 2016. Behavioural response of dairy cows with and without calf-contact to hair of own and alien calves presented in the milking parlour. Appl Anim Behav Sci 180, 11–17. https://doi.org/10.1016/j.applanim.2016.05.001

Zipp, K.A., Barth, K., Knierim, U., 2013. Milchleistung , Milchfluss und Milchinhaltsstoffe von Kühen mit und ohne Kalbkontakt in Abhängigkeit von verschiedenen Sti- mulationsverfahren beim Melken. Ideal und Wirklichkeit - Perspektieven ökologischer Landbewisrtschaftung 462–465.

Zobel, G., Neave, H.W., Henderson, H. V., Webster, J., 2017. Use an automated brush and a hanging rope when pair-housed. Animals 7, 1–11. https://doi.org/10.3390/ani7110084

7 Papers

I Paper I- Interrelationships between cow, calf, and human in cow-calf contact systems–An interview study among Norwegian dairy farmers

J. Dairy Sci. 106:6325–6341
https://doi.org/10.3168/jds.2022-22999

Interrelationships between cows, calves, and humans in cow-calf contact systems—An interview study among Norwegian dairy farmers

Juni Rosann E. Johanssen,[1]* Gunn-Turid Kvam,[2] Brit Logstein,[2] and Mette Vaarst[3]
[1]Norwegian Centre for Organic Agriculture (NORSØK), 6630 Tingvoll, Norway
[2]Institute for Rural and Regional Research (Ruralis), 7049 Trondheim, Norway
[3]Department of Animal and Veterinary Sciences, Aarhus University, 8830 Tjele, Denmark

ABSTRACT

In recent years, the common dairy farming practice of early separation of dam and calf has received increased attention. Our aim was to explore how Norwegian dairy farmers with cow-calf contact (CCC) systems apply these systems in practice, and how they experience and perceive the interrelationships between cows and calves and humans within these systems. We conducted in-depth interviews with 17 farmers from 12 dairy farms and analyzed responses inductively, inspired by the grounded theory approach. The farmers in our study practiced their CCC systems differently from each other and had varying as well as common perceptions about these systems. Calves' intake of colostrum was not seen as a challenge, regardless of practice. The farmers generally perceived that any aggression shown by cows toward humans was merely an exhibition of cows' natural protective instinct. However, when the farmers had good relationships with their cows and the cows felt safe around them, the farmers could handle the calves and build good relationships with them as well. The farmers experienced the calves learning a lot from their dams. Most of the farmers' dairy housing systems were not adapted for CCC, and CCC systems could require modification in terms of placing greater emphasis on observing the animals and making adjustments in the barn and around milking. Some thought having CCC on pasture was the best and most natural, while others were reluctant to have CCC on pasture. The farmers encountered some challenges with stressed animals after later separation, but several had found methods to minimize stress. Generally, they had different opinions about workload, but agreed they spent less time on calf feeding. We found that these farmers were thriving with their CCC systems; they all described positive emotions around seeing cows and their calves together. Animal welfare and natural behavior were important to the farmers.

Key words: semistructured interviews, dam-rearing, farmers' perceptions

INTRODUCTION

Separating dairy cows from their calves immediately or shortly after birth is a common practice in dairy farming (Hötzel et al., 2014; Pempek et al., 2017; Abuelo et al., 2019). For many decades, most farmers have not questioned the practice. They base their arguments mostly on lower volumes of saleable milk (see review by Meagher et al., 2019), more stress around separation after more time together (Weary and Chua, 2000; Berge and Langseth, 2022), and potential risk of transmitting infection between cows and calves (see review by Beaver et al., 2019). Others have argued that calves would become "wild" when in the cow group and not fed by humans (Vaarst et al., 2020). Another concern has centered on possible aggressive behavior of mother cows as they attempt to protect their calves, thus creating a less safe working environment (Berge and Langseth, 2022; Neave et al., 2022). Last, the adaptations required to create housing systems that would allow accommodating calves together with dairy cows can be costly (Knierim et al., 2020; Berge and Langseth, 2022).

However, the early separation of dairy cows and their calves has received increased attention recently from stakeholders concerned about this practice (Busch et al., 2017). This concern is apparent from animal welfare organizations' emphasis on this topic (Dalgaard, 2020; Dyrevernalliansen, 2022), and within the scientific community, for example, in the article by Brombin et al. (2019), with the title "Are we ready for the big change in dairy production?" The big change they refer to is stopping early separation of dairy cows and calves. Surveys carried out in different countries show that many citizens' knowledge about common animal husbandry practices, such as the early separation of a cow and her calf, is limited (see review by Placzek

Received November 8, 2022.
Accepted February 28, 2023.
*Corresponding author: rosann.johanssen@norsok.no

et al., 2021). When given this information, including the rationale behind it, most citizens do not support this practice. Generally, Western concern regarding food origin is increasing (Boyle et al., 2022), and so is knowledge about and expectations for farm animal welfare (Bock and Buller, 2013). According to Fraser et al. (1997), the concept of animal welfare contains 3 dimensions: normal biological functioning, emotional state, and ability to express natural behavior. Social groups outside agriculture often tend to value natural living as the most important for animal welfare (e.g., Prickett, 2008; Vanhonacker et al., 2008). When early separation is rejected, it is usually on the grounds that it is unnatural and stressful for the animals (see review by Placzek et al., 2021).

Over the past few years, more farmers have become interested in keeping dairy cows and calves together for a longer period and have therefore tested and developed different cow-calf contact (**CCC**) systems (Vaarst et al., 2020; Lehmann et al., 2021; Neave et al., 2022). Research has been initiated to investigate CCC systems in countries such as Norway, Germany, Canada, and the United Kingdom, using different approaches (see reviews by Johnsen et al., 2016; Beaver et al., 2019; Meagher et al., 2019; Barth, 2020; Placzek et al., 2021). Experimental studies have been conducted to investigate cow and calf production and the animals' health and behavior, and some qualitative and quantitative studies have been conducted to investigate people's perceptions and experiences. Recently, 2 survey studies about CCC were carried out, one with 104 CCC dairy farmers from 6 different countries (including farmers using foster cow systems or having CCC for only 7 d) (Eriksson et al., 2022), and another with 1,038 Norwegian dairy farmers including 31 CCC farmers (CCC for >2 wk) (Hansen et al., 2023). The CCC farmers in the first study perceived building constraints and animal stress around separation as the main challenges with CCC systems (Eriksson et al., 2022), similar to farmers practicing early separation in the second study (Hansen et al., 2023). Among the 31 Norwegian farmers practicing CCC, separation distress was also the prominent challenge, and one of the main advantages was the farmers' own well-being with having these systems.

However, relatively few qualitative interview studies with CCC farmers have been carried out. Exceptions include the studies by Vaarst et al. (2019, 2020) and Lehmann et al. (2021). Farmers from 4 European countries were interviewed in each study, and they showed that CCC was practiced in a wealth of different systems. Vaarst et al. (2020) found that CCC farmers expressed satisfaction and pleasure from having CCC systems. The cows were able to care for and protect their calves, and the calves' needs for nutrition, care, protection, and learning in early life were met (Vaarst et al., 2020). Another study was by Neave et al. (2022), who interviewed farmers both with and without these systems to contrast their perceptions and experiences; however, only 4 CCC farmers participated in that study. Neave et al. (2022) noted that it would be valuable to conduct more interviews with farmers having experience with both early separation and CCC systems. As far as we have seen, no earlier research has focused on farmers' experiences and perceptions of the interrelationships between cows and calves and humans in CCC systems.

This article is based on interviews with Norwegian dairy farmers from 12 farms with CCC systems. The aim was to explore how Norwegian dairy farmers with CCC systems practice these systems and how they experience and perceive the interrelationships between the cows and calves and the humans within these systems.

MATERIALS AND METHODS

The Setting: Current Norwegian Dairy Farming

In Norway, the agricultural sector is highly regulated (e.g., Almås, 2004; Almås et al., 2013), and dairy production is the most regulated (Almås and Brobakk, 2012). In 2021, the country had 6,925 registered dairy farms, with an average of 30.9 cows per farm. During 2021, each cow produced on average 8,191 kg of milk (Tine SA, 2022). In total, 91.3% of the dairy cows were Norwegian Red, a dual-purpose animal bred to produce both meat and milk.

The Qualitative (Interview) Study

The target group of this study was composed of farmers with experience in practicing CCC systems. As little is known about how farmers experience such systems and especially how they perceive the interrelationship between cows, calves, and humans in such systems, a qualitative approach with semistructured interviews was suitable for our study (Vaarst and Sørensen, 2009; Ferneborg et al., 2020).

Selection and Invitation of Interviewees

Our most important inclusion criterion for the interviews was that farmers had at least 1 yr of experience with CCC systems, with calves together with their dams for at least 4 wk. Further, we aimed to reach saturation with the sampling to cover a range of different factors that may be important in how farmers practice CCC systems and in their experiences and perceptions (Yin, 2013). Thus, different types of farm practices needed to be represented, and we therefore wanted at least 3 or-

Table 1. Themes from the interview guide that were used for interviews with Norwegian farmers with cow-calf contact systems in the SUCCEED (sustainable systems with cow-calf-contact for higher welfare in dairy production) project

Short version of the interview guide
About the farmer, the farm, the housing, and the animals
Practice with cow-calf contact from before, the beginning, and until today
The change/why they started with cow-calf contact
Economy questions
Benefits and challenges with cow-calf contact
If they want any changes, what is important for cow-calf contact, advice for other farmers
Obstacles and benefits for more farmers to have cow-calf contact

ganic farms and farms with different housing systems, including freestalls with an automatic milking system (**AMS**), freestalls with milking parlors, and farms with tiestalls. We were also aware of the practice of CCC on pasture in Norway and therefore aimed to include at least 4 farms with the practice. Last, we aimed to interview both male and female farmers in different age groups and to have variation in the location, number of animals, and calving season.

In the summer of 2020, the first author posted on Facebook (social media platform), in a group for people interested in CCC, about our plans to interview farmers and invited eligible group members to participate. The group, Samvær ku og kalv—forum for melkebønder (Cow calf togetherness—a forum for dairy farmers), had 1,500 members in 2022. Five farms were recruited by farmers contacting the first author in response to this post, while farmers from 5 other farms were contacted after we identified them through social media as probably matching our criteria. Farmers from 2 farms were found and contacted after a small survey in another part of the SUCCEED project (sustainable systems with cow-calf-contact for higher welfare in dairy production, project number 310728) that our study was part of. The farmers were contacted through Messenger or by phone. We told them about the project, confirmed that they fitted our criteria, and then asked if we could interview them.

The Norwegian Centre for Research Data (a part of Sikt-Norwegian Agency for Shared Services in Education and Research from January 1, 2022) determined that the processing of personal data in this interview study was in accordance with privacy regulations. The study has been reported in line with the COREQ checklist (Booth et al., 2014)

All the interviewees received an information letter with a statement of consent to sign before the interviews. The letter contained information including the aim of the project and why the interviewees were being asked to participate. It also stated that participation was voluntary and explained our privacy policy and their rights. The interviewees were informed that one researcher (first author) was working at NORSØK and was doing her PhD and that the other 2 researchers (second and third authors) were working at Ruralis, with one of them (second author) leading the part of the SUCCEED project that included interviews. Some of the interviewees were familiar with the first author from earlier research on CCC and previous communication.

Interviews

The first 3 authors collaborated on the interviews, which were conducted in synergy between the SUCCEED project and another project. In total, 17 farmers from 12 farms located in 5 different Norwegian counties were interviewed in Norwegian. One other farmer who had initially agreed to participate eventually withdrew her participation due to time constraints.

A team of researchers within the SUCCEED project developed the interview guide, and a short version of this is shown in Table 1 (the full guide is available at https://acrobat.adobe.com/link/review?uri=urn:aaid:scds:US:141793f9-00b6-3fcb-93d4-294c4e7bc009; Johanssen et al., 2020). The collected interview data were intended to be used for 2 scientific articles (including the current one) and a report on economy in CCC systems. The first author conducted one pilot test of the guide and made some modifications to improve it before interviews were conducted. Since the interviews were semistructured, different questions were asked given different degrees of attention and time, guided by the course of the conversation.

Our 12 in-depth interviews with a semistructured approach were conducted from October 2020 to March 2021. To ensure that interviews were conducted consistently by the 3 researchers, the first 3 interviews were conducted by 2 researchers together. The first author took a course in qualitative interview methodologies in 2019 with the last author as course leader. The others had experience with conducting in-depth interviews from earlier work.

Seven of the interviews were done during farm visits, with 6 taking place in the house and 1 taking place in

Table 2. Background information about farmers interviewed, their animal housing, number of dairy cows, milk quota, and calving time

Farmer ID code[1]	Age (yr)	Type of farming	Animal housing[2]	No. of cows in 2020	Milk quota in 2020 (t)	Calving time
1M and 1W	47 and 34	Organic	Freestall, milking parlor	14.1	44 (+cheese)	Spring
2W	52	Conventional	Tiestall	14.4	118	Autumn
3W	38	Conventional	Freestall, AMS	52.8	440	All year
4M and 4W	35 and 36	Conventional	Freestall, AMS	36.0	276	All year
5M and 5W	39 and 39	Organic	Freestall, AMS	24.5	196	Sep.–Mar.
6S and 6F[3]	35 and 61	Conventional	Tiestall	14.7	173	Autumn
7M and 7W	32 and 36	Conventional	Freestall, AMS	14.1	122	All year (focus spring)
8W[4]	39	Conventional	Freestall, AMS	60.0	320	All year
9M	48	Conventional	Freestall, AMS	38.7	365	All year
10M[5]	61	Organic	Freestall, milking parlor	20.7	81 (+cheese)	All year
11W[6]	58	Organic	Tiestall	18.8	137	Spring and late summer
12M	49	Conventional	Tiestall	16.0	99	All year

[1]M = man; W = woman. The number is the farm number.

[2]AMS = automatic milking system.

[3]F = father; S = son (where the son has taken over the farm).

[4]Cows per year and milk quota were not retrieved from Kukontrollen for interviewee 8.

[5]Son (31 yr) has taken over the farm.

[6]Son (34 yr) has taken over the farm.

the barn. During some of the interviews, other people were present in the interviewees' homes, but they did not disturb the interviews to any notable degree. Because of COVID-19-related restrictions at the time, the other 5 interviews were done via Microsoft Teams with audio and video. Some risk exists that interviews can be different when conducting them in different formats (Lobe et al., 2022), but the interviews went satisfactorily and we received the necessary data we needed from each interview to meet the aim for this article.

At 6 of the 7 interviews with farm visits, a tour of the barn took place after each interview and included talking about the solutions in the barn and taking some notes and photographs. After 12 interviews were conducted, the authors agreed that data saturation was reached, as additional interviews would only contribute to the aim formulated to a minor degree (Glaser, 1978).

Data Editing and Analysis

All interviews were audio recorded and had an average duration of 101 min (range: 51–130 min). They were transcribed verbatim by first author, and no transcripts were returned to interviewees. Through guidance from and discussions with the last author, the first author analyzed the interviews in NVivo version 12 Plus software (QSR International: https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home/). The analysis was done inductively, inspired by the methodological approach used in grounded theory (Corbin and Strauss, 2015). All the material from the transcribed interviews was used in the analysis, with sequences of statements being given a heading in line with the content through open coding, before axial coding was performed to identify themes across the interviews. Interviewees' statements were translated into English by the first author and are presented in this article to illustrate the themes and findings. Each statement is identified by the interviewee ID code (Table 2), with the number denoting the farm and the letter indicating either the interviewee's gender (W = woman; M = man) or the farmers' relationships to each other, where relevant (S = son; F = father).

RESULTS

Background information about the interviewees and their farms is presented in more detail in Table 2. A diverse group of farmers were represented in the study. Three farms (6, 10, and 11) started having most cows and calves together in the 1990s. The other 9 farms started having most cows and calves together between 2015 and 2019. On farms 2, 3, and 12, the farmers also had previous experience with having cows together with calves, either nursing cows or cows with their own calves.

Some similarities could be identified regarding the ways in which farmers practiced CCC systems, but generally, the results showed that the farmers from the 12 farms had widely different systems and routines while practicing CCC systems, as shown in Table 3. On all farms, cows and calves were together inside the barns in the cow area; on 7 farms, cows and calves were also together outside on pasture.

From the qualitative analysis, we identified several themes related to farmer experiences and perceptions

Table 3. How the cow-calf contact system is applied at the 12 Norwegian farms participating in the interview study[1]

Farm no.	Calving and cow-calf alone-time	Full time together (how long, where)	Less time together, weaning, and separation	On pasture
1	Mostly on pasture, if inside; a separate pen until the pen is occupied by other cows	3 mo, mostly on pasture, some in the freestall.	Gradually less time together till weaning at 4 mo. Calves in own pen when not with cows and after weaning.	Yes, preferably
2	Calving pen of 2 tiestall cubicles; alone for 2 d	2–3 wk in an area with 3 lying cubicles. Cows are tied, calves are loose; then cows are moved to the other side of the feeding area and the calves to their own pen.	Cows are tied, calves are let out to be with cows for several hours 2 periods per day until wk 4. Then a period around milking morning and evening until just before wk 8, and 1 period per day till weaning at 8 wk.	No, not yet
3	Calving pen; alone for 4 d	9–10.5 wk. Cows are in the welfare area often for around 2–3 wk before they are moved to the freestall area. The calves use the whole barn after 1 wk.	Nose flap for the last 1.5–2 wk they are together, then calves are moved to their own pen.	No, not yet
4	Calving pen; alone for 4–7 d	9.5 wk in the freestall area after calving pen. Access to pasture during grazing season.	Nose flap for the last week they are together, then calves are moved to their own pen.	Yes
5	Calving pen; alone for 2–5 d	1 mo, with cows (dams) in the freestall; after, calving pen; then 2 mo with foster cows in own pens with 1 cow and 2–4 calves.	Fence-line contact with dam for a few days after 1 mo. Moved from foster cows after 3 mo.	No, do not want to
6	Preferably outside; if inside, calving pen; alone for 1–2 d	4 wk on pasture or in the tiestall, where cows are tied and calves are loose before calves are moved to their own pen.	Cows are tied. Calves are let out to be with cows for a period after milking morning and evening until wk 8, then for 1 period per day until 9 wk.	Yes, preferably
7	Calving pen; alone for at least 5 d	6–9 wk. Cows are in the welfare area for at least 1 wk, then moved to the freestall area; calves can move around the whole barn.	Cows and calves are moved to the welfare area, where they have fence-line contact for 3 d before being moved again. Calves get milk until weaning at 12 wk or more.	No, do not want to
8	Calving pen; alone for at least 1 d (the calves can move out of the pen)	3 mo (6 mo before). Cows are in the welfare area as long as space is available, then moved to the freestall area. Calves can move around the whole barn and have access to pasture in the grazing season.	Abrupt moving of calves to their own pen.	Yes, preferably
9	Calving pen, preferably alone in colostrum period (4–5 d)	2 mo together in the freestall area after calving pen. Access to pasture in the grazing season.	Abrupt by moving calves to their own pen, but some (if strong bonds or a lot of vocalizations) are together for some more days when the farmer is in the barn.	Yes
10	Calving pen, alone for 5 d	8 wk together, in the freestall area after calving pen. Access to pasture/go outside almost all year round.	Calves are moved to a pen where they have fence-line contact with the cows for at least 5 d before being moved again. Heifer calves get milk until 4 mo, and bull calves until 6 mo.	Yes
11	Calvings take place in tiestall cubicles	Most of the calves are with the cows full time for the first 2 d, lying on hay beside the cow. Then the calves are moved to their own pen.	Calves are let out in the tiestall area for periods morning and evening until 3 mo. In the beginning, they get more hours together and before milking, then gradually less time and after milking instead.	No
12	Outside in grazing season, when inside; the cow is released from her tiestall cubicle when calving until a couple of days afterward	2–4 wk together inside where cows are tied and calves are loose, outside on pasture before calves are moved to their own pen, or both.	Calves are let out from their pen for half the day until between 70 and 100 d.	Yes

[1]The farms are numbered in the same order as in Table 2.

of the interrelationships between cows, calves, and humans in their CCC systems. In the following, we have structured the presentation of these themes chronologically in relation to the life cycle of the calves in the CCC period. First, we have 2 themes: how the farmers ensured adequate colostrum intake after birth, and how they experienced establishing a strong bond between the dam and her calf after birth. Next, we have a theme regarding farmers establishing their own relationships with their cows and calves. That theme is followed by a theme about milking of cows during the CCC period and a theme about calves learning in the CCC systems. Next, we describe a theme about housing systems for CCC and CCC on pasture, followed by a theme about the last phase of the CCC period: separation of cows and calves and weaning. Last, a cross-cutting theme is presented, which is relevant for all the stages of the CCC systems; this theme encompasses being a farmer working in a CCC system and how farmers perceive natural behavior and animal welfare in the CCC systems.

Ensuring Adequate Colostrum Intake

Colostrum intake is a critical phase, and farmers had different strategies to ensure that it was adequate. Half of the farmers said they almost always bottle-fed the calves with colostrum after birth. Some measured the quality of the colostrum, and if the quality was insufficient, they used frozen colostrum of better quality. Some farmers had modified their colostrum practices based on previous experiences, as farmers 1M and 1W from farm 1 explained:

> After each calving, we try to give [the calves] colostrum from a bottle to ensure that they get enough colostrum the first days. (1M)

> There was actually one calf that died. We thought he drank, but he did not. It looked like he drank, but he did not get any milk. So, he did not get any colostrum, and he became in poor condition, and nothing helped. It was just horrible. (1W)

The other half of the farmers were more focused on observing and maybe helping the calves suckle from their dams, and they bottle-fed colostrum only when they felt it was needed for different reasons, as in the case of farmer 8W:

> It is only for some I [give colostrum from a bottle] because I think no matter how poor quality colostrum that the mother has, it is actually the mother's milk that has the immune substances that are best for the calf, and, if you have beef cows—I also have some of them—then you almost always let the calf suckle freely from its own mother. And I have found out that the health of calves that I have given colostrum from a bottle from its mother, and the health of calves that have been suckling freely, there is no difference. If I give some from a bottle, it is because of reasons like when there is blood in the milk, visible poor-quality colostrum or some mastitis, or, yes, if the cow is in bad shape.

Farmer 9M had several reasons for changing his practice regarding colostrum:

> I used to give the calves colostrum from a bottle to be sure, but now, if I see the calf suckling, I do not do this. There are several reasons for that, but the most important is that, why should I make a possible bacterial bomb and put that into the intestinal system of the calf. They can do this very well themselves. But it happens, for example, with a heifer with a hard udder and very short teats. It can be challenging for the calf to suckle, so then you must consider it. If you see on the first milking of the heifer that the amount of milk is equal in all glands, then you understand that the calf has not drunk. You will see it on the calf as well, so you must keep an eye on them in the beginning.

Ensuring that Dam and Calf Establish a Strong Bond

For all farmers in the study, a good relationship between the dam and her calf was obviously of high importance. To ensure this, several farmers pointed to the importance of keeping a cow and her calf together on their own during the first days after birth in a calving pen to help establish a strong bond between them (see Table 3), including preventing the calf from suckling from other cows in the herd. Regarding calving pens, some farmers talked about the importance of the cow being able to see herd members through this pen. If this pen had solid walls, the cow would get stressed about be isolated from the herd and thereby not being able to bond properly with her calf.

Farmer 11W talked about the bonding between a cow and her calf:

> It is very important that they actually get these first days to make a bond because it is actually so solid a bond that it takes quite a lot for the calf to go to another neighbor cow. It can be, if there is some special reason for it, like a disease or that the cow is treated with penicillin or, yes,

> things like that, then we may have to get the calf to suckle from another cow, and that also usually works fine as well, but then you must be more careful because they have full control over who is their own calf.

Calf rejection was generally not seen as a problem by the farmers, but some talked about experience with calves rejected by their own mothers. The farmers shared different practices used for these calves. Farmer 5M was convinced that if calves, for some reason, could not suckle from their own mothers, they would find other cows and be satisfied:

> It often requires some effort to get cows to adopt a calf that is not their own. But the calves that are out here, they always find themselves an udder to suckle from anyway. When it is a calf standing and suckling from its mother's udder, the mother stands still, and the other calves can see this and take this opportunity to suckle from this udder at the same time as the cow's own calf is suckling.

Farmer 8W said that she always allowed all her cows to be with their calves, but she experienced some cows that she perceived as rejecting their calves, and she removed those calves from their mothers. Later, she had observed these cows "stealing" calves from other cows. Some farmers had also observed that calves occasionally suckled from cows, for instance, when they were hungry or when they were older.

The farmers' dairy cows were generally perceived as being very good mothers, but several farmers talked about how some cows can seem stressed and some can seem aggressive toward their calf or like they do not want it or do not understand what is happening after calving. Some farmers also talked about differences between primiparous and multiparous cows in different ways. For example, farmer 1W said:

> We often see it in older cows. Because we bought a full herd, and then we see it in those who have been separated early before, that they have in a way, their instinct has been destroyed because the heifers are much more protective [of their calf].

In contrast to farmer 1W's perception of primiparous cows, other farmers, if they experienced some cows being stressed and aggressive toward their newborn calves, it was most often primiparous cows. Some farmers had felt forced to practice early separation of calf and dam in such cases, while others, such as farmer 11W, had found methods to calm down such cows. She explained:

> Like, for, example a primiparous cow, who is a bit, like, in shock after calving… she is not herself, and then she can be a bit rabid both against us and with her calf— perhaps mostly with her calf—and she can be kicking towards it, and then, all you have to do is to take it easy, be patient and pet and stroke and talk to [the cows], massage the udder and keep this going until they sort of slowly but surely calm down and find out that this is not so bad after all.

Almost all the interviewed farmers had experienced cows showing aggression toward people to protect their calves. This aggression was mainly within a short time after calving, and most of the farmers had experienced it with only a few cows. Furthermore, some farmers talked about how this aggression was an expression of a strong maternal instinct and not a general characteristic of the cow. Some farmers described how, compared with multiparous cows, primiparous cows showed more aggression to humans when protecting their calves. The farmers explained that it was because the primiparous cows did not yet know the farmer that well or because they could be more stressed after calving, having just experienced it for the first time.

When the relationship between a cow and her calf was well established, it was a pleasure to experience the interactions between calves and cows, as explained by farmer 10M: "..then you saw that face and the eyes and the body of that cow, it was absolutely amazing, it was… the eyes shone and the body… it showed a happiness that I had not seen before." He thought the most important thing for a cow was to be the mother of her calf, and he said: "My definition of a happy cow was a cow that was together with her calf."

Farmers Establishing Their Own Relationships with Cow and Calf

In parallel with facilitating a good relationship between a cow and her calf, the farmers seemed concerned with developing a good relationship between themselves and the calves. To be able to handle the calves, the farmers simultaneously had to have a good and trusting relationship with the cows. The farmers often explained that they understood the dams' need to protect their calves. Farmer 4W said:

> I think they are much happier with being allowed to be together with their calf. You can see that they really love their calf, and that they protect it. They will not let anyone come and mess with their calf.

Farmer 10M talked about the importance of cows feeling safe around the farmer:

> You [as a farmer] need a good relationship with your cows. The cows need to be used to you and to feel safe around you. The person that the cows feel safe around, that person, she will not be angry at during and after calving.

Some of the farmers talked about how they had to handle the animals differently, behave differently, and read the animals more closely, as farmer 3W noted:

> If a cow thinks her calf is threatened, she will run straight at you. Then, you do not have a chance. And this, this is something that you really must be aware of. You must handle the animals in a different way because the calf is there with the cow, which has not been there before. And it does not need to be you threatening the calf; it might just as well be the neighboring cow. But it is just that you are standing there.

However, the interviewed farmers were also aware that even though they themselves had developed a good, trusting relationship with the animals, the risk of aggression toward other people was higher. Farmer 5M gave the example that the cows seemed to feel very safe having him around, but especially children whom the cows did not know well were more vulnerable to aggressive behavior. Farmer 10M mentioned that it was safer for employees to work with the cows when the calves were artificially reared compared with when the cows were together with their calves that they wanted to protect. He said:

> If you have a lot of employees whom the animals do not know, then it will be much easier to take the calf from the cow immediately, milk the cow, and give milk to the calf. You must think about the health risk for the employee. If you, as an employee, are there when cow and calf are together, make sure the calf is suckling. Be present and pay a lot of attention to them. This can be a bigger challenge, maybe the biggest.

Some farmers perceived calves in CCC systems as different from artificially reared calves, as explained by farmer 10M:

> Most of the calves that are together with their mothers are not very interested in having contact with you. They will accept that you pet them a bit and that, but they will not come towards you and let you do whatever you want with them as they would if it was you who was giving them the milk from day one, the whole time. They are two different calves [the calves with their dams versus calves artificially milk fed by humans].

Other farmers perceived their calves being just as tame now as they had been before when they were artificially reared, or even that the relationship between farmer and calf had become more pleasant, as farmer 2W explained:

> I think it is a lot nicer now to be around the calves. They come to me when I am milking the cows as well. People say that they do not form any attachment with me now, but that is not true, because now, they do not associate me with food. They come to me when they want to be cuddled, and that is a lot nicer compared to standing there being pushed, chewed on, and butted because they are not getting their food.

Some, such as farmer 9M, talked about individual differences among the calves:

> If you are good at cuddling them, especially during the first period in the calving pen—that is, during the colostrum period—then you can imprint them well with that. But it is very individual as well. Some calves will stand up and run away once they see you, and others will come and meet you. And this is how it will be when they are in a separate calf pen as well. But then you will not notice it in the same way because then there will be many together in a small area, but when you have six calves together with 40 cows, then you will see it right away if that one calf is a bit skeptical.

In relation to observing individual differences, some farmers had also experienced that the calves copied their mothers' behavior, so a shy cow would transfer this attitude to her calf and her calf also became shy. This could incentivize the practice of consciously choosing the calmer cows and calves to keep and, in this way, breeding for a good temperament.

Farmers from farm 1 had realized that they had to spend more time handling calves, as 1W explained:

> The first calves we weaned, they were so wild, they were not used to being handled, you know. It is something completely different when you are standing there, and the calf knows it is you who

> is giving the food. But here, you are kind of the enemy when you are out there [on the pasture]. So, we had to do something about that; we had to start socializing them. It was our veterinarian who gave us advice that we could make a sort of a calf creep out there, where they could get some hay and concentrates, a teat, and some water, and then we could take them in there and sort of force them to get cuddled.

Farmer 1M noted "Two times a day, we handle them."

Milking of Cows During the CCC Period

Through the CCC period, farmers found that less milk was delivered from the cows while the calves were suckling. Some farmers had also experienced problems with milk let-down during milking, but this seemed to be most common with primiparous cows and mostly during the first days after calving.

Farmer 2W described solutions for this challenge:

> Some cows do not let down their milk unless their calf is present. If the calf is present all the time, I will also not get any milk from her. So, then it happens that I must take away the calf, even though the calf is newborn. I have to take away the calf around an hour before milking, and then I will bring it back when I am going to milk because then she will let down the milk. It mostly works. And when the calves are bigger, then it happens that I put on the milking cluster, then take it off one teat, get the calf, then she will look at her calf and start to let down the milk when she sees her calf.

Farmer 2W also talked about how she thought some CCC farmers may believe that the calves are drinking more milk than they actually are, because of poor milk let-down in CCC cows during milking. Farmer 10M thought it could be hard to know when the udders were full or empty, even after more than 20 yr of experience with CCC systems, and he stated: "You must let go of controlling everything. You can't be a person who wants to control everything. The cow should also contribute to control a little. But the udder, it behaves differently when the calf is working with it." Farmer 8W said she had no problems with milk let-down and referred to the fact that cows and calves were together full time, which she thought made them more relaxed.

Some farmers had AMS, including a separate area which they called the "welfare area," where they could keep a closer eye on newly calved cows and their calves. As farmer 7M said:

> One of the reasons we have them in the welfare area is so we can get them into the milking robot manually morning and evening, when we are in the barn cleaning and feeding and so on. If they are together with the others, there can be some that do not have enough milk. There can be a lot of incorrect milkings, and I do not think that is good for their udders.

Farmer 3W talked about doing this mostly with the primiparous cows because they are more often empty in one or more quarters after their calves have been suckling, and mostly in the beginning after calving.

Calves Learning in the CCC Systems

Almost all the farmers talked about the positive effects of calves learning from cows in CCC systems, while also mentioning individual differences and the fact that calves also learned from other calves. They talked mostly about this in connection to eating behavior, emphasizing that the calves learned to eat roughage, concentrates, and silage, and that they learned how to graze and drink water. In addition, some talked about how the calves learned how to live as cows. Farmer 9M said:

> So, the calves learn all the automatics in the barn from day one. They know where everything is, and how everything works. The mother has kind of taught them this. Such a simple thing like learning to lie down in the lying cubicles. If I buy heifers that have been in a tiestall before, then I can have heifers that for a whole week will lie down on the slatted floor. Now I do not need to think about that [when the calves have grown up]. They will understand this because they have been lying on the mattresses from day one.

This impression was also backed up by farmer 2W, who stated:

> It is the most natural thing; the calf is together with the mother and learns from the mother and learns how to behave. And if you have a nice, calm cow, you will get a nice, calm calf. It is easy to see that, if there is some handling of animals, and calf and cow are together, then the calf is calm. If you have a nervous cow, then the calf will be stressed

and will stay very close to the mother, so it can be both positive and negative.

Housing Systems for CCC

As shown in Table 2, the farmers in this study had different housing and milking systems. They generally experienced that dairy cow areas were not built to accommodate CCC and therefore were not adapted for small calves. Several farmers experienced calves accessing places in the barn where they should not be, such as on the cows' feeding table, leading to a greater need to clean and more waste of feed. Others did not see this as a problem. Farmer 9M said the calves learned where they should go:

> Sometimes you get some calves that think it is nice lying [on the feeding table], but, if you are a bit determined… I also have camera surveillance, so if you are good at taking them away from there in the beginning, they will understand that this is not the place to be.

Farmers also talked about "childproofing" the barn by putting up planks and gates around areas that the farmers did not want the calves to enter. Farmer 5W talked about the calves living in a more dangerous environment and said:

> Compared to a squared pen, that is completely safe. Now they are kind of everywhere [in the barn]. But you can compare it with kids. You can lock them inside so they are safe, but you have to let them out to experience the world as well.

Some farmers thought that freestalls were more suitable and worked better for CCC than tiestalls, as farmer 2W said:

> When the cow is loose, she gets control. Now when she is tied, she does not have control. And the calves are like kids; they have full control over their mothers. And then some cows can get very stressed. So, I think this will work better when the cow is loose because then she can more naturally control her calf better.

Interviewees generally agreed that sufficient space for the animals to move around in the housing system and free access to resources such as roughage were important to have calm animals, especially when having small calves with the cows. It was also seen as important to have areas, such as calf creeps, where the calves could get away from the cows as needed. They also experienced calves lying between, in, or in front of the cubicles, and sometimes taking up a whole cubicle, which the cows seemed to accept.

CCC on Pasture or Not?

On 7 of the farms, cows and calves were together outside on pasture in the grazing season, which usually lasted from between May and June until between September and October. On one of these farms, farm 10, cows and calves could go outside almost all year round. Two farmers wanted to have the CCC on pasture, but felt that it was challenging, and 2 other farmers did not want to have cows and calves together on pasture because they used forest and mountain pastures. Farmer 7M explained: "Just the combination of cow and calf in the forest I think is a bad combination. These areas are not suitable for small calves, and a little calf will not be able to walk that far." Farmer 5W had similar concerns:

> If the small calves run far up in the mountains as well, then they would not come back in the evening ever again. The cow would have no reason to come back in the evening. She could just stay in the mountains with the calf. Ah, no. …[…]… no, we have not tried that, but for now we are trying to steer away from that. We are trying to keep it as simple as possible in the summer.

Some of the farmers who had CCC on pasture preferred to have cows calve outside and to have CCC on pasture. They had several reasons for this, such as it being more natural, more space being available, the risk of infection and injuries being reduced, and the workload being lessened. Farmer 6S said:

> The advantage of having calving in the autumn is that then they can be outside and calve outside on pasture. I want to have as much calving outside as possible. When they calve outside, the animals are much faster, or healthier and fitter.

His father, farmer 6F, added:

> I really like to have the animals outside on pasture as long as possible. Before, the calves stayed inside while the cows were outside, but now it is no problem, and we do not need extra fences for the calves, because they are together with their mums that are taking care of them.

Several farmers with cows and calves together on pasture talked about how calves could escape the pasture by slipping under the electric fence. However, they did not see this as a problem because the calves did not go far, and they would come back when the cows called them or went inside. Farmer 10M said:

> All mothers are amazing. The cows are very kind and very good mothers—like most mothers, regardless of species. And if you thrive at home, you will always come back home. It is like that with the calves as well. The calves can be away exploring on their own when they are outside, but they will always come back home. So that is not a problem. But many people call me, saying, "There are some calves here. . . ." It would be a problem if they went out onto the big road or the railway track or something like that, but they have never done that.

Some talked about how difficult it could sometimes be to find newly calved calves outside. They would hide during the first few days after calving, and had to be searched for and found, or, as approached by farmer 1M: "When a cow has calved it can take two to three days before we see the calf because it is lying down and hiding. We just have to wait until the calf shows up, and it does show up." Farmer 1W said, "Yes, they behave like wild deer." During the first year with this system, they spent a lot of time searching until realizing that the calf would turn up eventually.

Separation of Cow and Calf and Weaning

The farmers approached weaning differently, as can be seen from Table 3. Some experienced the strongest reactions to separation from the calves, such as farmer 11W, whereas others experienced that the cow reacted more than the calf. Some farmers experienced the cows vocalizing for some days after separation. For example, farmer 5M said: "The cow will vocalize for two days, and she does that if you take away the calf from day three or week three. She will stand and vocalize for two days." Farmer 8W said that when the cows vocalize, they stop because they lost their voice, and farmer 10M said he thought they stopped vocalizing because they gave up.

Farmer 8W thought that many cows do not react much because they are tired of the calves by the time they are separated. As farmer 12M explained:

> When cows are taken away from their calf, there can be heart-breaking sounds for a couple of days. We do not have that. There is a bit of noise when we take them away if they have been together for 80 or 90 days, but it is mostly the calf that still wants access to dessert. The cow, she does not care much anymore.

However, several farmers talked about individual variations in reaction to separation, both between cows and between calves. As farmer 7M said:

> It is very varied. Some do not. Most cows vocalize on the first day—some more, some less. All react a little, but as long as the calf is full and satisfied and knows where the mother is, it will lie down, rest, and sleep with its friends. It is the mother who is most stressed. But we have also had a couple where it just seems like it was nice, no reaction.

Two out of 12 farms (farms 7 and 10) continued giving milk to the calves after separation from the cows, and the farmers talked about how it could be challenging to get the calf to drink from a teat bucket or bottle after being used to suckling from a cow. Farmer 7M said:

> I manage to do it with strength and power. The calves are enormously huge, so it is not easy. I manage to do it, but my father does not manage it. I must grab the calf, and the calf needs to be a bit hungry. Often, a clever method is to separate them in the morning and try giving them milk in the afternoon.

Some farmers had identified some ways of separating and weaning that worked well for both cows and calves. Farmer 1W experienced that separating more cow-calf pairs at the same time helped, and farmer 11W said:

> It can be a bit noisy at weaning, but it has to do with how you do it. I have found a method that actually works quite well. For the calf it is not a problem, but the mum. . . Some mothers can make a little noise for a day or something, but now I do it successfully. [The cows] are so tired of those bullies that are fooling around with them by the time [the calves] are three months old, so they are happy to get rid of them. They can [still] see them. They pass them and sniff them every day.

Some compared this late separation with previous experience with early separation. Farmer 8W remembered that the cows did not react and the calves did not care when they were separated early; however, farmer 10M had a different experience:

> If we let [the cows] lick [the calves after calving], for five minutes, or half an hour, or an hour more or less, they just got sad. The easiest thing for them was just when we took the calf away im-

> mediately after calving. Then they would stand there quietly. They were actually apathetic is how I would describe my cows.

Being a Farmer Working in a CCC System

Compared with when the farmers had artificially reared calves, half thought that they spent less time working and the other half thought that they spent as much or more time working with CCC systems. All agreed that they spent less time on calf feeding. Several talked about the work being more flexible, especially when having AMS and no longer having to go to the barn at certain time points for calf feeding. Several also talked about that they used the time differently, for example, by spending more time on observing, moving animals, making adjustments to the barn, and cleaning up after the calves. The interviewees generally agreed that they needed to be more observant and alert. Farmer 3W explained:

> You must keep an eye on that calf and how it behaves and things like that to a much greater extent. There is more herd focus now. Also on an individual level, so you try to keep a certain clue on who is the mother of whom, so you can control and check on them.

All the interviewed farmers talked about their own sense of well-being in relation to having CCC. They talked about it being pleasant and cozy; it felt good; they felt proud, satisfied, and had a good conscience; they were happy with it; it was motivating; it gave a nicer environment in the barn; it was very interesting, very exciting, and great fun; and they had faith in CCC.

Farmer 11W said: "I think it is pleasant, it is nice to see, they have a good interaction. Instead of having to stand holding the bottle for the calf, I can stand and watch them enjoy themselves together." Farmer 10M said: "A farmer wants to see healthy and clean animals that thrive and grow. When you see that in your barn because cow and calf are together, it is a factor that makes you think it is fun working there." A similar perception was described by farmer 1M:

> It is very interesting, and it is fun. This is much better than having a routine job because you can produce milk and only produce milk, but it is a lot more fun to make milk and to do it more on [the animals'] terms.

Some talked about how it promotes well-being for the cow, the calf, and the farmer. Several talked about how important it is to thrive in a workplace, and therefore, it was important for farmers to thrive when they were working in the barn. Farmer 2W said: "Sometimes I think that there are certain things that are more important than the economy. One should thrive in one's workplace. I am out here [in the barn] for many hours per day."

Several farmers seemed to appreciate CCC because its naturalness enabled the animals to express their natural behaviors, which in turn was seen to confer better animal welfare. Farmer 7M said:

> We think it is better animal welfare when the calf is together with the cow. This is our way of interpreting animal welfare. Because it is a bit like a loose concept. The cow can get to express her natural needs because it is a natural need. When you see how they handle the calf, after calving and how they follow it in the freestall, calling for it and it comes and suckles from its mother, it is a natural instinct, a need that is being covered, that mothering role. So that is what we think good animal welfare is. But it does not mean that we think it is poor animal welfare to separate them early.

Others, such as farmer 5W, were not so sure: "I feel like animal welfare has increased. Or, I do not know, they had very good welfare when we separated them early as well."

Overall, animal welfare was important to the farmers. Farmer 7W, who was also educated as a veterinarian, talked about wanting to be a good example as one reason for keeping a cow and her calf together. She also saw their CCC system as a continuation of the farm history with a focus on good animal welfare:

> [Farmer 7M's] grandmother was known for taking very good care of her calves, and this [focus on] animal welfare has been like the mainstay of the farm history. So, we wanted to continue, and to try something that might provide even better animal welfare.

Farmer 5W thought it was also important that the animals' welfare did not come at the expense of the family's own welfare:

> We have [realized] that we have to think about what is good enough. We can work [in the barn] all day, and make sure the animals are doing opti-

mally, but then our kids and our own health will be negatively affected, so this must be balanced.

DISCUSSION

The current study aimed to explore and analyze how Norwegian dairy farmers applied CCC systems on their farms and how they experienced and perceived the interrelationships between cows, calves, and humans in these systems.

CCC Systems Were Widely Different

Our results showed that interrelationships between cows, calves, and farmers were perceived differently, and the farmers were practicing their CCC systems differently, which has also been shown in previous studies (Vaarst et al., 2020; Lehmann et al., 2021; Eriksson et al., 2022). It was highlighted that the current housing systems were not suited for these systems, which can partly explain why farmers found individual and farm-specific solutions for housing and grazing.

The farmers had different management practices around ensuring sufficient colostrum for the calves. Neave et al. (2022) showed that CCC farmers were not worried about calves' colostrum intake, while farmers practicing early separation were worried about it regarding CCC systems. Likewise, the experiences regarding separation and weaning and methods for them varied. Berge and Langseth's (2022) survey found that, among the 213 farmers who had tried having CCC but did not want to continue, the main reason among more than half (114) was stress in their animals after later separation.

The perceptions of farmers in our study of having cows and calves together on pasture ranged from thinking that the best and most natural way was to let them calve and be together outside to being wary of having small calves on pastures with the cows. Some farmers in a study by Vaarst et al. (2019) perceived that cow and calf were especially able to engage in natural behavior together on pasture. The farmers we interviewed who let cows calve outside talked about newborn calves hiding as a natural behavior and whether or not they spent time searching for these calves. In the study by Lehmann et al. (2021), one farmer viewed calves hiding on pasture as a challenge. Differences in management practice, such as searching for calves on pasture, may contribute to having a different degree of control and workload in CCC systems.

Calves from the CCC Systems

Our interviewed farmers agreed that handling of calves was important in CCC systems for the calves to become calm, tame animals. In the study by Vaarst et al. (2020), some interviewees said that calves that were together with their dams became calm and confident adults, and they talked about how you could have contact with the calves regardless of milk feeding by being around them and talking to them. Neave et al. (2022) found from interviews that farmers who did not have CCC were concerned that the calves could be more independent and wild with CCC systems and as the heifers grew, handling them could be difficult and dangerous. However, the CCC farmers in that same study said the heifers were still quite friendly and did not become wild.

Some of the farmers in our study had experienced the calves being a bit wild or shy on pasture, but when they focused on handling them through this period or afterward, they had no problem. In the study by Vaarst et al. (2020), some farmers experienced calves being a bit wild when they were with the cows, and especially on pasture, but it was not a problem when the farmers spent time handling them.

Regardless of having CCC systems, research has shown that bigger farms have more fearful calves (Leruste et al., 2012) and that the behavior and attitude of the people working with the calves are important influences on how the calves will react to people (Calderón-Amor et al., 2020). If calves are handled only when they are exposed to something uncomfortable, they will try to avoid being handled at all, but if the farmers handle them with patience, cuddle them, and speak to them with calm voices, they will be easier to handle (Ellingsen et al., 2014).

Cows, Calves, and Farmers Learning and Being in CCC Systems

Several of the farmers we interviewed talked about how a cow and her calf being together was natural, and they generally saw this as good animal welfare, similar to what has been reported in other studies (e.g., Wagenaar and Langhout, 2007). The general public's concept of animal welfare has been shown to often involve allowing farm animals to express their natural behavior (Placzek et al., 2021). However, as shown in the results, farmers had different perceptions and feelings regarding how much they could leave to the cow and the calf and how much control they needed to have over the CCC systems. A clear need existed to find a balance and to learn to let the calves and cows interact and have space and surroundings that encouraged natural behavior and play behavior and enabled cows to nurse their calves safely, while also developing a trusting relationship with humans.

This balance between "allowing naturalness" and "being in control" also related to how the farmers should ensure that the calves had sufficient amounts of colostrum and were nursed well. The farmers in this study generally perceived that most of their cows were good mothers. Most of the farmers who did not have CCC systems in the study by Neave et al. (2022) stated that modern dairy breeds did not always take proper care of their calves instinctively, and this ability might have been lost due to other breeding goals. Interviews by Vaarst et al. (2020) showed that CCC farmers experienced dairy cows as strongly motivated to nurse, protect, and care for their calves. The finding in this study that CCC farmers generally perceived calves' colostrum intake as not being a challenge and dairy cows as being good mothers reveals several themes whereby farmers practicing early separation of cow and calf and farmers with CCC systems can have different perceptions.

Regarding animal welfare concerns, Neave et al. (2022) showed that the main concern about CCC systems by farmers practicing early separation (n = 63) was poor animal welfare due to a risk of mastitis, inadequate colostrum for the calf, increased stress from delayed separation, and lack of shelter for calves that were outdoors with cows. However, animal welfare was also important for the CCC farmers (n = 4) in the same study, and they perceived that animal welfare was promoted in their CCC systems. According to the review by Beaver et al. (2019) about cow and calf health in CCC systems, letting calves suckle cows shows beneficial or no effects on mastitis.

Farmers experienced that calves were learning in the CCC systems. Previous research showed that calves that are reared alone have difficulties with learning (Gaillard et al., 2014; Meagher et al., 2015) and that offspring learn from their mothers (Newberry and Swanson, 2008; Mogi et al., 2011). Similar to our findings, reports by Vaarst et al. (2020) and Lehmann et al. (2021) referred to farmers who also experienced that calves seemed to learn how to behave in the housing and grazing systems when they are with dams or other cows.

Supporters of early separation argue that the calves will be more trusting of people with artificial rearing (Neave et al., 2022). In addition, they argue that the farmer gets better supervision of the calves' milk intake (Flower and Weary, 2003) when the calves are artificially milk fed, often in restricted amounts.

This was related to another experience when changing to CCC systems: When a calf is allowed to suckle freely, it can drink a lot of milk. Farmers in the study by Lehmann et al. (2021) estimated that calves could drink up to 15 to 16 L/d, and thus, another argument against having CCC is a smaller volume of saleable milk (Meagher et al., 2019). In many cases, a smaller volume would make the CCC system less profitable for the farmer, whose main income comes from selling milk. Some farmers in our study talked about problems with milk let-down in CCC cows and that it could be hard to know how much milk remained in the udder in cows being both suckled and milked. One farmer in the study by Lehmann et al. (2021) had decided to combine dam-rearing and nursing cows for their calves because of problems with milk let-down, while other farmers in the same study said they did not have any problems with milk let-down.

Although farmers in our study had widely different perceptions of how much time they spent working in their CCC systems compared with when they separated cow and calf early, they agreed that time on calf feeding was saved and that work was more flexible, especially when having an AMS. In a Norwegian survey, farmers with CCC also experienced increased flexibility (Berge and Langseth, 2022). The decreased workload was seen as a positive consequence of CCC in the same survey, but the survey also included 213 farmers who had tried having CCC but did not continue doing it. Eight of these farmers reported "higher workload" as the main reason for not continuing with CCC. Several of the farmers in our study said they used time differently, for instance dedicating more time to observing the animals. Farmers interviewed in the Vaarst et al. (2020) study also perceived that CCC systems required increased observation and evaluation of the animals. Farmers who did not have CCC systems in the study by Neave et al. (2022) talked about being worried that these systems would increase labor and stress on the staff working with the animals and thus compromise staff well-being. However, 3 of 4 farmers having CCC systems in the same study talked about it being a simple system and that they saved time from not having to feed the calves.

All interviewed farmers in our study seemed to agree that having CCC systems benefited their well-being. They used a range of positive words to describe how they felt about seeing cows and calves together on their farms. Farmers practicing early separation interviewed by Neave et al. (2022) were worried about the stress and mental health of the staff if they had CCC systems. Vaarst et al. (2020) interviewed CCC farmers who expressed satisfaction and joy as a strong motivation to continue with these systems. Studies by Berge and Langseth (2022) and Wagenaar and Langhout. (2006) found that having CCC increased the farmers' own well-being. A Swedish study revealed similarities, in that dairy farmers felt happy when they knew their cows were doing well (Hansson and Lagerkvist, 2016), and other studies have shown that farmers' well-being was directly correlated with their animals' welfare (Hansen and Østerås, 2019; King et al., 2021). This may be an important aspect of the emerging concept of "one-welfare," as for example outlined by García Pinillos et al. (2016), as it might suggest constantly interwoven perspectives between humans and animals throughout the different stages of the calves' lives. The perspectives from the cows and calves are their welfare and well-being in terms of being allowed natural behavior, learning, freedom of choice for both cow and calf to move in the system, and the cow having fulfilled a strong motivation to protect and care for her calf. The farmers' perspectives are about enjoying seeing this interaction, learning from and reacting to it, being challenged and gradually developing the system to suit CCC, and at the same time supporting their work satisfaction.

CONCLUSIONS

All the interviewed farmers in our study followed different practices in their CCC systems regarding having cows and calves together and methods for separation and weaning. We noted differences in their experiences and perceptions, but also similarities. They were generally not concerned about the colostrum intake. They seemed to agree that their dairy cows were generally good mothers that took good care of their calves. The farmers perceived that they had good interrelationships with both the cows and calves in their systems, but they also faced a risk of aggressive behavior from cows wanting to protect their calves. When the calves were not artificially reared, it was important for the farmers to spend time handling them. The farmers agreed that calves learned a lot from being with their dams. Some found it best and most natural to have a cow and her calf together on pasture, while others felt that this situation would not be safe for the calves. Farmers experienced challenges with stressed animals after later separation, but several had found methods to minimize stress. The CCC systems can require more focus on observation and adjustment to the barn and milking routines. The farmers had different perceptions about the amount of work connected to the CCC systems, but they agreed that they spent less time on calf feeding. They were generally thriving with their CCC systems and experienced positive emotions seeing cows and calves together. Animal welfare and the animals' natural behavior were important to the farmers.

ACKNOWLEDGMENTS

This work was a part of the project SUCCEED with project number 310728 funded by the Norwegian Research Council (Oslo, Norway), research funding for the agriculture and food industry (FFL-JA). The project "Dairy cow and calf together on pasture" is provided by the Norwegian Animal Protection Alliance's Research Fund (Oslo, Norway). The contribution of the last author (Mette Vaarst) was funded by the Organic RDD4 project "KALVvedKO" (GUDP J.nr. 34009-18-1387 Mother-bonded calf rearing in organic dairy farming; Tjele, Denmark). We send a special thank you to all the interviewed farmers who participated in our study. The authors have not stated any conflicts of interest.

REFERENCES

Abuelo, A., P. Havrlant, N. Wood, and M. Hernandez-Jover. 2019. An investigation of dairy calf management practices, colostrum quality, failure of transfer of passive immunity, and occurrence of enteropathogens among Australian dairy farms. J. Dairy Sci. 102:8352–8366. https://doi.org/10.3168/jds.2019-16578.

Almås, R. 2004. Norwegian Agricultural History. 1st ed. Tapir Academic Publishers, Trondheim.

Almås, R., H. Bjørkhaug, H. Campbell, and A. Smedshaug. 2013. Fram Mot Ein Berekraftig Og Klimatilpassa Norsk Landbruksmodell. Akademika Forlag, Trondheim.

Almås, R., and J. Brobakk. 2012. Norwegian dairy industry: A case of super-regulated co-operativism. Res. Rural Sociol. Dev. 18:169–189. https://doi.org/10.1108/S1057-1922(2012)0000018010.

Barth, K. 2020. Effects of suckling on milk yield and milk composition of dairy cows in cow–calf contact systems. J. Dairy Res. 87(S1):133–137. https://doi.org/10.1017/S0022029920000515.

Beaver, A., R. K. Meagher, M. A. G. von Keyserlingk, and D. M. Weary. 2019. Invited review: A systematic review of the effects of early separation on dairy cow and calf health. J. Dairy Sci. 102:5784–5810. https://doi.org/10.3168/jds.2018-15603.

Berge, C., and E. Langseth. 2022. Animal Welfare and Economics in the Dairy Industry. Norwegian School of Economics, Bergen.

Bock, B., and H. Buller. 2013. Healthy, happy and humane: Evidence in farm animal welfare policy. Sociol. Ruralis 53:390–411. https://doi.org/10.1111/soru.12011.

Booth, A., K. Hannes, A. Harden, J. Noyes, J. Harris, and A. Tong. 2014. COREQ (Consolidated Criteria for Reporting Qualitative Studies). Pages 214–226 in Guidelines for Reporting Health Research: A User's Manual. D. Moher, D. G. Altman, K. F. Schulz, I. Simera, and E. Wager, ed. John Wiley & Sons.

Boyle, L., M. Conneely, E. Kennedy, N. O'Connell, K. O'Driscoll, and B. Earley. 2022. Animal welfare research—Progress to date and future prospects. Ir. J. Agric. Food Res. 61:87–108. https://doi.org/10.15212/ijafr-2020-0151.

Brombin, A., A. Pezzuolo, and M. Brščić. 2019. Are we ready for the big change in the dairy production system? Res. Vet. Sci. 126:17–19. https://doi.org/10.1016/j.rvsc.2019.08.006.

Busch, G., D. M. Weary, A. Spiller, and M. A. G. Von Keyserlingk. 2017. American and German attitudes towards cow-calf separation on dairy farms. PLoS One 12:e0174013. https://doi.org/10.1371/journal.pone.0174013.

Calderón-Amor, J., A. Beaver, M. A. G. von Keyserlingk, and C. Gallo. 2020. Calf- and herd-level factors associated with dairy calf reactivity. J. Dairy Sci. 103:4606–4617. https://doi.org/10.3168/jds.2019-16878.

Corbin, J., and A. Strauss. 2015. Basics of Qualitative Research—Techniques and Procedures for Developing Grounded Theory. 4th ed. SAGE Publications.

Dalgaard, A. 2020. Kan Ko Og Kalv Få Mere Tid Sammen? Accessed Apr. 6, 2023. https://www.dyrenesbeskyttelse.dk/artikler/kan-ko-og-kalv-faa-mere-tid-sammen.

Dyrevernalliansen. 2022. Ku Og Kalv i Melkeindustrien. Accessed Apr. 6, 2023. https://dyrevern.no/article/ku-og-kalv-i-melkeindustrien/.

Ellingsen, K., G. J. Coleman, V. Lund, and C. M. Mejdell. 2014. Using qualitative behaviour assessment to explore the link between stockperson behaviour and dairy calf behaviour. Appl. Anim. Behav. Sci. 153:10–17. https://doi.org/10.1016/j.applanim.2014.01.011.

Eriksson, H., N. Fall, S. Ivemeyer, U. Knierim, C. Simantke, B. Fuerst-Waltl, C. Winckler, R. Weissensteiner, D. Pomiès, B. Martin, A. Michaud, A. Priolo, M. Caccamo, T. Sakowski, M. Stachelek, A. Spengler Neff, A. Bieber, C. Schneider, and K. Alvåsen. 2022. Strategies for keeping dairy cows and calves together—A cross-sectional survey study. Animal 16:100624. https://doi.org/10.1016/j.animal.2022.100624.

Ferneborg, S., F. Napolitano, M. Vaarst, C. M. Mejdell, S. Waiblinger, and D. de Oliveira. 2020. Methodology for studying human attitudes and behaviour to cow-calf contact systems. J. Dairy Res. 87(S1):122–127. https://doi.org/10.1017/S0022029920000448.

Flower, F. C., and D. M. Weary. 2003. The effects of early separation on the dairy cow and calf. Anim. Welf. 12:339–348. https://doi.org/10.1017/S0962728600025847.

Fraser, D., D. M. Weary, E. A. Pajor, and B. N. Milligan. 1997. A scientific conception of animal welfare that reflects ethical concerns. Anim. Welf. 6:187–205. https://doi.org/10.1017/S0962728600019795.

Gaillard, C., R. K. Meagher, M. A. G. von Keyserlingk, and D. M. Weary. 2014. Social housing improves dairy calves' performance in two cognitive tests. PLoS One 9:e90205. https://doi.org/10.1371/journal.pone.0090205.

García Pinillos, R., M. C. Appleby, X. Manteca, F. Scott-Park, C. Smith, and A. Velarde. 2016. One Welfare—A platform for improving human and animal welfare. Vet. Rec. 179:412–413. https://doi.org/10.1136/vr.i5470.

Glaser, B. G. 1978. Theoretical Sensitivity: Advances in the Methodology of Grounded Theory. Sociology Press.

Hansen, B. G., E. Langseth, and C. Berge. 2023. Animal welfare and cow-calf contact-farmers' attitudes, experiences and adoption barriers. J. Rural Stud. 97:34–46. https://doi.org/10.1016/j.jrurstud.2022.11.013.

Hansen, B. G., and O. Østerås. 2019. Farmer welfare and animal welfare—Exploring the relationship between farmer's occupational well-being and stress, farm expansion and animal welfare. Prev. Vet. Med. 170:104741. https://doi.org/10.1016/j.prevetmed.2019.104741.

Hansson, H., and C. J. Lagerkvist. 2016. Dairy farmers' use and non-use values in animal welfare: Determining the empirical content and structure with anchored best-worst scaling. J. Dairy Sci. 99:579–592. https://doi.org/10.3168/jds.2015-9755.

Hötzel, M. J., C. Longo, L. F. Balcão, C. S. Cardoso, and J. H. C. Costa. 2014. A survey of management practices that influence performance and welfare of dairy calves reared in southern Brazil. PLoS One 9:e114995. https://doi.org/10.1371/journal.pone.0114995.

Johanssen, J. R. E., B. Logstein, and G.-T. Kvam. 2020. SUCCEED–Interview guide–Interviews with Norwegian dairy farmers (English version). Accessed Jun. 20, 2023. https://acrobat.adobe.com/link/review?uri=urn%3Aaaid%3Ascds%3AUS%3A141793f9-00b6-3fcb-93d4-294c4e7bc009.

Johnsen, J. F., K. A. Zipp, T. Kälber, A. M. de Passillé, U. Knierim, K. Barth, and C. M. Mejdell. 2016. Is rearing calves with the dam a feasible option for dairy farms?—Current and future research. Appl. Anim. Behav. Sci. 181:1–11. https://doi.org/10.1016/j.applanim.2015.11.011.

King, M. T. M., R. D. Matson, and T. J. DeVries. 2021. Connecting farmer mental health with cow health and welfare on dairy farms using robotic milking systems. Anim. Welf. 30:25–38. https://doi.org/10.7120/09627286.30.1.025.

Knierim, U., D. Wicklow, S. Ivemeyer, and D. Möller. 2020. A framework for the socio-economic evaluation of rearing systems of dairy calves with or without cow contact. J. Dairy Res. 87(S1):128–132. https://doi.org/10.1017/S0022029920000473.

Lehmann, J. O., L. Mogensen, M. Bertelsen, and M. Vaarst. 2021. Dam-rearing of dairy calves: Lessons from practice for future research & development. Department of Agroecology and Department of Animal Science, Aarhus University, Tjele, Denmark.

Leruste, H., E. A. M. Bokkers, L. F. M. Heutinck, M. Wolthuis-Fillerup, J. T. N. van der Werf, M. Brscic, G. Cozzi, B. Engel, C. G. van Reenen, and B. J. Lensink. 2012. Evaluation of on-farm veal calves' responses to unfamiliar humans and potential influencing factors. Animal 6:2003–2010. https://doi.org/10.1017/S1751731112001346.

Lobe, B., D. L. Morgan, and K. Hoffman. 2022. A systematic comparison of in-person and video-based online interviewing. Int. J. Qual. Methods 21. https://doi.org/10.1177/16094069221127068.

Meagher, R. K., A. Beaver, D. M. Weary, and M. A. G. von Keyserlingk. 2019. Invited review: A systematic review of the effects of prolonged cow–calf contact on behavior, welfare, and productivity. J. Dairy Sci. 102:5765–5783. https://doi.org/10.3168/jds.2018-16021.

Meagher, R. K., R. R. Daros, J. H. C. Costa, M. A. G. von Keyserlingk, M. J. Hötzel, and D. M. Weary. 2015. Effects of degree and timing of social housing on reversal learning and response to novel objects in dairy calves. PLoS One 10:e0132828. https://doi.org/10.1371/journal.pone.0132828.

Mogi, K., M. Nagasawa, and T. Kikusui. 2011. Developmental consequences and biological significance of mother-infant bonding. Prog. Neuropsychopharmacol. Biol. Psychiatry 35:1232–1241. https://doi.org/10.1016/j.pnpbp.2010.08.024.

Neave, H. W., C. L. Sumner, R. J. T. Henwood, G. Zobel, K. Saunders, H. Thoday, T. Watson, and J. R. Webster. 2022. Dairy farmers' perspectives on providing cow-calf contact in the pasture-based systems of New Zealand. J. Dairy Sci. 105:453–467. https://doi.org/10.3168/jds.2021-21047.

Newberry, R. C., and J. C. Swanson. 2008. Implications of breaking mother-young social bonds. Appl. Anim. Behav. Sci. 110:3–23. https://doi.org/10.1016/j.applanim.2007.03.021.

Pempek, J. A., G. M. Schuenemann, E. Holder, and G. G. Habing. 2017. Dairy calf management—A comparison of practices and producer attitudes among conventional and organic herds. J. Dairy Sci. 100:8310–8321. https://doi.org/10.3168/jds.2017-12565.

Placzek, M., I. Christoph-Schulz, and K. Barth. 2021. Public attitude towards cow-calf separation and other common practices of calf rearing in dairy farming—A review. Org. Agric. 11:41–50. https://doi.org/10.1007/s13165-020-00321-3.

Prickett, R. W., F. B. Norwood, and J. L. Lusk. 2010. Consumer preferences for farm animal welfare: Results from a telephone survey of US households. Anim. Welf. 19:335–347.

Tine SA. 2022. Statistikksamling fra Ku-og Geitekontrollen 2021. Årsrapport fra helsekortordningen. Tine SA.

Vaarst, M., F. Hellec, C. Verwer, J. R. E. Johanssen, and K. Sørheim. 2020. Cow calf contact in dairy herds viewed from the perspectives of calves, cows, humans and the farming system. Farmers' perceptions and experiences related to dam-rearing systems. J. Sustainable Organic Agric. Syst. 70:49–57. https://doi.org/10.3220/LBF1596195636000.

Vaarst, M., and J. T. Sørensen. 2009. Danish dairy farmers' perceptions and attitudes related to calf-management in situations of high versus no calf mortality. Prev. Vet. Med. 89:128–133. https://doi.org/10.1016/j.prevetmed.2009.02.015.

Vaarst, M., K. Sørheim, J. E. R. Johanssen, and N. C. Verwer. 2019. Calves with their dams in dairy cow systems. Accessed Jun. 20, 2023. https://orgprints.org/id/eprint/36915/2/fullreport-pdf-version-december-2019.pdf.

Vanhonacker, F., W. Verbeke, E. Van Poucke, and F. A. M. Tuyttens. 2008. Do citizens and farmers interpret the concept of farm animal welfare differently? Livest. Sci. 116:126–136. https://doi.org/10.1016/j.livsci.2007.09.017.

Wagenaar, J. P., and J. Langhout. 2006. Rearing calves with cows nature works! LBI Publications, no. LV60E. Louis Bolk Instituut.

Wagenaar, J. P. T. M., and J. Langhout. 2007. Practical implications of increasing "natural living" through suckling systems in organic dairy calf rearing. NJAS Wagening. J. Life Sci. 54:375–386. https://doi.org/10.1016/S1573-5214(07)80010-8.

Weary, D. M., and B. Chua. 2000. Effects of early separation on the dairy cow and calf. 1. Separation at 6 h, 1 day and 4 days after birth. Appl. Anim. Behav. Sci. 69:177–188. https://doi.org/10.1016/s0168-1591(00)00128-3.

Yin, R. K. 2009. Case Study Research: Design and Methods. Fourth Edition. Sage.

ORCIDS

Juni Rosann E. Johanssen https://orcid.org/0000-0002-3073-895X
Gunn-Turid Kvam https://orcid.org/0000-0002-8643-3020
Brit Logstein https://orcid.org/0000-0003-1444-7148
Mette Vaarst https://orcid.org/0000-0003-2830-2847

II Paper II – A pilot study of the behavior of dairy calves with or without their dams on pasture

A pilot study of the behavior of dairy calves with or without their dams on pasture

Juni Rosann E. Johanssen[1*], Julie Føske Johnsen[2], Kristin Sørheim[1], Knut Egil Bøe[3]

[1]Norwegian Centre for Organic Agriculture, 6630 Tingvoll, Norway

[2]Norwegian Veterinary Institute, 1433 Ås, Norway

[3]Norwegian University of Life Sciences, 1430 Ås, Norway

*** Correspondence:**

Juni Rosann Engelien Johanssen, Gunnars veg 6, 6630 Tingvoll, Norway, +47 46 68 36 56,

rosann.johanssen@norsok.no

Abstract

Dairy calves are usually separated from their dams immediately post-partum and kept inside during the milk feeding period. Conversely - keeping them on pasture with their dams can promote natural behavior and be more accepted by the public. Our aim was to compare the behavior of dairy calves with or without their dams on pasture. Our pilot study included four groups of cow-calf pairs, 17 Norwegian Red (NRF) and three NRF x Holstein crossbreds allocated to each of two treatments: cow-calf contact (CC, n=10 pairs) and early separation (ES, n=10 pairs). The CC pairs were kept together on pasture for 6 weeks after calving with free suckling except during milking; calves were gradually weaned with part-time suckling in weeks 7-8 and were separated from the cows in week 9. The ES cows and calves were separated one to three hours after birth and kept on pastures without any contact; calves got access to 12-14 L milk/calf/day until week 6 and were gradually weaned in weeks 7-8. Observations of calf behavior were done once weekly in weeks 3, 6, and 9 and a food neophobia test was done in week 8. For the observations, the analyzed behaviors had a treatment*week interaction ($P < 0.005$). The CC calves used the calf hide less than the ES calves, but more so with increasing age. Before weaning, the CC calves played more and were lying less than the ES calves in week 3, and the CC calves played more and were lying less in week 3 than in week 6. The ES calves grazed more than the CC calves in week 6, and unlike the CC calves, the ES calves grazed more in week 6 than in week 3. Allogrooming between peer calves was similar across the treatments. In week 9 (post-weaning), all calves increased their time spent grazing, and the CC calves spent less time lying and vocalized more than the ES calves. Descriptively, our food neophobia test showed numerically lower latencies to approach all buckets for the CC calves on the first test day. Our pilot study indicated that the calves behaved differently with and without their dams on pasture during our observations and that for most behaviors, the difference was dependent on age. However, the study was limited mainly by sample size and limited replication. Future studies should investigate how calf development may be affected through social facilitation by the cow.

Keywords: Dam rearing, cow-calf contact, animal welfare

1 Introduction

Cow-calf contact (CCC) systems in dairy farming are receiving increased attention from different stakeholders (Sirovica et al., 2022; Vaarst et al., 2020; Ventura et al., 2013). In contrast to the early separation of cow and calf, this practice is more supported by the public (see review by Placzek et al., 2021). Also, farmers practicing CCC on pasture have reported several benefits, such as the calves and their dams having access to more space and thus being enabled to express their natural behavior (Johanssen et al., 2023). However, there is limited knowledge about how CCC affects dairy calves' behavior on pasture.

Natural behavior for a calf is to suckle 4-10 times per day depending on age, whereas a suckling bout will last for around 7-10 minutes (de Passillé, 2001). After a milk-feeding period, the transition to solid feed is considered a main stressor for both CCC and artificially reared calves (Weary et al., 2008). Yet there is a lack of studies comparing dairy calves' behavior on pasture in response to weaning from suckling versus artificial milk feeding.

Studies have shown that pastured cattle prefer to stay inside or seek shelter under certain environmental conditions, such as relatively low (Sawalhah et al., 2016) or high (Van Laer et al., 2015) ambient temperatures, during windy conditions alone or in combination with precipitation (Smid et al., 2019). However, it is unknown how cow-calf contact affects calves' use of a calf shelter.

When artificially milk-fed indoors, young calves spend most of their time lying down (17-18 h/d) (Bonk et al., 2013; Duthie et al., 2021). A study with pastured Zebu calves kept with their dams found a somewhat lower lying time (14-15 h/d) and that the duration of “moving” was similar between the calves and their dams (Hutchison et al., 1962). Studies of calves both with (Mac et al., 2023) and without (Roy et al., 1955) their dams on pasture describe calves grazing in their first week of life. Grazing behavior in CCC calves has been shown to be determined by their dams after their first month of life (Hutchison et al., 1962). This social facilitation of moving and grazing with the mother may result in less time spent lying. Generally, calves spend less time lying (Kerr and Wood-Gush, 1987; Webster et al., 1985) and more time grazing with increased age (Hutchison et al., 1962)

Food neophobia is defined as the avoidance of and reluctance to taste unfamiliar foods (Cooke et al., 2006) and might be problematic when animals refuse novel feeds provided by the farmer (Villalba et al., 2010). If cattle are cautious about eating novel feed, it can decrease food intake and productivity (Launchbaugh et al., 1997). Costa et al. (2014) found that housing calves in a complex social group indoors reduced food neophobia, as individually housed calves showed more food neophobia than calves housed with their dams. Given that the management of dairy calves entails transit through different types of feeding, housing, and social groups, we need knowledge of how CCC affects food neophobia.

Calf play behavior is known to be affected by age for calves kept on pasture (Das et al., 2000; Reinhardt et al., 1978). It may also be affected by the presence of the dam, as shown for calves kept indoors in a study where CCC calves showed more solitary play than artificially milk-fed calves (Waiblinger et al., 2020). Play behavior has short durations and occurs sporadically throughout the day (Duve et al., 2012). Other factors that have been shown to affect play in calves kept indoors include available space (Jensen and Kyhn, 2000), social circumstances (Jensen et al., 2015; Lv et al., 2021), and hunger (Krachun et al., 2010). Since play may indicate positive emotions (Boissy et al., 2007; Špinka et al., 2001), it is relevant to investigate how CCC affects play on pasture.

Allogrooming is an important behavior that serves several functions for cattle (Reinhardt et al., 1986; Sato et al., 1991). It aids the formation of the bond between calf and dam after calving (Jensen, 2011), and is generally used to form and maintain social bonds in cattle, often between pairs close in age or between relatives (Sato et al., 1993). Calves reared artificially and indoors rarely groom each other (Horvath and Miller-Cushon, 2019), compared to calves and dams on pasture (Reinhardt et al., 1978), but while allogrooming between calves has been shown to increase with age, dam-calf allogrooming wanes with age (Kerr and Wood-Gush, 1987). Because of the importance of allogrooming for cattle, it is valuable to examine if pastured CCC calves experience most allogrooming because of the calf-dam interaction or if artificially reared calves show more allogrooming between calves to compensate for the lack of grooming between calf and dam.

Most studies on dairy calf behavior focus on artificially reared calves kept indoors (see e.g., reviews by Costa et al., 2016; Miller-Cushon and Devries, 2015). Similarly, CCC calf behavior studies mostly refer to indoor conditions (e.g. Johnsen, 2015; Wenker, 2022). The comparison of CCC calves to artificially reared calves may be biased when artificially reared calves are fed restricted amounts of milk (e.g., Nabukalu, 2020). Calf behavior studies in a pasture-based setting are most often performed on beef cattle (e.g., Lidfors and Jensen, 1988; Walker, 1962) or semi-wild cattle (e.g., Reinhardt and Reinhardt, 1982; Vitale et al., 1986). Although some recent CCC studies are carried out on pasture (Mac et al., 2023; Nicolao et al., 2020; Sinnott, 2023), they do not compare CCC calves and artificially reared calves during their milk-feeding period on pasture. Mac et al. (2023) described behavior in six dairy calves kept with their dams on pasture, and the study by Nicolao et al. (2022, 2020) as well as the Ph.D. thesis by Sinnott (2023) compared behavior in dairy calves having experienced different levels of CCC with artificially reared calves, but pasture access was not constant across the treatments.

The aim of our pilot study was to compare behavior in pastured dairy calves kept with or without their dams by use of a calf hide (Figure 1), lying, grazing, playing, and allogrooming between peer calves. We also aimed to describe indicators of food neophobia, sucking/suckling behavior, allogrooming between cow and calf, as well as the calves' vocalizations after weaning.

We hypothesized that the presence of the dam on pasture may lead to less use of a calf hide, less lying, more grazing, more play, and less allogrooming between calves, but the effects may be modulated by calf age and weaning.

2 Materials and Methods

This pilot study complied with the Norwegian Regulation on Animal Experimentation (Forsøksdyrforskriften, 2015) under the Norwegian Animal Welfare Act (Dyrevelferdsloven, 2009). The study was conducted from May to August 2021 on a private commercial dairy farm (220 meters above sea level) with a free-stall barn and 80 dairy cows in Central Norway, including the farm's summer pasture (17 km from the farm, 580 meters above sea level), where the farm usually grazed all lactating cows during summer (Figure 2). The farm had concentrated calving in three periods, with one period in May and June.

2.1 Pilot Study Design

In a parallel-group designed controlled pilot study, 20 cow-calf pairs were allocated to two treatments: cow-calf contact (CC, n=10 pairs) and early separation (ES, n=10 pairs). Each treatment had two groups of five cow-calf pairs: CC: groups CC1 and CC2, ES: groups ES1 and ES2. Treatments were assigned to the groups in the following (non-random) order to account for pasture conditions (snow) at the summer pasture at the start of the study: ES, ES, CC, CC. All groups were let out on pasture (see details in 2.4) and the study period was 9 weeks for each group (week 0 was defined by the average group calf birth week). More information about the two treatments is shown in Table 1.

Table 1. Design of the pilot study with pastured dairy cows and calves in two treatments: Cow-calf contact (CC, n=10 pairs) and early separation (ES, n=10 pairs).

Treatment	Milk feeding	Week 0-3	Week 4-6	Week 7	Week 8	Week 9

Cow contact (CC)	Suckling allowance	Free suckling except during milking	Free suckling except during milking	Fence line contact, except suckling after milking: 2 h morning, 2 h evening	Fence line contact, except suckling after milking: 1 h morning, 1 h evening	None (cows moved 120 m away)
	Cow-contact	Whole day CC	Whole day CC	Partial CC	Partial CC	Total separation (auditory and visual contact)
Early separation (ES)	Milk allowance	12 L /calf/day in four meals	14 L /calf/day in four meals	8 L/calf/day in two meals	4 L/calf/day in two meals	None
	Cow-contact	1-3 hours on calving day, then none	None	None	None	None

The ES calves were fed tempered whole milk from teat buckets with one teat/calf (Figure 1) with feedings at 06.30 AM, 10.30 AM, 04.00 PM, and 08.00 PM in weeks 0-6, and at 06.30 AM and 04.00 PM in weeks 7-8. The teat bucket (see Table 1 for details on milk allowance) were available at each meal until none of the calves within the group showed interest in the milk.

2.2 Animals

Seventeen of the cow-calf pairs included in the pilot study were Norwegian Red (NRF), and three pairs were NRF x Holstein crossbreds. The three-crossbreed cow-calf pairs were one CC pair and two ES pairs, but of these, one ES cow was excluded due to ketosis. The calves used in the study were born between 7th of May and 14th of June and we decided to assign the pairs' treatment group based on calving date to minimize calf age variation in each group. Thus, it was not possible to additionally distribute the treatments evenly according to calf sex and cow parity. The calf age range was between 6 and 8 days per group. The calves' birth weight ranged from 29.8 to 56.0 kg (average: 44.0 kg). The distribution of primiparous cows relative to multiparous cows in each group was: CC1: 2/5 and 3/5, CC2: 2/5 and 3/5, ES1: 1/4 and 3/4, and ES2: 0/5 and 5/5. Finally, the distribution of bull versus heifer calves in each group was: CC1: 1/5 and 4/5, CC2: 1/5 and 4/5, ES1: 4/5 and 1/5, and ES2: 2/5 and 3/5.

2.3 Indoor management

Before or shortly after calving, each cow was moved from the free stall area to an individual calving pen with a rubber mattress and saw-dust bedding (14.4 m^2). Within the first three hours after calving, each cow was health checked, milked in the automatic milking system's (AMS) milking robot (GEA Mione, GEA Group, Düsseldorf, Germany), and each calf was health checked and weighed. While all calves were offered colostrum at ad libitum from a teat bottle at their first feeding, the ES calves were tubed if voluntary intake of colostrum was < 4.5 L, according to the farm's regular practice for artificially reared calves. The CC pairs were observed after birth to make sure the cows were taking care of their calves and that the calves suckled. Each CC pair stayed in the calving pen during the first three days after calving before being moved temporarily to the free-stall area. Once the fifth calf within a CC group was three to four days old, the whole group was let out on pasture (see details in 2.4). The ES calves were separated from their dams within one to three hours after birth and moved to individual straw-bedded pens (1.1 m^2) for three days before they were temporarily moved to a group pen (35.0 m^2). In the group pen, the calves had ad libitum access to silage, concentrates, and water. Once the fifth calf in an ES group was three days old, the whole calf group was let out on pasture (see details in 2.4).

2.4 Pasture management

Due to the calving order (explained in 2.2), the ES calves were first let out on pasture areas of 0.12 hectares per ES group on the farm. They were let out on 18^{th} and 28^{th} of May, at an average group calf age of 7.6 and 7.4 days for the groups ES1 and ES2, respectively. Thereafter, the ES calves and the ES cows were transported separately to the summer pasture (Figure 2) on 7^{th} of June, at an average group calf age of 27.6 and 17.6 days for ES1 and ES2, respectively. The ES pairs were let out on separate areas on the summer pasture without any contact between cows and calves (>130 m between them, and they could not see each other). The CC pair groups were transported directly from the barn to the summer pasture on 10^{th} and 17^{th} of June at an average group calf age of 6.8 and 6.0 days for the groups CC1 and CC2, respectively. The cows were milked daily in a milking parlor by the summer pasture at 06.30 AM and 05.30 PM.

Each calf group had access to what we have called a calf hide (Calf-O-Tel XL-5, VDK Products, the Netherlands) (10.9 m^2) consisting of a hutch (5.8 m^2) and a steel-fenced area outside the hutch (5.1 m^2) (Figure 1). The open gates to the calf hides were too small for the cows to enter, so that only the calves could use the calf hides. The hides contained straw bedding and provided ad libitum access to water and concentrates. The pasture areas for the CC pairs and the ES calves had electric net fences (DeLaval Premium, Sweden). Throughout the study, the groups were regularly moved to new areas on the summer pasture (Figure 2), depending on available forage plants, which were visually assessed by a nutrition researcher. The CC pair groups, and the ES calf groups were in 3-4 different areas (including the first area on the farm for the ES calves) for each group until week 9. The pasture yields on the summer pasture were measured before and after a group grazed a new area. The size of the pasture areas was determined by both the forage yields and the number and size of the animals. Pasture areas for each group were between 0.42 and 0.78 hectares for the CC pairs and 0.12 hectares for the ES calves.

The botanical composition of the pastures was estimated using the dry-weight rank method (Mannetje and Haydock, 1963) modified by Jones and Hargreaves (1979). The average botanical composition of the pastures for the CC groups was 77 % timothy, 6 % other grasses, 5 % clover, and 12 % other herbs, while it was 42 % smooth meadow grass, 2 % other grasses, 4 % clover, and 52 % other herbs for the ES calf groups. Herbage samples were taken from each area before grazing. Dried and ground samples were analyzed by NIR spectroscopy (NIRS™ DS2500 F, FOSS, Hilleroed, Denmark) (Table 2).

Table 2. Feed value and chemical composition (NIRS) (average ± SD) of herbage samples taken from summer pasture areas before grazing in a pilot study with the two treatments: Cow-calf contact (CC) and early separation (ES).

	Number of pasture areas analysed per treatment (n) – Animals	
Analysed variable	CC (n=13) – Pairs	ES (n=8) – Calves
NE_L MJ/kg of DM	6.6 ± 0.6	6.6 ± 0.4

Digestability, % of DM	76.6 ± 4.7	77.1 ± 3.4
PBV, g/kg of DM	25.1 ± 30.2	10.0 ± 16.0
AAT, g/kg of DM	86.7 ± 5.6	86.4 ± 3.8
Crude protein, % of DM	17.5 ± 3.8	15.9 ± 2.2
NDF, % of DM	50.9 ± 4.6	46.4 ± 4.8
uNDF, % of NDF	13.8 ± 6.8	15.6 ± 3.1

A weather station from Netatmo (Netatmo Smart Home Weather Station, Boulogne Billancourt, France) recorded the daily outdoor temperatures. The average temperature for the study period was 14.1 ℃, with an average variation from 6.6 to 22.2 ℃ per day. Average daily rainfall was 2.2 mm, with a variation from 0.0 to 29.8 mm per day (53/88 days <0.5 mm and 5/88 days >10 mm). The average daily temperature was similar for both treatments.

2.5 Direct behavioral observations

Each calf group was observed directly on pasture one day per week in weeks 3, 6, and 9 after birth, by the first author. All calves in one group were observed simultaneously, while the behavior of each calf was registered individually. All observations except the week 3 observation for the ES1 group were carried out at the same place (summer pasture, Figure 2). The observations each day were done in two periods of four hours: from 06.00-10.00 AM and from 04.00-08.00 PM. Time and limited project funding constrained our observation protocol. Hence, we chose to do the observations at two different ages pre-weaning (week 3 and 6), and once post-weaning (week 9). The periods during the morning and in the afternoon/evening were chosen due to results from other behavioral studies conducted on pasture in which cattle were found to have periods of grazing (Kilgour et al., 2012; Martins et al., 2017; Walker, 2012), suckling (Day et al., 1987; Odde et al., 1985) playing (Das et al., 1999; Vitale et al., 1986) and grooming (Reinhardt et al., 1986). As the cows were milked at 06.30 AM and 05.30 PM, the observation periods in weeks 3 and 6 included periods in which the CC calves' dams were away for milking. The times of when the CC cows left for and returned from milking (weeks 3 and 6) were noted in the scoring sheets. On average, they were away for 30 minutes/milking/group.

To be able to observe the calves' behavior properly on pastures, we decided to do direct observations where the observer followed the calves around by sitting, standing, and walking outside and inside the fences around the pastures. The observer tried her best not to disturb the calves by being quiet, moving calmly and always keeping a distance of at least six meters from the calves. The calves seemed not to care about the observer's presence. However, even if they may have been disturbed a bit by the observer, the same method was used for all groups and weeks.

Observations were never done on the same day or the day after a group was moved from one pasture to another. In case of rain, since weather conditions affect behavior (Sawalhah et al., 2016), observations were carried out on the nearest possible day. Twice, the observer had to observe two groups in the same calendar week (when group ES1 was in week 6 and 9, and group CC1 was in week 3 and 6 simultaneously). For these reasons, the observations could not be done on the same weekday each week for each group, but they were done on either Monday, Tuesday, or Wednesday. In week 9, after the calves had ingested their last milk on Sunday evening the week before, groups ES1 and CC1 were observed on Tuesday and groups ES2 and CC2 were observed on Wednesday. Identification of individual calves was enabled by using colored neck collars.

Sampling methods for different behaviors are explained in Table 3. Instantaneous sampling was done at intervals every second minute (120 registrations per calf within 4 hours). The behaviors "Lying", "Standing/moving" and "Grazing" were mutually exclusive, while "In calf hide" could happen simultaneously. We decided not to include "Standing/moving" in the results because when the calves were not lying or grazing, they were either standing or moving, but we did not differentiate between standing and moving. One-zero sampling was done at intervals of 30-second periods for 1.5 minutes followed by 30-second breaks for the instantaneous sampling, repeated every second minute (360 possible registrations per behavior per calf within 4 hours). The one-zero behaviors were recorded as they happened or not during each 30-second period, and these behaviors could happen within the same 30-second period. Vocalizations were recorded by continuous sampling in the same 30-second periods as the one-zero sampling.

The behaviors of suckling and sucking milk could not be compared between the treatments because the CC calves could suckle freely except when their dams were milked, while the ES calves did not have ad libitum access to milk. The ES calves got four meals per day where the teat buckets were available until none of the calves showed interest in the milk, as described in Table 1. We recorded suckling and sucking milk, to describe suckling and sucking bout length among the ES and the CC calves, respectively.

Table 3. Ethogram for the direct behavior observations of the pastured calves in the two treatments cow-calf contact (CC, n=10) and early separation (ES, n=10). For each behavior recorded, a description and method for recording as well as the week and reference are shown.

Behavior	Description	Method for recording	Week	Reference
In calf hide	The calf is inside the calf hutch or in the fenced area outside the hutch (if they are not in the calf hide, they are on the pasture)	Instantaneous	3, 6 & 9	None
Lying	The calf is lying on the ground in any position. The whole body is in contact with the ground. The head may or may not be in contact with the ground	Instantaneous	3, 6 & 9	Gladden et al., 2020
Standing or moving	Standing on all four feet or moving one or more extremities either in a forward or reverse motion, but not grazing	Instantaneous	3, 6 & 9	Johnsen et al., 2015a, adapted
Grazing	The calf is grazing with its head down, while actively engaged in consuming and masticating grass; this can include forward movement, but it is clear that the calf is in the process of grazing	Instantaneous	3, 6 & 9	Nickles, 2019
Suckling milk (CC)	Standing in a suckling position, the neck is bent, the head is near an udder and a teat is enclosed within the calf's mouth	One-zero-sampling	3 & 6	None
Sucking milk (ES)	An artificial teat on the teat bucket is enclosed within the calf's mouth	One-zero-sampling	3 & 6	None
Play	Running equivalent to trotting (two-beat leg movements synchronized diagonally), cantering (three-beat gait in between a trot and a gallop), or galloping (four-beat gait with a phase where all legs are off the ground) and jumping (both forelegs lifted off the ground and body moves upwards), bucking (head is lowered, and rear legs are lifted off the ground), kicking with one or two legs, butting and/or mounting.	One-zero-sampling	3, 6 & 9	Jensen et al., 1998, adapted
Allogrooming calf-calf	Initiating or receiving licking (tongue touches calf)/sniffing (nose <5 cm from calf air is pulled through the nose) or rubbing (nose or other body part touches any other body part)	One-zero-sampling	3, 6 & 9	Johnsen et al., 2015a, adapted
Allogrooming cow-calf/calf-cow (CC)	Initiating or receiving licking (tongue touches cow/calf)/sniffing (nose <5 cm from cow/calf air is pulled through the nose) or	One-zero-sampling	3 & 6	Johnsen et al., 2015a

	rubbing (nose or other body part touches any other body part)			
Vocalizations high pitched	Every single open-mouthed “muh” vocalization with inhalation between two occurrences	Continuous	9	Johnsen et al., 2015b
Vocalizations low pitched	Every single closed-mouthed ‘mm’ type vocalization with inhalation between two occurrences	Continuous	9	Johnsen et al., 2015b

2.5.1 Food Neophobia Test

To describe food neophobia in the calves from the two treatments, a test adapted from Costa et al. (2014, 2020) was carried out on Tuesday, Wednesday, and Thursday in week 8 after birth (during weaning) for each group. Week 8 seemed most suitable for this test since the calves were likely to be more interested in food during weaning compared to earlier when they were younger and had an unrestricted suckling or high milk allowance. Additionally, they were less likely to be affected by stress during week 8 compared to the first week of weaning (week 7) or after weaning (week 9). Following Costa et at. (2014), we conducted the test for three consecutive days, each lasting 30 minutes. However, instead of being tested individually as in the study by Costa et al. (2014), our calves were tested in their groups as they were not used to being alone. We expected that the neophobic response in the calves would decline on days 2 and 3 of testing, and the chosen duration was to ensure ample time for the calves to decide to approach and eat novel feed. The tests in our study started at 01.00 PM each day. During each test, the calves were enclosed in a rectangular arena (36 m^2) located on the pasture, immediately adjacent to the calf hide. This arena contained four 90 l black plastic buckets. Two buckets contained novel feed: hay (1.5 kg), and carrots (5.0 kg), one bucket contained familiar feed: concentrates (5.0 kg), and one bucket was empty. To make it possible for all five calves in one group to eat from the same bucket at the same time, the buckets were placed on each of the rectangle’s sides, one meter from the fence. The position of the buckets was chosen randomly and was changed each test day. The amounts of feed were weighed before and after each test to record the calves’ consumed feed at the group level. Two video cameras (GoPro Hero 4, California, US) were used for video recording, and one research technician used the videos to perform behavioral recordings of each calf according to an ethogram shown in Table 4.

Table 4. Ethogram describing the behaviors recorded during continuous behavioral observations from video recordings of the calves from the two treatments: cow-calf contact (CC, n=10) and early separation (ES, N=10) in the food neophobia test. The descriptions are adapted from Costa et al. 2014.

Behavior	Behavior description
Latency to eat hay, carrots, or concentrates	Putting head/muzzle in the bucket for the first time in the test
Latency to manipulate empty bucket	Licking, sniffing, or head/muzzle in the empty bucket for the first time in the test
Start eating hay, carrots, or concentrates	Putting head/muzzle in the bucket
Start manipulating empty bucket	Starts licking, sniffing, or putting head/muzzle in the empty bucket
Stop eating hay, carrots, or concentrates	Taking head/muzzle out of the bucket and more than 5 seconds before taking head/muzzle in the bucket again
Stop manipulating the empty bucket	Stop licking, sniffing, or having head/muzzle in the empty bucket and more than 5 seconds before doing it again

2.6 Statistical analysis

Statistical analyses were conducted in Minitab 21 Statistical Software. The behaviors “In calf hide”, “Lying”, “Grazing”, “Play” and “Allogrooming calf-calf” were our main response variables, and each of these was analyzed separately using the Mixed Effects Model.

For each response variable (y), we calculated the mean proportion of behavior in % of total sample points for each calf (n=20) in each period (morning and evening) for each week (weeks 3, 6, and 9) and used these numbers for the analysis. We first fitted the same model for each y, and the residual plot from the model fit was visually checked for normality and homogeneity of variance. Additionally, we did the normality tests Anderson Darling and Ryan-Joiner for each y and got suggestions for transformation by using the Box-Cox transformation methods. With guidance from a statistician we decided to transform the behavior “In calf hide” with “Calfhide* = ln(Calfhide + 1)” and the behavior “Play” with “Play* = (Play + 1)–0.5”. The other response variables met assumptions of normality without any transformations, while “Play” and “CalfHide” met assumptions of normality after the transformations.

The full model for each y: y = intercept + treatment + group(treatment) + calf(treatment; Group) + week + period + sex + treatment*week + treatment*period + week*period + treatment*week*period

In this model, treatment was the main effect of treatment (fixed factor with two levels: CC, ES). Group(treatment) was the effect of the group within treatment (random factor) and calf(treatment; group) was the effect of calf within group within treatment (random factor). Week (fixed factor, three levels: weeks 3, 6, and 9), sex (fixed factor, two levels: male, female), and period (fixed factor, two levels: morning, evening) were main effects. The interactions were 2^{nd} and 3^{rd} order interactions between the relevant fixed factors. The first model was reduced for each y through guidance from the statistician by manually removing clearly non-significant higher-order interactions. First interactions with $P > 0.40$ were moved, then interactions with $P > 0.10$ were moved before reaching the final model used for analysis of each y. Subsequently, we ran post hoc analyses with Tukey pairwise comparison tests to examine the differences between each level of the factors and interactions having p-values less than 0.1. Significance was declared at $P < 0.05$; a tendency was declared at $P < 0.10$.

To create graphs showing the results, we used Microsoft Office Excel and the numbers used were the least squares means ± standard errors (SE) from the analyses in Minitab. For the transformed results of the behaviors “In calf hide” and “Play” we used the back-transformed means for the lines, and the numbers for back-transformed confidence limits are shown in the graphs beside the letters for the significant differences.

Suckling (CC) or sucking milk (ES) was considered a new bout if it was at least one minute without any suckling or sucking between the recordings. The variables “Allogrooming cow-calf” and “Suckling milk”/”Sucking milk” are shown descriptively as they could not be compared between the treatments. The vocalizations are shown descriptively as the number of vocalizations within each 30-second period had no limitation. Additionally, the behavior results from the food neophobia test are shown descriptively as the test should preferably have been done as an individual test but was done as a group test where calves might have influenced each other’s behavior with the buckets. The amount of the different feeds ingested during each test was recorded at the group level and is described accordingly.

3 Results

3.1 Suckling and sucking milk

The CC calves suckled in more frequent, but shorter bouts in week 3 compared to week 6: mean (range): 3.1 (1-5) vs 1.7 (1-3) suckling bouts (from daily totals of 8 h/day) of 4.2 (0.5-13.0) vs 6.7 (0.5-13.5) minutes per calf, respectively. During the two observation periods for the ES calves, including two of their four meals per day, the number of sucking bouts for the two meals in total, and time per bout were similar in week 3 and week 6: 2.6 (2-4) vs 2.4 (2-3) sucking bouts of 7.3 (0.5-12.0) vs 7.7 (0.5-13.5) minutes per calf, respectively.

3.2 Use of calf hide

During the observation periods, the CC calves used the calf hide less than the ES calves in each of the three observation weeks, see Figure 3a (treatment*week: $F_{2.00, 106.01} = 23.02$, $P < 0.001$). The post hoc test showed that while the CC calves used the calf hide increasingly with age, there were no differences for the ES calves in the different weeks.

3.3 Lying

The CC calves were lying less than the ES calves during the observation periods in weeks 3 and 9 (post-weaning) but with no difference in week 6, see Figure 3b (treatment*week: $F_{2.00, 110.04} = 20.52$, $P < 0.001$). The CC calves were lying most in week 6, less in week 3, and least in week 9, while the ES calves had similar lying times in weeks 3 and 6, but less in week 9. The calves were lying more in the evening than in the morning (58.9 ± 2.0% vs 49.5 ± 2.0%, respectively) ($P<0.005$).

3.4 Grazing

The CC calves grazed less than the ES calves in week 6, but there were no differences between the treatments in weeks 3 and 9 (post-weaning), see Figure 3c (treatment*week: $F_{2.00, 92.99} = 8.89$, $P < 0.001$). Both the CC and the ES calves grazed most in week 9. While the CC calves tended to be grazing more in week 3 compared to week 6, the ES calves grazed more in week 6 compared to week 3.

3.5 Play

The CC calves played more in week 3 compared to weeks 6 and 9 (post-weaning), and compared to the ES calves' week 9, see Figure 4a (treatment*week: $F_{2.00, 110.01} = 26.88$, $P < 0.001$). The ES calves played more in week 6 compared to week 9. Referring to the comments about the CC cows' absence during milking, we could see that the CC calves played more during these times in week 3 than in week 6.

3.6 Allogrooming

The CC calves showed more allogrooming between calves in week 9 (post-weaning) than in week 3, while the ES calves showed more allogrooming between calves in week 6 than in weeks 3 and 9, see Figure 4b (treatment*week: $F_{2.00, 94.45} = 12.13$, $P < 0.001$).

Our descriptive data on allogrooming between CC cows and their calves indicate that the proportions were similar during the observation periods in weeks 3 and 6 (mean of sample points ± SD): 2.8 ± 4.0 % and 2.7 ± 4.1 %, respectively.

3.7 Vocalizations

Descriptive statistics showed numerically more high-pitched vocalizations in the CC calves than the ES calves (mean frequency of vocalizations/hour ± SD: 61.68 ± 58.73 and 6.31 ± 13.1, respectively) in week 9 post-weaning and separation. Low-pitched vocalizations were numerically low for both the CC and the ES calves (1.91 ± 2.49 and 1.79 ± 2.40, respectively).

3.8 Food neophobia test

During the food neophobia test in week 8 (gradual weaning), the CC calves had numerically shorter latency (median) to put their heads/muzzles in all the buckets compared to the ES calves on day 1, see Figure 5. The differences seemed to be smaller on day 2 and similar between the treatments on day 3. The calves in both treatments spent numerically the most time (median) in the buckets with novel feed, and somewhat more time with hay than with carrots. The CC calves spent numerically the most time with hay on day 1, while the ES calves spent the most time with hay on day 3. The CC calves ingested mostly hay, and more similar amounts of carrots and concentrates, while the ES calves ingested mostly carrots, then hay, and the least amounts of concentrates, see Table 5. When we look at the two ES groups, ES2 ingested more carrots than ES1. We observed large individual variations among the calves in each group for both latencies to approach the buckets and time spent with each bucket. For example, the ES calves had a latency between 58 and 1658 seconds to approach the empty bucket on day 1, and spent between 0.0% and 38.3% of the test period on day 1 with the carrot bucket.

Table 5. Results from weighing of feed for each group in the food neophobia test from before and after each test in week 8. Shown as intake of feed in grams at group level from the different buckets for each treatment and group; cow-calf contact (two groups: CC1 and CC2) and early separation (two groups: ES1 and ES2).

Day	Group	Hay	Carrots	Concentrates	Group	Hay	Carrots	Concentrates
D1	CC1	500	180	60	ES1	60	20	120
D1	CC2	380	40	100	ES2	280	400	40
D2	CC1	120	80	100	ES1	120	120	220
D2	CC2	200	80	60	ES2	220	580	160
D3	CC1	240	60	140	ES1	260	60	20
D3	CC2	180	60	0	ES2	380	720	120

4 Discussion

This pilot study is limited by a number of factors that should be acknowledged when interpreting its results. The number of study units and treatment replicates were low, and a potential effect of time (of birth) could not be prevented when allocating groups to the treatments. ES calves were exposed to pastures in different places (the farm and the summer pasture), which may have affected the registered behaviors, but not beyond week 3. Since the groups were observed different days according to their age, even though we avoided observing rainy days, other weather conditions, such as the amount of sun and wind has probably influenced the calves' behavior.

In our study, the CC calves could suckle freely except during the milking of their dams, while the ES calves were given four meals and up to 14 L of milk/calf/day. We originally planned to offer the ES calves up to 16 L milk/calf/day, as done in another study (Wormsbecher et al., 2017). However, when the calves got four meals per day from week 0 to week 6, they usually drank all the milk at their first and third meal, but left milk residuals of several liters at their second and fourth meal. To limit the amount of milk waste we therefore gave the amounts shown in Table 1. The suckling and sucking of milk could not be compared, but we found that both the CC and the ES calves spent up to around 13 min/suckling or sucking bout. Thus, we can assume that the need to suck was satisfied in both treatments. The CC calves' suckling bouts were numerically higher but of shorter duration in week 3 compared to week 6, which is consistent with what has been found in other studies where the number of suckling bouts decreases while the duration of suckling bouts increases with age (Das et al., 2000; Vitale et al., 1986). It would have been interesting to compare the suckling and sucking of milk between pastured calves with and without their dams, and this could have been done if the ES calves had ad libitum access to milk through automatic milk feeders. However, this was not practically or economically feasible in our study.

The CC calves spent less time using their calf hides than the ES calves during the observation periods in our study. We could presume that all calves would use the calf hide to seek shelter (Sawalhah et al., 2016; Van Laer et al., 2015) and to lie on soft straw bedding, which has been shown to be a preferred bedding material by cattle (Lowe et al., 2001). There may be several reasons for why the CC calves used the calf hide less, and one is the social facilitation by their dams. The CC calves used the calf hide more with increased age, which may reflect that they spent more time near their dams when they were 3 weeks compared to 6 weeks of age. This agrees with other studies showing that time spent in close proximity between calf and dam decreases with age (Hirata et al., 2003; Vitale et al., 1986). Hutchison et al. (1962) showed that calves' time spent on "moving" was similar to that of their dams, which indicates that calves follow their dams around on pasture. The larger area available for the CC pairs in our study might also have contributed to the CC calves having naturally spent more time further away from the calf hide, and thus used it less.

The CC calves in our study were lying less than the ES calves in weeks 3 and 9. In an earlier study conducted indoors, it was found that calves with their dams were more active than calves separated immediately from their dams, but this was during the first four days after calving (Lidfors, 1996). In her thesis, Sinnott (2023) found no difference in lying behavior between calves with different levels of CCC or control (artificial milk-fed), where only the full-time CCC calves were kept on pasture, although she found the CCC calves to be standing less but moving more than the control calves. Lying time did not decrease with age during the observation periods in our study (from weeks 3 to 6), as had been shown in other studies (Kerr and Wood-Gush, 1987; Webster et al., 1985). During our observation periods, in contrast, the CC calves were lying significantly less in week 3 than in week 6. This may have been affected by social facilitation while being with their dams, and the fact that the cows were temporarily separated from the calves for milking during the observation periods may have influenced this even more. We found the CC calves to be lying less around the time of their dams' milking in week 3 than in week 6. Mac et al. (2023) observed cows and calves on pasture around milking and reported that the cows' vocalizing and their attempts to get back to their calves decreased with calf age. If calves and their dams are more concerned about being with each other when the calves are, e.g., 3 weeks compared to 6 weeks, the calves might be more affected by their dams' behavior at week 3 versus week 6, as can be indicated by our results.

From our observation periods, we found no differences in grazing behavior between the CC and the ES calves at 3 weeks after birth. Earlier studies have shown how restricted calf milk allowances influence calf behavior (De Paula Vieira et al., 2008; Rosenberger et al., 2017), and that hungry calves play less (Jensen et al., 2015; Krachun et al., 2010) and eat more solid feed at an early age (Fröberg et al., 2011; Miller-Cushon et al., 2013). Because the calves in both treatments in our study could drink close to ad libitum of milk, we did not expect hunger levels to differ between ES and CC calves. However, in contrast to the results, we initially thought that the CC calves would be grazing more than the ES calves at an early age if they copied their dams' behavior. Other studies have reported that CCC calves learn from their dams how to graze (Nicolao et al., 2020; Vaarst et al., 2020), and calves around the age of one month showed grazing patterns determined by their dams in another study (Hutchison et al., 1962). During the observation periods in our study, only the ES calves grazed more with increased age, and they grazed more than the CC calves in week 6. The fact that the ES calves did not have ad libitum access to milk, even though they were given large amounts of milk, could have influenced their grazing time in weeks 3 and 6 as they might have spent totally less time ingesting milk than the CC calves. Other factors that may have affected grazing behavior is that the ES1 group was observed on another place (the farm) in week 3 while the other observations were done on the summer pasture. In the latter place, the botanical composition of the ES calves' pasture areas was different, and the pasture quality was somewhat lower (Table 2) compared to the pasture areas grazed by the CC calves.

Our results showed that the CC calves played more than the ES calves in week 3. If the CC calves were able to fulfill their natural behavior to a higher degree by being on pasture with their dams, this could have made them show more play behavior, but other factors may also have affected this. For calves kept indoors, available space has been shown to affect play behavior (Jensen and Kyhn, 2000). The CC calves in our study had access to more space than the ES calves. The different space allowances across our treatments may have influenced the results. However, since all the calves in our study had access to large areas for expressing natural behavior like playing, areas much larger than for most calves kept indoors, we believe that available space was not the reason why the CC calves played more than the ES calves in week 3. Waiblinger et al. (2020) video-recorded play behavior in CCC calves and artificially reared (but ad libitum fed) calves indoors and found that CCC calves performed more solitary play than artificially reared calves, which they suggested could indicate improved welfare. In her thesis, Sinnott (2023), did also not distinguish between different play behaviors and did not find differences in the amount of play between CCC calves, part-time CCC calves, and artificially milk-fed calves. We did not differentiate between play behaviors due to limitations associated with the (direct) observation method. Furthermore, when the behavior of running was included in play, it could also include calves running to follow their dams. Thus, it could be interesting to know if the difference in play between the CC and the ES calves in week 3 was due to the running behavior and if the CC calves showed more solitary play, as found by Waiblinger et al. (2020). We also saw that the CC calves were playing more around the CC cows' milking times in week 3 compared to week 6, which indicates that the cows' milking may have influenced the calves' behavior. We could thus have gotten different results for both play and other behaviors if our observation protocol did not include milking hours. Bailly-Caumette et al. (2023) found cow milking to influence calves' play behavior indoors, where calves performed locomotor play more intensively after the cows had left for milking than during other periods.

The time cow-calf pairs spent allogrooming in our study was numerically stable in the observation periods in weeks 3 and 6. In contrast to our findings, Kerr and Wood-Gush (1987) found that allogrooming between cow and calf decreased with age. Other studies indicate a peak in suckling bout frequency and allogrooming after calving (von Keyserlingk and Weary, 2007). The lack of any such difference in our study could be related to the limitations of our study such as the low number of study units and treatment replicates. The allogrooming between calves was not different between the CC and the ES calves during the observation periods in our study, even though the between-calf allogrooming seemed to increase with age in the CC calves, but not in the ES calves. Webster et al. (1987; 1985) found calves on pasture with their dams to groom each other less than calves artificially reared and kept indoors. Kerr and Wood-Gush (1987) found that social behavior between calves increased with age. The CC calves in our study did perform more allogrooming between calves during the observation periods in week 9 (post-weaning) compared to week 3. Generally, we had few recordings on allogrooming, and there is a possibility that if the observations were done at other or for longer periods, we could have obtained other results. Before the study, we presumed that the ES calves would show more allogrooming between calves to compensate for the lack of opportunity to perform allogrooming with their dams. It is also possible that the ES calves performed more self-grooming than the CC calves to compensate for this, but we did not record self-grooming.

During the observation periods in week 9 post-weaning, the CC calves were still using the calf hide less, and they were lying less and vocalizing more often than the ES calves, which indicates a higher stress response in the CC calves after separation from their dams. The other behaviors, however, were not different between treatments. In an indoor study, it was found that calves weaned from suckling showed a higher stress response early post-weaning, compared to calves weaned from artificial milk feeding (Fröberg et al., 2011). However, in the study by Fröberg et al. (2011), all calves were weaned abruptly, and it is known that abrupt weaning and/or separation is associated with lower intakes of solid feed and secondary weaning stress (Weary et al., 2008). Hence, in our study we attempted to wean our calves gradually. The time spent grazing increased and was similar between the treatments, indicating that all calves transitioned well to eating more solid feed after being weaned off milk. The fact that the CC calves still used the calf hide less than the ES calves might have been affected by that the CC calves were also lying less and vocalizing more than the ES calves. The CC calves' previous experience or habit of lying mostly on the pasture, instead of in the calf hide, may also have influenced their use of calf hide in week 9 The vocal behavior of the CC cows and calves may have been influenced by the ability for auditory contact between them (Julie Føske Johnsen et al., 2015b).

Costa et al. (2014) found that calves housed indoors with cows had both shorter latencies to eat novel feed and ate more of the novel feed during all three test days compared to calves kept individually. The study indicates that housing dairy calves in a complex social group reduces food neophobia and that this can enable calves to more easily transition to other changes in their environment. In our study, all calves were on pasture. The CC calves had a more complex social environment than the ES calves, but the ES calves were kept in groups and not individually. In our food neophobia test, we found the CC calves to have numerically shorter median latencies to eat from the buckets on test day 1. This could be seen as an indication of less food neophobia (Costa et al., 2014), but the results applied to both the buckets with novel feed (hay and carrots), the bucket with familiar feed (concentrates), as well as to putting their heads in the empty bucket. Because of this, we cannot say that the ES calves showed more food neophobia than the CC calves, as the artificially reared calves did in the study by Costa et al. (2014). Our test rather indicated that the ES calves were generally more cautious towards the buckets, and that the CC calves were more exploratory. However, the increased latencies towards the buckets by the ES calves did not affect their median time spent with the buckets, and the group intakes of novel feed. The median time spent with the buckets and the group intakes of novel feed were numerically more similar between the treatments, as well as the different test days. Furthermore, the calves' intake of novel feed seemed to differ even more between different groups than between the two treatments. We also found a considerable individual variation among the calves', and we can assume that the calves in each group affected each other as it was a group test. According to Neave et al. (2018), calves' personalities often differ in level of exploration, and this has been shown to be associated with their feeding behavior. Perhaps, our CC calves were generally more exploratory on test day 1 than the ES calves, but it could also be that a few individual calves being more exploratory affected the others. If the CC calves were generally more exploratory and the ES calves more cautious or neophobic, the CC calves could be better adapted to cope with different changes in their environment. An explanation for this could be the extra protection and learning they experienced by being with their dams, unlike the ES calves. However, since the other variables, as well as day 2 and 3 were more similar, it is improbable that the slight caution shown by the ES calves towards the buckets would influence their feed intake and production negatively if offered novel feeds later, as food neophobia might do (Launchbaugh et al., 1997).

Future studies should aim to increase knowledge about how calf development may be affected through social facilitation by the cow. Like what and how much calves learn from the cows, as Nawroth and Rørvang (2022) suggested, and about the importance of cows regarding learning and protection for the calves, as Whalin et al. (2021) suggested. This could, for example, be done by conducting tests to examine calves' responses to different novelty (like feeds, objects or unfamiliar animals or humans) and their cognitive skills. We suggest research using mobile milking robots for the milking of suckled cows on pasture, in order to study how the dams' proximity to their calves during milking affects the calves' behavior. The CC calves in our study showed behavior indicating more stress than for the ES calves after weaning and separation. Our CC cows and calves had fence-line contact in week 7-8, except for periods together after milking, before the cows were moved to another pasture 120 meters away where vocal and possibly visual contact were still possible. Various studies have shown different results regarding gradual weaning methods with for example fence-line (Enríquez et al., 2011). We suggest more research on methods for weaning and separation of dairy CCC cows and calves on pasture to minimize animal stress. A suggestion is that if we had let the cows and calves have fence-line contact without any suckling for a period of e.g., one week before moving the cows. Then, moved the cows further away from the calves (or vice versa) so that no contact was possible, this might have lessened the stress response. It could also be an option to teach CCC calves to drink milk from automatic milk feeders after separation from the cows so that they do not lose the milk and their dams simultaneously (Johnsen et al., 2015). In that case, they could also be weaned more gradually from milk later, and more similar to artificially reared calves. Behavior could preferably have been observed for more days than in our pilot study, including the first days on pasture, days during and after weaning and separation, and more hours per day. More behaviors could preferably have been registered, including standing and moving separately, self-grooming, abnormal sucking as well as distinguishing between different play behaviors.

5 Conclusion

We found the pastured CC calves to behave differently from the ES calves during the observation periods in our study, and that most differences were dependent on age. The CC calves used the calf hide less than the ES calves, but more with increased age. The cows influenced the CC calves through more play and less lying time in week 3 post-partum. The CC calves did not increase their time spent grazing pre-weaning from weeks 3 to 6, as the ES calves did. The time spent allogrooming between cow and calf did not change from weeks 3 to 6, and allogrooming between calves was similar across the treatments. The CC calves had shorter latencies to approach the different buckets (with hay or carrots as novel feed, concentrates as familiar feed and empty bucket) in the food neophobia test on test day 1 but not after, which might indicate them being more cautious towards the buckets independent of novel feed. Post-weaning, all calves spent more time grazing, although the CC calves were lying less and vocalizing more than the ES calves, which might reflect their stress response due to the added stress of losing their dam. Our study provides valuable descriptions under pastured conditions and thus contributes to increased knowledge about dairy calves' behavior with or without their dams on pasture. However, our pilot study was conducted on a commercial farm, and had several limitations, including a low number of study units and treatment replicates. Future studies should further investigate how calf development may be affected through social facilitation by the cow.

6 Acknowledgments

This work was a part of the project SUCCEED with project number 31200 funded by The Norwegian Research Council, Research funding for the agriculture- and food industry (FFL-JA), and the project "Kalvelykke" funded by the Regional Research Fund Mid-Norway. We would like to send a special thanks to the farmers who let us conduct our study with their animals on their farm and summer pasture and to both the farmers and their family members who helped us with the study. Also, a big thanks to all the others who helped us with the study: Steffen Adler, Lilian Lambret, Peggy Haugnes, Anne de Boer, Sara Hansdotter, Turid Strøm, Martha Ebbesvik & Tor Kalseth. We also thank Torfinn Torp for guidance in statistical analyses.

7 References

Bailly-Caumette, E., Bertelsen, M., Jensen, M.B., 2023. Social and locomotor play behavior of dairy calves kept with the dam either full time or half time in straw-bedded pens. JDS Communications. https://doi.org/10.3168/jdsc.2022-0337

Boissy, A., Manteuffel, G., Jensen, M.B., Moe, R.O., Spruijt, B., Keeling, L.J., Winckler, C., Forkman, B., Dimitrov, I., Langbein, J., Bakken, M., Veissier, I., Aubert, A., 2007. Assessment of positive emotions in animals to improve their welfare. Physiol Behav 92, 375–397. https://doi.org/10.1016/j.physbeh.2007.02.003

Bonk, S., Burfeind, O., Suthar, V.S., Heuwieser, W., 2013. Technical note: Evaluation of data loggers for measuring lying behavior in dairy calves. J Dairy Sci 96, 3265–3271. https://doi.org/10.3168/jds.2012-6003

Cooke, L., Carnell, S., Wardle, J., 2006. Food neophobia and mealtime food consumption in 4-5 year old children. International Journal of Behavioral Nutrition and Physical Activity 3, 1–6. https://doi.org/10.1186/1479-5868-3-14

Costa, J.H.C., Daros, R.R., von Keyserlingk, M.A.G., Weary, D.M., 2014. Complex social housing reduces food neophobia in dairy calves. J Dairy Sci 97, 7804–7810. https://doi.org/10.3168/jds.2014-8392

Costa, J.H.C., von Keyserlingk, M.A.G., Weary, D.M., 2016. Invited review: Effects of group housing of dairy calves on behavior, cognition, performance, and health. J Dairy Sci 99, 2453–2467. https://doi.org/10.3168/jds.2015-10144

Das, S.M., Forsberg, M., Wiktorsson, H., 1999. Influence of Restricted Suckling and Level of Feed Supplementation on Postpartum Reproductive Performance of Zebu and Crossbred Cattle in the Semi-Arid Tropics. Acta Vet Scand 40, 57–67. https://doi.org/10.1186/BF03547041

Das, S.M., Redbo, I., Wiktorsson, H., 2000. Effect of age of calf on suckling behaviour and other behavioural activities of Zebu and crossbred calves during restricted suckling periods. Appl Anim Behav Sci 67, 47–57. https://doi.org/10.1016/S0168-1591(99)00115-X

Day, M.L., Imkawa, K., Clutter, A.C., Wolfe, P.L., Zalesky, D.D., Nielsen, M.K., Kinder, J.E., 1987. Suckling behaviour of calves with dams varying in milk production. J Anim Sci 65, 1207–1212.

de Passillé, A.M., 2001. Sucking motivation and related problems in calves. Appl Anim Behav Sci 72, 175–187. https://doi.org/10.1016/S0168-1591(01)00108-3

De Paula Vieira, A., Guesdon, V., de Passillé, A.M., von Keyserlingk, M.A.G., Weary, D.M., 2008. Behavioural indicators of hunger in dairy calves. Appl Anim Behav Sci 109, 180–189. https://doi.org/10.1016/j.applanim.2007.03.006

Duthie, C.A., Bowen, J.M., Bell, D.J., Miller, G.A., Mason, C., Haskell, M.J., 2021. Feeding behaviour and activity as early indicators of disease in pre-weaned dairy calves. Animal 15, 100150. https://doi.org/10.1016/j.animal.2020.100150

Duve, L.R., Weary, D.M., Halekoh, U., Jensen, M.B., 2012. The effects of social contact and milk allowance on responses to handling, play, and social behavior in young dairy calves. J Dairy Sci 95, 6571–6581. https://doi.org/10.3168/jds.2011-5170

Dyrevelferdsloven, 2009. Lov om dyrevelferd (LOV-2009-06-19-97) [WWW Document]. URL https://lovdata.no/dokument/NL/lov/2009-06-19-97

Enríquez, D., Hötzel, M.J., Ungerfeld, R., 2011. Minimising the stress of weaning of beef calves: a review. Acta Vet Scand 53, 28. https://doi.org/10.1186/1751-0147-53-28

Forsøksdyrforskriften, 2015. Forskrift om bruk av dyr i forsøk (FOR-2015–06-18–761) [WWW Document]. URL https://lovdata.no/dokument/SF/forskrift/2015-06-18-761

Fröberg, S., Lidfors, L., Svennersten-Sjaunja, K., Olsson, I., 2011. Performance of free suckling dairy calves in an automatic milking system and their behaviour at weaning. Acta Agriculturae Scandinavica A: Animal Sciences 61, 145–156. https://doi.org/10.1080/09064702.2011.632433

Gladden, N., Cuthbert, E., Ellis, K., McKeegan, D., 2020. Use of a tri-axial accelerometer can reliably detect play behaviour in newborn calves. Animals 10, 1–19. https://doi.org/10.3390/ani10071137

Hirata, M., Nakagawa, M., Funakoshi, H., 2003. Mother – young distance in Japanese Black cattle at pasture. J Ethol 161–168.

Horvath, K.C., Miller-Cushon, E.K., 2019. Characterizing grooming behavior patterns and the influence of brush access on the behavior of group-housed dairy calves. J Dairy Sci 102, 3421–3430. https://doi.org/10.3168/jds.2018-15460

Hutchison, H.G., Woof, R., Mabon, R.M., Salehe, I., Robb, J.M., 1962. A study of the habits of zebu cattle in Tanganyika. J Agric Sci 59, 301–317. https://doi.org/10.1017/S0021859600015379

Jensen, M.B., 2011. The early behaviour of cow and calf in an individual calving pen. Appl Anim Behav Sci 134, 92–99. https://doi.org/10.1016/j.applanim.2011.06.017

Jensen, M.B., Duve, L.R., Weary, D.M., 2015. Pair housing and enhanced milk allowance increase play behavior and improve performance in dairy calves. J Dairy Sci 98, 2568–2575. https://doi.org/10.3168/jds.2014-8272

Jensen, M.B., Kyhn, R., 2000. Play behaviour in group-housed dairy calves, the effect of space allowance. Appl Anim Behav Sci 67, 35–46. https://doi.org/10.1016/S0168-1591(99)00113-6

Jensen, M.B., Vestergaard, K.S., Krohn, C.C., 1998. Play behaviour in dairy calves kept in pens: The effect of social contact and space allowance. Appl Anim Behav Sci 56, 97–108. https://doi.org/10.1016/S0168-1591(97)00106-8

Johanssen, J.R.E., Kvam, G.-T., Logstein, B., Vaarst, M., 2023. Interrelationships between cow, calf, and human in cow-calf contact systems – An interview study among Norwegian dairy farmers. J Dairy Sci. https://doi.org/10.3168/jds.2022-22999

Johnsen, J.F., 2015. Suckling in dairy production, Welfare and management, Bonding and debonding. Norwegian University of Life Sciences, Faculty of Veterinary Medicine and Biosciences.

Johnsen, J. F., Beaver, A., Mejdell, C.M., Rushen, J., de Passillé, A.M., 2015. Providing supplementary milk to suckling dairy calves improves performance at separation and weaning. J Dairy Sci 98, 4800–4810.

Johnsen, Julie Føske, de Passille, A.M., Mejdell, C.M., Bøe, K.E., Grøndahl, A.M., Beaver, A., Rushen, J., Weary, D.M., 2015a. The effect of nursing on the cow-calf bond. Appl Anim Behav Sci 163, 50–57. https://doi.org/10.1016/j.applanim.2014.12.003

Johnsen, Julie Føske, Ellingsen-Dalskau, K., Grøndahl, A.M., Bøe, K.E., Lidfors, L., Mejdell, C.M., 2015b. The effect of physical contact between dairy cows and calves during separation on their post-separation behavioural response. Appl Anim Behav Sci 166, 11–19.

Jones, R.M., Hargreaves, J.N.G., 1979. Improvements to the dry-weight-rank method for measuring botanical composition. Grass and Forage Science 34, 181–189. https://doi.org/10.1111/j.1365-2494.1979.tb01465.x

Kerr, S.G.C., Wood-Gush, D.G.M., 1987. A comparison of the early behaviour of intensively and extensively reared calves. Anim Prod 45, 181–190. https://doi.org/10.1017/S0003356100018778

Kilgour, R.J., Uetake, K., Ishiwata, T., Melville, G.J., 2012. The behaviour of beef cattle at pasture. Appl Anim Behav Sci 138, 12–17. https://doi.org/10.1016/j.applanim.2011.12.001

Krachun, C., Rushen, J., de Passillé, A.M., 2010. Play behaviour in dairy calves is reduced by weaning and by a low energy intake. Appl Anim Behav Sci 122, 71–76. https://doi.org/10.1016/j.applanim.2009.12.002

Launchbaugh, K.L., Provenza, F.D., Werkmeister, M.J., 1997. Overcoming food neophobia in domestic ruminants through addition of a familiar flavor and repeated exposure to novel foods. Appl Anim Behav Sci 54, 327–334. https://doi.org/10.1016/S0168-1591(96)01194-X

Lidfors, L., Jensen, P., 1988. Behaviour of free-ranging beef cows and calves. Appl Anim Behav Sci 20, 237–247. https://doi.org/10.1016/0168-1591(88)90049-4

Lidfors, L.M., 1996. Behavioural effects of separating the dairy calf immediately or 4 days post-partum. Appl Anim Behav Sci 49, 269–283. https://doi.org/10.1016/0168-1591(96)01053-2

Lowe, D.E., Steen, R.W.J., Beattie, V., 2001. Preferences of housed finishing beef cattle for different floor types. Animal welfare 10, 395–404.

Lv, J., Zhao, X.W., Su, H., Wang, Z.P., Wang, C., Li, J.H., Li, X., Zhang, R.X., Bao, J., 2021. Effects of group size on the behaviour, heart rate, immunity, and growth of Holstein dairy calves. Appl Anim Behav Sci 241, 105378. https://doi.org/10.1016/j.applanim.2021.105378

Mac, S.E., Lomax, S., Clark, C.E.F., 2023. Dairy cow and calf behavior and productivity when maintained together on a pasture-based system. Anim Biosci 36, 322–332. https://doi.org/10.5713/ab.22.0135

Mannetje, L., Haydock, K.P., 1963. the Dry-Weight-Rank Method for the Botanical Analysis of Pasture. Grass and Forage Science 18, 268–275. https://doi.org/10.1111/j.1365-2494.1963.tb00362.x

Martins, L.S., Paulino, M.F., Rennó, L.N., Detmann, E., de Almeida, D.M., Ortega, R.M., Moreno, D.P.S., Cárdenas, J.E.G., 2017. Creep feeding effects on male Nellore calves influencing behavior and performance of their dams. Trop Anim Health Prod 49, 1669–1676. https://doi.org/10.1007/s11250-017-1375-8

Miller-Cushon, E.K., Bergeron, R., Leslie, K.E., DeVries, T.J., 2013. Effect of milk feeding level on development of feeding behavior in dairy calves. J Dairy Sci 96, 551–564. https://doi.org/10.3168/jds.2012-5937

Miller-Cushon, E.K., Devries, T.J., 2015. Invited review: Development and expression of dairy calf feeding behaviour. Can J Anim Sci 95, 341–350. https://doi.org/10.4141/CJAS-2014-163

Nabukalu, M.M., 2020. Social behaviour and sociability traits of dairy calves raised in a cow-calf contact system Cow-calf together project.

Nawroth, C., Rørvang, M. V., 2022. Challenges and opportunities in cattle cognition research: Future research areas from an industry point of view. Appl Anim Behav Sci.

Neave, H.W., Costa, J.H.C., Weary, D.M., von Keyserlingk, M.A.G., 2018. Personality is associated with feeding behavior and performance in dairy calves. J Dairy Sci 101, 7437–7449. https://doi.org/10.3168/jds.2017-14248

Nickles, K.R., 2019. Pharmacological and Behavioral Weaning Strategies to Reduce Stress in Beef Calves. The Ohio State University.

Nicolao, A., Coppa, M., Bouchon, M., Sturaro, E., 2020. Early-Life Dam-Calf Contact and Grazing Experience Influence Post-Weaning Behavior and Herbage Selection of Dairy Calves in the Short Term. https://doi.org/10.3389/fvets.2020.600949

Odde, K.G., Kiracofe, G.H., Schalles, R.R., 1985. Suckling behaviour in range beef calves 61, 307–309.

Placzek, M., Christoph-Schulz, I., Barth, K., 2021. Public attitude towards cow-calf separation and other common practices of calf rearing in dairy farming—a review. Organic Agriculture 11, 41–50. https://doi.org/10.1007/s13165-020-00321-3

Reinhardt, C., Reinhardt, A., Reinhardt, V., 1986. Social behaviour and reproductive performance in semi-wild Scottish Highland cattle. Appl Anim Behav Sci 15, 125–136. https://doi.org/10.1016/0168-1591(86)90058-4

Reinhardt, V., Mutiso, F.M., Reinhardt, A., 1978. Social behaviour and social relationships between female and male prepubertal bovine calves (Bos indicus). Applied Animal Ethology 4, 43–54. https://doi.org/10.1016/0304-3762(78)90092-5

Reinhardt, V., Reinhardt, A., 1982. Social behaviour and social bonds between juvenile and sub-adult Bos indicus calves. Appl Anim Behav Sci 9, 92–93. https://doi.org/https://doi.org/10.1016/0304-3762(82)90177-8

Rosenberger, K., Costa, J.H.C., Neave, H.W., von Keyserlingk, M.A.G., Weary, D.M., 2017. The effect of milk allowance on behavior and weight gains in dairy calves. J Dairy Sci 100, 504–512. https://doi.org/10.3168/jds.2016-11195

Roy, J.H.B., Shillam, K.W.G., Palmer, J., 1955. 591. The outdoor rearing of calves on grass with special reference to growth rate and grazing behaviour. Journal of Dairy Research 22, 252–269. https://doi.org/10.1017/S0022029900007809

Sato, S., Sako, S., Maeda, A., 1991. Social licking patterns in cattle (Bos taurus): influence of environmental and social factors. Appl Anim Behav Sci 32, 3–12. https://doi.org/10.1016/S0168-1591(05)80158-3

Sato, S., Tarumizu, K., Hatae, K., 1993. The influence of social factors on allogrooming in cows. Appl Anim Behav Sci 38, 235–244. https://doi.org/10.1016/0168-1591(93)90022-H

Sawalhah, M.N., Cibils, A.F., Maladi, A., Cao, H., Vanleeuwen, D.M., Holechek, J.L., Rubio, C.M.B., Wesley, R.L., Endecott, R.L., Mulliniks, T.J., Petersen, M.K., 2016. Forage and Weather Influence Day versus Nighttime Cow Behavior and Calf Weaning Weights on Rangeland. Rangel Ecol Manag 69, 134–143. https://doi.org/10.1016/j.rama.2015.10.007

Sinnott, A.M., 2023. Finding the balance - Improving labour efficiency and animal welfare in calf rearing. the Graduate School of Wageningen Institute of Animal Sciences (WIAS).

Sirovica, L. v., Ritter, C., Hendricks, J., Weary, D.M., Gulati, S., von Keyserlingk, M.A.G., 2022. Public attitude toward and perceptions of dairy cattle welfare in cow-calf management systems differing in type of social and maternal contact. J Dairy Sci 105, 3248–3268. https://doi.org/10.3168/jds.2021-21344

Smid, A.M.C., Burgers, E.E.A., Weary, D.M., Bokkers, E.A.M., von Keyserlingk, M.A.G., 2019. Dairy cow preference for access to an outdoor pack in summer and winter. J Dairy Sci 102, 1551–1558. https://doi.org/10.3168/jds.2018-15007

Špinka, M., Newberry, R.C., Bekoff, M., 2001. Mammalian play: Training for the unexpected. Quarterly Review of Biology 76, 141–168. https://doi.org/10.1086/393866

Vaarst, M., Hellec, F., Verwer, C., Johanssen, J.R.E., Sørheim, K., 2020. Cow calf contact in dairy herds viewed from the perspectives of calves, cows, humans and the farming system. Farmers' perceptions and experiences related to dam-rearing systems. Landbauforschung (Braunschw) 70, 49–57. https://doi.org/10.3220/LBF1596195636000

Van Laer, E., Moons, C.P.H., Ampe, B., Sonck, B., Vandaele, L., De Campeneere, S., Tuyttens, F.A.M., 2015. Effect of summer conditions and shade on behavioural indicators of thermal discomfort in Holstein dairy and Belgian Blue beef cattle on pasture. Animal 9, 1536–1546. https://doi.org/10.1017/S1751731115000804

Ventura, B.A., von Keyserlingk, M.A.G., Schuppli, C.A., Weary, D.M., 2013. Views on contentious practices in dairy farming: The case of early cow-calf separation. J Dairy Sci 96, 6105–6116.

Villalba, J.J., Provenza, F.D., Manteca, X., 2010. Links between ruminants food preference and their welfare. Animal 4, 1240–1247. https://doi.org/10.1017/S1751731110000467

Vitale, A.F., Tenucci, M., Papini, M., Lovari, S., 1986. Social behaviour of the calves of semi-wild maremma cattle,. Appl Anim Behav Sci 16, 217–231.

von Keyserlingk, M.A.G., Weary, D.M., 2007. Maternal behavior in cattle. Horm Behav 52, 106–113. https://doi.org/10.1016/j.yhbeh.2007.03.015

Waiblinger, S., Wagner, K., Hillmann, E., Barth, K., 2020. Play and social behaviour of calves with or without access to their dam and other cows. Journal of Dairy Research 87, 144–147. https://doi.org/10.1017/S0022029920000540

Walker, D.E., 2012. Suckling and grazing behaviour of beef heifers and calves 8233. https://doi.org/10.1080/00288233.1962.10419963

Walker, D.E., 1962. Suckling and grazing behaviour of beef heifers and calves. New Zealand Journal of Agricultural Research 5, 331–338. https://doi.org/10.1080/00288233.1962.10419963

Weary, D.M., Jasper, J., Hötzel, M.J., 2008. Understanding weaning distress. Appl Anim Behav Sci 110, 24–41. https://doi.org/10.1016/j.applanim.2007.03.025

Webster, A.J.F., Saville, C., Church, B.M., Gnanasakthy, A., Moss, R., 1985. The effect of different rearing systems on the development of calf behaviour. British Veterinary Journal 141, 249–264. https://doi.org/10.1016/0007-1935(85)90061-2

Wenker, M.L., 2022. Welfare implications of prolonged cow-calf contact in dairy farming. Wageningen University, Wageningen, the Netherlands.

Whalin, L., Weary, D.M., von Keyserlingk, M.A.G., 2021. Understanding behavioural development of calves in natural settings to inform calf management. Animals 11. https://doi.org/10.3390/ani11082446

Wormsbecher, L., Bergeron, R., Haley, D., de Passillé, A.M., Rushen, J., Vasseur, E., 2017. A method of outdoor housing dairy calves in pairs using individual calf hutches. J Dairy Sci 100, 7493–7506. https://doi.org/10.3168/jds.2017-12559

Figures:

Fig. 1. Showing one of the calf hides with descriptions. This photo was taken with group ES1 on their pasture area on the farm in their second week.

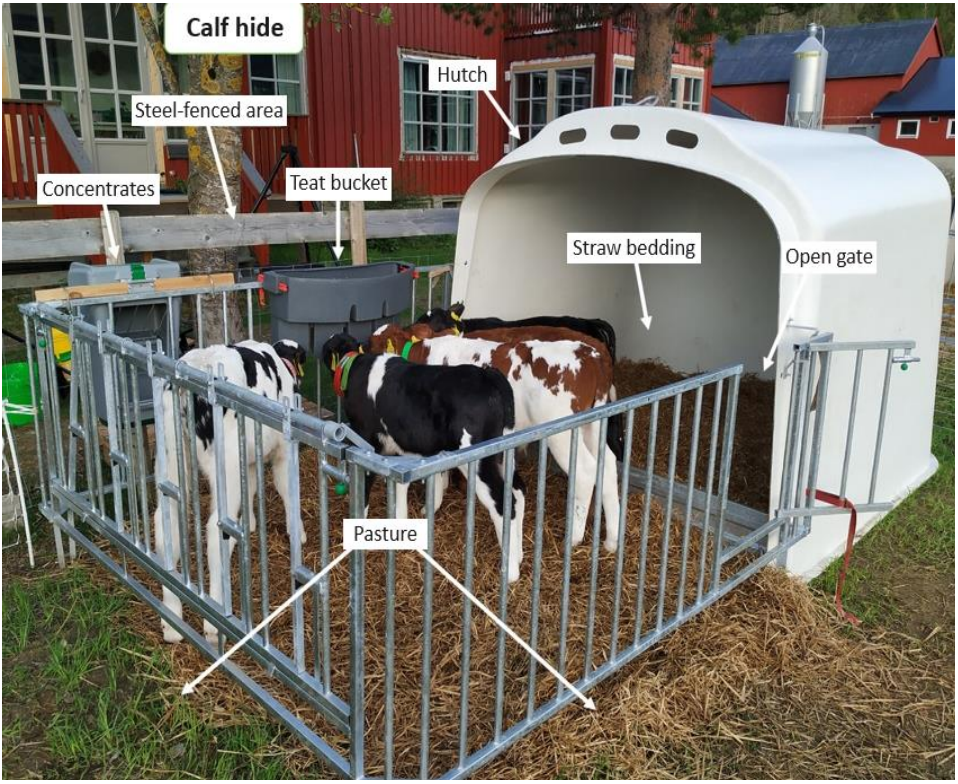


Fig. 2. A map of the summer pasture with inserted descriptions on which areas the CC pairs, the ES cows and the ES calves were kept on, and where the milking parlor was located.

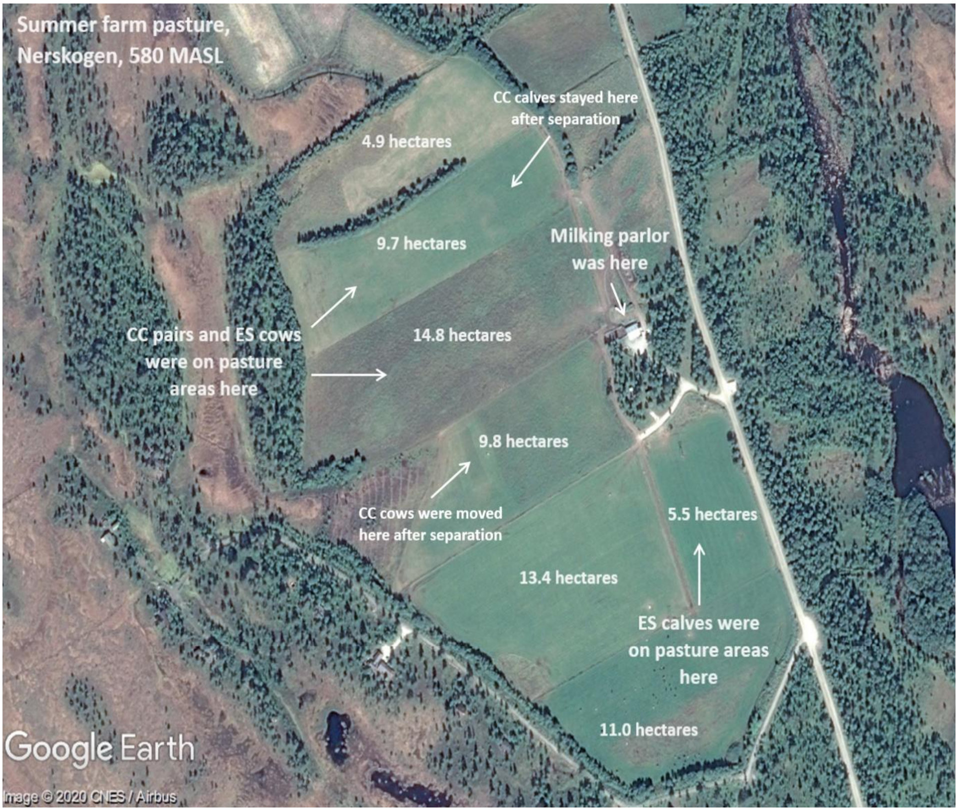
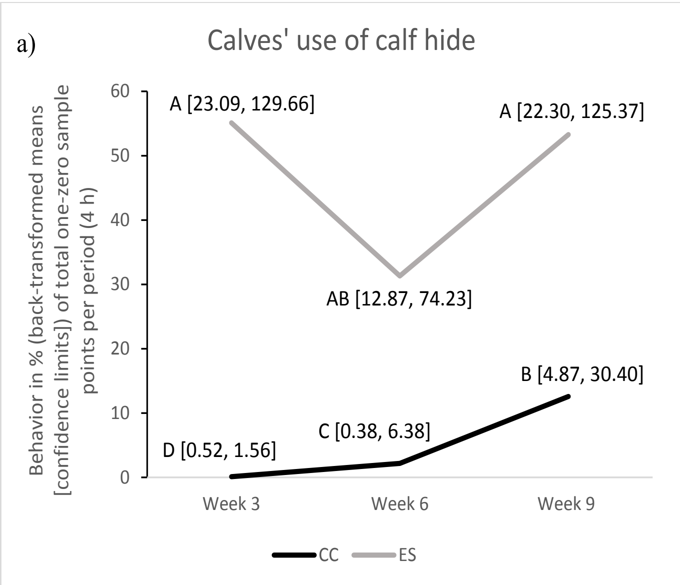
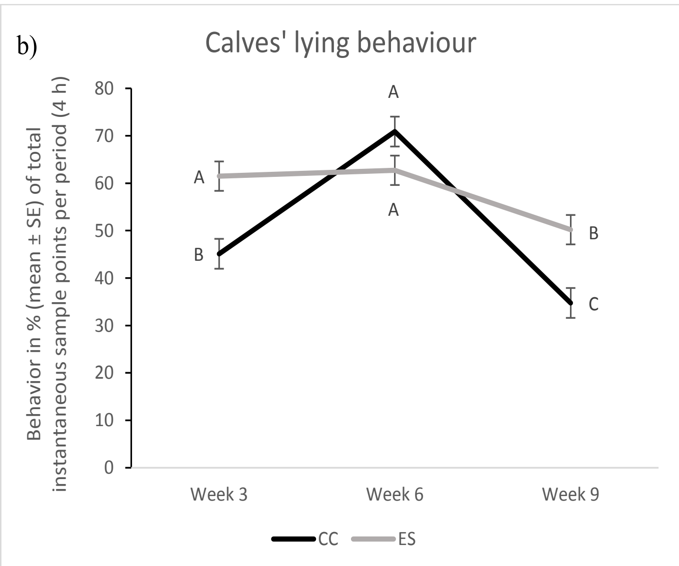


Fig. 3.a-d. Calves use of calf hide, lying behavior, and grazing for the two treatments: Cow-calf contact (CC, n=10) and early separation (ES, n=10) in weeks 3 and 6 before and week 9 post-weaning. The behaviors are shown in % (mean ± SE) of total instantaneous sample points per period (4 hours). Means that do not share a letter are significantly different interactions between treatment and week (P < 0.005) For “In calf hide”, back-transformed means are used for the lines, and back-transformed confidence limits are shown beside the letters.





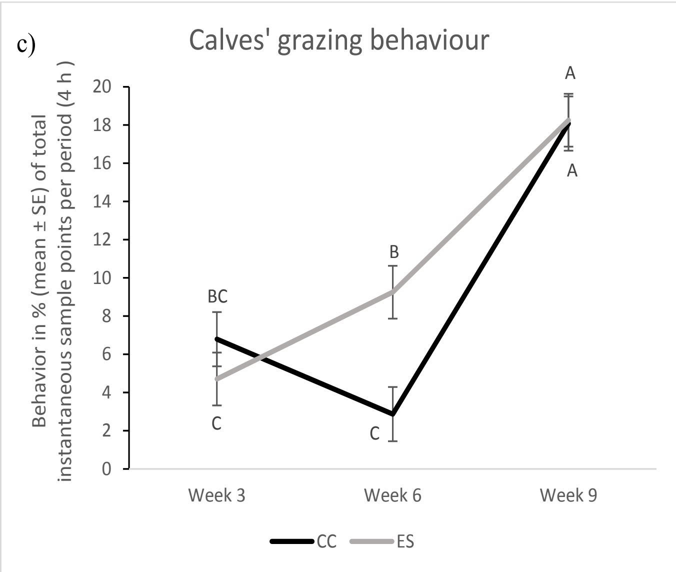

c)
Calves' grazing behaviour
Behavior in % (mean ± SE) of total instantaneous sample points per period (4 h)
0
2
4
6
8
10
12
14
16
18
20
Week 3
Week 6
Week 9
BC
C
B
C
A
A
CC
ES

Fig. 4.a-b. Calves play and allogrooming between calves for the two treatments: Cow-calf contact (CC, n=10) and early separation (ES, n=10) in weeks 3 and 6 before and week 9 post-weaning. The behaviors are shown in % (mean ± SE) of total one-zero sample points per period (4 hours). Means that do does not share a letter are significantly different interactions between treatment and week (P < 0.005). For "Play", back-transformed means are used for the lines, and back-transformed confidence limits are shown beside the letters.

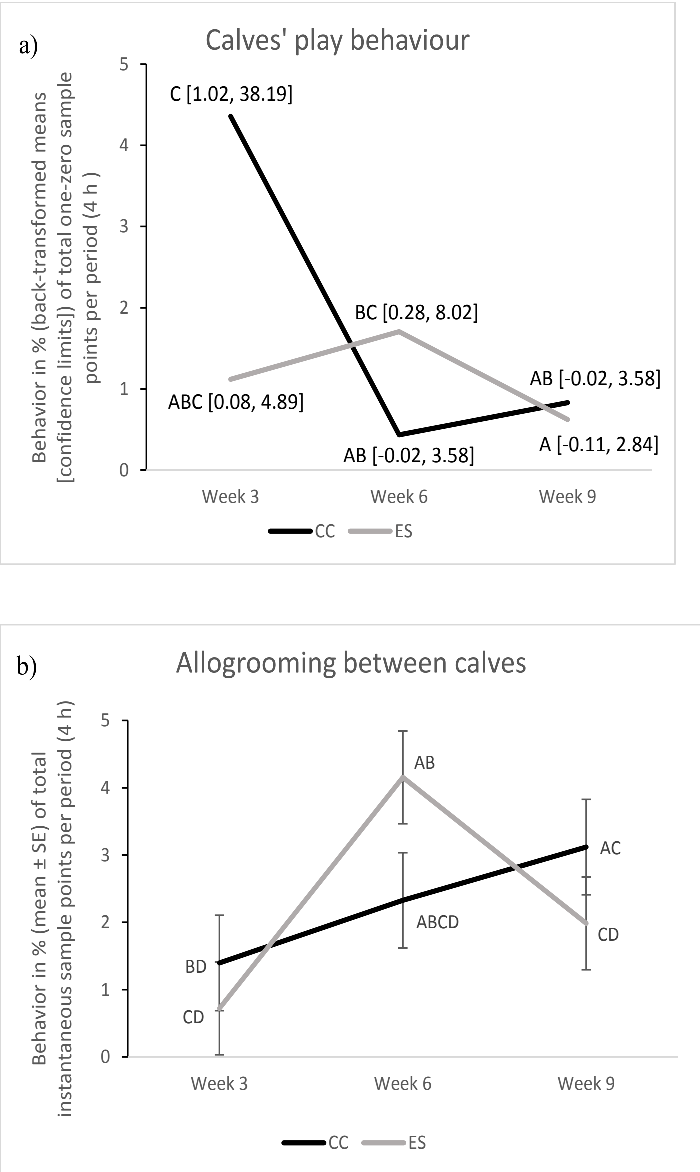
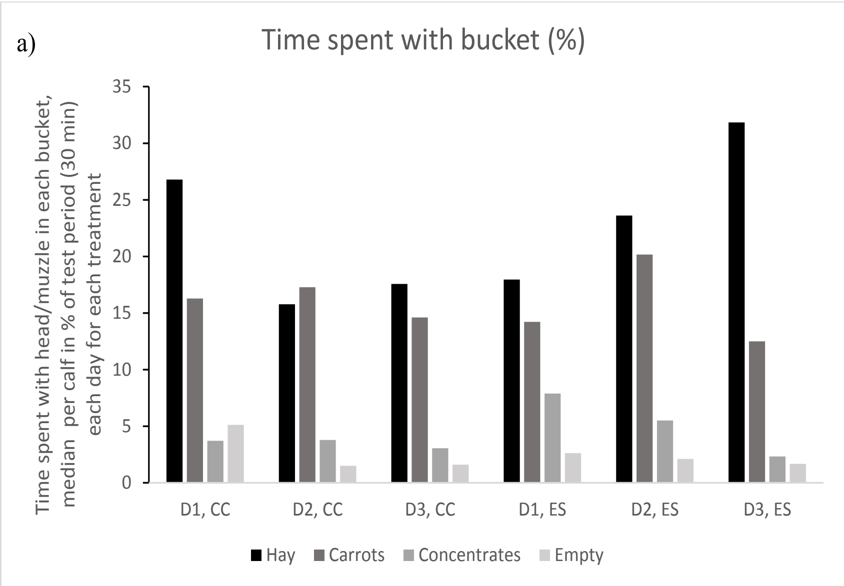
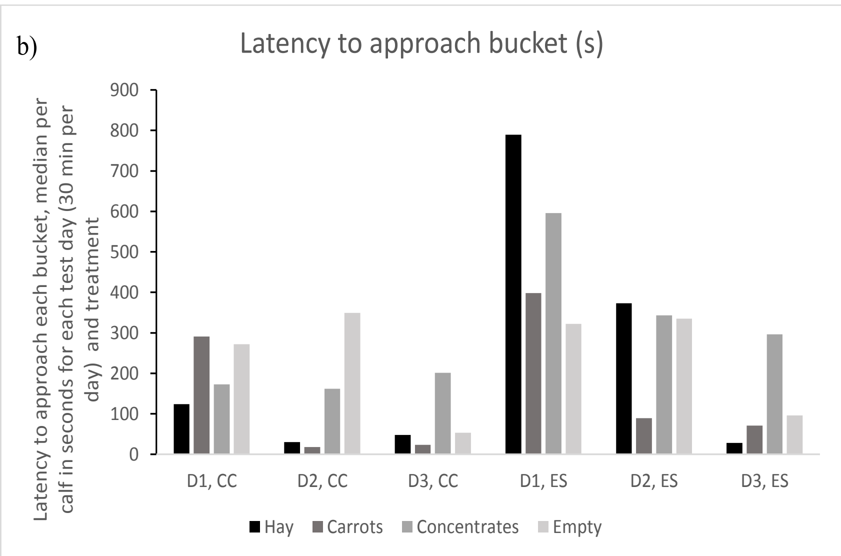


Fig. 5.a-b. Results from the food neophobia group test shows median per calf for latency to approach each of the four buckets (hay, carrots, concentrates and empty) (in seconds per day) and time spent putting head/muzzle in each bucket (in % of test period of 30 minutes each day) for each treatment: cow-calf contact (CC, n=10) and early separation (ES, N=10) during three consecutive days (D1, D2 and D3) in week 8.





III Paper III – Performance in dairy cows and calves with or without cow-calf contact on pasture – A pilot study

Performance in dairy cows and calves with or without cow-calf contact on pasture – A pilot study

Juni Rosann E. Johanssen[1*], Steffen Adler[2], Julie Føske Johnsen[3], Kristin Sørheim[1], Knut Egil Bøe[4]

[1]Norwegian Centre for Organic Agriculture, 6630 Tingvoll, Norway

[2]Norwegian Institute of Bioeconomy Research, 6630 Tingvoll, Norway

[3]Norwegian Veterinary Institute, 1433 Ås, Norway

[4]Norwegian University of Life Sciences, 1430 Ås, Norway

*** Correspondence:**

Juni Rosann Engelien Johanssen, Gunnars veg 6, 6630 Tingvoll, Norway, +47 46 68 36 56, rosann.johanssen@norsok.no

Abstract

Interest in dairy cow-calf contact (CCC) systems is growing, but few CCC studies have been performed in a pasture setting. Our aim was to evaluate performance in pastured dairy cows and calves with or without CCC through machine milk yield and composition, and calf daily weight gain. Additionally, our aim was to describe cow body weight and condition, calf intake of concentrates, artificially reared calves' milk intake, and cow and calf health. The study was conducted on a commercial dairy farm from May to August 2021 in Norway. Twenty cow-calf pairs, 17 Norwegian Red and three Norwegian Red × Holstein crossbreds, were allocated to one of two treatments: cow-calf contact (CC, n=10) or early separation (ES, n=10). Each treatment had two groups of five cow-calf pairs. The CC pairs were kept together on pasture with free suckling for 6 weeks postpartum and had part-time contact in weeks 7-8 (weaning). The ES pairs were separated one to three hours after birth and kept on separate pastures without contact between the ES cows and the ES calves. The ES calves' daily milk allowance was 12-14 L during weeks 0 to 6 and was reduced to 8 L in week 7 and further to 4 L in week 8. From week 9, all calves were denied access to any milk (ES) or cows (CC). In weeks 0-6, daily machine milk yield for CC cows was 23.7 kg lower per cow than for ES cows. Differences in machine milk yield persisted during weaning and could be detected at least until weeks 10-11 postpartum. Fat and protein content in machine milk did not differ significantly with treatment, while lactose content was lower in the CC cows (week 5 postpartum). Inhibited milk ejection during machine milking was a challenge in CC cows throughout the study, and oxytocin injections were given to cows to prevent mastitis. The ES calves' daily milk intake measured at group level was 10.7 L/calf from week 0 to week 6. ES calves consumed more concentrates than CC calves. The calves' daily body weight gains were similar between the treatments and decreased for both treatments during weaning. Letting calves have full CCC or feeding them natural milk close to ad libitum can result in similar body weight gain in calves. Further research may aim to study strategies for enhancing milk ejection in pastured CCC cows.

Keywords: Pastured dairy cattle, dam rearing, animal welfare, milk performance, calf weight gain

1 Introduction

A common practice in dairy farming is to separate the calf from the dam within the first day after calving (Abuelo et al., 2019; Hötzel et al., 2014; Pempek et al., 2017), and keep the calves indoors during the milk-feeding period (Hötzel et al., 2017; USDA, 2016; Winder et al., 2018). However, different stakeholders show growing interest in cow-calf contact (CCC) systems (Sirovica et al., 2022; Vaarst et al., 2020; Ventura et al., 2013). Surveys indicate that many consumers prefer cow and calf to be kept together (Hötzel et al., 2017; Ventura et al., 2013) and keeping cattle outdoors on pasture (Hötzel et al., 2017; Schuppli et al., 2014).

A recent survey among 1038 Norwegian dairy farmers showed that 3 % utilized CCC systems, and that 15 % wanted or planned to implement such systems (Hansen et al., 2023). Furthermore, Norwegian regulations require to keep dairy cows on pasture for at least 8 (free stall barns) or 16 weeks (tie stall barns) during summer (Lovdata FOR-2004-04-22-665, 2004). Keeping cow and calf together on pasture may be a viable option for dairy farmers, but more knowledge is needed on how CCC affects the cow and the calf in a pasture setting.

One main barrier for dairy farmers to adopt CCC systems is the expected lower profitability if the calves suckle large amounts of milk, hence decreasing milk volume for sale (Hansen et al., 2023; Meagher et al., 2019). It is obvious that free nursing dairy cows yield less machine milk. However, after the separation of cow and calf, the machine milk yields have been shown to become similar for free suckled compared to non-suckled cows kept indoors (Flower and Weary, 2001; Metz, 1987; Wenker et al., 2022a).

Studies have shown that machine milk from suckled cows contains less fat than that of non-suckled cows (Barth, 2020; Fröberg et al., 2007; Zipp, 2018). The effect of CCC on the contents of protein and lactose seems less clear. Whereas some studies found a higher protein (Barth, 2020) and lactose content (Boden and Leaver, 1994) in CCC cows' machine milk, others found no differences (Carbonneau et al., 2012; Dymnicki et al., 2013). After separation from the calves, the composition of machine milk has been shown to become similar for suckled and non-suckled cows (Mendoza et al., 2010).

Some studies have shown that cows that are both suckled and milked lose more weight than cows that only are milked (Bar-Peled et al., 1995; Margerison et al., 2002), while others did not find any difference (Junqueira et al., 2005; Thomas and Spiker, 1981). However, in these studies, the cows were restrictively suckled.

Studies comparing artificial milk feeding versus suckling have found higher weight gains in suckling calves (e.g., Fröberg et al., 2011; Wenker et al., 2022b), but in most of such studies, the artificially reared calves have been provided restricted milk allowance (e.g., Bar-Peled et al., 1997; Flower and Weary, 2001; Roth et al., 2009). Milk allowance has been shown to determine calves' weight gain, especially during the first weeks, when an underdeveloped rumen function prevents digestion of solid feed (Khan et al., 2011). However, in a study by Krohn et al. (1999) calves that had been suckling their dams the first four days postpartum had higher weight gains than non-suckling calves, even though they had similar milk intakes.

Farmers practicing early cow-calf separation in a study by Neave et al. (2022) were concerned about cow-calf health in CCC systems on pasture, while the CCC farmers in the same study actually experienced cow-calf health benefitting from CCC. A review by Beaver et al. (2019) showed that for cows' udder health, there is either no difference or better udder health in nursing compared to non-nursing cows. For calf health, an argument in favor of early separation is the minimization of infection pressure for calves (Grøndahl, 2011; Relić et al., 2020). The review by Beaver et al. (2019) did, however, not find support for a recommendation of early dairy cow-calf separation, on the basis of either cow or calf health. However, most studies in the review were from indoors conditions, and as pointed out by Neave et al. (2023), there might be differences in health issues for pasture based CCC that have not yet been determined.

A recent study conducted in Australia described indicators of performance as cow machine milk yield and calf weight gain in six CCC pairs kept on pasture (Mac et al., 2023). However, limited knowledge is available on the causative relationship between CCC and performance in pasture systems. Sinnott (2023), in her Ph.D. thesis, and Nicolao et al. (2022), studied performance in CCC pairs in comparison to pairs without suckling opportunities, however the non-suckling calves were not fed milk to satiety and were not on pasture during the milk-feeding period.

Our study aimed to evaluate performance in dairy cows and calves with or without CCC on pasture through measuring machine milk yield and composition, and calf daily weight gain. Additionally, the aim was to describe cow body weight and condition, calf intake of concentrates, artificially reared calves' milk intake, and cow and calf health.

We hypothesized that after weaning and separation are completed, the machine milk yield from both suckled and non-suckled cows would be similar. Likewise, we hypothesized that the milk fat content in the machine milk from suckled cows would be lower compared to that from non-suckling cows but would equalize after weaning and separation. Furthermore, we hypothesized that calves reared in a CCC system on pasture would exhibit higher weight gains compared to those fed natural milk close to ad libitum, but that this difference would disappear after weaning and separation.

2 Materials and methods

This study complied with the Norwegian Regulation on Animal Experimentation (Forsøksdyrforskriften, 2015) under the Norwegian Animal Welfare Act (Dyrevelferdsloven, 2009). The study was conducted from May to August 2021 on a commercial dairy farm (220 meters above sea level) with a free-stall barn and 80 dairy cows in central Norway and included the farm's summer pasture (17 km from the farm, 580 meters above sea level), where the farm usually grazed all lactating cows during summer. The farm had concentrated calving in three periods, with one period in May and June.

2.1 Study design

In a parallel-group designed pilot study, 20 cow-calf pairs were allocated to one of two treatments: cow-calf contact (CC, n=10 pairs) and early separation (ES, n=10 pairs). Each treatment had two groups of five cow-calf pairs, namely for CC: groups CC1 and CC2, and for ES: groups ES1 and ES2. Treatments were assigned to the groups in the following (non-random) order to account for adverse pasture conditions (snow) on the summer pasture at the start of the study: ES, ES, CC, CC. All groups were let out on pasture (see details in 2.4), and the study period was 9 weeks for each group (week 0 was defined as the average calf birth week). More information about the two treatments is shown in Table 1.

Table 1. Description of the two treatments cow-calf contact (CC) and early separation (ES) in the pilot study with pastured dairy cows and calves.

Treatment	CC (n=10 pairs in two groups)		ES (n=10 pairs in two groups)	
Weeks postpartum	Cow-contact	Suckling allowance	Cow-contact	Milk allowance
0-3	Whole day	Free, except during milking	1-3 hours on calving day, then none	12 L/calf/day (four meals)
4-6	Whole day	Free, except during milking	None	14 L/calf/day (four meals)
7	Partial (fence-line): 20 h/d, full contact: 4 h/d	After milking: 2 h morning, 2 h evening	None	8 L/calf/day (two meals)
8	Partial (fence-line): 22 h/d, full contact: 2 h/d	After milking: 1 h morning, 1 h evening	None	4 L/calf/day (two meals)
9	Total separation (audible and visible contact)	None (cows moved 120 m away)	None	None

The ES calves were fed natural milk heated to 40 °C from milk bars with one artificial teat per calf (Figure 1), with feedings at 06.30 AM, 10.30 AM, 04.00 PM, and 08.00 PM in weeks 0-6, and at 06.30 AM and 04.00 PM in weeks 7-8. The milk bars were accessible at each meal until empty or until none of the calves within the group showed interest in the residual milk.

2.2 Animals

Seventeen of the cow-calf pairs included in the pilot study were of the breed Norwegian Red (NRF), and three pairs were NRF × Holstein crossbreds. One crossbred pair was allocated to the CC treatment and two were allocated to the ES treatment. One of the ES cows was excluded from the study due to serious ketosis. Before the experiment we decided on criteria for when to exclude animals, and these were; if a cow showed aggression towards her calf or humans, if a calf did not manage to suckle its dam, or if a cow or a calf got seriously ill or died. The calves used in the study were born between 7 May and 14 June, and we assigned the pairs to their groups based on calving date to minimize calf age variation in each group. Thus, it was not possible to additionally distribute the treatments evenly according to calf sex and cow parity. The calf age range was between 6 and 8 days per group. The calves' birth weight ranged from 29.8 to 56.0 kg (average: 44.0 kg). The distribution of primiparous cows relative to multiparous cows in each group was: CC1: 2/5 and 3/5, CC2: 2/5 and 3/5, ES1: 1/4 and 3/4, and ES2: 0/5 and 5/5. Finally, the distribution of bull and heifer calves in each group was: CC1: 1/5 and 4/5, CC2: 1/5 and 4/5, ES1: 4/5 and 1/5, and ES2: 2/5 and 3/5.

2.3 Management from birth to pasture release

Before or within three hours after calving, each cow was moved from the free stall area to an individual calving pen with a rubber mattress and saw dust bedding (14.4 m^2). Within the first three hours after calving, each cow was milked by the milking robot (GEA Mione, GEA Group, Düsseldorf, Germany), and all calves were offered colostrum ad libitum from a teat bottle at their first feeding within three hours after birth. The ES calves were tubed if voluntary intake of colostrum was < 4.5 L, according to the farm's regular practice for artificially reared calves. The CC pairs were observed after birth to make sure the cows were taking care of their calves and that the calves suckled. Each CC pair stayed in the calving pen during the first three days after calving, before being temporarily moved to the free stall area. Once the fifth calf within a CC group was three to four days old, the whole group was transported to and let out on the summer pasture (see more details in 2.4). The ES calves were separated from their dams within one to three hours after birth and moved to individual straw-bedded pens (1.1 m^2) for three days before they were temporarily moved to a group pen (35.0

m^2). In the group pen, the calves had ad libitum access to silage, concentrates, and water. Once the fifth calf in an ES group was three days old, the whole calf group was let out on a farm pasture (see more details in 2.4).

When the cows were in the calving pens or the free stall at the farm, they were milked by the milking robot. Inside the barn, the cows were fed a total mixed ration (close to ad libitum) containing grass silage (average: 89 % of weight on dry matter basis), concentrates (average: 11 %, DRØV Orkla 80 % Kåinn, Norgesfôr, Norway), and minerals. They also had ad libitum access to water and were fed concentrates in an automat during robotic milking (DRØV Energirik, Norgesfôr, Norway). When the CC calves were in the calving pen or the free stall area, they had no access to concentrates but access to the same silage as the cows.

2.4 Grazing management

Due to the calving order (explained in 2.2), the ES calves were the first to be let out on pasture areas of 0.12 hectares per ES group on the farm. They were let out on 18 and 28 May, at an average group calf age of 7.6 and 7.4 days for the groups ES1 and ES2, respectively. Thereafter, the ES calves and the ES cows were transported separately to the summer pasture on 7 June at an average group calf age of 27.6 and 17.6 days for ES1 and ES2, respectively. The ES pairs were let out on separate areas on the summer pasture without any contact between the ES cows and their calves. It was >130 m between them, and they could not see each other (Figure 2). The CC pair groups were transported directly from the barn to the summer pasture on 10 and 17 June at an average group calf age of 6.8 and 6.0 days for the groups CC1 and CC2, respectively. While on pasture, the cows were milked and given concentrates twice daily in a herringbone milking parlor, at 06.30 AM and 05.30 PM. From when they were let out on pasture and until week 9, the CC cows received an average (± SD) of 8.1 ± 2.2 kg and the ES cows 10.0 ± 1.7 kg of concentrates/cow/day (DRØV Energirik and DRØV Genial, Norgesfôr, Norway). The amount of concentrates provided was decided by the number of days post-calving and expected milk production for each cow.

Rotational grazing was applied for CC pairs, ES cows and ES calves. Pasture areas and grazing duration were adapted to available herbage. Pasture areas were 0.42 to 0.78 ha for CC pairs, 0.45 to 0.78 ha for ES cows and

0.12 ha for ES calves. Electric net fences (DeLaval Premium, Sweden) (CC pairs and ES calves) and electric fences (ES cows) were used. After grazing, each area was chopped, and some areas were grazed twice.

All cows and calves had ad libitum access to pasture and water, and the CC pairs and the ES cows had ad libitum access to silage throughout the study (from day four for the CC pairs and from day one for the ES cows). Each calf group had ad libitum access to concentrates (DRØV Intro, Norgesfôr, Norway) provided in a calf hide (Calf-O-Tel XL-5, VDK Products, the Netherlands) (10.9 m^2). Each calf hide contained straw bedding and consisted of a hutch (5.8 m^2) and a steel-fenced area outside the hutch (5.1 m^2) (Figure 1). The open gates to the calf hides were too small for the cows to enter, so that only the calves could use them.

The botanical composition of the pastures was estimated using the dry-weight rank method (Mannetje and Haydock, 1963), modified by Jones and Hargreaves (1979). The average botanical composition of the pastures for the CC cows and calves was 63 % timothy, 18 % other grasses, 6 % clover, and 14 % other herbs, while for the ES cows, it was 56 % timothy, 29 % other grasses, 5 % clover and 10% other herbs, and for the ES calves it was 42 % smooth meadow-grass, 2 % other grass, 4 % clover, and 52 % other herbs. Herbage samples were taken from each area before grazing. Dried and ground samples were analyzed by NIR spectroscopy (NIRS™ DS2500 F, FOSS, Hilleroed, Denmark) (Table 2).

Table 2. Feed value and chemical composition (NIRS) (average ± SD) of herbage samples derived from pastures before grazing in the pilot study with the two treatments: Cow-calf contact (CC) and early separation (ES).

Variable	CC pasture	ES-cows pasture	ES-calves pasture
n	13	8	8
NE_L MJ/kg of DM[1]	6.6 ± 0.6	7.0 ± 0.6	6.6 ± 0.4
Digestability, % of DM	76.6 ± 4.7	79.8 ± 4.3	77.1 ± 3.4
PBV, g/kg of DM[2]	25.1 ± 30.2	30.4 ± 35.4	10.0 ± 16.0
AAT, g/kg of DM[3]	86.7 ± 5.6	90.3 ± 5.9	86.4 ± 3.8
Crude protein, % of DM	17.5 ± 3.8	18.6 ± 4.6	15.9 ± 2.2
NDF, % of DM[4]	50.9 ± 4.6	51.5 ± 3.5	46.4 ± 4.8
Indigestible NDF, % of NDF	13.8 ± 6.8	9.4 ± 4.7	15.6 ± 3.1

[1] Net Energy Lactation (NEL), [2] Protein Balance in rumen (PBV), [3] Amino acids absorbed from the intestine (AAT), [4] Neutral detergent fiber (NDF)

Air temperature and rainfall were recorded every hour during the grazing period (Netatmo Smart Home Weather Station, Boulogne Billancourt, France). The average temperature for the study period was 14.1 °C with an average variation from 6.6 to 22.2 °C per day. Average daily rainfall was 2.2 mm with a variation from 0.0 to 29.8 mm per day (53/88 days <0.5 mm and 5/88 days >10 mm). The average daily temperature was similar for both treatments.

2.5 Animal performance – Sampling and data collection

Cow performance

Throughout the 9 weeks of the pilot study, and for a post-treatment period in weeks 10 and 11, machine milk yields were recorded automatically for each cow and milking. Due to lasting challenges with low machine milk yields at the same time as a perceived high udder fill (hereafter referred to as "inhibited milk ejection") in CC cows during milking, the veterinarian and the farmers were concerned about mastitis, and the farmers were also concerned about prolonged low milk yields. Hand massage of the udders before and during milking was tried without success, and oxytocin was injected intramuscularly (i.m.) in doses of 2 mL (see 2.6 for more details) as a necessary treatment. Milk recordings affected by oxytocin injections were excluded from the analysis (see section 2.6 Statistical analysis for details on how the data was handled).

Aliquot milk samples for the gross composition of machine milk were collected from individual cows in weeks 5 and 9, preserved with Bronopol (2-Bromo-2-nitropane-1,3 diol, Broad Spectrum Microtabs® II), and stored chilled (4 °C) until analysis of fat, protein, lactose, urea, free fatty acids (FFA) and somatic cell count (SCC) using Fourier Transform Spectrometry (Bentley FCM and IBC, Chaska, US). Because the i.m. oxytocin injections affect milk composition, we decided not to include the machine milk samples from week 9, since eight of ten CC cows got injected once that day. Instead, we used machine milk samples from 16 cows (8 from each treatment), taken post-treatment in September (weeks 14-18 postpartum, depending on the group).

Cows' body weight and body condition score (BCS) were recorded on the first day on pasture and in week 9. The cows were weighed using a portable scale (Gallagher, Hamilton, New Zealand) connected to an enclosure designed for handling and weighing livestock (IAE Agriculture, Stoke-on Trent, United Kingdom). Body condition scores were estimated visually by the method developed by Geno for NRF (Geno, 2020), which is based on the method of Edmonson et al. (1989) by using a 5-point scale (1 = emaciated to 5 = severely over-conditioned).

Calf performance

Calves' intakes of concentrates were recorded on group level by weigh out-weigh in (with Brecknell ElectroSamson, England) at 07.30 AM on four days each week. Milk amounts given to the ES calves were measured at each meal, and to record their milk intakes we also measured the milk residuals after each meal on four days each week.

Each calf was weighed after birth (IAE Digital Lamb Weigher, United Kingdom). Then, all calves in a group were weighed in their study weeks 6 and 9, and again during post-treatment in December 2021 (calf age between 6 and 7 months, depending on the group), using the equipment described above.

Cow and calf health

Each cow was clinically examined and manually scored by a veterinarian on the first day on pasture and once in week 9, and each calf was examined on the calving day, the first day on pasture, once in week 6 and once in week 9, using a standardized health scoring system modified and supplemented with some extra investigations related to diseases that are more frequent on pasture (Table 3). Daily overall assessments, during which health deviations were recorded, were performed by the project staff. In case of fever, inappetence, lameness, mastitis, or udder injuries, the animal was subjected to veterinary examination, and diagnosis and treatment were noted.

Table 3. Clinical health parameters examined by a veterinarian for cows and calves in the two treatments: Cow-calf contact (n=10 cows and 10 calves), and early separation (n=9 cows and 10 calves). Mastitis, cell count, and udder or teat injuries were only examined in the cows.

Clinical parameter	Score	Reference

Fecal consistency	1= Normal consistency	2 = Pasty, semi-formed	3 = Pasty with large amounts of water, content adhered in the perineum and tail	4 = Liquid with fecal content adhered in the perineum and tail	5 = Liquid with blood	Hulsen, 2005
Coughing	1 = No cough	2 = Single cough	3 = Induced repeated coughs or occasional spontaneous coughs	4 = Repeated spontaneous coughs		Adapted from Renaud et al., 2018
Temperature	<38 = Low	38-39.5 = Normal	>39.5 = Fever			Løken, 2013
Temperature, calf > 2 weeks	<38.5 = Low	38.5-40 = Normal	> 40.0 Fever			Løken, 2013
Respiration	Low	Normal	High			Løken, 2013
Heart frequency	Low	Normal	High			Løken, 2013
Lameness	1 = Normal	2 = Mildly lame	3 = Moderately lame	4 = Lame	5 = Severely lame	Sprecher et al., 1997
Mastitis	Normal	Subclinical mastitis	Acute mastitis			Tine, 2017
Cell count by Schalm test	1 < 200 000	2 = 150 000 – 550 000	3 = 400 000 – 1.5 mill	4 = 800 000 – 5 mill	5 > 5 mill	Whyte et al., 2005
Teat or udder injuries	0 = No wound/damage (completely intact skin)	1 = Wound/damage (any hair loss or damaged skin				Clin. Observation, vet.

In addition, quarter milk samples were taken for all cows in weeks 5 and 9 and from cows when they were diagnosed with mastitis, irrespective of week. The samples were taken according to the instructions of TINE SA’s (Norway’s largest producer, distributor, and exporter of dairy products) laboratory (TINE, 2019).

2.6 Statistical analysis

Statistical analyses were conducted in Minitab 21 Statistical Software. The response variables from the cow recordings were: “Milk per day” (daily machine milk yield/cow in kg), and for the composition of machine milk in week 5 and post-treatment (week 14-18) they were in %: “Fat”, “Protein”, “Lactose”, “Total solids”, in kg: “Energy corrected milk (ECM)”, and in mEq/L: “FFA”, mmol/l: “Urea” and 10^3/mL: “SCC”. The calf response variable for statistical analysis was: “Weight gain” (daily gain/calf in grams calculated from the weighings). Each response variable was analyzed separately using Mixed Effects Models.

Criteria for including and excluding data during the analysis were not established *a priori*. For the response variable “Milk per day” we excluded data from four days for four different CC cows (one day per cow; three days because only one milking was recorded, and one day because the recorded yield was considered erroneous). After this, we calculated milk per day by adding together the recorded milking for each day and each cow. Because of the use of i.m. oxytocin injections and its associated effects on machine milk yield (Bruckmaier, 2003), we then excluded the data from days with oxytocin injections and the following day, and if injected more than once, two consecutive days after the last injection. Thus, we removed on average 9 out of 77 days with milk recordings per CC cow due to oxytocin injections.

For milk yield and milk gross composition, the cow was considered the experimental unit as herd behaviour is considered to have minor effects on milk composition, as discussed by Dumont and Iason (2000).

The full models were fitted for the different response variables, as shown below. For each of them, the residual plot from the model fit was visually checked for normality and homogeneity of variance. Additionally, we did the normality tests Anderson Darling and Ryan-Joiner for each Y. Due to failed normality tests, we transformed the contents in machine milk of “Urea” with Urea* = $\text{Urea}^{-0.5}$ and “SCC” with SCC* = $e^{(\text{SCC}+1)}$, so that they met the normality assumptions after the transformations. The other variables met the normality assumptions without any transformations.

The full models for the response variables (Y) were:

1. Milk per day = intercept + treatment + group(treatment) + cow ID(group; treatment) + period + parity + treatment*period + period*parity + DIM + error

2. Fat, Protein, Lactose, Total dry solids, ECM, FFA, Urea* or SCC* (week 5) = intercept + treatment + group(treatment) + cow ID(group; treatment) + parity + DIM + error

3. Fat, Protein, Lactose, Total dry solids, ECM, FFA, Urea or SCC (week 14-18) = intercept + treatment + group(treatment) + parity + week + error

4. Weight gain = intercept + treatment + group(treatment) + calf ID(group; treatment) + sex + period + treatment*period + sex*period + birth weight + error

In the models, treatment was the main effect of treatment (fixed factor with two levels: CC, ES). Group(treatment) was the effect of the group within treatment (random factor), calf(treatment; group) was the effect of calf within group within treatment (random factor). The other fixed factors were parity (two levels: primiparous and multiparous cows), sex (two levels: bull and heifer calves), period for “Milk per day” (three levels: weeks 7-8 (weaning), week 9 (full separation) and weeks 10-11 (after separation)), period for “Weight gain” (three levels: weeks 0-6, weeks 6-9 and week 9 till 6-7 months). The interactions were 2nd order interactions between the relevant fixed factors. We decided not to include interactions with parity and treatment or sex and treatment because we only had one primiparous cow among the ES cows and two bull calves among the CC calves. The full model was reduced for each Y by removing non-significant covariates and higher-order interactions, to have the final model we used for analysis for each Y. Subsequently, we ran post hoc analyses with Tukey pairwise comparison tests to examine the differences between each level of the factors and interactions having P-values less than 0.10. Significance was declared at $P<0.05$ and a tendency was declared at $P<0.10$. Because it is well known that machine milk yield will be lower for cows when they have free-suckling calves, we decided to analyze weeks 0-6 of machine milk yield (milk per day) only descriptively. Regarding covariates, for model no. 1 and 3 the covariate “DIM” was removed, for model no. 4 the covariate “Week” was removed, and for model no. 5 the covariate “Birth weight" was removed ($P<0.05$).

Other data shown descriptively are cows’ body condition scores, body weights and body weight decrease in g/day (calculated by dividing the weight decrease from the first day on pasture till week 9 by the number of days in this period for each cow, a similar method was used by Adler et al. (2013a)), calves’ intakes of concentrates, and ES calves’ intakes of milk. Individual intakes of concentrates (CC and ES calves) and milk (ES calves) were estimated by dividing the group’s daily intake by the number of calves in the group. Although we do not know the variations in intakes of concentrates and milk among the individual calves, as these variables were recorded at group level, we decided to show the results as average intakes/calf/day for each week and each group.

3 Results

3.1 Machine milk yield

During suckling, the average daily machine milk yield from week 0 till week 6 was (± SD) 10.8 ± 5.5 kg for the CC cows and 34.5 ± 6.8 kg for the ES cows (Figure 3). Lower machine milk yield in CC compared to ES cows continued during weaning (weeks 7-8), separation (week 9) and in the post-treatment period (weeks 10-11). ($F_{2.00,\ 530.31} = 327.92$, $P < 0.001$). The CC cows' machine milk yield increased from weeks 7-8 to weeks 10-11, while there was no difference in the ES cows' machine milk yield between the different periods.

3.2 Composition of machine milk

In week 5, fat content in machine milk was numerically lower for the CC cows compared to the ES cows, however, the difference was not significant (Table 4a). We also found the CC cows to have a lower content of lactose in their machine milk compared to the ES cows in week 5 (P=0.005), and ECM was lower for the CC cows than for the ES cows (P=0.010). For the other variables protein, total solids, FFA, urea, or SCC in the cows' machine milk, there were no differences between the treatments in week 5. Post-treatment, there were no differences between the treatments for any of the variables (P>0.05) (Table 4b).

Table 4a & b. Composition of machine milk (mean ± SE) in a. week 5 postpartum and b. post-treatment (weeks 14-18 postpartum) for pastured cows with cow-calf contact (CC) and pastured cows with early separation from their calves (ES). Urea and SCC in week 5 are presented as back-transformed means with transformed means ± SE in brackets.

a. Variable	Treatment		Test statistics for treatment	
	CC (n=10)	ES (n=9)	DF Num, DF Den, F-value	P-value
Fat, %	2.6 ± 0.2	3.3 ± 0.3	$F_{1.00,\ 2.43} = 4.48$	0.146
Protein, %	3.2 ± 0.1	3.2 ± 0.1	$F_{1.00,\ 2.70} = 0.26$	0.647
Lactose, %	4.5 ± 0.1	4.9 ± 0.1	$F_{1.00,\ 16.00} = 10.88$	0.005
Total solids, %	10.3 ± 0.3	11.5 ± 0.3	$F_{1.00,\ 2.26} = 6.52$	0.111
ECM, kg/day	7.8 ± 2.2	33.8 ± 2.4	$F_{1.00,\ 2.18} = 72.32$	0.010
FFA, mEq/L	0.14 ± 0.06	0.12 ± 0.07	$F_{1.00,\ 2.36} = 0.07$	0.810
Urea, mmol/L	2.2 (0.67 ± 0.04)	2.4 (0.65 ± 0.04)	$F_{1.00,\ 2.07} = 0.21$	0.693
SCC, 10^3/mL	24.4 (3.23 ± 0.46)	47.8 (3.89 ± 0.57)	$F_{1.00,\ 16.00} = 0.89$	0.360
b. Variable	CC (n=8)	ES (n=8)		

Fat, %	3.9 ± 0.4	4.0 ± 0.4	$F_{1.00, 1.98} = 0.01$	0.944
Protein, %	3.6 ± 0.1	3.6 ± 0.3	$F_{1.00, 13.00} = 0.40$	0.536
Lactose, %	4.9 ± 0.2	4.8 ± 0.2	$F_{1.00, 1.78} = 0.24$	0.675
Total solids, %	12.3 ± 0.5	12.4 ± 0.7	$F_{1.00, 1.96} = 0.00$	0.977
ECM, kg/day	23.4 ± 4.4	28.4 ± 4.4	$F_{1.00, 1.98} = 0.89$	0.447
FFA, mEq/L	0.5 ± 0.1	0.7 ± 0.4	$F_{1.00, 13.00} = 1.64$	0.222
Urea, mmol/L	5.3 ± 0.4	5.9 ± 0.8	$F_{1.00, 1.98} = 0.55$	0.535
SCC, 10^3/mL	47.5 ± 56.3	191.3 ± 315.8	$F_{1.00, 13.00} = 1.10$	0.313

3.3 Cow body weight and body condition

Both the CC and ES cows' body weights and BCSs decreased numerically during the grazing period (Table 5). The decrease was numerically lower among the CC cows.

Table 5. Body weight and body condition score/cow (BCS: 1=emaciated to 5=severely over-conditioned) (average ± SD) the first day on pasture and in week 9 postpartum, as well as body weight decrease in g/day for cows from the two treatments: Cow-calf contact (CC, 56 d between the two measurements) and early separation (ES, 37 and 45 days between the two measurements for the two ES groups respectively).

		Treatment	
Item	Time	CC (n=10)	ES (n=9)
BCS, 1–5-point scale	First pasture day	3.9 ± 0.6	3.7 ± 0.7
	Week 9	2.9 ± 0.4	2.5 ± 0.5
Body weight, kg	First pasture day	657 ± 98	691 ± 47
	Week 9	603 ± 82	622 ± 50
	Decrease in g/day	973 ± 462	1647 ± 552

3.4 Calf intake of milk and concentrates

The ES calves' average milk intake was 10.7 L/calf/day from week 0 till week 6 (Figure 4) (10.1 L/calf/day in weeks 0-3 and 11.6 L/calf/day in weeks 4-6), which was lower than the offered milk allowance of 12 L/calf/day in weeks 0-3 and 14 L/calf/day in weeks 4-6. ES calves started to eat concentrates earlier and they ate more concentrates than CC calves, however, group ES2 had a relatively low concentrate intake in weeks 5 to 7 (Figure 4). The CC calves' calculated average concentrate intake was 142 g/calf/day from week 0 till 9

(19 g/calf/day weeks 0-6 and 428 g/calf/day weeks 7-9) and the ES calves average concentrate intake was 340 g/calf/day from week 0 till 9 (66 g/calf/day in week 0-6 and 980 g/calf/day in weeks 7-9).

3.5 Calf body weight and daily weight gain

Body weights for the CC and the ES calves increased similarly from birth till week 9 (Figure 5a). The results of the calves' daily weight gains showed no main effect of treatment (mean ± SE: 1150 ± 30 vs 1110 ± 30 g/calf/day for the CC and the ES calves, respectively) ($F_{1.00, 52.00} = 0.68$, P=0.413). However, there was an interaction between treatment and period ($F_{2.00, 52.00} = 3.22$, P=0.048; Figure 5b). Regardless of treatment, the calves had higher weight gains in weeks 0-6 (free suckling/high milk allowance) compared to weeks 6-9 (including weaning). The CC calves also showed higher daily weight gains in the period from week 0 to 6 compared to the period from week 9 to 6-7 months (after weaning and separation). The ES calves had higher daily weight gains in the period from week 9 to 6-7 months compared to the period from week 6 to 9.

3.6 Cow and calf health

Except for the challenges with inhibited milk ejection during milking in CC cows, the cow and calf health recordings (including detailed clinical examinations and daily recordings) obtained throughout the study do not indicate noticeable differences regarding health between the two treatments.

Only the two oldest CC cows (lactation no. 5 and 6) were considered to have normal milk ejection throughout the study. The challenge with inhibited milk ejection was most prominent during weaning and separation, and with three of the four primiparous CC cows. The cows had no events of respiratory diseases or lameness, but diarrhea (score >3) was recorded in six of nine ES cows the first 2-3 days on pasture (Table 6). There were some challenges with mastitis, teat wounds, and udder injuries in both treatments. Fever was recorded only in cows with clinical mastitis.

Diarrhea (score >3) was recorded in four of the 10 CC calves and all 10 ES calves for one or a few days in the study (Table 6). For the ES calves, this occurred during the weaning period. Coughing was recorded in three of the ES calves. None of the calves' general condition was affected by the diarrhea or coughing. Some hairless parts and small wounds on front knees were recorded in most of the CC calves, but they had no signs of arthritis, lameness, or affected condition.

Table 6. Number of pastured cows and calves with clinical diagnosis in the two treatments: Cow-calf contact (group CC1 and CC2) and early separation (group ES1 and ES2), and oxytocin injections in number of treatments before weaning (weeks 0-6), as well as during weaning and separation (weeks 7-9).

Health incident, cows	Item	CC1 (n=5)	CC2 (n=5)	ES1 (n=4)	ES2 (n=5)
Fecal consistency > 3	No. cows	0	1	4	2
Coughing score > 1	No. cows	0	0	0	0
Lameness	No. cows	0	0	0	0
Mastitis, clinical[1]	No. cows	1	2	1	1
Teat wounds/udder injuries	No. cows	1	2	0	2
Inhibited milk ejection	No. cows	3	5	0	0
Oxytocin in. week 0-6	No. of treatments	12	2	-	-
Oxytocin in. week 7-9	No. of treatments	26	26	-	-
Health incident, calves		CC1 (n=5)	CC2 (n=5)	ES1 (n=5)	ES2 (n=5)
Fecal consistency > 3	No. calves	1	3	5	5
Coughing (scores 1-2)	No. calves	0	0	0	4
Lameness	No. calves	0	0	0	0

[1] Detected bacteriae in mastitis diagnosis: *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Strepylococcus dysgalactiae*; *Staphylococcus warneri*; *Streptococcus agalactiae*, *Streptococcus uberis*

4 Discussion

This study is limited by a number of factors, such as few study units and replicates, that should be acknowledged when interpreting the results. However, the study contributes with valuable results and more knowledge about CCC systems on pasture.

It is obvious that dairy cows have lower machine milk yields while having free-suckling calves (e.g., Mac et al., 2023; Wenker et al., 2022; Zipp, 2018), and the CC cows in this study delivered on average 23.7 kg less milk/cow/day than the ES cows during weeks 0-6 postpartum. Our results showed a sustained lower yield during and after separation and weaning, when the CC calves' suckling allowance was restricted to 1-2 hours after milking (weeks 7-8 postpartum) and after week 8 suckling was completely prevented. In another study in which calves suckled for limited periods after milking, the authors found that the machine milk yields in suckled versus non-suckled cows became similar within three weeks after weaning (Mendoza et al., 2010), while several other studies found that suckled cows had similar machine milk yields as non-suckled cows within the first week after separation from their calves (de Passillé et al., 2008; Flower and Weary, 2001; Metz, 1987; Nicolao et al., 2022).

A limitation of our study is the lack of longer-term data on machine milk yields, so we do not know how the yields would have developed throughout the cows' full lactations. Except for being suckled or not, other factors may also affect cows' machine milk yields, like parity (Hansen et al., 2006), and health (Deluyker et al., 1991). Regarding parity, it was a limitation in our study that the CC treatment had more primiparous cows than the ES treatment, as it is well-known that primiparous cows have lower milk yields than multiparous cows (Hansen et al., 2006). The imbalance in parity across treatments may explain some of the sustained lower machine milk yield beyond separation. Machine milk yields were also affected by inhibited milk ejection in CC cows.

Although milk ejection of high-yielding *Bos taurus* cows is not conditioned on the presence of the calf as is the case for *Bos Indicus* (Akers and Lefcourt, 1982; Ryle and Orskov, 1990), it is established that suckling (vs. milking) is associated with a better milk ejection through higher oxytocin excretion (Bar-Peled et al., 1995; Lupoli et al., 2001). Thus, it is likely that oxytocin secretions in suckled cows in our study were too low to elicit a proper milk ejection in the milking parlor. A disturbed milk ejection during milking might specifically arise when cows leave their calves to be machine milked (Kälber and Barth, 2014; Krohn, 2001). As indicated in our study, inhibited milk ejection is more frequent in primiparous cows (Bruckmaier, 2005). Another factor is stress because of unfamiliar surroundings (Wellnitz and Bruckmaier, 2001), and in our study, the primiparous cows had no previous experience from the summer pasture, the milking parlor, or the routines there. Training the primiparous cows to the milking routines prepartum could have enhanced their milk ejection (Ujita et al., 2021). Hand massage of the udder has been shown to stimulate milk ejection (Kentjonowaty et al., 2021), and this was tried without any success in our study. However, we did not try tactile vaginal or cervical stimulation, which according to Bruckmaier (2013) is a potential method for when the response to udder stimulation is insufficient. This is however not a practical method for use in farming. The cows' milk ejection could also have been enhanced if the calves had been suckling their dams for a few seconds before milking (Mejia et al., 1998) and/or had been together with their calves during milking, as for tropical cattle breeds (Hernández et al., 2006; Junqueira et al., 2005). It is well known that cows also experience stress during separation from their calves (Newberry and Swanson, 2008), even when it happens gradually (Johnsen et al., 2015). Such a separation stress may have contributed to inhibited milk ejection being prominent during weaning and separation.

In our study, the only significant differences in composition of machine milk between CC and ES cows was lactose content, where CC cows had a lower content. These findings diverge from what others have reported (Boden and Leaver, 1994; Dymnicki et al., 2013; Fröberg et al., 2007), but aligns with Wenker et al. (2022b), who found a tendency for lower lactose content in free nursing cows. They suggested that few cases of high SCC in free nursing cows could explain this, referring to Costa et al. (2019). Despite the lower mean SCC in CC cows in our study, the difference was not significant, and is not likely the cause of the lower lactose content in CC cows' machine milk in our study. The mean fat content in our study was 0.7 % lower in CC cows than ES cows, yet this difference was not significant, contrasting with other studies conducted indoors (Barth, 2020; Zipp, 2018) and on pasture (Nicolao et al., 2022; Ospina Rios et al., 2023). The generally low fat contents observed in our study, which were below the Norwegian average of 4.4 % (Tine, 2023), may be attributed to grazing, as Adler et al. (2013b) found lower fat content in machine milk from Norwegian farms during the pasture periods compared to the indoor periods. Our limited sample size and greater variation in fat content, compared to e.g., lactose, might explain the lack of a significant difference.

Choosing the appropriate concentrate amounts for CC cows presents a challenge, as it is difficult to determine the total milk production (machine milk + suckled milk) in nursing cows. Nevertheless, even though CC cows in our study got on average 2 kg less concentrates per cow per day compared to ES cows, the decrease in body weight and BCS was numerically lower for CC cows than for ES cows. A lower decrease in body weight and BCS in suckled cows differs from what has been found when cows were suckled restrictively (Bar-Peled et al., 1995). In our study, this result might have been affected by the possibly higher milk yields and thus higher energy requirements in the ES cows compared to the CC cows. It is known that BCS becomes lower with higher parity (Harrison et al., 1990; Pryce et al., 2001), and the fact that we had more primiparous cows among the CC cows in our study, makes the direct comparison between the two treatments more difficult. Studies examining cows' BCS in CCC systems are limited, but in a master thesis, Tufvesson (2021) had similar findings as us regarding BCS in suckled and non-suckled cows.

Our descriptive data on calf concentrate intakes showed that the ES calves consumed concentrates earlier and in larger amounts than the CC calves. Fröberg et al. (2011) had similar findings in calves kept indoors. However, factors affecting concentrate intakes in our study may include that the ES calves were also milk fed in the calf hide and used the calf hide where the concentrates were located more than the CC calves (Johanssen et al., in review). Additionally, the CC calves had free access to milk through suckling (except during cows' milking) in weeks 0-6, whereas the ES calves were fed four meals daily. The ES calves in our study had an average milk intake of 10.7 L/calf/day in weeks 0-6, when their milk allowance was close to ad libitum. Some studies with calves fed ad libitum of milk artificially also found calves' milk intakes to be around 10 L/calf/day (Appleby et al., 2001; Jasper and Weary, 2002; Welboren et al., 2019), while in other studies milk intakes were up to 13-14 L/calf/day (Miller-Cushon et al., 2013; Von Keyserlingk et al., 2004; Wormsbecher et al., 2017). It is possible that our ES calves would have drunk more milk if the meals had been more evenly distributed around the clock or with ad libitum access through an automatic milk feeder. Comparing the CC cows' machine milk yield during the free suckling period with the period in weeks 10-11, the difference was 12.2 kg/cow/day. This figure may more realistically correspond to the CC calves' actual milk intake than the difference of 23.7 kg/cow/day in the CC versus the ES cows' machine milk yields in weeks 0-6 since the calves' daily weight gains were similar.

The similar calf weight gain between the two treatments in our study can be compared to studies with free-suckling calves versus studies with calves given ad libitum of milk artificially where similar weight gains also have been found. Free suckling: between 1.0 and 1.4 kg/calf/day (Flower and Weary, 2001; Grøndahl et al., 2007; Johnsen et al., 2021; Mac et al., 2023), artificial milk-fed ad libitum: between 1.1 and 1.3 kg/calf/day (Miller-Cushon et al., 2013; Welboren et al., 2019). In our study, while CC and ES calves exhibited similar weight gains, there may have been variations in milk intake. Free suckling calves engage in 4-10 suckling bouts daily (de Passillé, 2001), with about half occurring at night (Ewbank, 1969). However, the ES calves in our study lacked nighttime access to milk. Additionally, the ES calves had a higher energy intake through concentrates and perhaps also grazing, potentially compensating for a reduced milk intake.

There were some health challenges with the cows during our study, but the calves were generally healthy. There were no obvious differences in cow or calf health between the two treatments, except for the challenges with inhibited milk ejection in the CC cows explained above. A recent study found that calf health could be a challenge when the calves were kept in the cows’ environment indoors (Wenker et al., 2022b). This can be due to a higher animal density and thus infection pressure indoors than on pasture, as well as hygiene and climate not being optimal for the calves in the cow area. In a recent interview study (Johanssen et al., 2023), some farmers preferred having CCC on pasture for reasons like a reduced risk of infection and injuries. Furthermore, interviewed farmers practicing CCC have mentioned better calf weight gain and health among the main benefits of applying these systems (Johanssen and Sørheim, 2021; Neave et al., 2022; Vaarst et al., 2020). The interviews included farmers practicing CCC both indoors and/or on pasture.

Further research should aim to study methods for improved milk ejection in pastured dairy cows with CCC. This is crucial for ensuring the welfare of the cows, facilitating the farmers’ work, and reducing the risk of lower profitability when practicing CCC systems in dairy farming. Potential strategies include allowing calves to accompany cows to the milking parlors, if feasible, using mobile milking robots for milking CCC cows on pasture, and training primiparous cows in milking routines before calving. One should also examine how to enhance milk ejection in the stressful period around cow-calf separation, including more research on gradual separation methods on pasture to reduce stress.

5 Conclusion

In this study, the pastured CC cows’ machine milk yields were consistently low during free suckling (weeks 0-6), weaning (weeks 7-8) and at least until weeks 10-11, past the point of full cow-calf separation in week 9. Calves that were separated from their dams within three hours after birth and offered up to 14 kg of milk per day had similar daily weight gain and health as calves suckling for 8 weeks. The main challenge identified in this study was the inhibited milk ejection during milking of pastured CC cows in a milking parlor, and further research should aim to study methods to enhance milk ejection in pastured dairy cows with CCC.

Declarations of interest

None.

Ethics approval and consent to participate

No ethics approval was required for this study.

Acknowledgments

This work was a part of the project SUCCEED, with project number 31200, funded by the Norwegian Research Council, research funding for the agriculture- and food industry (FFS-JA), and the project “Kalvelykke” funded by the Regional Research Fund Mid-Norway. We would like to send a special thanks to the farmers who let us perform this study with their animals and on their farm and summer pasture, and to both the farmers and their family members who helped us carry out the study. Also, thanks to all the others who helped us out with the study: Lilian Lambret, Peggy Haugnes, Anne de Boer, Sara Hansdotter, Turid Strøm, Martha Ebbesvik & Tor Kalseth. We also thank Torfinn Torp for guidance in statistical analyses.

References

Abuelo, A., Havrlant, P., Wood, N., Hernandez-Jover, M., 2019. An investigation of dairy calf management practices, colostrum quality, failure of transfer of passive immunity, and occurrence of enteropathogens among Australian dairy farms. J Dairy Sci 102, 8352–8366. https://doi.org/10.3168/jds.2019-16578

Adler, S.A., Dahl, A. V., Jensen, S.K., Thuen, E., Gustavsson, A.M., Steinshamn, H., 2013a. Fatty acid composition, fat-soluble vitamin concentrations and oxidative stability in bovine milk produced on two pastures with different botanical composition. Livest Sci 154, 93–102. https://doi.org/10.1016/j.livsci.2013.03.013

Adler, S.A., Jensen, S.K., Govasmark, E., Steinshamn, H., 2013b. Effect of short-term versus long-term grassland management and seasonal variation in organic and conventional dairy farming on the composition of bulk tank milk. J Dairy Sci 96, 5793–5810. https://doi.org/10.3168/jds.2012-5765

Akers, R.M., Lefcourt, A.M., 1982. Milking- and suckling-induced secretion of oxytocin and prolactin in parturient dairy cows. Horm Behav 16, 87–93. https://doi.org/10.1016/0018-506X(82)90009-5

Appleby, M.C., Weary, D.M., Chua, B., 2001. Performance and feeding behaviour of calves on ad libitum milk from artificial teats. Appl Anim Behav Sci 74, 191–201. https://doi.org/10.1016/S0168-1591(01)00171-X

Bar-Peled, U., Maltz, E., Bruckental, I., Folman, Y., Kali, Y., Gacitua, H., Lehrer, A.R., Knight, C.H., Robinson, B., Voet, H., Tagari, H., 1995. Relationship Between Frequent Milking or Suckling in Early Lactation and Milk Production of High Producing Dairy Cows. J Dairy Sci 78, 2726–2736. https://doi.org/10.3168/jds.S0022-0302(95)76903-X

Bar-Peled, U., Robinzon, B., Maltz, E., Tagari, H., Folman, Y., Bruckental, I., Voet, H., Gacitua, H., Lehrer, A.R., 1997. Increased weight gain and effects on production parameters of Holstein heifer calves that were allowed to suckle from birth to six weeks of age. J Dairy Sci 80, 2523–2528.

Barth, K., 2020. Effects of suckling on milk yield and milk composition of dairy cows in cow-calf contact systems. Journal of Dairy Research 87, 133–137. https://doi.org/10.1017/S0022029920000515

Beaver, A., Meagher, R.K., von Keyserlingk, M.A.G., Weary, D.M., 2019. Invited review: A systematic review of the effects of early separation on dairy cow and calf health. J Dairy Sci 102, 5784–5810. https://doi.org/https://doi.org/10.3168/jds.2018-15603

Boden, R.F., Leaver, J.D., 1994. A dual purpose cattle system combining milk and beef production. Proceedings of the British Society of Animal Production (1972) 1994, 145.

Bruckmaier, R.M., 2013. Oxytocin from the pituitary or from the syrine Importance and consequences for machine milking in dairy cows. NMC Annual Meeting Proceedings 4–11.

Bruckmaier, R.M., 2005. Normal and disturbed milk ejection in dairy cows. Domest Anim Endocrinol 29, 268–273. https://doi.org/10.1016/j.domaniend.2005.02.023

Bruckmaier, R.M., 2003. Chronic oxytocin treatment causes reduced milk ejection in dairy cows. Journal of Dairy Research 70, 123–126. https://doi.org/10.1017/S0022029902005940

Carbonneau, E., de Passillé, A.M., Rushen, J., Talbot, B.G., Lacasse, P., 2012. The effect of incomplete milking or nursing on milk production, blood metabolites, and immune functions of dairy cows. J Dairy Sci 95, 6503–6512. https://doi.org/10.3168/jds.2012-5643

Costa, A., Lopez-Villalobos, N., Sneddon, N.W., Shalloo, L., Franzoi, M., De Marchi, M., Penasa, M., 2019. Invited review: Milk lactose—Current status and future challenges in dairy cattle. J Dairy Sci 102, 5883–5898. https://doi.org/10.3168/jds.2018-15955

de Passillé, A.M., 2001. Sucking motivation and related problems in calves. Appl Anim Behav Sci 72, 175–187. https://doi.org/10.1016/S0168-1591(01)00108-3

de Passillé, A.M., Marnet, P.-G., Lapierre, H., Rushen, J., 2008. Effects if twice-daily nursing on milk ejection and milk yield during nursing and milking in dairy cows. J Dairy Sci 91, 1416–1422. https://doi.org/https://doi.org/10.3168/jds.2007-0504

Deluyker, H.A., Gay, J.M., Weaver, L.D., Azari, A.S., 1991. Change of Milk Yield with Clinical Diseases for a High Producing Dairy Herd. J Dairy Sci 74, 436–445. https://doi.org/10.3168/jds.S0022-0302(91)78189-7

Dumont, B., Iason, G.R., 2000. Can we believe the results of grazing experiments? Issues and limitations in methodology 171–180.

Dymnicki, E., Sosin-Bzducha, E., Gołębiewski, M., 2013. Effects of calf separation and injection of oxytocin on milk performance and milk composition of the Polish Red cows. Arch Anim Breed 56, 882–891. https://doi.org/10.7482/0003-9438-56-088

Dyrevelferdsloven, 2009. Lov om dyrevelferd (LOV-2009-06-19-97) [WWW Document]. URL https://lovdata.no/dokument/NL/lov/2009-06-19-97

Edmonson, A.J., Lean, I.J., Weaver, L.D., Farver, T., Webster, G., 1989. A Body Condition Scoring Chart for Holstein Dairy Cows. J Dairy Sci 72, 68–78. https://doi.org/10.3168/jds.S0022-0302(89)79081-0

Ewbank, R., 1969. The frequency and duration of the nursing periods in single-suckled hereford beef cows. Br Vet J 125, ix–x. https://doi.org/10.1016/S0007-1935(17)49115-9

Flower, F.C., Weary, D.M., 2001. Effects of early separation on the dairy cow and calf: 2. Separation at 1 day and 2 weeks after birth. Appl Anim Behav Sci 70, 275–284. https://doi.org/10.1016/S0168-1591(00)00164-7

Forsøksdyrforskriften, 2015. Forskrift om bruk av dyr i forsøk (FOR-2015–06-18–761) [WWW Document]. URL https://lovdata.no/dokument/SF/forskrift/2015-06-18-761

Fröberg, S., Aspegren-Güldorff, A., Olsson, I., Marin, B., Berg, C., Hernández, C., Galina, C.S., Lidfors, L., Svennersten-Sjaunja, K., 2007. Effect of restricted suckling on milk yield, milk composition and udder health in cows and behaviour and weight gain in calves, in dual-purpose cattle in the tropics. Trop Anim Health Prod 39, 71–81. https://doi.org/10.1007/s11250-006-4418-0

Fröberg, S., Lidfors, L., Svennersten-Sjaunja, K., Olsson, I., 2011. Performance of free suckling dairy calves in an automatic milking system and their behaviour at weaning. Acta Agriculturae Scandinavica A: Animal Sciences 61, 145–156. https://doi.org/10.1080/09064702.2011.632433

Geno, 2020. Hold og holdvurdering for NRF [WWW Document]. geno.no. URL https://www.geno.no/fagstoff-og-hjelpemidler/fagstoff/brunst-og-fruktbarhet/fruktbarhetsstyring/hold-og-holdvurdering-for-nrf/

Grøndahl, A., Skancke, E., Mejdell, C., Jansen, J., 2007. Growth rate, health and welfare in a dairy herd with natural suckling until 6–8 weeks of age: a case report. Acta Vet Scand 49, 16. https://doi.org/10.1186/1751-0147-49-16

Grøndahl, A.M., 2011. Overføring av smittestoffer fra ku til kalv i melkefôringsperioden – en litteraturstudie 211–219.

Hansen, B.G., Langseth, E., Berge, C., 2023. Animal welfare and cow-calf contact-farmers' attitudes, experiences and adoption barriers. J Rural Stud 97, 34–46. https://doi.org/10.1016/j.jrurstud.2022.11.013

Hansen, J. V., Friggens, N.C., Højsgaard, S., 2006. The influence of breed and parity on milk yield, and milk yield acceleration curves. Livest Sci 104, 53–62. https://doi.org/10.1016/j.livsci.2006.03.007

Harrison, R.O., Ford, S.P., Young, J.W., Conley, A.J., Freeman, A.E., 1990. Increased Milk Production Versus Reproductive and Energy Status of High Producing Dairy Cows. J Dairy Sci 73, 2749–2758. https://doi.org/10.3168/jds.S0022-0302(90)78960-6

Hernández, C., Orihuela, A., Fröberg, S., Lidfors, L.M., 2006. Effect of restricted suckling on physiological and behavioural stress parameters in dual-purpose cattle in the tropics. Livest Sci 99, 21–27. https://doi.org/10.1016/j.livprodsci.2005.05.020

Hötzel, M.J., Cardoso, C.S., Roslindo, A., von Keyserlingk, M.A.G., 2017. Citizens' views on the practices of zero-grazing and cow-calf separation in the dairy industry: Does providing information increase acceptability? J Dairy Sci 100, 4150–4160. https://doi.org/10.3168/jds.S0022-0302(02)74391-9

Hötzel, M.J., Longo, C., Balcão, L.F., Cardoso, C.S., Costa, J.H.C., 2014. A survey of management practices that influence performance and welfare of dairy calves reared in southern Brazil. PLoS One 9, 1–17. https://doi.org/10.1371/journal.pone.0114995

Hulsen, J., 2005. Cow signals: a practical guide for dairy farm management. Roodbont Publishers.

Jannerman, K., 2022. Ko och kalv tillsammans i mjölkproduktion – fältförsök på två ekologiska gårdar farms (Independent Project). Swedish University of Agricultural Science, Sweden.

Jasper, J., Weary, D.M., 2002. Effects of Ad Libitum Milk Intake on Dairy Calves. J Dairy Sci 85, 3054–3058. https://doi.org/https://doi.org/10.3168/jds.S0022-0302(02)74391-9

Johanssen, J.R.E., Kvam, G.-T., Logstein, B., Vaarst, M., 2023. Interrelationships between cow, calf, and human in cow-calf contact systems – An interview study among Norwegian dairy farmers. J Dairy Sci. https://doi.org/10.3168/jds.2022-22999

Johanssen, J.R.E., Sørheim, K., 2021. Ku og kalv sammen i melkeproduksjon - Intervjuer med melkeprodusenter. Tingvoll.

Johnsen, J.F., Ellingsen-Dalskau, K., Grøndahl, A.M., Bøe, K.E., Lidfors, L., Mejdell, C.M., 2015. The effect of physical contact between dairy cows and calves during separation on their post-separation behavioural response. Appl Anim Behav Sci 166, 11–19. https://doi.org/10.1016/j.applanim.2015.03.002

Johnsen, J.F., Kischel, S.G., Rognskog, M.S., Vagle, I., Johanssen, J.R.E., Ruud, L.E., Ferneborg, S., 2021. Investigating cow−calf contact in a cow-driven system performance of cow and calf. Journal of Dairy Research 88, 56–59. https://doi.org/https://doi.org/10.1017/S0022029921000200

Jones, R.M., Hargreaves, J.N.G., 1979. Improvements to the dry-weight-rank method for measuring botanical composition. Grass and Forage Science 34, 181–189. https://doi.org/10.1111/j.1365-2494.1979.tb01465.x

Junqueira, F.S., Madalena, F.E., Reis, G.L., 2005. Production and economic comparison of milking F1Holstein X Gir cows with and without the stimulus of the calf. Livest Prod Sci 97, 241–252. https://doi.org/10.1016/j.livprodsci.2005.05.005

Kälber, T., Barth, K., 2014. Practical implications of suckling systems for dairy calves in organic production systems – a review. Landbauforsch 1, 45–58. https://doi.org/10.3220/LBF_2014_45-58

Kentjonowaty, I., Mardhotillah, A.B.A., Susilawati, T., Surjowardojo, P., 2021. Effects of mammae hand massages on oxytocin release, milk yield, and milk quality in dairy cows. Livestock and Animal Research 19, 311. https://doi.org/10.20961/lar.v19i3.49120

Khan, M.A., Weary, D.M., von Keyserlingk, M.A.G., 2011. Invited review: Effects of milk ration on solid feed intake, weaning, and performance in dairy heifers. J Dairy Sci 94, 1071–1081. https://doi.org/10.3168/jds.2010-3733

Krohn, C.C., 2001. Effects of different suckling systems on milk production, udder health, reproduction, calf growth and some behavioural aspects in high producing dairy cows - A review. Appl Anim Behav Sci 72, 271–280. https://doi.org/10.1016/S0168-1591(01)00117-4

Krohn, C.C., Foldager, J., Mogensen, L., 1999. Long-term effect of colostrum feeding methods on behaviour in female dairy calves. Acta Agriculturae Scandinavica A: Animal Sciences 49. https://doi.org/https://doi.org/10.1080/090647099421540

Løken, T., 2013. Klinisk diagnostikk hos produksjonsdyr. Oslo, Norge.

Lovdata FOR-2004-04-22-665, 2004. Forskrift om hold av storfe [WWW Document]. lovdata.no. URL https://lovdata.no/dokument/SF/forskrift/2004-04-22-665

Lupoli, B., Johansson, B., Uvnäs-Moberg, K., Svennersten-Sjaunja, K., 2001. Effect of suckling on the release of oxytocin, prolactin, cortisol, gastrin, cholecystokinin, somatostatin and insulin in dairy cows and their calves. Journal of Dairy Research 68, 175–187. https://doi.org/10.1017/S0022029901004721

Mac, S.E., Lomax, S., Clark, C.E.F., 2023. Dairy cow and calf behavior and productivity when maintained together on a pasture-based system. Anim Biosci 36, 322–332. https://doi.org/10.5713/ab.22.0135

Mannetje, L., Haydock, K.P., 1963. the Dry-Weight-Rank Method for the Botanical Analysis of Pasture. Grass and Forage Science 18, 268–275. https://doi.org/10.1111/j.1365-2494.1963.tb00362.x

Margerison, J.K., Preston, T.R., Phillips, C.J.C., 2002. Restricted suckling of tropical dairy cows by their own calf or other cows' calves. J Anim Sci 80, 1663–1670. https://doi.org/10.2527/2002.8061663x

Meagher, R.K., Beaver, A., Weary, D.M., von Keyserlingk, M.A.G., 2019. Invited review: A systematic review of the effects of prolonged cow–calf contact on behavior, welfare, and productivity. J Dairy Sci 102, 5765–5783. https://doi.org/10.3168/jds.2018-16021

Mejia, C.E., Preston, T.R., Fajersson, P., 1998. Effects of restricted suckling versus artificial rearing on milk production, calf performance and reproductive efficiency of dual purpose Mpwapwa cattle in a semi-arid climate [WWW Document]. Livestock Research for Rural Development. URL http://www.lrrd.org/lrrd10/1/meji101.htm

Mendoza, A., Cavestany, D., Roig, G., Ariztia, J., Pereira, C., La Manna, A., Contreras, D.A., Galina, C.S., 2010. Effect of restricted suckling on milk yield, composition and flow, udder health, and postpartum anoestrus in grazing Holstein cows. Livest Sci 127, 60–66. https://doi.org/10.1016/j.livsci.2009.08.006

Metz, J., 1987. Productivity aspects of keeping dairy cow and calf together in the post-partum period. Livest Prod Sci 16, 385–394. https://doi.org/https://doi.org/10.1016/0301-6226(87)90007-8

Miller-Cushon, E.K., Bergeron, R., Leslie, K.E., DeVries, T.J., 2013. Effect of milk feeding level on development of feeding behavior in dairy calves. J Dairy Sci 96, 551–564. https://doi.org/10.3168/jds.2012-5937

Neave, H.W., Sumner, C.L., Henwood, R.J.T., Zobel, G., Saunders, K., Thoday, H., Watson, T., Webster, J.R., 2022. Dairy farmers' perspectives on providing cow-calf contact in the pasture-based systems of New Zealand. J Dairy Sci 105, 453–467. https://doi.org/10.3168/jds.2021-21047

Newberry, R.C., Swanson, J.C., 2008. Implications of breaking mother-young social bonds. Appl Anim Behav Sci 110, 3–23. https://doi.org/10.1016/j.applanim.2007.03.021

Nicolao, A., Veissier, I., Bouchon, M., Sturaro, E., Martin, B., Pomiès, D., 2022. Animal performance and stress at weaning when dairy cows suckle their calves for short versus long daily durations. Animal 16, 100536. https://doi.org/10.1016/j.animal.2022.100536

Ospina Rios, S.L., Lee, C., Andrewartha, S.L., Verdon, M., 2023. A Pilot Study on the Feasibility of an Extended Suckling System for Pasture-Based Dairies. Animals 13, 1–17. https://doi.org/10.3390/ani13162571

Pempek, J.A., Schuenemann, G.M., Holder, E., Habing, G.G., 2017. Dairy calf management—A comparison of practices and producer attitudes among conventional and organic herds. J Dairy Sci 100, 8310–8321. https://doi.org/10.3168/jds.2017-12565

Pryce, J.E., Coffey, M.P., Simm, G., 2001. The relationship between body condition score and reproductive performance. J Dairy Sci 84, 1508–1515. https://doi.org/10.3168/jds.S0022-0302(01)70184-1

Relić, R., Starič, J., Ježek, J., 2020. Management practices that influence the welfare of calves on small family farms. Journal of Dairy Research 87, 93–98. https://doi.org/10.1017/S0022029920000539

Renaud, D.L., Duffield, T.F., LeBlanc, S.J., Haley, D.B., Kelton, D.F., 2018. Clinical and metabolic indicators associated with early mortality at a milk-fed veal facility: A prospective case-control study. J Dairy Sci 101, 2669–2678. https://doi.org/10.3168/jds.2017-14042

Roth, B.A., Barth, K., Gygax, L., Hillmann, E., 2009. Influence of artificial vs. mother-bonded rearing on sucking behaviour, health and weight gain in calves. Appl Anim Behav Sci 119, 143–150. https://doi.org/10.1016/j.applanim.2009.03.004

Ryle, M., Orskov, E.R., 1990. On milk yields and calf rearing. Livestock research for Rural Development 2.

Schuppli, C.A., Keyserlingk, M.A.G. Von, Weary, D.M., 2014. Access to pasture for dairy cows : Responses from an online engagement 5185–5192. https://doi.org/10.2527/jas2014-7725

Sinnott, A.M., 2023. Finding the balance - Improving labour efficiency and animal welfare in calf rearing (PhD thesis). Wageningen University and Research, the Netherlands.

Sirovica, L. v., Ritter, C., Hendricks, J., Weary, D.M., Gulati, S., von Keyserlingk, M.A.G., 2022. Public attitude toward and perceptions of dairy cattle welfare in cow-calf management systems differing in type of social and maternal contact. J Dairy Sci 105, 3248–3268. https://doi.org/10.3168/jds.2021-21344

Sprecher, D.J., Hostetler, D.E., Kaneene, J.B., 1997. A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performanc. Theriogenology 47.

Thomas, G.W., Spiker, S.A., 1981. Influence of suckling by Friesian milk production and anoestrus. Aust J Exp Agric 21, 5–11.

Tine, 2023. Statistikksamling for ku- og geitekontrollen for 2022 - Årsrapport fra Helsekortordningen 2022 [WWW Document]. medlem.tine.no. URL https://medlem.tine.no/fag-og-forskning/statistikksamling-for-ku-og-geitekontrollen-for-2022

Tine, 2019. Enkeltspeneprøver ku, Uttak av speneprøver [WWW Document]. medlem.tine.no. URL https://medlem.tine.no/tjenester/speneprover/_/attachment/inline/03740f1b-c47d-4b14-9618-2718e471969c:042b64631c3680793ae6a7e496da9ab7924fe3ff/Enkeltspeneprøver_21-50.pdf

Tine, 2017. Jurhelseboka [WWW Document]. medlem.tine.no. URL https://medlem.tine.no/dyr-og-helse/jurhelse

Tufvesson, C., 2021. Effects of Levels of Concentrates on Feed Intake and Milk Production of Dairy Cows in Early Lactation (Independent Project). Swedish University of Agricultural Science. https://doi.org/10.2508/chikusan.48.468

Ujita, A., El Faro, L., Vicentini, R.R., Pereira Lima, M.L., de Oliveira Fernandes, L., Oliveira, A.P., Veroneze, R., Negrão, J.A., 2021. Effect of positive tactile stimulation and prepartum milking routine training on behavior, cortisol and oxytocin in milking, milk composition, and milk yield in Gyr cows in early lactation. Appl Anim Behav Sci 234. https://doi.org/10.1016/j.applanim.2020.105205

USDA, 2016. Dairy 2014 Dairy Cattle Management Practices in the United States, 2014. USDA: Fort Collins, CO, USA.

Vaarst, M., Hellec, F., Verwer, C., Johanssen, J.R.E., Sørheim, K., 2020. Cow calf contact in dairy herds viewed from the perspectives of calves, cows, humans and the farming system. Farmers' perceptions and experiences related to dam-rearing systems. Landbauforschung (Braunschw) 70, 49–57. https://doi.org/10.3220/LBF1596195636000

Ventura, B.A., von Keyserlingk, M.A.G., Schuppli, C.A., Weary, D.M., 2013. Views on contentious practices in dairy farming: The case of early cow-calf separation. J Dairy Sci 96, 6105–6116. https://doi.org/10.3168/jds.2012-6040

Von Keyserlingk, M.A.G., Brusius, L., Weary, D.M., 2004. Competition for teats and feeding behavior by group-housed dairy calves. J Dairy Sci 87, 4190–4194. https://doi.org/10.3168/jds.S0022-0302(04)73563-8

Welboren, A.C., Leal, L.N., Steele, M.A., Khan, M.A., Martín-Tereso, J., 2019. Performance of ad libitum fed dairy calves weaned using fixed and individual methods. Animal 13, 1891–1898. https://doi.org/10.1017/S1751731119000181

Wellnitz, O., Bruckmaier, R.M., 2001. Central and peripheral inhibition of milk ejection. Livest Prod Sci 70, 135–140. https://doi.org/10.1016/S0301-6226(01)00206-8

Wenker, M.L., van Reenen, C.G., Bokkers, E.A.M., McCrea, K., de Oliveira, D., Sorheim, K., Cao, Y., Bruckmaier, R.M., Gross, J.J., Gort, G., Verwer, C.M., 2022a. Comparing gradual debonding strategies after prolonged cow-calf contact: stress responses, performance, and health of dairy cow and calf 253. https://doi.org/10.1016/j.applanim.2022.105694

Wenker, M.L., Verwer, C.M., Bokkers, E.A.M., te Beest, D.E., Gort, G., de Oliveira, D., Koets, A., Bruckmaier, R.M., Gross, J.J., van Reenen, C.G., 2022b. Effect of Type of Cow-Calf Contact on Health, Blood Parameters, and Performance of Dairy Cows and Calves. Front Vet Sci 9, 1–19. https://doi.org/10.3389/fvets.2022.855086

Whyte, D., Walmsley, M., Liew, A., Claycomb, R., Mein, G., 2005. Chemical and rheological aspects of gel formation in the California Mastitis Test. Journal of Dairy Research 72, 115–121. https://doi.org/10.1017/S0022029904000561

Winder, C.B., Bauman, C.A., Duffield, T.F., Barkema, H.W., Keefe, G.P., Dubuc, J., Uehlinger, F., Kelton, D.F., 2018. Canadian National Dairy Study : Heifer calf management. J Dairy Sci 1–15. https://doi.org/10.3168/jds.2018-14680

Wormsbecher, L., Bergeron, R., Haley, D., de Passillé, A.M., Rushen, J., Vasseur, E., 2017. A method of outdoor housing dairy calves in pairs using individual calf hutches. J Dairy Sci 100, 7493–7506. https://doi.org/10.3168/jds.2017-12559

Zipp, K., 2018. How to tackle alveolar milk ejection problems during milking in dam rearing? Influence of different stimuli in the parlour and effects of half-day compared to free contact (PhD thesis). University of Kassel, Germany.

Figure 1. One of the calf hides with descriptions. This photo was taken with group ES1 on their pasture area on the farm in their second week.

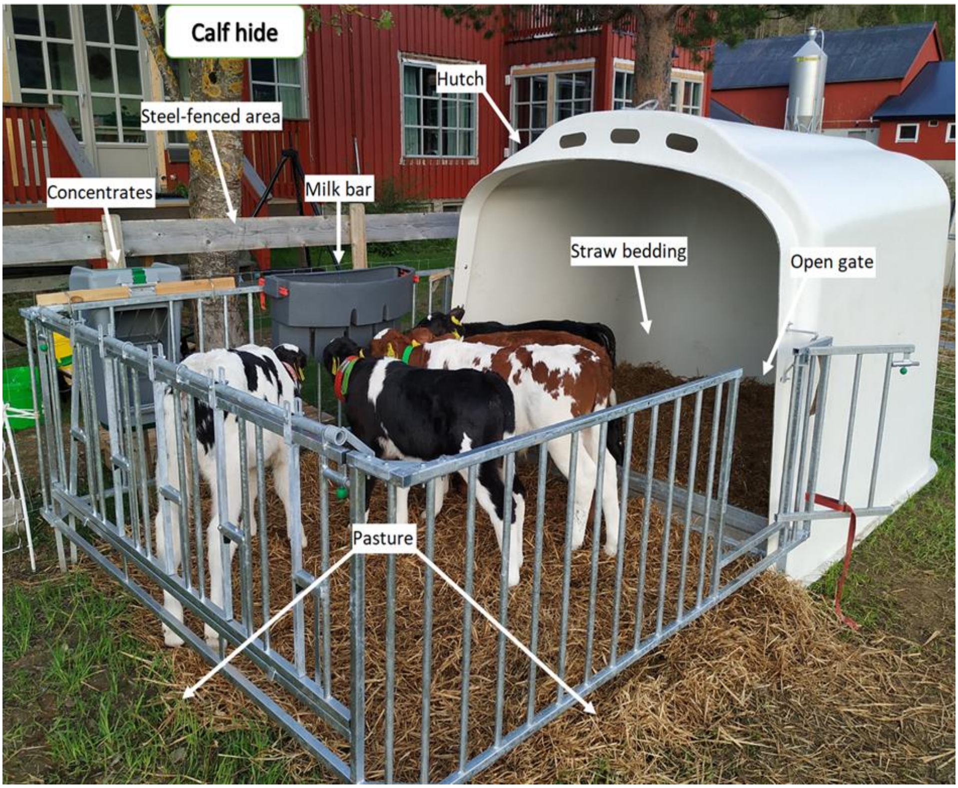


Figure 2. A map of the summer pasture with inserted descriptions on which areas the CC pairs, the ES cows and the ES calves were kept on, and where the milking parlor was located.

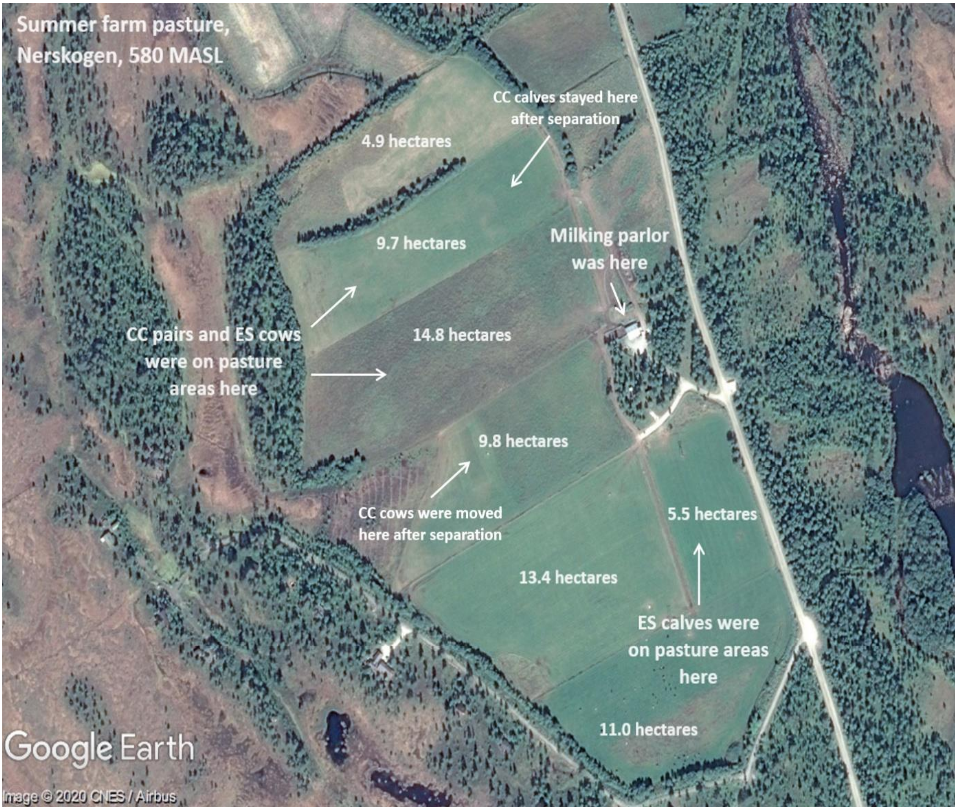


Figure 3. Daily machine milk yield/cow in weeks 0-6 postpartum (free suckling period for CC pairs) (average ± SD) and in weeks 7-8 (weaning), week 9 (full separation), and weeks 10-11 (after separation) (mean ± SE) for pastured cows from the two treatments: Cow-calf contact (CC) and early separation (ES). Means that do not share a letter are significantly different interactions between treatment and period (P<0.005).

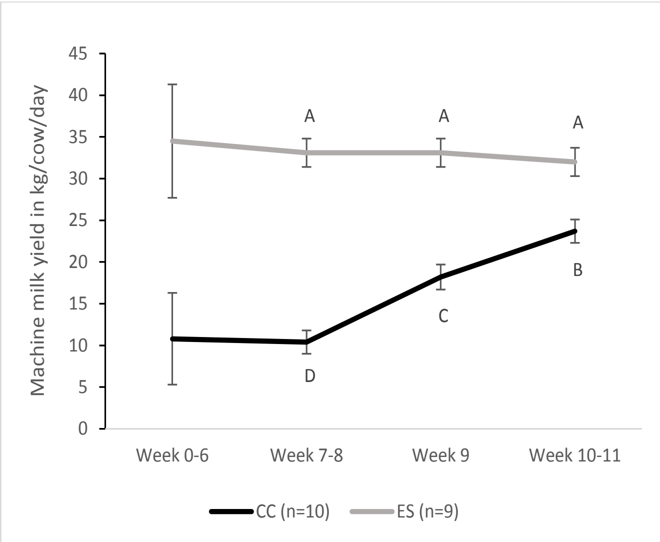


Figure 4. Average individual calf milk intake (measured on group level, solid lines) in the early separation (ES) treatment (ES1 (n=5) and ES2 (n=5) with close to ad libitum milk allowance) and average individual concentrate intake (measured on group level, dashed lines) in both treatments: Cow-calf contact (CC, groups CC1 (n=5) and CC2 (n=5) and ES. Both treatments were kept on pasture during the study.

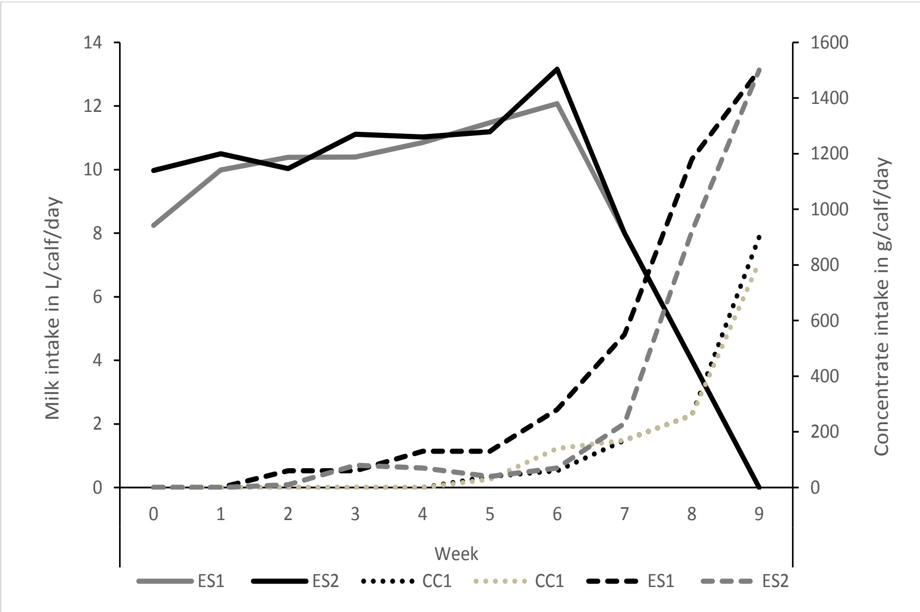
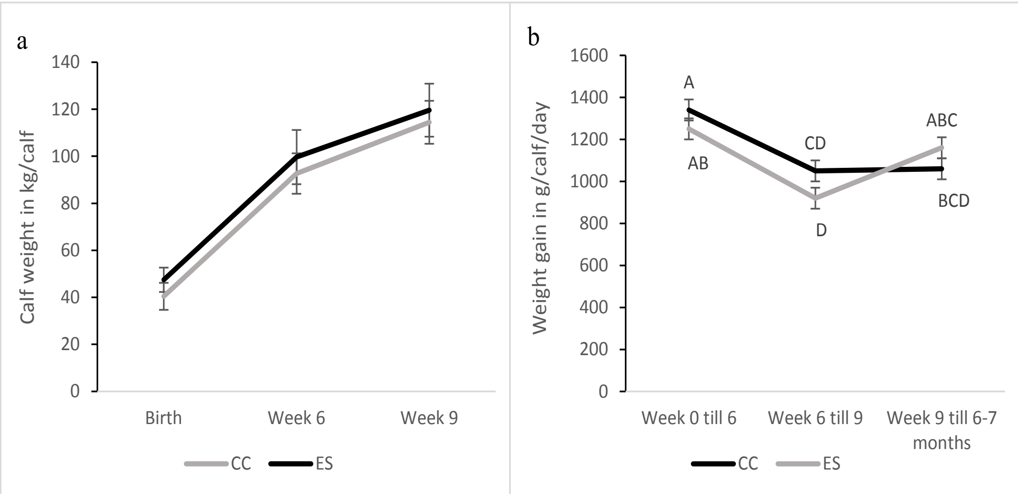


Figure 5a and b. a. Calf body weight (average ± SD) from birth till week 9 post-partum for pastured calves from the two treatments: Cow-calf contact (CC, n=10) and early separation (ES, n=10). b. Daily weight gain (mean ± SE) from birth till 6-7 months for the same treatments. Means that do not share a letter are significantly different interactions between treatment and period (P<0.005).



ISBN: 978-82-575-2110-3
ISSN: 1894-6402

Norwegian University
of Life Sciences

Postboks 5003
NO-1432 Ås, Norway
+47 67 23 00 00
www.nmbu.no

119343 / MEDIEHUSETANDVORD.NO