COMPARING COW-CALF CONTACT SYSTEMS

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AARHUS UNIVERSITY

Love as powerful
as your mother's for you
leaves it's own mark.

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List of Included Papers

Paper I

Bertelsen, M., Vaarst, M. Shaping cow-calf contact systems: Farmers' perspectives and choices behind a range of different cow-calf contact systems. *Resubmitted to Journal of Dairy Science (February 2023)*

Paper II

Bertelsen, M., Jensen, M. B. The behavior of calves reared with half-day contact to their dam. *Submitted to Journal of Dairy Science (February 2023)*

Paper III

Bertelsen, M., Jensen, M. B. Comparing weaning methods in dairy calves with different dam-contact levels. *Submitted to Journal of Dairy Science (February 2023)*

Paper IV

Bertelsen, M., Steinerová, K., Jensen, M. B. The effects of part-time dam-contact and stepwise weaning and separation on the voluntary human approach behaviour of dairy calves (2023). *Applied Animal Behaviour Science, https://doi.org/10.1016/j.applanim.2023.105871*

Preface

The present dissertation was submitted to the Graduate School of Technical Sciences (GSTS), Aarhus University in March 2023, to fulfil the requirements in the Ministerial Order for the degree of Doctor of Philosophy. The PhD project was part of the larger project *Cow'n'Calf* which was a collaboration between Innovation Centre for Organic Farming, Thise, Naturmælk, Merc Agro/Tru-test Scandinavia and Aarhus University. The project was financed by the Ministry of Food, Agriculture and Fisheries of Denmark, as part of the Organic RDD-4 programme, which is coordinated by the International Centre for Research in Organic Food Systems (ICROFS) in collaboration with GUDP. The funders had no role in study design, data collection, analysis, the decision to publish, or manuscript preparation. The dissertation is based on the research conducted from May 2019 to March 2023 at the Department of Veterinary and Animal Sciences at Aarhus University, Denmark. During the spring of 2022, I had the pleasure of visiting Cecilie Marie Mejdell and Julie Fønske Johnsen at the Norwegian Veterinary Institute in Ås, Norway, during a 3-week research mobility stay.

The dissertation is organised into twelve chapters, starting with a brief introduction to the broader relevance of the topic, a thorough background section leading up to the research questions, and an overview of the applied methods and materials. Then follows a summary of the main results from each of the conducted studies, as well as the four original research papers which offer in-depth methods, materials and results, discussions and conclusions. Next follows a collective discussion of the results, their implications and suggestions for future studies. The dissertation concludes by offering some final reflections and perspectives, before ending with an overall conclusion.

Author contributions

None of the presented work has been submitted for any other degree or professional qualification. According to the rules of GSTS, Aarhus University, elements of my qualifying exam are included in the present dissertation. Mette Vaarst (co-supervisor, project leader) and Margit Bak Jensen (main supervisor) were responsible for the acquisition of funding and project management. Planning, design and management of the conducted studies as well as data processing, interview transcription, and data analysis were performed by me under the supervision of Mette Vaarst and Margit Bak Jensen. Data collection was done by me, with assistance from students and technical staff. The writing of the four original research papers was done by me under the supervision of Mette Vaarst and Margit Bak Jensen. One research article is further co-authored by former master student Karolina Steinerová who performed a literature search and the initial draft of the methods and materials section. The present dissertation is my own and the assistance I have received has been duly acknowledged.

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I would also like to thank the rest of the project group of "Cow'n'Calf". I had the pleasure of collaborating with Anne Braad Kudahl, Lisbeth Mogensen, Jesper Lehman, Ove Nørregaard-Pedersen, Iben Alber Christiansen, Lone Prisak, and Anne Berg Olsen, and I thank you all for the ideas and discussions we have shared. A special thanks go to you, Ove (and Ove), my "on-farm buddies". You always brought good humour - and always appreciated it fittingly when I brought cake.

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This endeavour would not have been possible without the help of technical staff. Many thanks go to John Misa Obidah and Henrik Krogh Andersen for long, interesting conversations in the car, for gentle and thoughtful handling of the animals, and for taking the weight off my shoulders. Thanks should also go to Mads Ravn

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I would like to recognise the innovative and brave farmers involved in the project, both those who have been developing cow-calf contact systems on their own - thank you for sharing your stories and thoughts with me through the interviews - and to Østerlykke for trying out something completely new, with an open mind. The barn staff at DKC also deserves a big thank you for the collaboration. Camilla Juhl and Britta Muhlig deserve a special mention for always being positive and helpful.

It would not have been any fun without all of my colleagues in the behaviour, welfare and stress group. I thank you all for contributing to an enjoyable and safe work environment. Mona Lilian Vestbjerg Larsen deserves a special mention for mentoring end encouraging me ever since my bachelor's degree – *and* for the statistical advice. I would be remiss in not mentioning my fellow early-career colleagues Cecilie Kobek-Kjeldager, Guilherme Amorim Franchi, Kaitlin Wurtz, Heather Neave, Jeanet Winters, Sigga Nielsen, Lene Høeg Fuglsang-Damgaard, Emma Hvidtfeldt Jensen and Line Dinesen – thank you for all the talks, discussions, practise presentations, laughs and dances. Mathilde Coutant, we started our PhD journey together and it has been an absolute privilege to work, laugh and cry alongside you. I am so thrilled that you have found Denmark to be your home.

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Last, but absolutely not least; words cannot express my gratitude to my partner and soon-to-be husband Nicolaj. Thank you for everything you have done for us to reach this stage together – we managed an engagement, a house, a baby and a PhD for me during the last few years. You have been carrying the burden of two during these last stages of my studies and you made it look easy every step of the way with your unparalleled "can-do" attitude. The way you care for Birk and I means the world to me and even if I could, I would not have done this without you.

Summary

In the dairy sector, calves are commonly separated from the dam within 24 h of birth and reared artificially. This management system prevents both cows and calves from performing a range of natural and highly motivated behaviours. Cow-calf contact systems (CCC systems) where calves are reared by cows are starting to increase in numbers and may hold the potential to improve animal welfare in dairy farming. Research in CCC systems has focused on *dam-calf* contact, where each cow takes care of her own calf. However, *dam-calf* contact systems have several barriers to implementation such as reduced saleable milk, an increased weaning and separation response and a poorer human-animal relationship. Reducing the daily contact time between the cow and her calf or the use of foster cows, may overcome these barriers and be more feasible to implement in practice. However, little is known of how different CCC systems compare from the point of view of respectively the animals and the farmers. The present dissertation presents the results from a qualitative, semi-structured interview study with farmers who have CCC experience as well as an experimental study focusing on the effects of a specific version of CCC; half-day *dam-calf* contact.

In the interview study, farmers were asked about their motivation to establish a CCC system and the process leading to the current version of their CCC system. The interviewed farmers perceived CCC systems as flexible, easy to manage, and less labour-demanding. They also described CCC systems as more rational and natural. Due to economical considerations, some farmers chose a *foster cow* system which circumvented the barrier of decreased saleable milk while allowing for the opportunity to use potential cull cows as foster cows. Some farmers had chosen a *dam-calf* contact system based on aspects related to ethical responsibility. These farms all used half-day contact either to increase saleable milk or to have the opportunity of letting cows out to pasture without the calves. The farm's image as seen by the consumer was an important motivation for farmers with many on-farm visitors, while the farm's image in the eyes of the farming community may affect farmers' readiness to articulate welfare-related reasons for choosing a CCC system.

The experimental study investigated the effect of different daily durations of *dam-calf* contact and a stepwise weaning and separation strategy. A total of 72 dairy calves were allocated to one of three dam-contact treatments [Control (separated from dam

after 24h), Whole-day (housed with dam for 23 h/d), and Half-day (housed with dam for 10 h/d)]. Within each treatment, calves were allocated to one of two weaning treatments [Stepwise (weaning off milk at 8 weeks, dam-separation/pen change at 9 weeks) or Simultaneous (weaning off milk and dam-separation/pen change simultaneously at 9 weeks)]. Data on undisturbed home pen behaviour was recorded for 24 h using video when calves were on average 3, 5 and 7 weeks old. Data on weaning and separation were collected in experimental weeks 8 and 9 and summarised over the two weeks for analysis. Data on the human-animal relationship was recorded during a human approach test followed by an animal approach test conducted in an arena at 10 weeks of age. The results showed that Half-day calves spent less time suckling and received less grooming compared to Whole-day calves. Half-day calves were however faster to reunite with their dam when the cows returned from morning milking but were also more likely to suckle an alien cow, compared to Whole-day calves, indicating hunger. Half-day calves spent more time interacting with other calves and eating solid feeds, but this did not sufficiently prepare them better for separation from the dam and weaning off milk. Indeed, there was no difference between Whole-day and Half-day calves on the behavioural response to weaning and separation, but as expected, dam-reared calves reacted more strongly than the control group. Control calves had a higher average daily gain in the week after weaning than Whole-day calves, but Half-day calves were intermediate. Weaning and separation in a stepwise manner reduced the behavioural response of dam-reared calves by decreasing the number of high-pitched vocalisations. In the human-animal relationship test, Control calves were faster to approach and were more likely to come close to the test person than dam-reared calves, but this was only the case for calves weaned and separated in a stepwise manner. For calves who had been weaned and separated simultaneously, there was no effect of the contact treatments, except a higher frequency of vocalisations by dam-reared calves. This implies that controlling for the stress level related to weaning and separation from the dam is important when interpreting human-animal relationship tests.

In conclusion, CCC systems are shaped by a range of practical, economic, ethical and image-related factors and under present conditions, organic farmers in Denmark are likely to choose part-time or *foster cow* systems. Half-day contact allows much of the natural and highly motivated behaviours otherwise thwarted in artificial rearing systems. However, half-day contact did not improve weaning and separation compared to whole-day contact. Even with a stepwise weaning and separation strategy dam-reared calves still vocalised at high levels and experienced reduced growth compared to the artificially reared control group. Further advances are needed to sufficiently reduce the stress related to weaning and separation in cow-calf contact systems.

Sammendrag

I mælkeindustrien er det standard praksis at adskille ko og kalv fra hinanden inden for 24 timer. Den tidlige adskillelse forhindrer både køer og kalve i at udføre en række naturlige og stærkt motiverede adfærdsmønstre. Systemer med ko-kalv kontakt er begyndt at vinde frem og kan potentielt forbedre dyrevelfærden i mælkeproduktionen. Forskning i ko-kalv kontakt har fokuseret på *moderko-kalv* kontakt, hvor hver ko tager sig af sin egen kalv. *Moderko-kalv* kontakt har dog en række udfordringer når det kommer til implementering, så som reduceret mælk i tanken, en øget reaktion på fravænning og separation samt kalve, der er mere frygtsomme over for mennesker. En reduktion af den daglige kontakttid mellem ko og kalv, eller et ammetante system, kan måske overvinde disse udfordringer og gøre det mere realistisk at implementere ko-kalv kontakt. Der mangler dog viden om forskellige typer af ko-kalv kontakt set både fra dyrenes og landmændenes perspektiv. Denne afhandling præsenterer resultaterne fra et kvalitativt, semistruktureret interviewstudie med landmænd, som har erfaring med forskellige ko-kalv kontakt systemer samt et eksperimentelt stuide, der fokuserer på virkningerne af en bestemt type af ko-kalv kontakt: halvtids ko-kalv kontakt.

I interviewstudiet blev landmændene spurgt til deres motivation for at etablere ko-kalv kontakt og omkring processen, der førte til den nuværende version af deres system. De interviewede landmænd opfattede ko-kalv kontakt som mere fleksiblt og mindre krævende rent praktisk. De udtrykte også, at ko-kalv kontakt var mere rationelt og naturligt. På grund af økonomiske overvejelser havde nogle landmænd valgt et ammetante system, som omgik problemet med reduceret mælk i tanken, samt gav mulighed for at bruge udsætterkøer som ammetanter. Andre landmænd havde valgt *moderko-kalv* kontakt baseret på etiske aspekter. Gårde med *moderko-kalv* kontakt brugte alle halvtidskontakt, enten for at øge mængden af mælk i tanken eller for at have muligheden for at lade køerne græsse uden kalvene. For nogle landmænd var gårdens image, set fra forbrugerens synspunkt, en vigtig motivation. Det var især gældende for landmænd med mange besøgende på gården. Det tydede også på, at gårdens image, set fra landbrugssamfundets synspunkt, påvirkede landmændenes villighed til at formulere velfærdsrelaterede årsager til at vælge ko-kalv kontakt.

Det eksperimentelle studie undersøgte effekten af forskellige, daglige, længder af kontakt mellem ko og kalv og en trinvis fravænnings- og separationsstrategi. I alt blev 72 kalve fordelt på en af tre behandlinger [Kontrol (traditionel separation fra koen efter 24 timer), Fuldtid (kontakt med koen i 23 t/d) og Halvtid (kontakt med koen i 10 t/d)]. Inden for hver behandling blev kalvene fordelt på en af to fravænnings- og separationsstrategier [Trinvis (fravænning af mælk ved 8 uger, separation fra koen/miljøskifte ved 9 uger) eller Samtidig (fravænning af mælk og separation fra koen/miljøskifte samtidigt ved 9 uger)]. Data på adfærd i hjemmemiljøet blev registreret over 24 timer ved hjælp af video, da kalvene var 3, 5 og 7 uger gamle. Derefter blev data fra fravænnings- og separationsperioden indsamlet i henholdsvis uge 8 og 9. Kalvenes forhold til mennesker blev undersøgt i en arenatest da kalvene var 10 uger gamle. Resultaterne viste, at Halvtidskalve brugte mindre tid på at patte deres ko og modtog mindre maternel pleje, i forhold til Fuldtidskalve. Halvtidskalve var dog hurtigere til at genforene sig med deres ko, når køerne vendte tilbage fra morgenmalkning, men også mere tilbøjelige til at patte fra en fremmed ko, hvilket indikerer mere sult hos Halvtidskalve. I forhold til Fuldtidskalve, tilbragte Halvtidskalve mere tid på at interagere med andre kalve og åd mere foder. Der var ingen forskel i den adfærdsmæssige respons mellem Fuldtids- og Halvtidskalve ved fravænning og separation, men ko-kalv kalve reagerede generelt stærkere end Kontrolkalve. Kontrolkalve havde en højere gennemsnitlig daglig tilvækst i ugen efter fravænning end Fuldtidskalve, mens Halvtidskalve lå i mellem de to. En trinvis fravænning og separation reducerede responsen på fravænning og separation. Kontrolkalve var hurtigere til at tilgå testpersonen og var mere tilbøjelige til at komme tæt på, i testen af kalves forhold til mennesker. Dette var dog hovedsageligt tilfældet for kalve, der var fravænnet og separeret trinvist mens for kalve, der blev fravænnet og separeret samtidig, var der ingen effekt af ko-kalv kontakt, bortset fra en højere frekvens af vokaliseringer fra ko-kalv kalve. Det påpeger, at det er vigtigt at tage højde for stressniveauet når man fortolker på adfærdstests relateret til forholdet mellem mennesker og dyr.

Systemer med ko-kalv kontakt påvirkes af en række praktiske, økonomiske, etiske og image-relaterede faktorer. Under de nuværende forhold i mælkeindustrien, er det sandsynligt at økologiske landmænd i Danmark vil vælge halvtidskontakt eller ammetanter. Halvtidskontakt tillader de naturlige og stærkt motiverede adfærdsmønstre, der ellers forhindres ved tidlig fravænning, men i mindre grad end fuldtidskontakt. Halvtidskontakt forbedrede ikke stressresponsen ved fravænning og separation, i forhold til fuldtidskontakt. En trinvis fravænning og separation reducerede fravænnings- og separationsstress i nogen grad, men forskning med fokus på at reducere stressniveauet i forbindelse med fravænning og separation yderligere i ko-kalv kontakt systemer er fortsat nødvendigt.

Contents

Chapter 1

Introduction

Farm animal welfare is drawing still-increasing attention from society (Thompson, 2022; Thornton, 2010). For example, 82% of EU citizens interviewed for the Eurobarometer "Attitudes of Europeans towards Animal Welfare" in 2016 believed that the welfare of farmed animals should be improved and a growing number of citizens would like to be better informed on the husbandry practices in their respective countries (TNS opinion & social, 2016). Rossen et al. (2016) showed that more than half of German citizens asked deemed both castration without anaesthetisation, size of cage housing for hens, and keeping animals on slatted floors to be unacceptable in any situation. Further, they found that "Animal Welfare" and "Naturalness" ranked as the third and fourth most important food values, after food safety and taste (Rossen et al., 2016). The attention to animal welfare is also seen at a more institutional level with policymakers legislating and recommending improvements to animal welfare (Algers et al., 2009; Sykes, 2014). Likewise, the scientific community explores animal sentience and behaviour in the name of improving welfare (Bracke & Hopster, 2006; Lawrence et al., 2019; Webb et al., 2019). In other words, as a society, many of us are questioning aspects of animal husbandry and demanding improvements to the welfare of farm animals. Specifically, Denmark, the context in which this dissertation is written, was found among five European countries to have the highest awareness and sensitivity for the ethical side of animal welfare (Cembalo et al., 2016).

1.1 Animal Welfare in the Dairy Sector

Dairy farming is one type of animal husbandry practice which has received critique from citizens and consumers (e.g. Boaitey et al., 2022; Busch et al., 2017; Sirovica et al., 2022; Ventura et al., 2016; Weary & von Keyserlingk, 2017). Concerns for animal welfare include the lack of pasture access, tethering, dehorning, culling of male calves, and, the main focus of the present dissertation, the early separation of the cow and her calf within 12-24 h. The same concerns are found in the animal science community where researchers have pointed to the welfare issues of dairy cows and their calves under current management conditions, conventional as well as organic, and researched alternatives aimed at improving animal welfare, though in many cases best-practice, is still not implemented (see review by Duval et al., 2020). The early separation of the cow and her calf has received much scientific attention, especially in the past years (reviewed by Brombin et al., 2019; Johnsen et al., 2016; Meagher et al., 2019; Newberry & Swanson, 2008), but alternative rearing practices are still an area much less extensively researched than the current standard practice of artificial calf rearing. It is important for the dairy sector to respond to the concerns of citizens to ensure the future feasibility of the sector (reviewed by Weary & von Keyserlingk, 2017), as well as it, is important for research to further develop methods to not only improve animal welfare but also find ways to effectively implement the knowledge on-farm.

1.2 Animal Welfare

But what is animal welfare? Animal welfare has often been conceptualised as a three-pillar concept including health, affective states and natural living (Fraser, 2008), each pillar weighing differently depending on the cultural context driving ethical judgement (as discussed by Grethe, 2017). Increasingly, science has been emphasising the importance of affective states for animal welfare, which encompasses the animal's own experience of their well-being as the effects of both physical and mental health (e.g. an early and still suggestive Duncan (2005) and a more recent and direct Webb et al. (2019)). Especially the opportunity to not only avoid negative affective states but also experience positive affective states has been deemed important for good animal welfare (Lawrence et al., 2019). Thus, the present dissertation uses "The 2020 Five Domains Model for Animal Welfare Assessment and Monitoring" (Mellor et al., 2020) approach to assess animal welfare, with the aim to ultimately recognise that the resulting affective state of an animal is the defining measure of the animal's welfare state, see Figure 1.1.

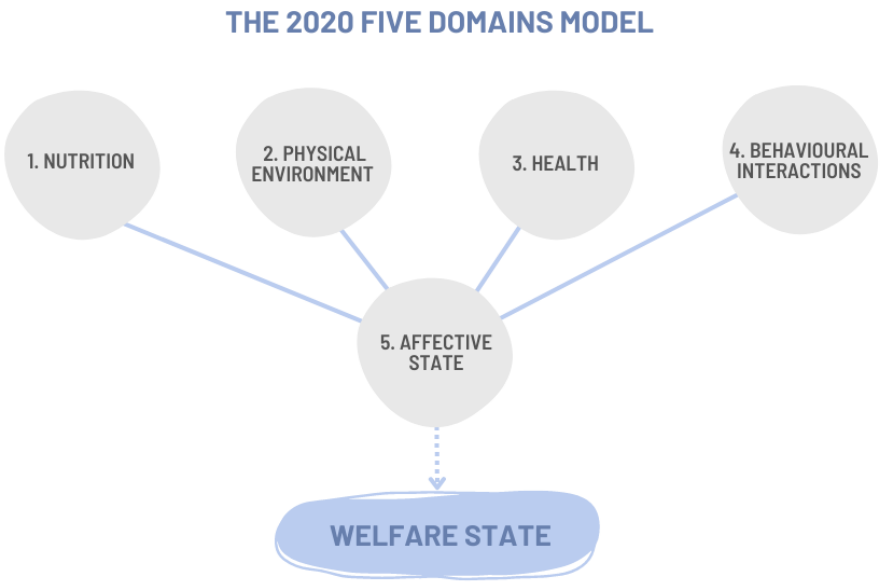

Figure 1.1: The 2020 Five Domains Model for Animal Welfare Assessment and Monitoring. Adapted from Mellor et al. (2020).

In this framework, the affective state is the result of four domains: 1) Nutrition, such as the appropriate type and amount of feed, 2) Physical environment, such as appropriate resting opportunities, 3) Health, such as the presence or absence of disease, and 4) Behavioural interactions, such as appropriate environment-to-animal, animal-to-animal or human-to-animal activity (see Mellor et al., 2020, for examples on the effect on the affective state and the resulting welfare).

1.3 Cow-Calf Contact

The present dissertation focuses on allowing cow-calf contact beyond the standard practice of 12-24 h, with the ultimate aim of improving the welfare of both dairy cows and calves. Using behavioural and social science approaches I seek to answer questions related to the implementation of different versions of cow-calf contact systems and the effects on production, management, and animal welfare. The main focus is on the calf, but perspectives on the cow are included when there is data to support doing so.

Chapter 2

Background

In this chapter, I provide a general introduction to the current standard practices of calf-rearing, focusing on both advantages and disadvantages. Subsequently, I review the benefits of CCC and the associated challenges and barriers as perceived by farmers. The subsequent section examines how farmers choose various versions of CCC systems to address these challenges, followed by a review of experimental research conducted on different versions of CCC systems. Finally, the chapter concludes with a more detailed examination of half-day contact systems and identifies knowledge gaps related to this version of CCC.

2.1 Why is Early Separation Standard Practice?

The separation of the cow and her calf within 24 h of birth ("early separation") and rearing the calf with either milk or milk replacer from buckets, bottles or automatic milk feeding systems ("artificial rearing") is the standard practice in high-income countries (reviewed by Cantor et al., 2019). Management methods for artificial rearing are extensively researched and practised, generating vast amounts of experience and recommendations for housing, feeding and treatment of disease. The reasoning and potential benefits of this practice cover a range of economic and welfare-related aspects which will be outlined below (reviewed by Flower & Weary, 2003).

Economic reasons for standard calf-rearing practice include controlling the amount of milk ingested by the calf, which traditionally has corresponded to ∼10% of calf body weight (reviewed by Khan et al., 2011), compared to the 20-30% ingested by young calves suckling freely on their dam (Barth, 2020; Roth et al., 2009). Further, milk let down in the milking parlour can be impaired if the calf is allowed to suckle, probably due to hormonal modulation by the calf's presence (Mendoza et al., 2010;

Mutua & Haskell, 2022; Tancin et al., 2001; Zipp et al., 2018). Artificial rearing thus allows for more saleable milk. At the same time, restricting calf milk intake promotes an earlier increase in solid feed intake which is often a cheaper and less labour-intensive way to feed calves (Palczynski et al., 2020). The removal of the calf is also reported to shorten the calving interval by a faster return to oestrus by the dam (reviewed by Stevenson et al., 1997), which has often been described as a desired efficiency measure.

Related to both economy and welfare, physical health ("health" unless otherwise specified, understood as free of detectable disease) is another reason for following standard practices of early separation and artificial rearing. As the calf is most often either individually housed or pair housed in specially designed crates, huts, or pens, the levels of pathogens can be controlled through rigorous hygiene and limited contact between peers (Johnson et al., 2017; Svensson & Liberg, 2006). Moreover, the classical milk feeding regime of two daily feedings (morning and evening) facilitates easy recognition-by-comparison of calves showing sickness behaviours such as not eating or not getting up, as calves are generally highly motivated to ingest the provided milk.

Another reason for applying early separation, which refers more heavily to welfare, is the increased stress response to separation (see Text Box "Definition: Stress" on Page 7) for both the cow and her calf, if they have been together for a longer time. For example both Chua et al. (2002) and Flower and Weary (2001) found that 4 days vs. 1 h/6 h and 2 weeks vs 1 day respectively, increased the stress response. The separation leads to a strong behavioural response, manifested as reinstatement behaviours such as vocalisations, pacing and standing with the head out of the pen (Chua et al., 2002; Nicolao et al., 2022; Wenker et al., 2022), as well as reduced calf weight gain (Fröberg et al., 2011; Johnsen et al., 2015a). Not much is known about the natural weaning age in cattle, especially not for *Bos Taurus*. However, the natural weaning process is expected to be earliest at 8 months of age (Reinhardt & Reinhardt, 1981b; Veissier et al., 1990), and to be a gradual process where the cow produces less milk and eventually refuses the calf to suckle, but continues to provide maternal care (Reinhardt & Reinhardt, 1981a; Veissier et al., 1990). Present dairy systems usually wean off milk at approximately 12 weeks of age for organic dairy systems and 8 weeks of age for conventional, and therefore a substantial behavioural response to weaning and separation is to be expected since cows and calves are strongly bonded and the calf is drinking large (12-15 L according to Barth (2020)) amounts of milk.

Definition: Stress

In this dissertation, stress is defined as the initially adaptive, collective physiological, psychological and behavioural reaction in response to a perceived challenge (Moberg, 2000), coordinated by the stress system mediators (Joëls et al., 2007) which might be maladaptive if too frequent or prolonged. Both adaptive and maladaptive stress can cause impaired welfare when negatively affecting the affective state (Mendl et al., 2010) of the animal.

The human-animal relationship ("HAR"), important for animal welfare e.g. by reducing stress during handling (reviewed by Mota-Rojas et al., 2020), may be impaired if calves are not reared artificially and by that do not experience close human contact related to daily feeding (though studies are needed on the effect of automatic milk feeders on the HAR as this rearing system also may reduce close human contact). Studies have shown increased avoidance distances in calves reared by their dam (Webb et al., 2022), though the difference to artificially reared calves may no longer be evident with age (Waiblinger et al., 2020b). The difference in the HAR observed between dam-reared and artificially-reared calves could be explained by two main factors. Firstly, dam-reared calves may not associate humans with milk provision, a factor known to enhance HAR according to Jago et al. (1999). Secondly, the presence of the dam may inhibit the socialisation of the calves to humans, as suggested by Krohn et al. (2003).

2.2 Challenges of the Standard Practice

Referring to the previous section, one may be tempted to ask why we should bother with alternatives to early separation and artificial rearing. However, early separation and artificial rearing have been criticised from an animal welfare perspective.

The behavioural reaction to separation is also present upon early rather than later separation, even though prevention of a fully formed maternal-offspring bond does appear to decrease the response to separation (Chua et al., 2002; Flower & Weary, 2001). Indeed, even though calves showed little response immediately after early separation (separation within 24 h of birth) they did show an increase in activity, searching behaviour (head out of the pen) and vocalisations 9-24 h after separation (Flower & Weary, 2001), indicative of reinstatement behaviour. This display of

reinstatement motivation was seen even though calves had been fed milk from a bucket which should prevent a hunger-related response. The calves' delayed response to separation is in accordance with the behaviour of newborn calves who would, when cover is available, hide quietly for the first 4-8 days after birth and thus, not expected to react to shorter periods of social isolation (Lidfors et al., 1994; Vitale et al., 1986).

After the early separation, common standard practice involves individual housing of each calf, often throughout the milk feeding period (Cantor et al., 2019). Research has found that for a range of measures, the welfare of individually housed calves is impaired when compared to pair or group housing with other calves (reviewed by Costa et al., 2016) and that calves are motivated to be with other calves (Ede et al., 2022). This is not surprising considering cattle are highly gregarious and social animals (Reinhardt & Reinhardt, 1981a, 1981b; Vitale et al., 1986).

Early separation from the dam followed by individual housing has also been linked to the modulation of both cognitive and social skills (see reviews by Cantor et al., 2019; Costa et al., 2016). Examples are that individually housed calves performed worse than socially housed calves in a reversal-learning task at approx. 45 days of age (Meagher et al., 2015) and were more fearful or reactive in a novel environment (De Paula Vieira et al., 2012a), during restraint (Duve et al., 2012) or when confronted with an unfamiliar calf (Jensen & Larsen, 2014).

Common feeding levels in artificial rearing (4-6 L) are much lower than *ad libitum* intake (10-15 L) (reviewed by Khan et al., 2011), and it has been shown that calves reared using standard practice show signs of hunger such as vocalisations (Thomas et al., 2001) and restless behaviour in the attempt to achieve more milk (De Paula Vieira et al., 2008).

In summary, both social isolation and hunger are welfare concerns for calves reared under standard practice. However, both social isolation and hunger may be alleviated by respectively pair or group housing calves and feeding adequate amounts of milk. Nonetheless, even calves receiving high milk volumes and housed with social partners perform abnormal behaviour such as sucking on each other ("cross-sucking") (Fröberg & Lidfors, 2009; Veissier et al., 2013). Abnormal behaviours are believed to be a result of thwarting the performance of behaviours that the animal is motivated to perform irrespective of the functional consequence (see Text Box "Definition: Behavioural Needs" on Page 9) and are indicative of impaired welfare.

Definition: Behavioural Needs

The notion of behavioural needs and its relation to the performance of abnormal behaviour has been developed and discussed for many years, see for examples Dawkins (1988), Duncan (1998), Friend (1989), and Hughes and Duncan (1988). In this dissertation, the definition of a behavioural need is based on the suggestions of Jensen and Pedersen (2008):

> *"A behavioural pattern represents a behavioural need when the animal is highly motivated to perform the behaviour, and that lack of suitable opportunity to perform this behaviour results in abnormal behaviour and stress responses."*

Studies have shown that suckling the dam for even short, daily durations reduces cross-sucking to low levels (Bieber et al., 2022; Margerison et al., 2003; Roth et al., 2009). This suggests that calves are highly motivated to suckle on their dam, and experience stress in the form of frustration when not able to perform this behaviour. Suckling the dam is one element of natural behaviour that dairy calves cannot perform when permanently separated from their dam, but other natural behavioural elements prevented by separation are the dam and calf grooming each other, communicating, playing together and spending time in close contact while resting and feeding (reviewed by Newberry & Swanson, 2008). As for suckling, not being able to perform these natural behaviours may also lead to frustration if they are highly motivated (Bracke & Hopster, 2006) but we need more research to understand whether all or which elements are important to the welfare of calves.

2.3 What are the Benefits of Cow-Calf Contact?

The previous section highlighted a range of challenges to the current standard practice of early separation and artificial rearing. In this section, I will present an overview of the advantages of an alternative; rearing dairy calves with cows ("cow-calf contact" or "CCC").

The repertoire of behavioural interactions between a cow and her calf mentioned in the previous section (suckling, grooming, communicating, playing together and spending time in close contact, resting and feeding together) holds promise to not only avoid frustration if allowed to be performed but, as argued by Mellor (2015) and

Rault (2019), induce positive emotions leading to an overall more positive affective state. Indeed, being licked and suckling/nursing releases high levels of oxytocin in cows and calves (Lupoli et al., 2001; Tancin et al., 2001), which illustrates one of the physiological aspects of positive, social interactions between mother and offspring.

With regard to social skills, some studies indicate that CCC may modulate these skills in a way that can improve welfare in a farm setting. Calves reared with dam-contact ("dam-reared") are thought to learn social skills through interactions with the dam (Meagher et al., 2019). Improved social skills may result in appropriate responses to threats and affiliative behaviour and therefore ensure that calves receive less aggression (Buchli et al., 2017; Wagner et al., 2012). Stěhulová et al. (2008) showed that 3-week-old calves, that were separated after 7 days of contact with the cow and were introduced to a small group of other calves, exhibited increased levels of resting on the subsequent day compared to calves separated after 1 day of contact to the dam, indicating a better ability to cope with a novel, social situation. Cows that were dam-reared as calves also showed longer lying durations 24-48 h after being grouped with the main milking herd, at the onset of first lactation (Zipp & Knierim, 2020), again interpreted as better coping with the situation.

Allowing CCC thus seems like a powerful management tool to improve the welfare of dairy calves in relation to behavioural interactions (Domain 4, Figure 1.1) by both reducing frustrations related to the thwarting of (potential) behavioural needs, while allowing for positive affective states based on social interactions with the dam, and improving competences.

In terms of the nutritional and health domains (Domain 1 and 3, Figure 1.1), dam-reared calves are often reported to have high weight gains (reviewed by Johnsen et al., 2016; Meagher et al., 2019), yet, this is most likely due to the high milk intake and not the CCC *per se*. If the cow has high-quality colostrum and the calf is ensured to suckle well and early, we may expect beneficial health effects of the continuous intake of colostrum and transition milk (reviewed by Godden et al., 2019). The recent, comprehensive review on health in CCC systems by Beaver et al. (2019), further backed up by Lorenz (2021), concludes that there is no consistent evidence for health to be worse in systems with CCC compared to artificial rearing, but also highlights the variability in results regarding health effects and the need for studies focusing on this aspect.

2.4 Challenges of Cow-Calf Contact

In summary, the above section indicates that CCC has the potential to improve animal welfare. However, echoing Section 2.1 covering the reasons for the widespread standard practice of early separation and artificial rearing, there are challenges to overcome if CCC is to ensure good welfare and be feasible in a production setting. It is thus relevant to develop knowledge on both economic, practical and welfare-related concerns to implementing CCC. Interview studies with farmers provide us with knowledge of barriers to CCC implementation while taking into consideration everyday management and the uniqueness of farms and farmers. The barriers of CCC systems as identified by farmers will be summarized in this section.

2.4.1 Main Barriers to CCC as Identified by Farmers

Combining the information from four identified questionnaires and interview studies concerning CCC (Eriksson et al., 2022; Hansen et al., 2023; Neave et al., 2022; Vaarst et al., 2020), three main barriers to implementation of CCC have been identified by farmers (both who have and who do not have CCC) which will be presented below (see Figure 2.1).

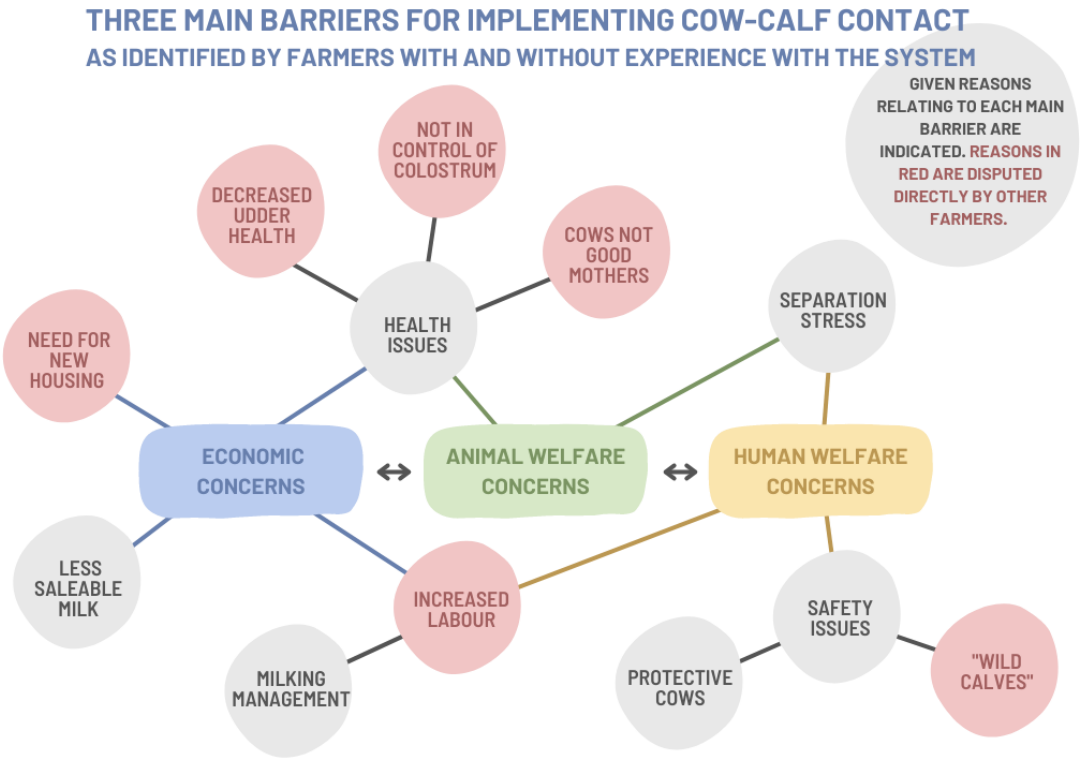

Figure 2.1: Schematic presentation of three main barriers for implementation of cow-calf contact systems based on the studies by Eriksson et al. (2022), Hansen et al. (2023), Neave et al. (2022), and Vaarst et al. (2020). Idea for figure from Neave et al. (2022).

2.4.2 Economic Concerns

What appears to be the most common economic concern is an expected decrease in saleable milk in *dam-calf* contact systems, due to calves suckling large amounts. However, some farmers argue that increased calf growth, fewer labour costs and improved health makes up for the decrease in saleable milk (Hansen et al., 2023). Some farmers described that they used part-time contact systems to reduce the amount of milk the calf drank (Neave et al., 2022).

Another major issue, repeatedly mentioned across studies, is the need to spend money on improving housing and fencing to be appropriate for calves and cows at the same time (Hansen et al., 2023; Neave et al., 2022; Vaarst et al., 2020). However, this is contrasting interestingly against the surveyed Norwegian CCC farmers in the study by Hansen et al. (2023), who mostly reported either making no investment (14 out of 31) or quite low investments (up to 5000 USD, 12 out of 31) to adapt their system to CCC.

Increased labour was another economic concern. Increased labour was mentioned to be expected related to milking management due to cows being harder to fetch or calves mixing in with the cows in the milking parlour (Hansen et al., 2023; Neave et al., 2022). However, some farmers mentioned that they spent equal to or less time on calf-care after changing to CCC (Eriksson et al., 2022; Vaarst et al., 2020). Eriksson et al. (2022) specifically found that 22 out of 104 farmers with CCC systems stated they spent less time on calf rearing and 77 the same amount of time across versions of CCC contact.

Farmers also mentioned health issues, which will also impact farm economy. Health issues were expected to rise from not being in control of colostrum feeding (Neave et al., 2022) (though it should be noted that this is a choice, one can have CCC and provide colostrum artificially or by assisted suckling, but most farmers did not artificially feed colostrum in the Eriksson et al. (2022) study (96 out of 104 did not)). The New Zealand farmers also expressed concern that modern cows were not good mothers (Neave et al., 2022). The mothering abilities were, however, directly mentioned by others as a non-issue, with farmers stating that cows took good care of their calves (Neave et al., 2022) and one way to ensure good mothering that was been suggested by farmers was to extend the 'alone time' after calving (Vaarst et al., 2020). Some farmers also expected increased issues with mastitis (Neave et al., 2022), but others farmers, with CCC, specifically addressed CCC resulted in fewer issues with post-partum disease such as mastitis or metritis (Eriksson et al., 2022; Neave et al., 2022; Vaarst et al., 2020). If calves are born on pasture then lack of shelter was another mentioned risk for health issues (Neave et al., 2022).

2.4.3 Animal Welfare Concerns

The health concerns mentioned above does not only relate to the economic barrier but also feeds into a barrier related to the welfare of the animals. Some farmers thus mention a concern for the health of especially calves, in relation to ensuring good welfare through good physical functioning (Hansen et al., 2023; Neave et al., 2022). On the other hand, other farmers, who practice CCC, see improved calf health as a benefit of their system (Eriksson et al., 2022; Hansen et al., 2023; Vaarst et al., 2020). Separation stress is another concern identified by both farmers with and without CCC experience, and which causes major concern. Indeed, separation stress was by far the most common reason (54% gave this reason) for Norwegian farmers to discontinue CCC after trying it out (Hansen et al., 2023). Nonetheless, Hansen et al. (2023) concludes that their findings indicate that CCC systems are mainly adopted by farmers who have a special interest in animal welfare. There is an interesting discrepancy, in the mentioned studies, that animal welfare is mentioned as both a main reason to have, and not to have CCC.

2.4.4 Human Welfare Concerns

Separation stress was also identified as a concern for human welfare, as it affects staff well-being to experience the cows' and calves' reaction to separation (Neave et al., 2022). The expected increased labour, by some farmers, is also mentioned as stress-inducing (Neave et al., 2022) and a decrease in the human-animal relationship resulting in wilder calves are mentioned as a safety issue, along with cows being protective of calves (Hansen et al., 2023; Neave et al., 2022).

2.4.5 Understanding Farmers Management Choices

In multiple areas of the above-mentioned studies, we are seeing discrepancies between farmers, possibly driven by differences in both their larger farm environment, the specific farm and their own personal experiences and perspectives. Thus, more in-depth information is needed to be able to correctly extend knowledge to the farmers who already have CCC on how to manage their system best, but also to inform farmers considering the system. By better understanding the reasoning behind the specific management choices made, we can both focus future research and better apply existing knowledge in a way fitting to the individual farm, in the overall setting of that farm.

2.5 Management Choices for Cow-Calf Contact

In order to address the challenges and barriers mentioned in Section 2.4, one approach is to investigate the effect of different strategic management choices, which may provide some solutions. The development of management methods which address the mentioned challenges and potentially solve some of them have already started among farmers. Indeed, interviews with Nordic farmers show that currently, they are implementing a wide variety of CCC systems on their farms (Hansen et al., 2023; Vaarst et al., 2020). Scientific research is also exploring a range of different CCC systems (Meagher et al., 2019). Before examining different versions of CCC systems both in practice and research, I would like to shortly introduce some terminology on different CCC systems (see Text Box "Terminology" on Page 15 and Figure 2.2).

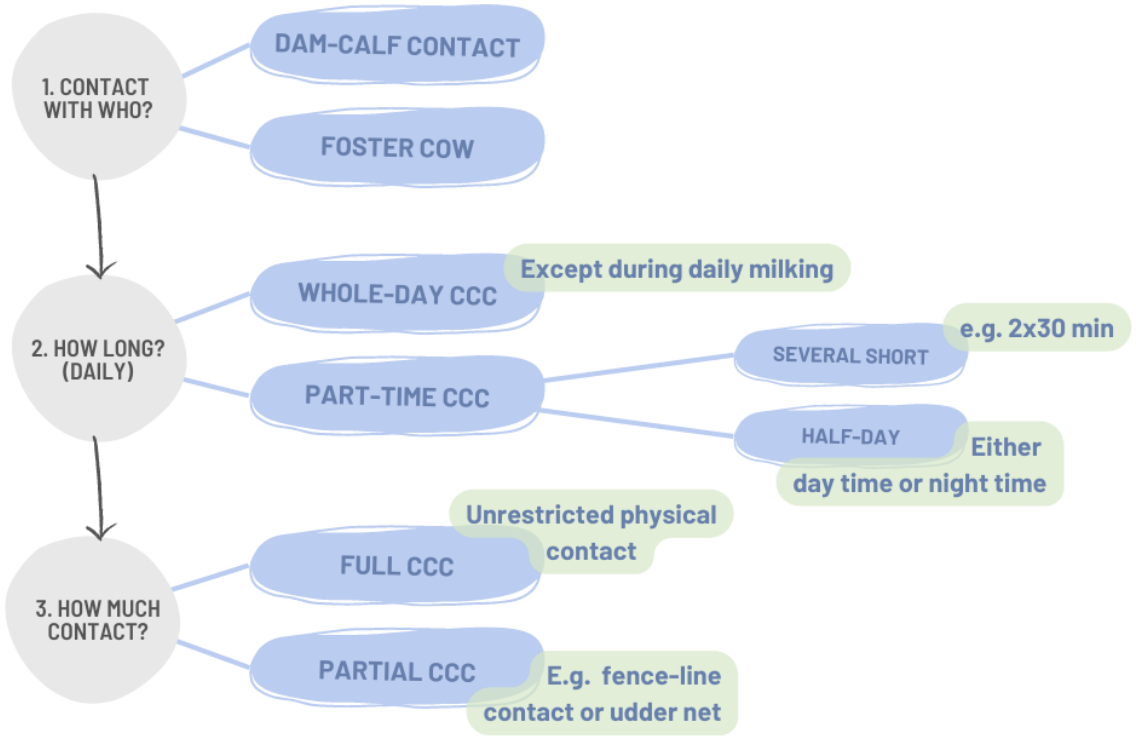

Figure 2.2: Overview of terminology related to cow-calf contact systems. See Sirovnik et al. (2020).

Terminology

Cow-calf contact ("CCC") is used generally as an umbrella term, covering all types of contact between a calf and any cow (see Figure 2.2). So far, the focus of this chapter has thus been on the specific type of CCC: *dam-calf* contact. However, CCC can also imply contact with a foster cow. Further, the type of contact can vary according to the daily duration of contact as well as the type of physical contact. In principle, a CCC system can be organised with a combination of any of the mentioned "subsystems" (blue shapes in Figure 2.2), however, some combinations are more used than others as can be seen in Section 2.5.1.

2.5.1 CCC Systems Implemented on Farms

CCC is becoming increasingly common but is still a minor system in high-income countries. Not much is known about the actual number of farms with CCC and which type of CCC they apply, but recent studies are starting to draw a picture of CCC in some European and Nordic countries.

A recent questionnaire study from Norway indicated that ∼3% of Norwegian farms have CCC for more than two weeks and ∼15% either want to have or are planning to have CCC in the future. Neave et al. (2022) stated that, to their knowledge, a total of 10 farms in New Zealand out of 11.179 had a CCC system with more than 48 h of *dam-calf* contact. Eriksson et al. (2022) investigated CCC defined as contact for more than 7 days, in each of the involved researchers' countries and identified CCC farms in Austria, France, Germany, Italy, Sweden, and Switzerland, but did not find any farms with CCC in Poland. CCC is also known to be practised in the Netherlands and Denmark (Vaarst et al., 2020), the UK (Thompson, 2022), Switzerland (Bisang et al., 2022) and the US (at least if defined as merely more than 24 h of contact (Pempek et al., 2017)). Most farms with CCC changed away from artificial rearing quite recently, e.g. in the study by Eriksson et al. (2022) the majority of farms, except in Italy, had made the change within the last 9 years and in a study by Constancis et al. (2022), on *foster cow* systems in France, involved farms had changed to CCC after 2010.

Studies inquiring into CCC have been met with a wealth of different versions of CCC systems, as mentioned by Eriksson et al. (2022), Hansen et al. (2023), and Vaarst et al. (2020). In the before mentioned terminology paper by Sirovnik et al. (2020)

they list the many ways in which CCC systems can differ, also beyond the already mentioned choices regarding who the calf has contact to, for how long daily and with how much contact (see Figure 2.2). Other aspects which differ between systems are in terms of shared resources, (e.g. if the cow and calf are eating and lying the same places), in terms of the time until permanent separation, (e.g. the whole milk feeding period or not) and in terms of the weaning and separation process, (e.g. gradual separation which implies decreasing the daily amount of CCC or partial separation where a fence-line or nose flap reduces the opportunity to suckle (Sirovnik et al., 2020). Interviews and questionnaires illustrates that on top of the above mentioned complexity in choices related to CCC systems, farmers use combinations of different systems, e.g. starting with *dam-calf* contact and then moving the calves to foster cows (Vaarst et al., 2020) or artificially rearing the calves for a period before bonding them to foster cows (Constancis et al., 2022). Lastly, farms differ greatly on whether all calves or only replacement heifers are reared in the CCC system (Eriksson et al., 2022; Vaarst et al., 2020).

Again, there is little knowledge on how the distribution between the different versions of CCC, but in the study by Eriksson et al. (2022), who surveyed 104 European farmers with CCC systems, approximately one-third was *dam-calf* contact systems, one-third *hybrid* systems, 23 were initially with *dam-calf* contact but then artificially reared for the remainder of the milk feeding period, 10 were *foster cow* systems and the remaining 3 farms manually fed the calves first and then paired them with foster cows. Approximately half had whole-day contact and 37 had several short periods of contact around milking while five had half-day contact either day or night (Eriksson et al., 2022).

Overall, the available literature illustrates that CCC systems can be implemented and run on very different types of farms both in regard to existing infrastructure and the purposes of CCC. However, it is further interesting to know which barriers guide the decision to have CCC or which version of CCC to manage.

2.5.2 CCC Systems in Research

The diverse and sometimes conflicting perspectives of farmers mentioned in the above section not only highlight the need to better understand what is shaping current implementations of CCC but also that research is needed in several areas relating to different management choices. This section will summarize the current knowledge from experimental studies on the most extensively researched versions of CCC systems.

Dam-Calf Contact — Whole-Day — Full Contact

Allowing full, whole-day, *dam-calf* contact throughout the milk-feeding period while milking cows twice a day, can be seen as the closest-to-natural version of CCC in a dairy context. This system allows cows and calves to maintain the mother-offspring bond and choose when, where, and how often to interact. Although only a few studies have reported on 24 h time budgets, the number of daily suckling bouts has been reported to range from four to nine (Fröberg & Lidfors, 2009; Reinhardt & Reinhardt, 1981b) and daily suckling duration is estimateed to be around 37-43 min (Fröberg & Lidfors, 2009). During hours with light (04:00-22:00) Wenker et al. (2021) observed that cows and calves spent approximately 11% of the time standing within 1 meter of each other.

This system generally results in a high milk intake, thus resulting high average daily gains (ADG) (Johnsen et al., 2021a; Roth et al., 2009). However, when compared to an artificially reared control group, this type of CCC system is heavily influenced by challenges mentioned in Section 2.4, such as a decrease in saleable milk (Barth, 2020; Wenker et al., 2022; Zipp et al., 2018), partly due to poor milk let-down (De Passille, 2001; Krohn et al., 2001) and an intense behavioural reaction to weaning and separation (Fröberg & Lidfors, 2009; Johnsen, 2015; Johnsen et al., 2015c), probably partly due to a low pre-weaning solid feed intake (Fröberg et al., 2011; Fröberg & Lidfors, 2009; Margerison et al., 2002).

Dam-Calf Contact — Whole-Day — Partial Contact

Partial whole-day contact allows for some level of physical, visual and olfactory contact between the calf and its dam, which potentially provides the expected benefits of maternal care that are not solely related to suckling. The primary objective of this system is to avoid suckling while still allowing other forms of contact. Although this system has not been extensively studied, Wenker et al. (2022) studied the use of ”cuddle boxes”, a specific type of fence-line contact that allowed cows to access their calves and engage in grooming, but without suckling. Their results indicated that, although dams initially displayed similar levels of close contact and grooming of their calves as dams with full-contact, the interactions waned over the milk feeding period, in comparison to the full-contact group (Wenker et al., 2020). The sample size in each treatment combination was small, thus warranting careful interpretation. Nonetheless, calves with partial contact exhibited less reaction at separation from the dam than calves with full contact (Wenker et al., 2022).

An alternative option that allows for more free interactions is the use of udder nets or nose flaps, both designed to prevent suckling. Duve et al. (2012) used udder nets and found that even though calves were fed milk in teat buckets they showed a poorer human-animal relationship than calves with no dam contact. However, calves that were reared with the dam showed less struggling behaviour during restraint than individually housed calves. Duve et al. (2012) also noted that calves with dam contact had very low concentrate intake levels, even though they had no access to the dam's milk. Whether this was due to calves instead eating TMR along with the cows was not stated.

Nose flaps have been associated with nasal sores (Bisang et al., 2022), making prolonged insertion unfeasible. In general, the use of nose flaps has been aimed at initiating weaning off milk before separation from the dam rather than a permanent rearing system (e.g. Enríquez et al., 2010).

Dam-Calf Contact — Part-Time: Half-Day — Full Contact

Half-day contact, either during day or night hours, is a system which has received scientific interest. Veissier et al. (2013) were the first to study this system and also compared it to whole-day contact, though each treatment was applied in one of two consecutive years. They allowed daytime contact with once-a-day milking and reported similar suckling duration (based on 10min scan sampling during day hours, which may over- or underestimate the true suckling duration) for half-day and whole-day contact. However, differences in response variables for the artificially reared control groups between years indicate that results should be interpreted with caution between the two years. Furthermore, since observations were only carried out during the day, the authors discuss that the duration of suckling for whole-day calves may have been underestimated, as they likely also suckled during the night. Half-day calves spent more time eating solids than whole-day before weaning and had somewhat improved weight gains at weaning compared to whole-day, according to the authors' discussion (data not shown).

Johnsen et al. (2015a) also investigated half-day contact, either in combination with an automatic milk feeder or without (calf semi-dependent on the dam or fully dependent on the dam) to see the effect of nutritional dependency at weaning. They found that semi-dependent calves used the opportunity for supplementary milk very little (less than 1.5 L/d) during the suckling period, even though they were separated throughout the day hours, indicating a preference for the dam. However, when separated from the dam, they started using the milk feeder which allowed them to maintain better post-separation weight gain than the dependent group. Cows

yielded less milk during the suckling period with no difference between dependent and semi-dependent but their lactation yield was not different from non-suckled cows.

A recent study by Nicolao et al. (2022) found that during the first 8 weeks of lactation, half-day contact (day time) resulted in 42% lower milk yields than control cows, who were not suckled. They noted that cows yielded better at the morning milking after the nightly separation than the afternoon milking, which is comparable to a similar treatment in the study by Barth (2020). A week after weaning (approximately 14 weeks of lactation) half-day cows reached control milk yield levels (Nicolao et al., 2022). At weaning and separation, Nicolao et al. (2022) found that half-day calves were vocalising more on day 1 than control calves, but levels were similar after 2 and 4 days. However, on day seven, 43% of half-day calves were still vocalising during observations while only 20% of control calves did.

Roadknight et al. (2022) compared whole-day contact to half-day contact focusing on any potential stress related to the repeated, longer, separation which in this study was during the day for half-day calves and cows while whole-day cows were only away to be milked twice daily. The animals were followed for 10 days, starting approximately at one week of age. Calves on both treatments had similar weights but half-day calves suckled more during the period just before cows were taken away for the separation period and again when they returned. There was no difference in cow milk cortisol or rumination times between half-day and whole-day but half-day cows were more restless in the milking parlour during the afternoon milking, before expected reuniting with the calves.

Dam-Calf Contact — Part-Time: Half-Day — Partial Contact

In the study by Johnsen et al. (2018) they included a treatment group which had half-day contact but in this case, was prevented from suckling by udder nets and obtained all their daily milk from an automatic milk feeder. They showed that even with no suckling and half-day contact the cow-calf pairs formed bonds, but they did react less at weaning and separation compared to calves that had the opportunity to suckle. Focusing on cognitive skills Meagher et al. (2015), found that calves reared with half-day contact and udder nets preventing nursing performed better at a reversal-learning task than individually reared calves, however, at comparable levels to group-housed calves. The same calves were utilised for a judgement bias test at the time of separation, showing that indeed, calves with no nutritional dependency of the dam and half-day contact still had negative judgement bias at separation at levels similar to that shown by calves experiencing pain after dehorning (Daros et

al., 2014). However, Wenker et al. (2020) found in a similar setup with half-day contact and partial contact, using udder nets, that cows were less motivated to push through an increasingly heavier push gate to access their calf, compared to cows who did suckle their calves.

Dam-Calf Contact — Part-Time: Several Short — Full Contact

Restricted suckling systems with several short meetings during the day are more common in tropical areas where *Bos Indicus* is the favoured subspecies of cattle, but is also practised in the Nordic countries (reviewed by Johnsen et al., 2016). Suckling periods can vary in daily number and duration, typically twice a day for 15-120 min (Passille et al., 2008; Roth et al., 2009), while cow and calf are separate for the rest of the day. Accordingly, reported milk intake and growth vary greatly in these systems. In the study by Nicolao et al. (2022) they had to discontinue one of their restricted suckling treatments, which consisted of (from two weeks of age) one daily suckling period of 2 h after the morning milking, due to calves simply not getting enough milk to sustain their growth (ADG: 0.34 kg/day). This is in contrast to studies by Bieber et al. (2022) and Passille et al. (2008) with similar systems, who reported milk intake of around 8-10 L and ADG before weaning of 0.8-0.9 kg/d, probably since they implemented twice-a-day suckling compared to one. In the study by Nicolao et al. (2022) they also had a part-time contact treatment where calves suckled for 20 min before the morning milking, again only once a day from two weeks of age. These calves had higher ADG (approx. 0.7 kg/d) than artificially reared control calves (approx. 0.6 kg/d) who received a milk allowance equivalent to 13% of their body weight, but the authors reported that this system resulted in impaired milk let-down (16.5-21.7% reduction in yield after taking suckled milk into account) of the suckled cows affecting the total milk yield at a similar level as half-day contact, where calves had more time to suckle. Hepola et al. (2007) found that even though calves only spent a small part of the day with the cow, they still had lower concentrate intake than artificially reared calves, resulting in impaired growth at the time of weaning.

Foster Cow Contact — Whole-Day — Full Contact

Until now the focus has solely been on *dam-calf* contact, but *foster cow* contact is another option. Typically two to four calves are ”adopted” (a preferential bond is formed) or ”accepted” (no preferential bond is formed but the calves are allowed to suckle) by a cow (Loberg & Lidfors, 2001). In the following, the process will be referred to as ”pairing” without distinguishing further between accepting and

adopting. *Foster cow* systems allow calves to suckle and potentially experience at least some maternal care from the foster cow, though little is known about the quality of the maternal care fostered calves receive. Nonetheless, it has been shown that both foster cows and calves react to separation with similar types of behavioural responses as in *dam-calf* contact systems (Loberg et al., 2008), and since stepwise nose flap weaning decreases the response (Haley et al., 2005), preferential bonds are to some degree formed. However, Loberg and Lidfors (2001) found that if the cow's own calf is nursed along with foster calves it seems to get a larger share of the milk. Little is known about calves in a *foster cow* system related to the development of cognitive or social skills. Issues in *foster cow* systems involve the pairing process where cows sometimes are unwilling to let calves suckle at least initially, and may show a preference for some of the calves (Loberg & Lidfors, 2001). Vaarst et al. (2001) showed that pairing calves to a foster cow were easier if the calf initially was allowed to suckle the dam for a few days, rather than being artificially fed, before pairing to the foster cow. However, calves experienced in suckling received more agonistic behaviours during the pairing phase (Vaarst et al., 2001). Weight gains in *foster cow* systems will depend on the number of calves per cow and the cow's current milk production. Little is known about the solid feed uptake of calves with foster cows. *Foster cow* systems can be combined with *dam-calf* contact systems, where the calf initially is reared by the dam and then, after a few weeks, are moved to a foster cow. These systems are called *hybrid* systems.

Advantages and Disadvantages of Different Version of CCC

In their respective reviews, Johnsen et al. (2016), Kälber and Barth (2014), and Meagher et al. (2019) assessed various CCC systems and evaluated their advantages and disadvantages. Taken together with the review of the latest research given in this section, it is suggested that part-time contact with the dam could be the most feasible option for the dairy industry, where milk production is the primary source of revenue, and early separation and weaning are considered necessary. Half-day *dam-calf* contact may have the potential to resolve the issues related to weaning and separation and allows calves to consume sufficient milk and engage in social behaviours with their dam, as opposed to the systems with several short contact periods. As a result, half-day *dam-calf* contact emerges as a promising management strategy that could represent a practical balance between welfare benefits, economy and practicality.

2.6 Half-Day Contact: A Compromise?

Half-day contact may offer a compromise between allowing *dam-calf* interactions and tackling common barriers to *dam-calf* contact. However, most studies so far have compared half-day contact to an artificially reared control group, and not a whole-day contact group (but see Roadknight et al. (2022)). Differences in housing, breeds, and management methods make it hard to reliably compare different versions of CCC to each other. For example, it is not known whether the maternal-offspring bond differs in half-day contact systems, compared to whole-day contact. If the bond is modulated, it may affect the amount or quality of positive social interactions between the cow and her calf. While this may be a downside to the half-day system, it can, on the other hand, also be speculated whether modulation of the maternal-offspring bond can prepare half-day calves better for weaning and separation (Newberry & Swanson, 2008). The next section will introduce the potential implications of half-day *dam-calf* contact (in the following just "half-day contact") and identify knowledge gaps.

2.6.1 Repeated Separations

The peak response to separation in young dairy calves and their cows are observed around 9-18 h after separation (Chua et al., 2002; Flower & Weary, 2001). This interval corresponds to the daily duration of the half-day contact separation period. The length of the daily separation is usually decided by the two daily milking times. Indeed, to reduce labour, the management of moving cows to their calves or calves to their cows is usually done in relation to existing milking management. Depending on whether it is a day-time or a night-time half-day contact system, the duration of separation will thus usually range from 9-15 h as most farmers strive to milk twice daily evenly distributed over the day. In other words, we can expect both cows and calves to react with separation-related responses when introduced to a half-day contact system. However, we do not know much about the development over time, i.e. if cows and calves get used to the system and if so, how fast that happens. In fact, little is known about the stress of separation during milking in whole-day contact systems as well. One study focused on this matter, and concluded that potential welfare issues in the half-day contact system, in this case with 9 h of separation during the day, were: calf hunger, cow restlessness during the evening milking (before being reunited with the calves) and cow discomfort when reunited due to calves suckling on an empty udder (Roadknight et al., 2022). On the other hand, they found no differences in vocalisations for cows on the two contact treatments during the period where half-day cows were separate from their calves, while

whole-day cows and calves were together (Roadknight et al., 2022). Corresponding data were not presented for calves, but it is mentioned that there were low levels of calf vocalisations during observations. Roadknight et al. (2022) also did not find any effect of time over a 10-day observation period, but observations started at an average age of 8 days and if cows and calves had either already habituated to the system after a few days or did not habituate until after the first few weeks, they may not have been able to detect a decrease in response with time. Knowledge is needed on the potentially detrimental effects of the repeated daily separation for both whole-day and especially half-day contact.

2.6.2 Modification of the Maternal Bond

Due to the prolonged daily separation period in half-day contact systems, it has been suggested that the maternal bond is weakened (Johnsen et al., 2016; Newberry & Swanson, 2008). Previous studies nonetheless concluded that cows and calves with half-day contact show behaviour indicative of having formed a strong and preferential mother-offspring bond (Wenker et al., 2020) even if the calf cannot suckle from the cow (Johnsen et al., 2015b). However, no studies compare the maternal bond between cows and calves with whole-day vs half-day contact with full contact.

The mother-offspring bond, as defined by Gubernick (1981) is:

> *"The preferential responding between parents and offspring as defined by various operational criteria. These include the preference for one individual over another, seeking and maintaining close proximity, a response to brief separation from the attachment figure, a response to extended periods of separation, a response to reunion with the attachment figure and finally the use of the attachment figure as a secure base to explore the world."*

The quality of the mother-offspring bond, as defined by Gubernick (1981) may thus be judged depending on the time spend in close proximity and performing grooming and suckling as well as reinstatement behaviours, e.g. short latency to reunite upon separation. Suckling in the inverse parallel position is expected to be indicative of a bonded pair (Fröberg & Lidfors, 2009; Sirovnik et al., 2020), while calves that are also suckling an alien cow may be less strongly bonded to the dam. If the bond is less strong in half-day contact systems this may come with both beneficial and detrimental effects. Advantages could be increased dam independence

leading to cows and calves being better prepared for weaning and separation (see Section 2.6.5) while disadvantages could be gaining less benefit from the pre-weaning contact period. If the maternal bond is modulated, half-day calves may receive less or a different quality of maternal care, resulting in less positive affective states stemming from the performance of natural, positive social interactions (Bracke & Hopster, 2006; Lawrence et al., 2019; Rault, 2019). This could also change the potential positive effects on the social and cognitive skills of calves reared with dam contact. Knowledge is needed on the strength of the maternal bond in half-day contact systems compared to whole-day, and the implications for the quantity and quality of mother-offspring interactions.

2.6.3 Effects on Health and Production

In regards to calf health, half-day contact is not expected to differ from whole-day contact as the infection risk can be managed in a similar way. In relation to production, only one study was found that directly compared the growth of half-day calves suckling their dam to whole-day calves and they had similar growth rates (∼0.9 kg/d pre-weaning) (Zipp, 2018). However, other studies applying half-day contact also report pre-wean ADG in the range of 0.85-1.1 kg/d (Johnsen et al., 2015a; Nicolao et al., 2022; Veissier et al., 2013), which may be somewhat less than that of calves with whole-day contact (range: 1.1-1.4 kg/d (Fröberg et al., 2011; Johnsen et al., 2021b; Roth et al., 2009; Wagenaar & Langhout, 2007), but inferences are hard to make between different experimental designs. It is not known whether the similarities and differences in growth are solely based on milk intake or if half-day calves potentially are eating more solids, induced by hunger during the prolonged separation period. For cows, there are some indications that half-day contact may improve saleable milk yield (Barth, 2020; Nicolao et al., 2022). Indeed, Barth (2020) showed that half-day contact improved saleable milk yields when calves had night-time contact compared to whole-day contact. Knowledge is needed on the basis of the comparable growth levels of half-day and whole-day contact calves.

2.6.4 Modifications of the Human-Animal Relationship

While it is generally observed that calves in CCC systems have a more poor human-animal relationship (HAR) than artificially reared calves (e.g. Waiblinger et al., 2020a) at least during an initial period, little is known on the effect of half-day contact on the HAR. The difference in HAR for calves with CCC systems is expected to stem from either the decrease in close contact experienced in relation to milk

feeding, the lack of association between humans and milk or the presence of the dam preventing socialising towards humans (Krohn et al., 2001). In a study by Duve et al. (2012) calves were housed with the dam (whole-day contact) but without the opportunity to suckle due to udder nets. Calves received 9 L of milk per day in teat buckets, providing the opportunity to associate human with milk provision. These calves showed a poorer HAR than artificially reared calves on the same milk allowance housed either individually or in pairs, indicating that indeed the presence of the dam itself seems to modulate the HAR. Perhaps, if half-day calves have less strong bonds to their dams and/or experience human presence without the cows presence during the daily separation period it can result in a better HAR and allow half-day calves to benefit from the positive welfare effects of a good HAR (Mota-Rojas et al., 2020). Indeed, a better HAR ensures that animals kept in production systems experience less stress related to routine management procedures and handling (Mota-Rojas et al., 2020; Waiblinger et al., 2006). Knowledge is needed on the effect of half-day contact on the HAR, compared to whole-day contact.

2.6.5 Increased Dam-Independence

As already mentioned, there may be some beneficial effects of a less strong mother-offspring bond in half-day contact systems. As suggested by Newberry and Swanson (2008) both cow and calf may get used to separation, decreasing the behavioural response at permanent weaning and separation. This process may be facilitated by the calf being less dependent on the dam's milk through a higher solid feed intake. An increase in solid feed intake could be expected based on the literature on the relationship between milk allowance and solid feed intake. It is generally accepted that artificially reared calves who receive higher amounts of milk eat less solid feed during the pre-weaning period (reviewed by Khan et al., 2011) and thus to a higher degree are dependent on gradual weaning strategies to ensure welfare and continued growth (Bittar et al., 2020; Eckert et al., 2015). Therefore, if half-day calves ingest smaller quantities of milk than whole-day calves, or are hungry during the separation period, they may start eating more solid feeds, preparing them better for weaning from milk. Knowing from Johnsen et al. (2018) that a higher level of nutritional independence facilitates a less stressful separation from the dam, this could reduce the response to the weaning and separation of half-day contact calves, compared to whole-day contact. From the cow's perspective, Stěhulová et al. (2008) showed that the response of the dam to separation from the calf depended on her judgement of the calf's independence, in which case half-day contact may also facilitate a more gentle separation for the dam. Knowledge is needed on the solid feed intake of half-day contact calves compared to whole-day contact.

Another factor that could be advantageous for half-day contact calves is if they are less reliant on their mother's social companionship. This could be achieved by enhancing their attachment to other calves. Calves are known to form groups with their peers and spend increasing time with other calves, and away from the dam, as they get older (reviewed by Whalin et al., 2021). Social companionship in calves is known to buffer stressful situations (Rault, 2012). This can be during management procedures such as weaning where calves housed with a peer have better post-wean growth (reviewed by Costa et al., 2016) or even during physical restraint where pair-housed calves showed a decreased stress response compared to individually housed calves (Duve et al., 2012). Knowledge is needed on the effect of half-day contact on the attachment of calves to peers, compared to whole-day contact.

2.6.6 Stepwise Weaning and Separation

While the intense weaning and separation stress experienced by CCC calves may be reduced by half-day contact due to the above outline of potential effects, it is still recommendable that calves who receive large amounts of milk are gradually weaned, irrespective of the milk source (Bittar et al., 2020; Eckert et al., 2015). However, obtaining a true gradual weaning process in calves suckling their dam poses a challenge, as calves have been shown to ingest large amounts of milk in short spans of time (Bieber et al., 2022; Nicolao et al., 2022; Roth et al., 2009; Roth et al., 2008). Acknowledging that gradual weaning is difficult in CCC systems, other efforts to reduce the stress surrounding weaning and separation may be necessary. It has been suggested to keep stressors separate in time; e.g. to not wean off milk and separate from the dam concurrently (Weary et al., 2008). Stepwise weaning and separation strategies are quite commonly used and researched in relation to beef production (Enríquez et al., 2011), though calves in beef systems are usually weaned at a much later age, and most likely with a much lower milk intake from the dam (Sapkota et al., 2020). Nonetheless, stepwise weaning and separation procedures have been investigated in dairy calves too. Johnsen et al. (2015c) investigated the effect of fence-line weaning with visual and some tactile contact compared to only auditory contact and concluded that fence-line weaning decreased the response to weaning. In much the same way Wenker et al. (2022) looked at fence-line weaning but allowing calves to suckle through the fence if cows positioned themselves correctly. They also reported decreased response to weaning and separation, also better than calves weaned with a nose flap. However, we do not know if the combined effect of half-day contact and stepwise fence-line weaning will further reduce the stress response. Knowledge is needed on the concurrent effect of using half-day contact and a stepwise weaning and separation strategy.

Chapter 3

Research Questions

Aim of dissertation

The overall aim of the present dissertation is to develop research-based knowledge which contributes to overcoming significant barriers to implementing cow-calf contact practices in Danish, organic dairy herds by investigating different strategic choices in the management.

3.1 Interview study - *Paper I*

The aim of the qualitative interview study is to investigate the motivations, perspectives and experiences that shapes the wealth of different cow-calf contact systems present in Danish, organic dairy herds as well as in relation to the benefits of cow-calf contact from the perspective of the calf.

Research questions

- What motivates farmers to choose a CCC system in the first place?
- What shapes the development of the CCC system applied on each farm?
- How do farmers perceive their calves to benefit from their CCC system?

3.2 Experimental study - *Paper II, III and IV*

The aim of the experimental study is to contribute to understanding the benefits as well as problematic behavioural effects of two different versions of *dam-calf* contact, respectively whole-day and half-day contact, by comparing them to artificial rearing.

Research questions and hypotheses

Are half-day contact calves benefiting differently than whole-day contact calves?

1. Half-day contact will result in less *dam-calf* interactions
2. Half-day contact will result in more daily separation-related stress as seen by reduced lying time, more social reinstatement behaviour and for the cows more reluctance to leave the calf
3. Half-day calves will spend more time eating solids, more time in calf creeps, and more time close to another calf, indicating less dependence on the dam.

Are half-day contact calves better prepared for weaning and separation than whole-day contact calves, how do they compare to a control group, and how does a stepwise approach to weaning and separation affect the related stress?

1. Half-day contact will result in a reduced response to weaning and separation compared with whole-day contact, while control calves react the least
2. Stepwise weaning and separation will reduce weaning and separation stress

Are half-day contact calves developing a better human-animal relationship (HAR) than whole-day contact calves, how do they compare to a control group, and do weaning and separation treatments affect the HAR?

1. Half-day contact will result in a better HAR compared to whole-day contact, while control calves have the best HAR.
2. Simultaneous weaning and separation will lead to hungrier calves at testing as compared to stepwise weaning and separation. Thus, control calves will show a relatively more positive HAR, as they associate humans with milk feeding. Dam-reared calves will show an unchanged HAR, as they do not associate humans with milk

Chapter 4

Materials & Methods

In this chapter, I aim at providing the reader with the required insights into the overall approach applied to respectively the interview study and the experimental study on which the present dissertation is based. The chapter is mainly based on the more detailed material and methods sections found in the four papers and reuse some parts but also includes a description of the materials and methods used in a pilot study which is not reported elsewhere.

4.1 Interview study

The study employed a qualitative research approach to explore the perceptions and experiences of Danish, organic farmers with knowledge of CCC systems. A total of 12 farmers were interviewed using a qualitative, semi-structured technique. All interviews were conducted face-to-face on the respective farm and were digitally recorded and transcribed with Nvivo®. The farm owners were the primary participants in the interviews, which began with introductory questions about their farm, followed by three main questions: their motivation for initiating a CCC system, the process of implementing and adapting to the current system, and how they perceived animal welfare changes associated with the CCC system. To prompt discussion on the benefits of CCC for calves, farmers were shown three flashcards with the headings 'nutrition', 'care', and 'learning', based on a previous study by Vaarst et al. (2020), which identified these aspects as key drivers for establishing CCC systems. The interviews were analysed using a modified grounded theory method (Brinkmann & Kvale, 2015). The transcribed text was organised into meaning condensates, which were grouped together and used to develop a model representing all the elements of the interviews. The interview guide developed can be found in Table 4.1.

Table 4.1: Interview guide used for the semi-structured interviews

Theme	Questions	Potential follow up
Presentation of interviewer and the interview	Who I am, the project and partners, semi-structured interview. Can I audio record? Can I take pictures of the farm? Will you sign an informed consent?	
Background info on the interviewee	*"Please introduce yourself with a bit of background "*	Education Experience Relation to this farm
Farm and general management information	*"Tell a bit about the/your farm, just the general things.."* *"Is there something you would say, you do differently here than most farms – besides CCC?"*	Farm staff Number of cows / breeds Milking system Feeding Yield Barn/Grazing Herd health Calving season
CCC system	*"Would you explain how you manage the CCC system"*	Cow / Foster Timing of different steps Duration of contact Housing, calf creeps Floor surface Pasture access Supplementary milk and feeds Milking management Hygiene Separation and weaning
Motivation to have CCC	*"Can you tell me what motivated you to have a CCC system?"* *"How did you get the idea to run a CCC system in the first place?"*	Experience from elsewhere? External factors Internal factors A special situation/issue?
The process towards and the effects of the chosen CCC system	*"How was the process towards reaching the current system – did anything change along the way?"* *"What is the best part about the way you manage your system?"* *"If you had the opportunity, is there something you would change in the future or would like to implement?"*	Expectations vs reality Tried out – did not work Restrictions Health, production/economy, work joy, welfare, behaviour, labour,
Welfare benefits focusing on the calf	*"Earlier, three different aspects relating to the welfare of the calf in a CCC system has been identified, how would you rank the importance of these for the calf?"*	Did it change along the way? How does CCC system support this?

4.2 Pilot study

The present PhD project was to be based on data from a large-scale experimental study on a commercial, organic dairy farm. The plan was to compare half-day and whole-day *dam-calf* contact on a subset of the farm's cows and calves, controlled by the installation of an automatic gate, and compare it to the farm's standard practice of artificial rearing. Unfortunately, it was not possible to conduct the experiment with the planned design. Due to complications which will be elaborated on below, the experiment was instead used as a pilot study.

The study was planned and initiated during the first months of the PhD study. The planned number of animals to be included was 90 across three treatments, starting 1/10-2019. Due to unexpected challenges with adhering to the experimental protocol and technical issues with the automatic gate due to power-outs, the experiment was simplified to only include one experimental treatment (half-day contact treatment was dropped). These challenges and the needed changes meant that the experiment was restarted the 15/1-2020. The final number of animals was further reduced by relatively high levels of illness (13 pairs). The included number of animals in the final version of the experiment was a total of 44 calves on two treatments: 19 calves were dam-reared in dynamic groups for 6 weeks, while 25 were housed under standard practices as a control group. Unfortunately, some calves were sold at weeks 6-7, meaning that not all calves could be included in the planned tests performed at age 7-9 weeks. The experiment ran until 15/5-2020. Due to the many issues and experimental protocol not being carefully adhered to it was decided to treat the experiment as a pilot study and will be mentioned as such throughout. In the below section, I will describe the experimental setup in its final form. In the results section I will briefly mention the practical experiences we took away from the study and implemented in the main study and report the descriptive results on health, growth, and the human-animal relationship.

4.2.1 Animals and housing

The study aimed to compare two levels of cow-calf contact before permanent separation: 24 hours or 6 weeks. The experimental study included 44 dairy breed calves (Danish Holstein crossed to either Danish Red or Montbeliarde) and their dams. The study was performed on a commercial, organic dairy farm with a total of 320 milking cows. Cows were milked at 04:00 and 16:00 in a milking carousel with room for 32 cows.

All cows calved in an individual calving pen (3.2 m x 4.1 m). Depending on the treatment, the cow and calf remained together in the individual pen for either 24 hours (Control) or at least 36 hours or until the calf suckled independently (Whole-day). Four litres of colostrum was given from a colostrum bank, at the latest 6 hours after calving, to all calves.

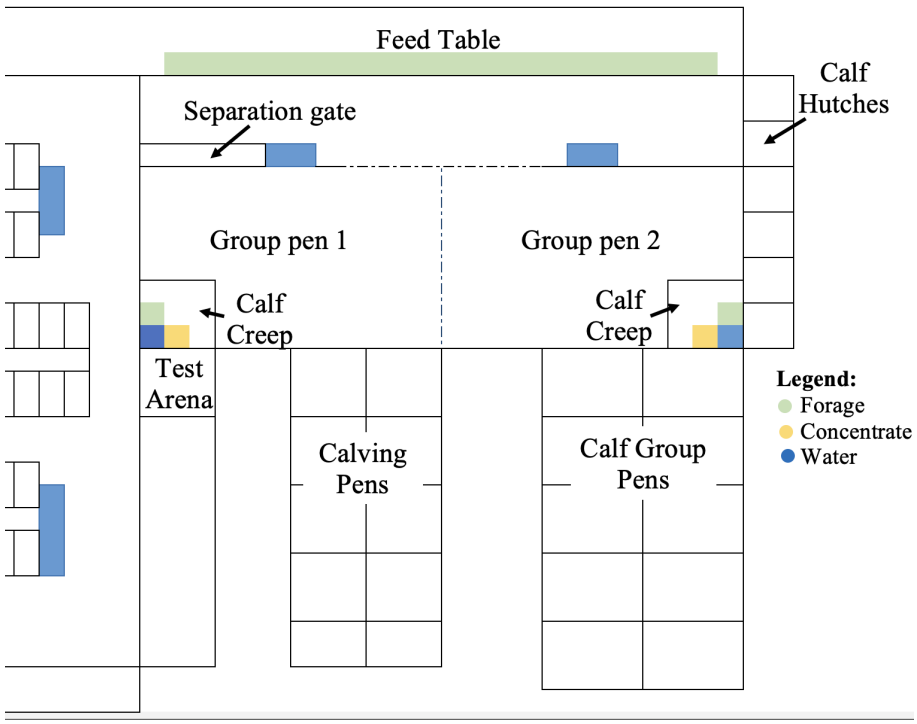

Figure 4.1: The layout of the commercial barn refitted for cow-calf contact with a separation gate and the possibility for two groups. Note that water and food were available in the Calving and Calf Group Pens even though not illustrated.

Control

After calving, the control cows were returned to the milking herd (cubicle stall with room for 250 cows) after the 24 hours agreed on by Danish, organic farmers (Økologisk Landsforening & Landbrug og Fødevarer, 2022) while their calves were moved to first pair-pens (approximately 2 weeks duration, 1.4 m x 2.4 m) and then larger calf group pens in groups of 6 (3.2 m x 4.1 m). See Figure 4.1. This was in accordance with the farm's standard procedure.

Whole-day

For Whole-day pairs, it was assessed whether the calf had been suckling (saliva on the udder, full belly, milk foam around the mouth). If it had not, then assisted

nursing was performed 2-6 hours after colostrum feeding. Assisted suckling was repeated if the calf was not suckling on its own after further 6 hours. If it did not seem like the calf would succeed in suckling independently, the pair was excluded. After 36-48 hours, the pairs (cow with calf) from the Whole-day treatment were moved to be housed in a group pen (deep-bedded area: 9 m x 27 m + slatted area along feed table; 2.3 m x 27 m) for six weeks. See Figure 4.1. The calves on the Whole-day treatment always stayed in the group pen during the six weeks, while the cows were away for milking twice a day. Calves had access to two calf creeps, one in each of the corners of the back wall made with two simple, horizontal bars and entrances along both walls (3.1 m x 3.9 m). Calves on the Whole-day treatment were abruptly separated from the cow after six weeks, when they were moved to calf group pens in groups of 6, of the same type as Control calves but were not grouped with Control calves. At this point, Whole-day cows were moved to the milking herd.

4.2.2 Feeding

Cows were fed by standard farm procedure, *ad libitum* TMR twice a day mainly based on grass and corn silage. Water was available from long, open troughs (2.5 m). Whole-day calves had access to water cups, calf starter (concentrate) and hay in their creep, which was not accessible for the cows. Control calves also had access to calf starter and hay and milk were fed (6 L/day) from bucket, distributed on two daily feedings and had access to water cups. From the time of separation from the cow, Whole-day calves were taught to drink milk from a bucket using a teat bottle initially then transferring to open troughs. Calves were offered TMR in the calf group pens, at 8 weeks of age.

4.2.3 Enrolment on treatments

A dynamic in/out roll went on throughout the period, but a max of 20 cows with calves could be housed in the contact group pens at any time (the number of pairs varied from 6 to 20). Cow-calf pairs were distributed to balance cow parity (primiparous vs. multiparous) between treatments, by alternating inclusion in each treatment within each of the two parity groups. Twin calves and meat breed calves were excluded. In case of illness which required treatment, the pair were removed from the experimental study. Both Control but especially Whole-day calves had a higher than expected level of diarrhoea and pneumonia which limited the number of animals used significantly (3 control, 10 full-time pairs excluded).

4.2.4 Registrations

Behavioural observations

Cameras were fitted over the home pen and recorded 24-hour video. Behavioural observations from the recorded videos were planned but due to the reasons mentioned above this was not followed through. The observations were to include time budgets including social interactions and use of the resources in the pen.

Health and weight

On a set weekday, all calves underwent clinical health scoring and were measured to estimate their weight. Calves were scored from 0 (normal) to 3 (clear signs of illness) on their nasal, ocular, navel, and respiratory health. Further, incidences of diarrhoea and temperature were recorded. This was combined with an average health score, for each calf, each week (McGuirk and Peek, 2014). The weight was estimated using a calf measuring tape (The Coburn Company - Holstein Calf Weigh Tape), ensuring the calves were positioned with head up and equal weight on all legs, for best reliability.

Human-animal relationship

All calves were handled once weekly for clinical health scoring by the researcher and a technician. Otherwise, Control calves received milk from one of the 3 farm staff personnel twice daily. Whole-day calves were only approached by humans in relation to the weekly assessment. Calves were scored on their handleability in the second, fifth, and eighth weeks of the experiment. This was done by haltering the calves and tying them to the pen side with approximately 1m of the lead rope. From when the lead rope was secured around the pen, the number of head shakes, leg stamps, and tail swishes was counted until the calf had undergone the described health scoring with the temperature being taken, as the last measure.

On week eight, when calves of both treatments were housed in the same type of pens, a human approach test was conducted. The pen was entered at a slow walking pace, approximately 1 step of 60 cm pr. second. The test person walked a round in the pen and then to the centre and paused for 30 seconds in order to get the attention of the animals and eliminate any startle response. If the test calf was placed tight in a corner or inaccessible due to other animals, another calf was chosen to be tested, and the first calf was to be tested later when accessible. The test person then

approached the calf without trying to establish eye contact but looking toward the muzzle. The test person walked with the arm lifted at a 45-degree angle from the body, the back side of the hand turning up and the hand not tense. The test person stopped when the hand was within 10 cm of the calf and then tried to touch the muzzle and, if allowed, stroke along the cheek. If the calf withdrew at any point, the test was stopped. Withdrawal was registered as the first part of a sequence of stepping away (to the side or back) by turning the head away, but if the calf turned the head without stepping away it did not count as a withdrawal. An observer noted the distance at withdrawal in 10 cm increments.

Behavioural tests

It was originally planned to do two different types of behavioural tests after weaning and separation when the calves were 3-4 months old. In order to assess potential differences in cognitive and social skills in dam-reared calves compared to artificially reared calves, a fear test, a social facilitation test and a social buffering test were planned, but only initial pilot attempts were achieved.

The fear test involved three repetitions of exposure to a suddenly opened umbrella when the calf was isolated in a novel environment. The aim was to evaluate the stress resilience of dam-reared calves compared to control calves.

The social facilitation test involved teaching demonstrator calves to navigate a simple fence to access a treat, while observers were only familiarized with the test arena and to associate it with the treat. Once demonstrators reliably navigated the fence, observer calves were allowed to observe them demonstrate the process before being allowed to try themselves. The purpose was to investigate whether dam-reared calves were better at learning from social facilitation than control calves.

The social buffering test involved habituating demonstrator calves to a novel environment and the sudden appearance of a brightly coloured object being thrown into the pen. Once calves were habituated, they were to be tested in pairs of two, with one demonstrator and one naive observer. The aim was to assess whether dam-reared calves relied more on the social buffering capacity of peers in a fear-eliciting situation than control calves

4.3 Experimental study

This section describes the main experimental study which was conducted at the research barn at Aarhus University, Foulum, and forms the basis for the three behavioural papers included in this dissertation. Throughout the dissertation, this study will simply be referred to as "the experimental study" distinct to respectively "the pilot study" and "the interview study".

4.3.1 Animals, housing, and management

A total of 72 purebred Danish Holstein calves and their dams were assigned to six blocks consisting of 12 cow-calf pairs each, based on the calves' birth date. Within each block, animals were randomly assigned to one of three calf-dam contact treatments: Control, Whole-day, and Half-day, with four cow-calf pairs per group. The treatment groups were balanced to the best extent possible for sex, ensuring that at least one calf of each sex was included in each group in all treatment pens. The groups were also balanced for dam parity, with either one or two first-parity cows in each group. Due to three disease incidences data was collected on a total of 69 calves.

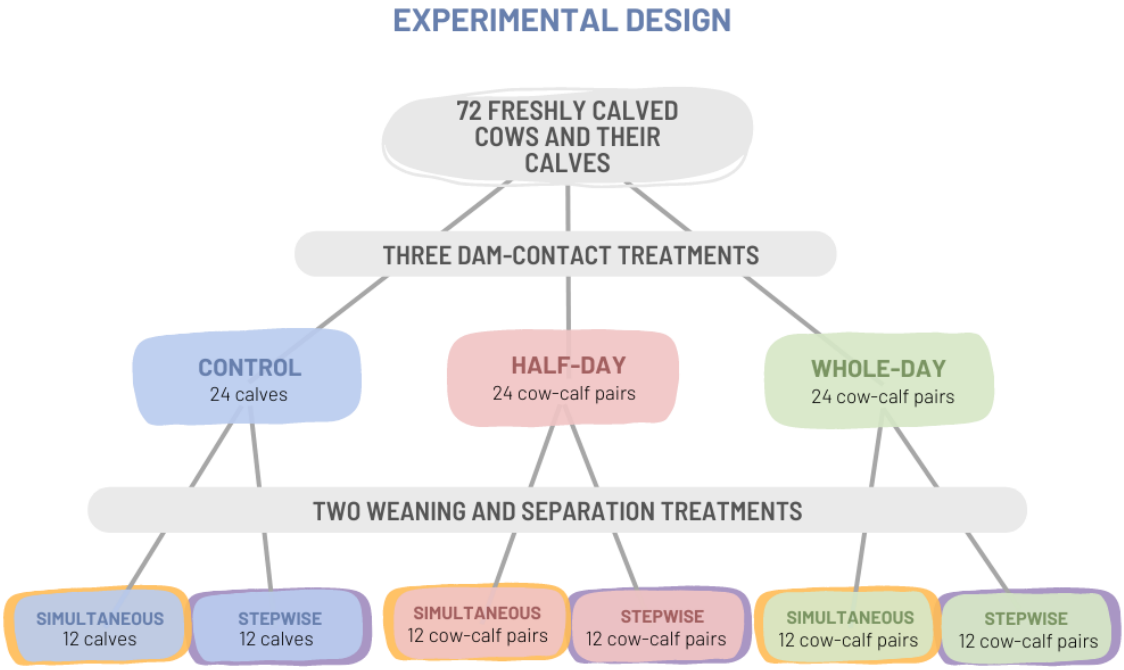

Figure 4.2: An overview of the experimental design showing how calves were distributed on one of three dam-contact treatments and further one of two weaning and separation treatments. The total number of animals enrolled was 72 calves with each of six blocks consisting of 12 calves

Figure 4.3: A group pen for four cows with their calves showing the type of fixtures and feed bins used

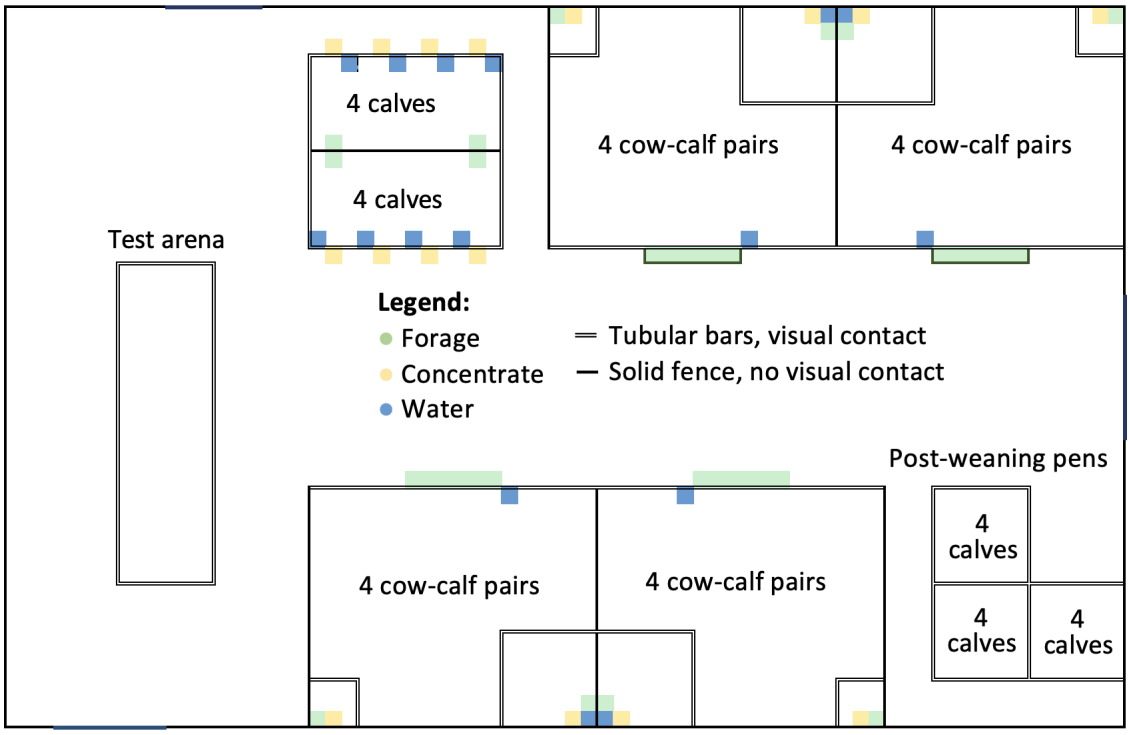

Figure 4.4: The layout of the experimental barn, set up to run two blocks simultaneously but shifted in time. The figure is reused from Paper IV.

All the calves received 4 L of colostrum from their dam within six hours of birth. Starting from day 2, the calves were housed in deep-bedded pens, either with or without their dams, depending on the treatment group. The calves had unrestricted access to calf-starter concentrate, hay, water, and the cows' total mixed ration (TMR). Calves experienced human contact during daily and weekly standard care procedures such as feeding, bedding replenishment, weekly weighing, and weekly experimental health checks. Evening farm-procedure health checks and refilling of hay and concentrate in the calf creep were performed during the period when Half-day dams were not present but without any physical handling of the calves. The calves were not disbudded during the experimental period.

4.3.2 Dam-Calf Contact Treatments

Whole-day and Half-day

After calving, the cow and calf stayed together in the calving pen for ∼24 hours. Calves not able to suckle within the first 24 hours did not enter the experiment and were replaced.

The cow-calf pairs were moved to a deep-bedded group pen (9 m x 7.5 m) that housed four cow-calf pairs receiving the same treatment. In the experimental barn, there were four treatment group pens, allowing for a new block to start while the preceding block was still in progress. All four pens had the same layout, which was mirrored, as shown in Figure 4.4. Each pen had two calf creep areas with sides made of tubular metal bars, one in each back corner, as illustrated in 4.4. Whole-day calves were kept with their dam at all times, except for approximately 30 min twice a day, while the cows were away for milking. Half-day calves were kept with their dam, except for approximately 14 h during the night (from when the cows were taken out of the pen for afternoon milking until they returned from morning milking).

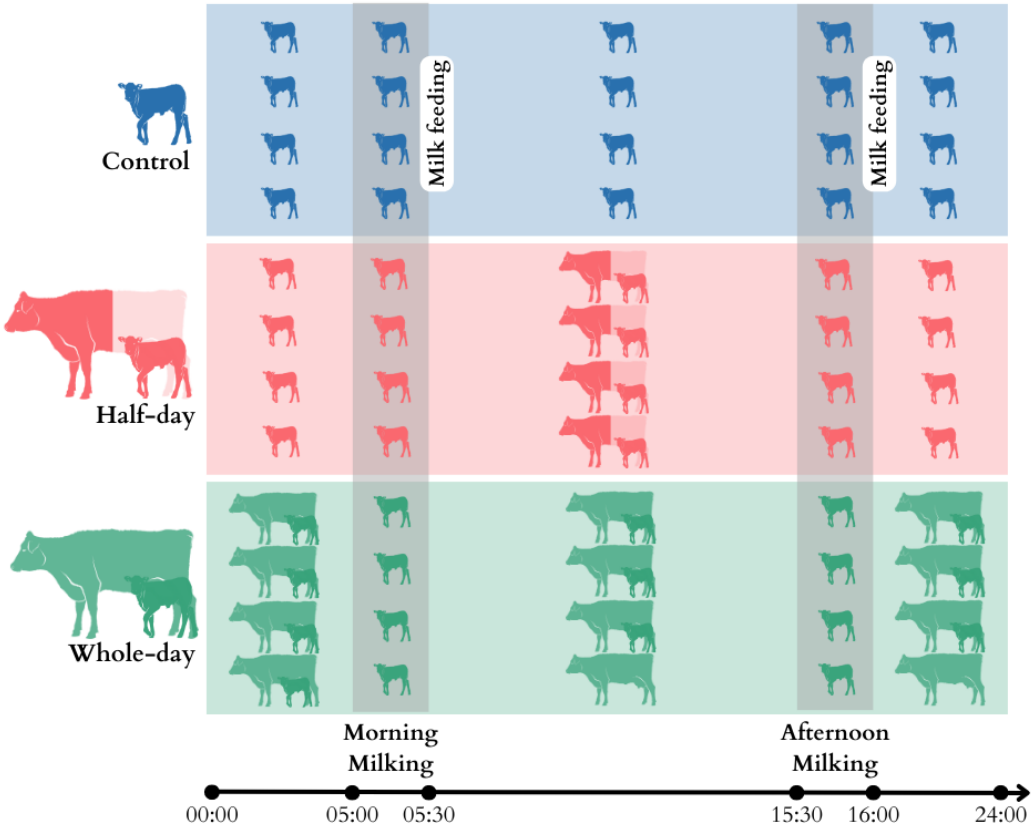

Figure 4.5: A graphical presentation of the three dam-contact treatments illustrating the daily time with and without cow-calf contact.

Control

Calves in the control group were mainly managed in accordance with standard farm procedures, and separation from dams occurred within 12 to 24 hours after birth. For the first seven days after separation, the calves were kept in individual straw-bedded pens measuring 1.5 m x 3 m, where they could have visual and tactile contact with neighboring calves in the same treatment and block. After seven days, they were grouped together and moved to a group pen measuring 3m x 6m, which housed the four control calves in each block.

During the first week of life Control calves were first offered 6L/d of whole milk in two daily feedings, which was gradually increased over seven days to 8 L/d in two daily feedings. From seven days old and throughout to weaning off milk they were offered milk to satiation twice daily at 06:30 h and 17:00 h. The calves had 20 min to drink milk before any leftovers were removed (mean daily intake per calf ±SD ranged from 7.9 L ±0.93 in the second week to 11.1 L ±1.7 in the eighth week).

4.3.3 Behavioural observations (Pre-weaning)

Video cameras were placed above each pen to record the behaviour of all four calves in a pen. The following types of observations were made: continuous recordings of calf behaviour in the home pen for 24 hours on one day in weeks 3 and 7, respectively; continuous recordings of calf behaviour upon reunion with their dams after morning milking for the first 30 minutes after each cow returned to the group pens in weeks 3, 5, and 7, respectively; instantaneous scan sampling of calf creep use and proximity to the dam and other calves at 10-minute intervals for 24 hours on one day in each of weeks 3, 5, and 7; and continuous direct observations of all cows' behaviour on the way to the milking parlour for afternoon milking and, for Half-day cows, upon entering their night pen during the first and last two weeks of the experimental period.

4.3.4 Weaning and Separation Treatments

Simultaneous

In week 9, calves on the Simultaneous treatment were abruptly and simultaneously weaned off milk and moved from their home pen to a new environment (group pens for 4 calves of 3 m x 3 m), in the other end of the barn, together with the calves from the same dam-contact treatment and block. This effectively also separated the dam-reared calves from their dams, who were moved away to a separate barn at the same time. Although Control calves were already separated from their dam and thus only moved to a new environment, the described procedure will for simplicity be referred to as separation (or, being separated) throughout. See Figure 4.6.

Stepwise

For calves on the Stepwise treatment, weaning off milk started in week 8, where dam-reared calves were confined in the larger calf creep (two calves, 9 m^2), abruptly weaning the calves of milk, while the other two calves remained with their dams (and the dams of the Stepwise calves) in the main pen, with no change. At the same time, the control pen was divided into two equally sized pens, each holding two calves. Control calves on the Stepwise weaning treatment were abruptly weaned off milk but stayed in the familiar environment. One week later, in week 9 and at the same time and way as for calves on the Simultaneous treatment, calves were moved to a group pen with the calves from the same dam-contact treatment and block and the dams were moved to a separate barn. See Figure 4.6.

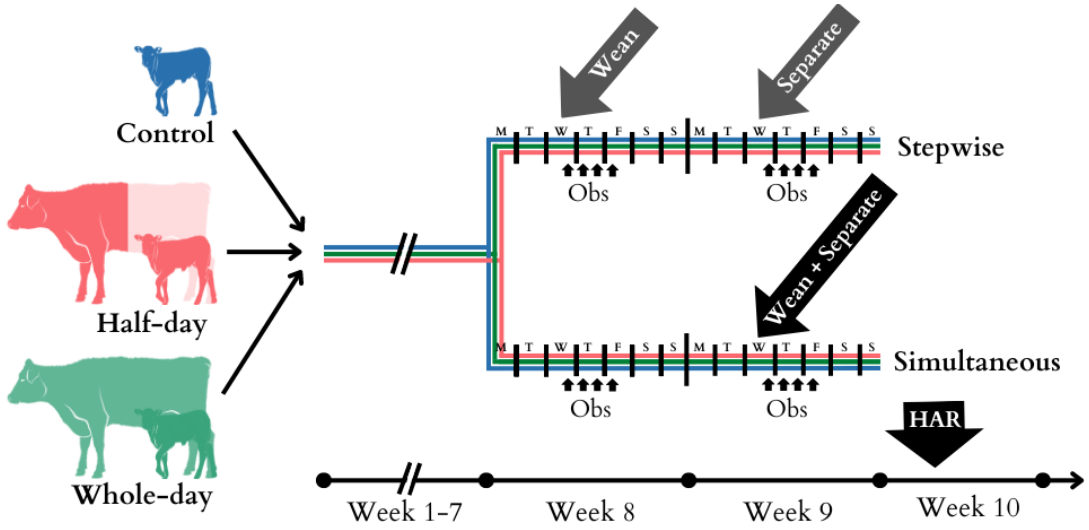

Figure 4.6: Timeline of the two weaning and separation treatments and the human-animal relationship test (HAR-test).

4.3.5 Behavioural observations (Post-weaning)

Weaning and Separation

We carried out behavioural observations on all calves at each of the two weaning interventions (weeks 8 and 9, see Figure 4.6). Observations were made at four-time points after the interventions had taken place: after 4 hours, 21 hours, 29 hours, and 45 hours, respectively. Observations amounted to a total of 2 h of observation per calf for weeks 8 and 9 combined. For Simultaneous calves, we expected week 8 to correspond to a baseline level, as they did not experience any weaning and separation yet.

Human-Animal Relationship tests

For all calves, the behavioural tests described below were performed at 10 weeks. We measured the calves' HAR by assessing their reactions toward a test person in a human approach test (HAT) and an animal approach test (AAT). Two people, an observer, and a test person conducted the tests. Behaviours were recorded directly by the observer. All calves were tested individually in an unfamiliar test arena.

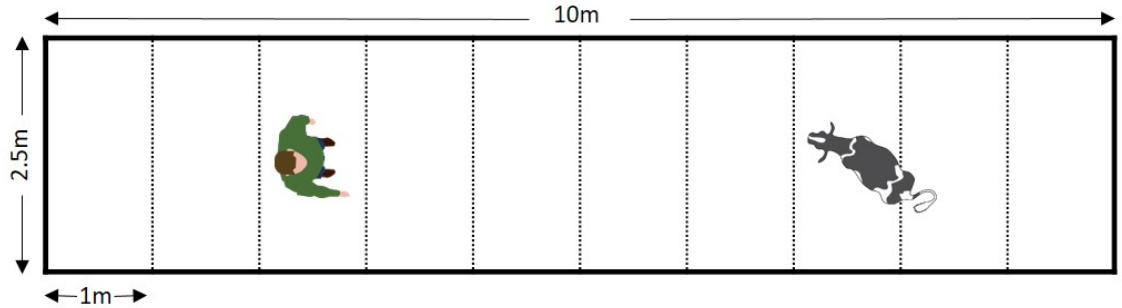

Figure 4.7: The experimental setup for the human-animal relation test conducted in an elongated arena. The figure is reused from Paper IV.

Human Approach Test

The HAT test started once the calf was standing still and at least 1.5 m from either of the two ends of the arena and the test person was positioned at four zones distance from the calf (see Figure 4.7). The test person started to approach the calf in a standardised manner. The test ended whenever the calf moved one of its forelegs backward or when the test person touched it.

Animal Approach Test

After a 2 min pause, the test person re-entered the test arena. The test person again entered and was positioned at a four zones distance from the calf. The test person stood motionless and waited for the calf to approach. The test lasted 3 min from when the test person was correctly positioned.

Chapter 5

Summary results

In this chapter, I provide a summary of the results included in the dissertation. Results based on the pilot study are not included in any papers and are thus only presented here. Results based on the interview study and the experimental study are given in detail in the four original papers included in the dissertation, see the overview of included papers in Chapter 6.

5.1 Pilot study

This section will give a short descriptive presentation of the results from the behavioural tests and the calf health checks (group-wise means and 95% confidence intervals based on 19 Whole-day calves and 23 Control calves) as well as the practical experiences from the pilot study. The descriptive results of the pilot study will not be further discussed in the discussion chapter, thus a few discussion points will be added along with the results in this section.

5.1.1 Descriptive Results from Pilot Study

Weight and Health

Throughout the pre-weaning period, Whole-day calves were only slightly heavier than Control calves (see Figure 5.1). However, at 10 weeks of age, Control calves were heavier than Whole-day calves. This is also reflected when looking at the ADG, where Whole-day calves had higher gains pre-separation than Control calves, but substantially lower gains than Control calves after separation (see Figure 5.2). Even though Whole-day calves were offered 6 L of milk daily after separation from the

dam, the issue with getting calves to actually drink the milk probably resulted in the strongly reduced ADG post-separation.

The ADG, pre-separation, for Whole-day calves (see Figure 5.2, was lower than expected, which may reflect either a poor health status of the calves or that calves did not have access to their cow as consistently as planned.

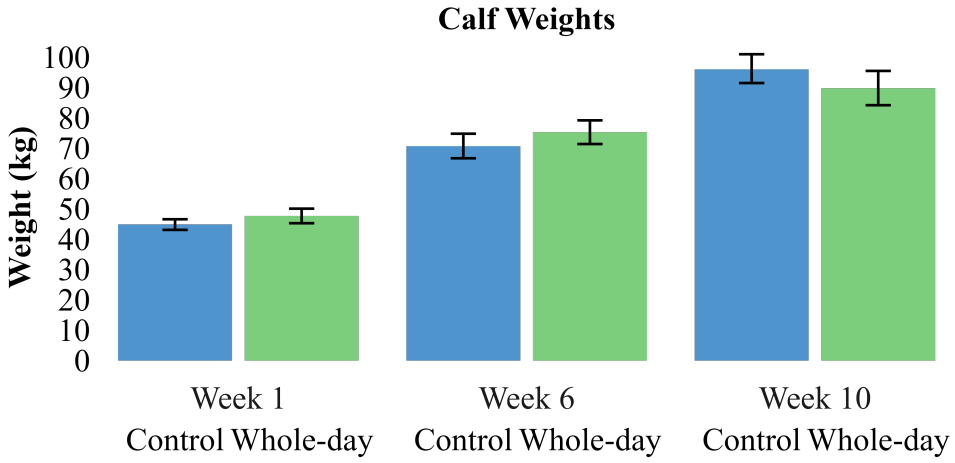

Figure 5.1: The weight of calves on respectively the Control and Whole-day treatment at the first weighing (week 1), before Whole-day calves separation (week 6) and after separation (week 10)

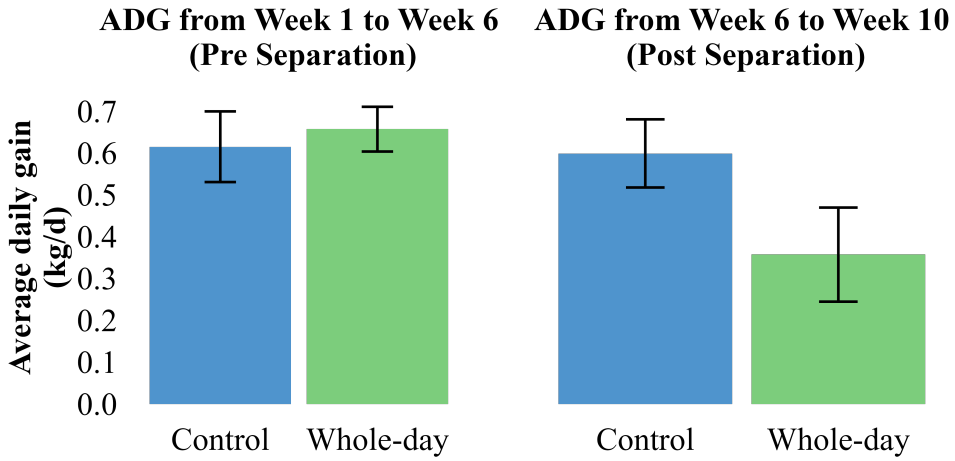

Figure 5.2: Average daily gain (ADG) before and after Whole-day calves were separated from their dam

The average health score was indeed poorer for Whole-day calves than for Control calves. Health scores were summed and averaged for each calf to get a sense of the overall health status. The higher score, the more signs of illness. Whole-day calves showed on average more signs of illness (Health score of 2.57 (SD $\pm$ 0.91)) than control calves (Health score of 1.87 (SD $\pm$ 0.77)). During the experiment, 10 Whole-day and 3 Control calves were removed due to either diarrhoea or pneumonia. The higher levels of disease in the Whole-day calves may be caused by the more complex social environment in the dynamic group, as well as issues with not all cows being reunited with their calves each day, creating more unstable conditions for Whole-day calves.

Handleability and Avoidance Distance

Whole-day calves showed, on average, more struggling behaviour (summed head jerks, leg stamps and tail swishes) during the restraint test (calf tied up in halter and handled as part of health check) than Control calves, looking across weeks 2, 5 and 8 (see Figure 5.3). The average avoidance distance for Whole-day calves was also larger than for Control calves as measured in week 8 5.4. This is most likely because dam-reared calves had less close contact with humans and did not have specific positive associations with humans such as milk feeding.

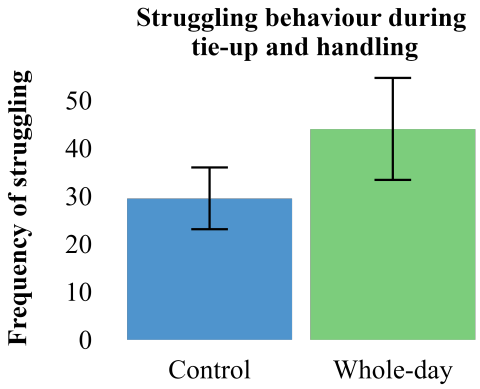

Figure 5.3: The sum of head flicks, leg stamps and tail swishes during a restraint test across weeks 2,5 and 8.

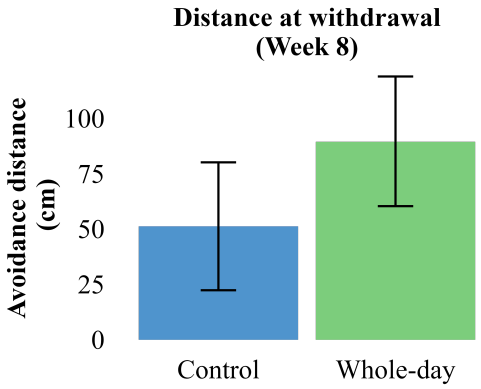

Figure 5.4: Avoidance distance during a forced human approach test in week 8 performed in the home environment

5.1.2 Experiences and Learning

This section provides the main lessons carried over from the pilot study to the experimental main study.

Marking of Animals for Video Observation

We needed a way for the farm staff to mark newborn calves and the mothers easily for recognition on video, as the farm was located far from the university research department and visited once a week. We have normally used commercial hair bleach to mark cows and calves but this was too time-consuming for the farm staff. We struggled to find marking sprays that would show up clearly on the black coat, even on the video. In the main experimental study, we thus went back to marking the coat with hair bleach.

Figure 5.5: Cow and calf at the feed table where extra vertical straps had been installed to keep calves in, but with no success

Pen Design

Along the feed table, there was a broad walkway with slats, designed for cows. There were no observations of calves being stuck or otherwise injured on the slats during the experimental period. Calves chose to lie down in the deep-bedded part of the pen and had no issues navigating the ”step-up” to the slatted area. The cow's feed table was open with no headlocks, but an upper and lower horizontal bar. While we were happy that calves were able to eat alongside the cow, we soon discovered that calves above 2 weeks were not confined by this type of feed front. An extra horizontal band was installed, however, this was not efficient in keeping older calves in the pen. See Figure 5.5 for a picture. It was, anecdotally, especially calves on the half-day contact treatment which slipped out of the pen during the separation period and went to the whole-day pen or main milking herd to suckle. The farmer had agreed to install headlocks but this was not achieved during the experimental period. We experienced that some calves worked out how to escape the pen via the separation gate by walking the opposite way out and ducking under the structure of the gate. However, this was easily fixed with an extra horizontal bar. For the design of pens in the main experimental study we had solid walls on 3 sides and the front was designed to fit large feed troughs with high ”back sides” to avoid calves escaping but still being able to eat with the cows. See Figure 4.3 for a picture.

Design of Calf Creeps

The calf creeps were produced on our asking by ”Jyden Bur A/S, Denmark”. Based on experiences from other researchers with cow-calf contact experience (Cynthia Verwer, Louis Bolk Institute, the Netherlands) we asked for simple, see-through partitions installed in the solid-walled back corners of the pen (away from the feed table) and with access to the creep along both solid walls (see Figure 5.6). The argumentation for this design was that calves had been observed to seek a hiding place by running along the solid wall when there was commotion in the pen and that cows stress if they cannot see their calf in the creep, due to solid walls. We hoped that the corner provided some sense of hiding while keeping the calves in view for both cows and staff. Cows were observed lying right next to their calf with the creep partitions in between. See Figure 5.6. We installed water cups, concentrate bowls and hay racks in the solid-walled corner of the creeps to make sure they were out of reach for cows. Barn staff expressed that having been able to empty and provide feed without having to walk through the entire pen and into the creeps would have reduced labour. The partitions were two horizontal bars, and calves up until approximately 5 weeks of age would also access and leave the creep by going

through the partition, between the bars. These creeps worked very well and calves used them a lot. For weekly health scoring and handleability testing, we used creeps to round up the calves and keep them confined. In this situation, we had to use extra fencing/gates to close off the creeps on all sides. When designing the creeps for the main experimental study we chose the same overall design but with narrow vertical bars (15 cm), not allowing for calves to get through.

Figure 5.6: Calf creeps were designed with access along the walls and such that cows could easily keep an eye on the whereabouts of the calves. Concentrate, hay and water was provided in the creeps. Dimensions were 3.1 m x 3.9 m.

Transition to Artificial Rearing

Separation from the dam at 6 weeks of age, with the purpose of starting calves up on artificial milk feeding, was difficult. An experienced calf caretaker struggled to even introduce a bottle of milk to many of the calves. The result was a mix of systems, as some calves would drink from a teat bucket, others from the trough and others never learned it. For the main experimental study, it was thus prioritised to keep cow and calf together for the entire milk-feeding period.

5.2 Summary of Main Findings

A short summary of the main findings from the papers included in Chapters 6 to 9 is given in this section, to facilitate a quick overview.

5.2.1 Paper I

Shaping cow-calf contact systems: Farmers' perspectives and choices behind a range of different cow-calf contact systems

Motivation for Choosing Cow-Calf Contact

The motivation mentioned most often by the interviewed farmers, in the context of choosing a cow-calf contact system, was practical considerations related to reduced labour, increased flexibility and a sense of a more rational system. Ethical responsibility motivated farmers through the opportunity for animals to perform natural behaviours. Image was also identified as a motivator, and related to the image of the farm in the eyes of the consumer which motivated farmers with on-farm sale of dairy products. Lastly, a fourth motivation was related to economy, based on the perspective that it should be possible to get a really good milk price for *dam-calf* contact milk.

Factors Shaping the Cow-Calf Contact Systems

Economic and practical considerations were crucial and intertwined factors in making strategic choices for the farm's CCC systems. These were related mainly to mitigating a reduction in saleable milk, finding a use for cows who are undesirable in the milking herd and finding a suitable space for housing calves with cows. Ethical responsibility was an important factor for especially farmers with *dam-calf* contact systems rather than *foster cow* systems and related to fairness in the sense that ethical considerations should not only be for a chosen subset of animals e.g. the replacement heifers or only some of the cows. Lastly, the farmers' image in the eyes of the farming community appeared to influence whether farmers were comfortable articulating that their chosen management methods were based on ethical considerations rather than practicality and economy.

5.2.2 Paper II

The behaviour of calves reared with half-day contact to their dam

Half-day contact calves spend less time suckling and being groomed by the dam over 24 h than Whole-day contact calves. After the nightly separation, Half-day calves were faster to reunite and suckle both their own cows and alien cows, than Whole-day calves separated for milking only. Both Whole-day and Half-day cows were more reluctant to leave the calf for afternoon milking during the first days after calving, compared to in the eighth experimental week. Half-day calves spend twice as long daily eating solid feeds as Whole-day calves. Calves spend an equal amount of time in the creep during the day. During the night when cows were not present in the Half-day contact pen, their calves used the main pen for resting.

5.2.3 Paper III

Comparing weaning in dairy calves with different dam-contact levels

There was no difference between Half-day and Whole-day calves in the frequency of high-pitched vocalisations upon weaning and separation. Half-day calves emitted more low-pitched vocalisations when stepwise weaned and separated during observations where the cow was present in the pen. Control calves vocalised the least. Control calves had a higher ADG the week after weaning off milk than Whole-day while Half-day calves were intermediate. Stepwise weaning and separation reduced the high-pitched vocalisations of Half-day and Whole-day calves to the level of Control calves.

5.2.4 Paper IV

The effects of part-time dam-contact and stepwise weaning and separation on the voluntary human approach behaviour of dairy calves

Whole-day and Half-day calves were not different from each other but were slower to approach the test person and less likely to come within 1 m of the test person than Control calves when calves were weaned and separated in a stepwise manner. When calves were simultaneously weaned and separated there was no dam-contact treatment difference.

Chapter 6

Paper I

Submitted to Journal of Dairy Science

Shaping cow-calf contact systems: Farmers' perspectives and choices behind a range of different cow-calf contact systems

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Abstract

Most dairy farms rear calves artificially by separating the newly born calf from the dam and feeding the calf milk from a bucket. However, the general public and scientific community have begun to question the impact of artificial rearing on animal welfare. Research so far has focused mainly on dam-calf contact, where each cow takes care of her own calf. However, previous studies show that Danish and other European farmers are using and showing interest in a variety of different cow-calf contact (CCC) systems. In the present study, we used qualitative research methods to explore the perspectives of Danish farmers who either had or have tried to establish a version of a CCC system. Farmers were asked about their motivation for establishing the system, what had shaped the system to its current form and how they perceived the calves to benefit from the system. Practical considerations were the theme most commonly brought up and related to both why farmers chose to have CCC in the first place and in what way they had chosen to organize their CCC system. Practical considerations included a sense of ease, flexibility and a more natural and therefore rational approach. The economy was also a repeated theme, but while to a large degree shaping the CCC systems, it was rarely mentioned in relation to choosing a CCC system in the first place. Ethical considerations were a strong motivator for farmers with dam-calf contact systems, while less so for farmers with foster cow contact. The farm's image as seen by the consumer was an important motivation for farmers with many on-farm visitors, and possibly the farm's image in the eyes of the farming community was also influencing farmers. Farmers generally perceived the calves to benefit from the care of the cow and there was no difference in the importance attributed to care between farmers choosing dam-calf contact and foster cow systems.

Keywords: Dam-rearing; Foster cow systems; Farmer experience; Organic Dairy Farming

6.1 Introduction

Under natural conditions, cows usually nurse their calves until 7-14 months of age and the calf is continuously cared for by its dam, even after the next calf is born (Reinhardt & Reinhardt, 1981; Veissier et al., 1990). Studies have shown that dairy cows in today's dairy systems will show the same maternal behaviors if given the opportunity (reviewed by Rørvang et al., 2018). It is well founded in the literature that the separation of a calf and its dam causes stress for both animals (reviewed by Newberry & Swanson, 2008; Weary et al., 2008). Nevertheless, separation within

hours of birth is the most common practice in the management of calves and dairy cows, both in conventional and organic herds. This practice is referred to in the literature as "artificial rearing" (Sirovnik et al., 2020).

In Denmark, organic farmers have voluntarily agreed to keep the calf with the cow for 24 hours, compared to 12 hours for conventional farms (Økologisk Landsforening & Landbrug og Fødevarer, 2022). In the agreement, the organic community specifically states an interest in improving animal welfare and ethical conduct. However, the separation after 24 h in organic farming could still be argued to conflict with the organic principle of "fairness", according to which "animals should be provided with the conditions and opportunities of life that accord with their physiology, natural behavior and well-being" (IFOAM, 2005).

Rearing calves with their dam would improve adherence to the fairness principle and reviews of recent research establish that cow-calf contact systems (CCC) likely have the potential to improve welfare without compromising health (Beaver et al., 2019; Meagher et al., 2019), and better conforms with citizens and consumer views (Placzek et al., 2021; Sirovica et al., 2022; Weary & von Keyserlingk, 2017).

CCC systems on high-production dairy farms are however relatively scarce, though some farmers are starting to implement CCC in Nordic and European countries (Eriksson et al., 2022; Hansen et al., 2023) including Danish, organic farms (Vaarst et al., 2020). However, a range of barriers to the implementation of CCC has been identified (Eriksson et al., 2022; Hansen et al., 2023; Neave et al., 2022; Vaarst et al., 2020), which relates mainly to a reduction of saleable milk and issues with suitable housing.

Indeed, in the review by Johnsen et al. (2016) they suggest that having unrestricted, whole-day contact between a cow and her calf may be infeasible under current farming conditions, due to both economical and welfare-related concerns (Johnsen et al., 2016). Animal welfare, specifically related to increased separation stress seen in cows and calves that have formed a strong bond (Weary et al., 2008), was also among the main barriers to having CCC when farmers were asked (Eriksson et al., 2022; Hansen et al., 2023; Neave et al., 2022). Indeed, Hansen et al. (2023) surveyed 213 Norwegian farmers who had tried out a CCC system and found that more than half of those who discontinued the system did so mainly because of increased separation stress in the animals.

These barriers may explain why farmers are trying out different versions of CCC systems such as the use of foster cows who each suckle 2-4 calves, part-time contact systems or a combination of both (Eriksson et al., 2022; Vaarst et al., 2020), as these management choices may allow farmers to run a more feasible system (Johnsen et

al., 2016; Meagher et al., 2019). However little is known about the motivation and shaping factors related to the different choices farmers make when managing their CCC system.

The interview and survey studies are also pointing to discrepancies between farmers. Animal welfare is mentioned as a main barrier to implementation by some farmers, due to the increased separation stress, while aspects of animal welfare such as healthier calves, a more natural calf-rearing system and maternal care were mentioned as the main reasons to have CCC systems by other farmers (Eriksson et al., 2022; Hansen et al., 2023; Vaarst et al., 2020). This illustrates an interesting discrepancy, with animal welfare being both the reason to have and not to have CCC.

Behavioural research is emerging on the benefits of cow-calf contact systems in terms of the improved opportunity to experience positive social interactions and perform highly motivated behaviours (Johnsen et al., 2021; Wenker et al., 2021), which are both believed to facilitate good welfare (Lawrence et al., 2019; Rault, 2019), but the later separation of cow and calf induces a strong behavioural response, which is expected to be detrimental to welfare (Johnsen et al., 2015b; Wenker et al., 2022). Farmers' perceptions of how their CCC system affects animal welfare can inform our understanding of how they balance positive and negative effects and potentially suggest management choices that can improve animal welfare in CCC systems.

This paper aims to investigate the motivations, perspectives, and experiences that shape the variety of CCC systems currently practised in Danish, organic dairy herds as well as in relation to the benefits of cow-calf contact from the perspective of the calf.

The three research questions are 1) what motivates farmers to choose a CCC system in the first place, 2) what shapes the type of CCC system applied on each farm and 3) how farmers perceive their calves to benefit from their version of CCC system.

6.2 Methods

The Research Ethics Committee at Aarhus University, Denmark, has reviewed the study design and no ethical approval was needed under the Danish legislation. All interviewees signed a declaration of consent stating their anonymity and voluntary participation.

6.2.1 Research approach

This study was based on a qualitative research approach and explored the perceptions and experiences of farmers with experience in CCC systems through semi-structured interviews. This interview method allows each interviewee to add new perspectives to the whole picture, and interviewees are therefore encouraged to use examples from their experiences and focus the interview as wanted within the decided interview theme. The interviewer ensures the interview stays within the theme, asks follow-up questions, and investigates seemingly contradictory statements.

6.2.2 Data collection

We contacted Danish farmers who were shareholders of one of the two dairy companies involved in the project "Cow'n'Calf". The farmers were selected to be contacted based on the knowledge of each farm's production systems from the dairy companies' records and personal communication with an organic consultant, who had visited all farms delivering to each dairy within the past 6 months. Farmers were contacted if they had experience with any form of CCC, either in a current system, a system under development, or a system which they had chosen to discontinue. A total of 13 farmers were identified.

During the summer of 2020, 13 farmers were contacted via telephone, and 12 agreed to be interviewed, the last farmer not having time for an interview within the study period. All interviews were performed by the first author (female, Danish, MSc. in Animal Science, no farming background, currently PhD fellow focusing on different CCC systems, mainly focused on ethology, curious and interested in effects of CCC systems for animals and farmers) using semi-structured interview techniques and occurred in person on the respective farms, usually in the kitchen, in Danish. The interviewer had completed two PhD courses focusing on qualitative research and interview techniques. Interviews were audio recorded and manually transcribed *a verbatim* with Nvivo® by the interviewer. The interview duration varied from 30 min to 2 hours.

The farm owner was the primary person interviewed, but the farmer was asked to include others if they were crucial in the decision-making regarding the given CCC system. In some interviews, the spouse, the calf manager, or both were present. All interviews began with a farm tour during which notes were taken to be followed up on during the interview, but no further relationship between interviewer and interviewee was established prior to the interviews.

The interviews started with an introduction to the research project and the interviewer's background knowledge of farming. Then, introductory questions about the farmer's background and facts about the farm were asked (See Table 6.1 for an overview of farm characteristics). Following this, the farmers were asked about their initial motivation for starting a CCC system and to describe the path of change toward the current CCC system. Lastly, farmers were asked how they perceived calf welfare as a result of their CCC system and specifically prompted by four written flash cards to discuss and prioritize the benefit of CCC for the calf as being related to "nutrition" (natural meal frequency, right temperature of milk, satisfied suckling need, no contamination during storage), "care" (maternal grooming, close contact, protection), "learning" (observe the cow's behaviour, learn what and where to eat and rest, how to be herded and how to react socially correct), or "other" (the farmer was encouraged to add his or hers own perspectives). The perspectives used for the flashcards were based on emerging themes from previous research (Vaarst et al., 2020). Each flash card was described in a standardized manner. Farmers were asked to arrange the cards in front of them. This approach was chosen to guide farmers to be specific in which elements of calf welfare they found important in their system and reflect on whether these elements had guided their management choices. After each interview, the interviewer immediately wrote up a 1-2 page summary and impressions from the farm and the interview to help guide the analysis.

The interviews were analyzed by the interviewer using a modified grounded theory method (Brinkmann & Kvale, 2015) under supervision from the second author. The transcribed text was organized into meaning condensates, which were grouped into common themes across all interviews. These themes were further grouped and organized into a model which represented an overall structure, including all elements of the interviews. The transcripts were not returned to the participants due to a relatively long pause between interviews and analysis (1 year).

Table 6.1: An overview of the main characteristic of the farms enrolled in the interview study

Host farm	No. cows/ year	Cow Breed[1]	Calving pattern	Milking system	Housing of CCC system	Status of CCC	Experience with CCC	Organization of CCC system				
								Time with dam	Time with foster cow	Daily contact time	Calves in CCC system	
											Replace. heifers	Other calves
A	265	Cross	May-August	Carousel	Deep litter, slats and pasture	Active	24 years	4 days	-	All day	Yes	Yes
B	80	Cross	All year	Parlour	Deep litter	Stopped[6]	4 months	8 weeks	-	All day	Yes	Yes
C	250	Cross	October-December	Parlour	Deep litter and cubicles	Active	One year	1 day	6 months	2x1h daily	Yes	Sold ~ 2 weeks
D	230	Jersey	All year	Robots	Deep litter	Stopped[6]	5 months	10-15 days	2 months	All day	Yes	Yes
E	270	Jersey	All year	Carousel	Deep litter and pasture	On-off	Four years	2 days	Sold[2]	All day	No	Yes
F	150	Cross	All year	Robots	Deep litter	Active	One year	2-3 weeks	3-4 months	All day[3]	Yes	Yes
G	120	Jersey	April-August	Parlour	Deep litter and pasture	Active	Two years	3 months	-	Part-time, night.	Yes	Sold ~ 2 weeks
H	180	Cross	All year	Parlour	Deep litter	Stopped[6]	One year	2-3 months	-	All day	Yes	Sold ~ 2 weeks
I	50	Jersey	July-October	Tethered	Deep litter	Active	30 years	3-5 months	-	Part-time, night.	Yes	Sold ~ 8 weeks
J	53	Jersey	May-July	Parlour	Deep litter and pasture	Active	20 years	4-7 days	4-5 months	All day[4]	Yes	Sold ~ 2 weeks
K	180	Holstein-Friesian	June-September	Parlour	Cubicles and pasture	Active	Two years	3-4 months	-	Part-time[5]	Yes	Yes
L	55	Cross	June-August	(Mobile) Parlour	Deep litter	Active	20 years	1-2 days	3 months	All day	Yes	Yes

[1]Breeds used for crossing were Holstein-Friesian, Jersey, and Danish Red
[2]The farmer sold sets of foster cow with ~4 calves after bonding
[3]The cows had access to pasture after exiting the milking parlour, where the calves could not follow. The cows would normally return directly to their calves rather than go to pasture.
[4]During the first days after birth, until enough calves were ready for bonding to a foster cow, the calves stayed indoors while the cows were out on pasture during the day.
[5]Calves could follow their dam out to pasture immediately after milking, but if they did not, then they had to stay in the barn until the next milking. Most calves chose to stay in the barn.
[6]Farmer H managed all cows and calves in a CCC system for a period before discontinuing while Farmers B and D tried the system out on a subset of animals.

PAPER I

6.3 Results and Discussion

The analysis of data relating to the first two research questions (the initial motivation for CCC and factors shaping CCC systems) resulted in a range of factors enabling, encouraging, or hindering the conduct and practice of different CCC systems. These factors were grouped into four major themes 1) practical considerations, 2) economy, 3) ethical responsibility, and 4) image. For the last research question on the benefits of the CCC system from the calf's perspective, one theme emerged: care is care. The results and discussion section is organized around the three research questions and the corresponding main themes. Before the results and discussion are presented, a short description of the different CCC systems which farmers used is given to introduce the reader to the farms and the technical terms used to describe the systems throughout. An overview of each farm included in the interview study is given in Table 6.1 and references to farms/farmers are based on this.

6.3.1 Different versions of cow-calf contact systems

The CCC systems in the present study were either *dam-calf* contact systems where each cow is rearing her own calf or *foster cow* systems where a cow is rearing 2-5 calves, one of which can be her own. Some farmers practised *hybrid* systems where they started with dam-calf contact during the first weeks after calving and then moved the calf over to a foster cow. Half of the interviewed farmers had or had tried out a *dam-calf* contact system and the other half of the interviewed farmers had or had tried out some version of a *foster cow* system, including *hybrid* systems. Farmers had further chosen between whole-day or part-time contact between the calf and the cow. Part-time implies either half-day contact (between the two daily milkings, either during the day or the night, used in the three active *dam-calf* contact systems) or several short contact periods (in this case 2 x 1 h of contact a day in a *foster cow* system).

6.3.2 Motivation for choosing a CCC system

Farmers were asked to explain what had motivated them when they initially had chosen to manage a CCC system.

Practical considerations

The most repeated theme across all interviews regarding the motivation to adopt a CCC system was a perception of "ease of management", especially concerning daily routines and practical arrangements on the farm. There were some farmers who had chosen a CCC system many years ago when first buying their farm because they perceived it as the easiest approach and it made calf hutches, milk taxis, and other equipment unnecessary. Therefore, they had simpler farm structures and could rearrange their work time, since calves did not need to be fed at two set times daily. For example, farmers J and L described that having a small farm with little or no extra staff fitted well with a CCC system because they did not need a specific calf caretaker other than the cows. This sense of flexibility and reduced labour was also identified in other studies investigating dam-calf contact in respectively Norway (Hansen et al., 2023) and New Zealand (Neave et al., 2022) while the study by Vaarst et al. (2020) on Danish and Dutch farmers pointed more towards a change in the type of labour but not a reduction. This change in labour type was also echoed by farmer J in the present study who described how they preferred to spend the time observing calves instead of feeding them and cleaning after them.

According to a survey conducted across 6 EU countries, which included a broad range of CCC systems Eriksson et al., 2022, the majority of farmers reported a reduction in labor. However, some farmers reported no change or an increase in labor, particularly in part-time systems where animals had to be moved frequently throughout the day to reunite and separate calves or cows independently of milking times. In the present study, only one farmer practised several short daily periods of contact and they were moving away from this system to a simpler version with only one daily separation period in order to reduce the labour of moving calves.

In other cases, the decision to change was described as originating from the need to address some issue. One example of this was farmer K, who recently had taken over new farm facilities and moved their animals there due to better grazing opportunities. However, at this new farm, there was no suitable calf housing, therefore, the owners chose to leave the calves with the cows in the free-stall barn with cubicles,

> *"(. . .) in 2016, we took over the farm where we have the milk production today, and then, because there were no heifers or calf barn.. the set-up was not quite as one could have wished for, for the small calves... We decided to let the calves be with the cows instead since it was the easiest solution at the time... and then it just kind of continued that way (. . .) then they [the calves] were taken care of. . . "* [Farmer K]

Another example was Farmer A who had a major issue with Johne's disease when taking over the farm, and they struggled to break the contagious cycle in the calving area. The solution became to have the cows calving outside, where there was plenty of space and fresh air. They changed to a seasonal calving system with spring and summer calving and decided to leave the cow and calf together without interfering for approximately four days, rather than trying to catch the calves and feed them colostrum out on the pasture. In the present study, 7 farms were run with seasonal calving which was described to work well with CCC systems because during the most common spring and summer calving period their barns were largely empty as young stock and cows were out on pasture most, if not all, of the time. This also allowed for lots of space for calving and bonding cows and calves to each other indoors, and for housing calves indoors if they did not follow the cow on pasture.

As a third example of a practical issue motivating chance, farmer F described a specific situation where a calf seemed unable to drink from either a bottle or a bucket. The calf became weak, and as a last resort, the farmer introduced it to a lactating cow. Immediately, the calf started to suckle and got better. The cow had milk for more, so the farmer added more calves, which developed into a new foster cow system.

In summary, farmers argued most often that they chose their CCC systems based on what would be practical and easy to manage. Indeed, during the interviews, a common story emerged about a shift in perspective of what was rational or easy. This shift was described as a revelation that followed the first step of change towards a CCC system. The revelation made the old, artificial system suddenly seem irrational. The new system then continued to grow because of this new perspective. The irrationality was largely related to a feeling of performing work that would naturally happen if cow and calf were left together, as described by Farmer J:

> *"It was mainly... it was less work, in the way that I preferred to observe the animals, rather than first milking the cows, then making sure the milk had the right temperature, teaching the calf to drink from a bucket, which isn't natural for them, cleaning the buckets, mucking out the small*

> *hutches... I was just so tired of it, and it seemed completely foolish that I should spend time milking the cow and doing all of those things when it was something that would happen all naturally, right? So that was the motivation... it just had to be the easier way...”* [Farmer J]

“Naturalness” has been identified in different European contexts as crucial to the understanding of animal welfare in organic farming (Lund, 2006; Vaarst & Alrøe, 2012; Ver Hoef & Boveng, 2007), including meeting the natural needs and motivations of animals. In this context, “natural” is not understood as “how things are in nature”, but is closely connected to an ethical responsibility to care for the animals taken into one’s custody, in terms of intervening when necessary. All of the interviewed farmers in the present study were organic farmers and thus the perspective of utilizing the natural behaviour of cows and calves may have been an obvious point of reference to follow when organizing the farm.

Ethical Responsibility

Only three farmers mentioned ethical considerations as an initial motivator for deciding on a CCC system: Two had *dam-calf* systems and the third had a *hybrid* system. The ethical perspectives farmers mentioned related to naturalness and sustainability,

> *“It came from within... both my wife and I... we always thought that... if we decided we wanted to be independent farmers, then we wanted to do it our way, not to stand out from others, but we just had some ideas about how it should be done... we wanted to get as close to nature as we could while also being able to live off it.”* [Farmer I]

Until two years ago, Farmer I had a *hybrid* system in which all calves had some initial weeks with their dams before being fostered. Two years ago, they changed to only having *dam-calf* contact, arguing that it was more humane to the cow, even though it was less practical for the farmer. They felt that it was important that the cow’s welfare was prioritized, too and that this could only be achieved if each cow kept her own calf, reflecting the “fairness” aspect of the IFOAM principles of organic farming (IFOAM, 2005).

On Farm G, which also practised *dam-calf* contact, the dairy farm was run as a part of a large collective with a considerable focus on sustainability, and for them, a sense of increased naturalness when each cow rears her calf was described as a main driver for choosing a CCC system.

Farmer F, managing a hybrid system, described a hope to *"do better for both cows and calves"* when asked about the motivation to change. When asked to elaborate, the farmer described how behaviors such as cross-sucking (i.e. abnormal behaviour in dairy calves (Veissier et al., 2013)) indicated that something was wrong and that having to drink large quantities of milk in only two daily feedings was hard for the calves. The farmer stated that it did not feel nice to manage the animals this way and attributed that to the lack of naturalness in the system. However, the farmer had chosen to move the calves to a foster cow after a few initial weeks with the dam, to be able to produce more saleable milk.

Like Farmer F, multiple farmers mentioned that having CCC "felt nice" in the sense that they felt good when they saw a cow and a calf together and it gave them a sense of satisfaction to watch the cow perform maternal behaviour, as was also found in the study by Vaarst et al. (2020),

> *"Oh well, then they were allowed to stay for another day, and that turned into one more day, and then more... yeah, it was just the joy of seeing cows and calves together (...) ...there is just nothing better than seeing a cow and her calf lying together in the straw."* [Farmer K]

The sense of satisfaction and the system being "more right" seemed to follow as a secondary benefit, which multiple farmers enjoyed, but was mentioned as more of a bonus. These perspectives were shared by farmers across the different types of CCC systems.

In the study by Hansen et al. (2023) farmers who have CCC were identified as having a special interest in animal welfare as they agreed more with statements like "The cow has not equally good welfare without CCC" and "CCC provides good animal welfare" (Hansen et al., 2023). In the present study, only three farmers directly mentioned "animal welfare" as one of the primary motivations for having CCC and they did so in relation to naturalness.

In organic agriculture, introducing 'naturalness' in the farming system as a way of giving the animals good animal welfare, has been debated in the literature, especially in the years when organic animal farming was increasing (Lund, 2006; Vaarst & Alrøe, 2012; Verhoog et al., 2007). As highlighted above, 'natural' in this context is not understood as 'being like in nature', where animals also are subjected to predators, hunger, thirst and other dangers. The concept refers to the farm context, where the human caregivers take responsibility to care and intervene when necessary to avoid suffering. Lund et al. (2004) unfolded it as an ethical responsibility to allow animals naturalness and thereby meet their natural needs as much as possible, but at

the same time ensure their well-being through care and intervention when necessary.

However, the present study included a broad range of CCC systems, including *foster cow* systems, which can be argued to not allow the same level of fairness (IFOAM, 2005) as *dam-calf* systems, since it does not allow *all* cows to meet their natural needs and motivations to perform maternal care. On the other hand, *foster cow* systems can still ensure that the calf can suckle milk from a cow and have social interactions with a cow. Thus, the inclusion of *foster cow* systems in the present study may have changed the focus away from animal welfare as seen from a more ethical "fairness" perspective (IFOAM, 2005) and more towards a "naturalness" and "physical functioning" perspective (Fraser, 2008), while focusing on the calf.

Image

Three farmers mentioned their image from a consumer's point of view as an important motivation for change. These three farms (B, D, G) all had farm shops and therefore consumers visited their farms. They believed it looked better to "non-farm-educated" people when cow and calf were together, as described by farmer D, and liked to show the system to guests,

> *"I think it means a lot [for the motivation] that we have that [on-farm sale of ice cream]. People who come here to buy an ice cream can tour the farm, and... it is something they can understand, people from the city, they can relate to that [seeing cows and calves together]."* [Farmer D]

It thus seemed that at least part of the motivation to change was driven by the external pressure of society's expectations, but that it specifically became a driver when consumers or visitors had free access to the farm. As the public is showing an increasingly critical view of some practices in the current dairy industry, such as the handling of bull calves (Ritter et al., 2022), zero-grazing as well as the early separation of cow and calf (Busch et al., 2017; Hötzel et al., 2017) the motivation to change to CCC driven by public image may become increasingly important. However, many citizens also express that they are not aware of these practices and they thus only reject them when being made aware (reviewed by Placzek et al., 2021) which also points to the need for aligning expectations and sharing knowledge between producers and citizens. This may also be part of the explanation as to why citizens do not always reflect their opinions on animal welfare in their consumption patterns (Vanhonacker et al., 2010).

Economy

Just one farmer (Farmer H) described an initial motivation for choosing a CCC system related to economy. They believed that the milk produced in a *dam-calf* system was worth a large premium and should be sold at a higher price. However, Farmer H discontinued their system because they were not able to currently get a higher milk price from the dairy.

> *"There are two motivations for that [having a CCC system]. First, I am convinced that you can get a really good milk price, and second, I believe I can remove my calf barn. I really believe in it."* [Farmer H]

The perspective of CCC as the facilitator of an improved economy is not common in the literature other than when connected to less labour (Eriksson et al., 2022; Hansen et al., 2023) or increased health and growth of calves (Hansen et al., 2023), but in those cases, they are mentioned as ways of making up for the decrease in saleable milk, not as economic incentives themselves. However, in the study by (Knierim et al., 2020) they presented a case comparison of the full accounting of respectively a *dam-calf* system and an artificial rearing system and found that at least in some cases, *dam-calf* systems may improve net profit.

6.3.3 Factors shaping cow-calf contact systems

Farmers were asked to describe their version of a CCC system and what had influenced their choices in the process of developing the system. The two themes: "economy" and "practicality" were largely intertwined for this research question and are thus given together.

Practical and economical considerations

Saleable milk

All but one farmer who tried a *dam-calf* contact system reported a decrease in the amount of saleable milk compared to an artificial system, as calves drank much more milk when suckling directly from the dam than they would normally when fed artificially. Some farmers expressed that they could or would not continue with a *dam-calf* contact system without compensation because the production price was too high. As mentioned earlier on page 64, Farmer H described how the milk from a *dam-calf* contact system would be worth a higher price, and they had already tried

out a successful *dam-calf* contact system but had discontinued it due to lacking compensation from the dairy.

Farmer K, who had *dam-calf* contact due to the unavailability of calf housing facilities on their new farm, still considered moving the calves to another location and rearing them artificially instead. This was due to the decrease in saleable milk under the current *dam-calf* contact system. Thus, for this farmer, financial compensation would be a strong motivation to stick with the system, although it was not the original driving motivation.

> *"Ah, but if you could get that additional price, then I would probably prefer... to organize the system differently because it also needs a bit of investment if you want it to work optimally. You could make those investments, of course, but then you want to be sure to get the additional price. Otherwise, you would probably take those calves away, as most people do, and then rear them like most others, to get the higher yield from the cows..."* [Farmer K]

The reported decrease in saleable milk was also one of the main reasons for farmers not wanting or discontinuing a CCC system in the study by Hansen et al. (2023). That *dam-calf* contact decreases the amount of saleable milk is supported in the literature (Barth, 2020; Zipp et al., 2018). In the present study, the lack of compensation offered was thus described as the main reason for either stopping CCC or changing to a *foster cow* system when otherwise having the structural opportunity for a *dam-calf* contact system.

The remaining two farms with active *dam-calf* contact systems were Farm I and G, who did not consider discontinuing *dam-calf* contact. Farm I explained that *dam-calf* contact was not an issue with regards to the amount of saleable milk, but it was more work than a *foster cow* system because they had to milk all of the cows. They had recently started selling their milk labelled as cow-calf milk to the dairy but without extra compensation. The farmer explained that they had been operating a CCC system for more than three decades and had managed to keep their debt to the bank relatively low. Therefore, maximizing profits from milk production was not a top priority for them.

As mentioned earlier, Farm G was part of a large collective with an on-farm café and sale of milk and they also delivered milk as a niche product directly to restaurants. They were thus able to sell some of their milk at a higher price which somewhat reduced the concern about the decreased level of saleable milk.

It thus seemed that the two farms with active *dam-calf* contact *and* plans to keep

it had a farming system which allowed them to produce less saleable milk without economic issues due to either being low-input/low-output or selling products at a higher price on-farm. The three active *dam-calf* contact systems were all effectively managed with part-time contact, chosen to increase the amount of saleable milk (as also found by Barth (2020)). However, calves with half-day contact are still able to suckle large amounts (Roadknight et al., 2022; Wenker et al., 2020) and may to some degree impair milk let-down (Barth, 2020; Nicolao et al., 2022), which will result in less saleable milk than in an artificial rearing system.

Indeed, one of the reasons that farmers chose *foster cow* systems was the economic benefits related to saleable milk. Farmers mentioned that *foster cow* systems allowed them to choose how much milk they would allocate to the calf by adjusting the number of calves suckling each cow. Some farmers in the present study explained that they estimated their calves' milk intake in the *foster system* was similar to traditional levels in artificial rearing systems (approximately 6 L/day, (Cantor et al., 2019)). However, recent research points to calves being under-fed on traditional milk allowances (reviewed by Cantor et al., 2019; Khan et al., 2011), and thus care should be taken, when allocating a number of calves to a foster cow, that no calves will end up under-fed.

Farmer B also explained that the decrease in saleable milk in their *dam-calf* contact systems, was not only due to calves drinking a lot of milk but also issues with milk let-down when the cows were milked in the parlor. This issue is also reported in the literature (Fröberg et al., 2008; Zipp et al., 2016; Zipp et al., 2018). The impaired milk let-down was the main reason that Farmer B had discontinued their attempt at a *dam-calf* contact system. They described that if the cows had been willing to share the milk with the farmer, then the system had worked fine. None of the farmers with *foster cow* systems milked the foster cows, which meant that issues with milk let-down in the milking parlor were not a concern. This perspective was also reflected by farmer L who had chosen a *foster cow* system because they thought the milking cows should focus on being milking cows, and then the foster cows could focus on the calves,

> *"she [the dam] starts worrying about the calf instead of focusing on being a milking cow [if they are left together]."* [Farmer L]

The above perspectives on the cows underline how the milk is perceived as firstly a product to be sold. It can be speculated that a centuries-long emphasis on the production of milk and butter for export (Lampe & Sharp, 2018) still influences the general perceptions of cows as producers of milk for consumption.

Undesirable milking cows

Farmers pinpointed that by "splitting the work" between foster cows and milking cows, farmers had the opportunity to take certain, undesirable milking cows out of the lactating herd and let them take care of calves. The undesirable cows could have a high somatic cell count or be lame, low-yielders, difficult to work with, or weak in the herd.

> *"(. . .) then, if you have a high cell count cow, you can move it up there [to the foster cow system] for half a year, and then it can come back... so it is also a way to keep the cows longer... if you can save or nurture 10 cows every year that otherwise would have been slaughtered because you were tired of herding them back and forth because they were lame or they had too high a cell count and you had to milk it out manually each day... (. . .) So it can actually be a group of special-needs cows... it can be a cow with teats pointing in all directions–that is good teaching cow–it's easy to get hold of, so it's good care for the calf, but it is also good care for the cow that otherwise would not fit in the system..."* [Farmer C]

As seen from the above quote, the use of undesirable milking cows as foster cows was both motivated by practicality and economy, but also a sense of giving the cow in question a different type of care and finding a place for her in the system.

However, the ethical implications of using cows with impaired health status to care for calves should be considered carefully. Studies on the welfare of foster cows are lacking and should focus on both the effects of the bonding process (Loberg & Lidfors, 2001), of suckling multiple calves and of weaning and separation (Loberg et al., 2008).

There was another aspect, relating to the undesirable cows with high cell counts, which drove farmers towards *foster cow* systems. In an artificial system, Farmer G explained, high cell count milk was often fed to the calves by bucket, and thus not wasted. However, in a *dam-calf* contact system cows with high cell count would be milked, in contrast to a *foster cow* system, and the milk dumped since no calves were fed in buckets. Further, as mentioned by farmer G below, high cell count cows in a *dam-calf* contact system could not be culled for at least the calves' milk feeding period, whereas in *foster cow* systems they could either be culled or repurposed as foster cows which, in some cases, might allow the cow to recover from mastitis or a lameness issue.

> *"we have 40L a day [of high cell count milk] we throw out—actually twice a day—but that's also the problem, we have high cell count cows that could go [be culled], but we cannot let them go because they are with their calves! So, we just milk them in buckets for three months before we let them go..."* [Farmer G]

The issue raised about not being able to feed high cell count milk to calves in buckets because calves are suckling directly on the cows should also be considered from an ethical perspective, as feeding waste milk to calves may lead to detrimental health effects (Abb-Schwedler et al., 2014).

Housing and space

All but one farm had their CCC system in deep-bedded straw when indoors. It was evident from the interviews that most of the farmers only perceived deep-bedded environments suitable for CCC, thus the presence of such buildings had enabled them to try a CCC system. Often, this enabled a *foster cow* system, because deep-bedded barns or pens often were located away from the milking parlor.

Farmer D explained how on their farm, they would have preferred to have a *dam-calf* contact system, but due to having only a limited area of deep-bedding at a practical distance from the milking parlor, they had ended up with a *hybrid* system, where calves were moved to a foster cow in a different barn when there was no more room in the deep-bedded area close to the milking parlor.

> *"Well, so, in the perfect world, right here at our place, the cow and her calf would stay together for three months or so. That would be the perfect situation. But... given the space requirements... we can't do it."* [Farmer D]

Having whole-day *dam-calf* contact on organic farms during summer would require the calves to follow the cows onto pasture, which in turn would be costly in extra fencing for all the fields and it was perceived as an issue if calves were to walk long distances for fresh pasture. Indeed, Farmer K explained that because they also had sheep, all of their pastures were extra well-fenced, which meant that letting calves join the cows on the pasture was only an issue if they had to walk very far. Using a *foster cow* system, farmers only had to improve the fencing for a smaller part of the pastures. However, farmers with *dam-calf* contact systems in the present study had, as mentioned earlier, chosen a part-time system which meant young calves could be kept indoors or in a smaller well-fenced yard while the cows were away on pasture.

In summary, in *foster cow* systems, cows and calves could be housed without consideration for access to the milking parlour, since foster cows were not milked, and during summer only some of the fences had to be calf-proofed to allow cows and calves pasture access. This meant that farmers could utilize simple barns with straw bedding or pieces of land for foster cows and calves which was not suitable for milking cows, due to the infrastructure of the farm.

In the present study, having free-stall housing with cubicles was a barrier for dam-contact systems (in Denmark 60% of dairy farms have free stalls with cubicles vs 30% deep-bedded (Larsen, 2021)) since farmers explained that if they wanted a *dam-calf* contact system they had to rebuild their cow barns and change to deep-bedded systems to accommodate the calves. The issue of building constraints related to implementing CCC systems was also identified in the studies by Eriksson et al. (2022), Hansen et al. (2023), and Vaarst et al. (2020). On the other hand, farmers in the Hansen et al. (2023) study who had changed to a CCC system mostly reported having spent little or no money to facilitate the new system. This is similar to the current study where none of the farmers had invested in new housing due to their choice of a CCC system. This discrepancy could be explained by farms with CCC systems already having deep-bedding when deciding on a CCC system, making it an enabling factor. Nonetheless, one farmer in the present study managed a *dam-calf* contact system in a free-stall barn with cubicles. However, during the summer months, the cows grazed day and night, except during milking time, resulting in an empty cow barn for the calves to roam. Using a calving season ensured that there were no calves during the period when cows were housed indoors.

On the other hand, experimental studies on *dam-calf* contact have been made in a variety of housing systems including free-stall cubicle housing (Fröberg & Lidfors, 2009; Johnsen et al., 2015a; Waiblinger et al., 2020a; Wenker et al., 2021). None of these studies reported issues with the housing system. The common perspective of the interviewed farmers; that dam-calf contact should be in deep-bedded pens, may thus be challenged. Studies investigating the advantages and disadvantages of housing calves with cows on slats or solid floors with cubicles would be of great interest to farmers considering *dam-calf* contact and who do not have deep-bedded housing for the milking cows.

Detection of illness

Farmer D described how they, in their artificial rearing system, were used to judging the calves' health status based on whether or not the calf quickly drank all the milk provided in buckets. This was however not possible with suckling calves. Despite using *dam-calf* contact systems, Farmer C and K described how they, due to their

part-time systems, were able to assess the health of the calves by observing their behavior when they were reunited with the cows after a period of separation. They identified several positive indicators of good health, such as the calves getting up promptly upon the cows' arrival, stretching their bodies, and hastening to suckle. This use of a daily separation to condense the time needed to observe the health of the calves was mentioned as a practical management tool which also encouraged farmers to handle the calves daily. Farmer C believed this was the main reason their calves did not get "too wild". Literature on the health of calves in CCC systems shows conflicting results or often no difference from artificial rearing systems (Beaver et al., 2019). However, while standard operating procedures have been developed and refined for artificially reared calves through the years (e.g. Heinrichs & Jones, 2006), more knowledge is needed on the practical aspects of ensuring good physical health in dairy calves reared by cows.

Ethical Responsibility

As is evident from the above section there was a range of economical and practical reasons for farmers to choose *foster cow* systems. Nonetheless, three of the interviewed farmers had active *dam-calf* contact systems throughout the milk-feeding period (Farms G, I and K).

As mentioned earlier on page 61, the motivation of both Farmer G and I was largely based on ethical considerations. Nonetheless, calves were still separated from the dams after approximately 2-5 months which is still substantially earlier than the natural weaning age (expected to be somewhere between 7 and 14 months (Reinhardt & Reinhardt, 1981; Veissier et al., 1990)) and only replacement heifers were fully raised in the CCC system, illustrating the farmers probably still were constrained by either economy or practicality.

However, as mentioned earlier on page 59. Farmer K had landed on a *dam-calf* contact system, because of lacking calf housing, and was considering discontinuing CCC because of the decrease in saleable milk. However, Farmer K was not considering switching to a *foster cow* system to mitigate the economical issues. Farmer K argued that foster cow systems could have ethical issues, at least if the produced milk was labelled as "cow-calf",

> *"You have to ask yourself, should it [the calf] have access to a cow, or should it be its mother, or where are you at? ... And should you be allowed to sell your bull calves because you don't bother to castrate and finish them, so they leave the system after 14 days? ... And is the cow*

> *milked for the rest of her lactation for the additional profit anyway... or not? These are the type of issues there are... what kind of guidelines should be made, so it is not just 'all my milk is cow-calf milk', even though you actually only have a foster cow system in one end with 25 calves and some cows, and then 200 cows that are managed in another system... Then it becomes a bit too focused on the money, then the values are gone. (...) It has to do with ethics and morals then, then you need to inform the consumer about the foster cow system, otherwise it's a bit of a fraud."* [Farmer K]

In this quote Farmer K touches on a range of ethical concerns for CCC systems related to the fairness of only allowing some cows (foster cows) and some calves (e.g. replacement heifers) the increased contact. However, Farmer K also explained that they did not necessarily think *dam-calf* contact systems were more correct than *foster cow* systems, but that it was important not to deceive the consumer. As already discussed above, consumer and citizen attitudes are increasingly critical to the common dairy industry, and these statements open up for a future need to communicate and search for a common understanding between dairy farmers, dairy companies and citizens, as well as consumer communities.

Weaning and Separation

The time of permanent separation from the cow, and weaning off milk, differed between the farms, but most farmers weaned and separated close to 3 months of age, which is the legal minimum milk feeding period for Danish, organic farmers. When asked about the animal's reaction to the separation process farmers mentioned behavioural reactions such as calling for each other and searching behaviour for at least a couple of days. This was independent of whether it was a *foster cow* system or a *dam-calf* contact system. Some farmers had tried out different approaches to minimize the weaning and separation stress. Farmer J had found that decreasing the distance between the calves and cows after weaning improved the process,

> *"Back when we started having them on pasture, in the beginning, when we separated them, we took them far away, but that only meant trouble–calves that broke out–but now, when they are only separated by a double fence-line, then it is just like they are still with the herd... When the foster cows walk to one end, then the others also walk to that end, if they lie down, then they all lie down close to the fence... so even though they are each on their own side, they are still in the herd."* [Farmer J]

However, Farmer I had tried a weaning and separation strategy where they gradually closed a fence between the cows and calves more and more up and then finally put cows and calves on each side of the feed table. However, Farmer I thought this had just increased the period of stress and especially the cows had kept calling for longer than they did when separated suddenly and completely.

In the present study farmers across different CCC systems generally seemed to view the separation and weaning response seen after more than 3 months of suckling as acceptable in the light of the positive effects cows and calves had during the time together and none of the three farmers who had discontinued a CCC system did so because of separation stress. This differs somewhat from the study by Hansen et al. (2023) who found separation stress to be the main reason for farmers to discontinue a CCC system. Some farmers in the present study had tried out different approaches to ease the weaning and separation, but with mixed results. Research in dairy calves and cows generally shows that weaning with fence-line contact (Johnsen et al., 2015b; Wenker et al., 2022) or by increasing the calves' independence from the cow by introducing it to an alternative milk source (Johnsen et al., 2018) decreases weaning and separation stress. However, some farmers in the present study felt like it just prolonged the stressful period. Experiences on whether calves could be introduced to drinking milk from a bucket after weaning from the cow were very diverse. One farmer reported that it was no problem as long as the milk was nice and warm while two others had given up on this approach because calves did not figure out how to drink the milk.

Farmers who practised *hybrid* systems were faced with two rounds of separation, one for the calf and its own dam and then later for the calf and its foster cow. There was some discrepancy in what was perceived as the best time to separate from the dam to bond the calf to a foster cow, which influenced the choice between *hybrid* systems and *foster cow* systems. On one hand, farmers with active *hybrid* systems (F and J) argued to initially leave the calf with the freshly calved dam to ensure well-established suckling. They argued that calves and their dams were more ready to be separated when the calf was no longer hiding (cattle are usually perceived as hider species where the young hides during the first time (Langbein & Raasch, 2000)) and started seeking out the dam (approx. 1-2 weeks). Further, they argued that it was easier to create the foster groups, as the calves were experienced in suckling, so they would be able to suckle even a somewhat unwilling cow until she accepted. That later fostering may be easier was also found in the study by (Vaarst et al., 2001).

However this perspective differed greatly from Farmer D and L, who felt that in a *foster cow* system, cow and calf should be separated soon after birth because leaving them together for 1-2 weeks and then separating them was too hard on the dam,

> *"In my head, they should be together [calf and dam] ... for three, if not four, months. Otherwise, it's about getting that calf to the foster cow as quickly as possible... because I don't like to see how it is after 14 days [of the dam and calf together], like some do it... It was clear, the more days together bonded them in a way that was harder for the dam... it wasn't beneficial ... It was the worst for the dam, it was multiple days... of her pacing and calling. (...) The calves took it pretty well, they just suckled another cow down there [in the foster group]."* [Farmer D]

In summary, farmers had mixed perspectives about a semi-early (a few days to a few weeks) separation from the dam. For some farmers, even a short period of contact between the calf and its dam was valuable enough to justify the increased weaning and separation stress or they felt like the cow and calf were more ready to be separated after a few weeks, than right after birth. On the other hand, some farmers strongly felt that separating a dam and her calf should happen as early as possible (and then transfer the calf to a foster cow) to especially spare the cow from bonding to the calf. Experimental studies have shown that separation after 4 days or 14 days results in intense behavioral responses, lasting for days, compared to when separating within 1 day (Flower & Weary, 2001; Weary & Chua, 2000). However, little is known about the respective benefits of *dam-calf* contact vs *foster cow* contact, and thus more research is needed to compare the impacts of *hybrid* and *foster cow* systems.

Image

Largely, farmers did not elaborate on their image in the eye of the consumers as a guiding factor for how they managed their CCC systems. However, through the interviews, it became apparent that some farmers were influenced by how they were perceived in the general farming community. Though rarely articulated directly, there was a sense that especially farmers from the largest farms were reluctant to "stand out" from the general farming community, especially if being identified as particularly "animal welfare friendly". They emphasized that their CCC system had not been motivated primarily by animal welfare arguments in the first place. Hence, they did not want to be seen as, as one farmer put it, *"organic hippies"* or *"welfare gurus"*:

> *"I like to... have cow and calf together... I don't mind it... but that is not the motivation to do it... it's not to be some welfare guru... it was simply less labor (...)"* [Farmer C]

Through the interviews, there was the sense of farmers categorizing themselves and other farmers into "us" and "them". Some farmers with larger farms expressed that they may not be able to manage their farms in the same way as smaller farms in terms of CCC. They feel that larger farms require a different type of structure and control to be effectively managed. Indeed, Vaarst et al. (2020) pinpointed that readiness to lose some level of control and increase trust in the animals may be necessary to run a cow-calf contact system. In the study by Eriksson et al. (2022) they even found that one characteristic of farms with CCC was smaller farm sizes (number of animals). At the same time, these "larger farms" seemed to be hindered by a fear of being perceived as incompetent or not "a good business", which they measured e.g. on the amount of saleable milk. The data to support these themes were slight but if farmers indeed are afraid to "stick out", then this is a hindering to the implementation of CCC systems.

Earlier studies in a Danish context found similar experiences in the process of converting to organic production (Tress, 2001), where the social norms in farmer communities made converting farmers refer more to economic or practical reasons for their decisions to convert because these arguments were perceived as more valid and did not carry any criticism of other systems. On the other hand, the step to convert to nontraditional systems may also create stronger links between those taking initiative to new production systems, such as organic farming, as also discussed by Lähdesmäki et al. (2019). The surrounding society's perception may stimulate conversion, as discussed by Bouttes et al. (2019), and the network of peers was emphasized by Home et al. (2019). In relation to CCC systems, colleague interactions in farmer groups were shown important to support each other in developing CCC systems, finding practical solutions and also increasingly agreeing that *foster cow* systems were more feasible under current, Danish conditions (Vaarst and Christiansen, 2023 [unpublished data]).

Another concern in relation to farmers' self-concept was the fear of having "wild animals", which some farmers associated with "being a bad farmer". Due to cow-calf contact calves not associating humans with milk feeding and often being in less close contact with humans than artificially reared calves, farmers either feared or had experienced their calves to be less tame. Indeed, calves have been shown to be less interested in humans when reared by a cow, than artificially (Waiblinger et al., 2020b).

Farmer D described how they found pride in having calm animals,

> *"We brag about our calm animals... they almost "attack" us when we get in [the barn], and people tell us that, from the outside, that wow, they are very attention seeking. (...) Raising cows that are comfortable around humans is something a farmer should spend some resources on... because it's so annoying to have animals that won't "attack" you when you arrive—in a good way, of course. It should not be like Moses at the Red Sea. If it's like that, then you should start to get worried that you are doing something wrong... you want to zigzag between your cows."* [Farmer D]

Some farmers mentioned how they consciously tried to avoid allowing calves to become too wild. A couple of farmers hired young, uneducated help to come and spend time with the calves a couple of times a week. Farmer I stated that they housed calves in an easily accessible spot, where the farmer took care to answer all phone calls, to familiarize the calves with human contact. Farmer C was in the process of changing to a more traditional *foster cow* system rather than a part-time system with two daily suckling periods, and had put extra thought into keeping the calves calm:

> *"We are going to take the calves away for four to six hours a day to still get that handling... I also think it can be a bit of a stressful life to be a foster cow because there is never a quiet time, so I think they will appreciate it too. (...) But with the daily separation, we can handle the calves and see that they suckle well when they reunite, and we can spot a weak calf and make sure they don't get too wild."* [Farmer C]

On the other hand, there was a group of farmers who had been using CCC systems longer, and they had a different perspective, pointing out that the CCC calves changed and became less wild as they got older, and thus these farmers were not worried about the young animals being more fearful. Indeed, in the study by Waiblinger et al. (2020b) there was no longer any difference in the human-animal relationship when the animals were tested at the time of inclusion in the lactating herd.

6.3.4 Welfare benefits for the calf

When asked about how the calves' welfare benefited from the chosen CCC system in regards to the "care", "nutrition" and "learning" perspectives identified by (Vaarst

et al., 2020) farmers generally struggled to prioritize these aspects and felt like they overlapped or were equally important. For that reason, this part of the interview turned out to mainly touch upon one theme: care is care.

As it happened, throughout the interviews, in contrast to the findings of Vaarst et al. (2020) and Hansen et al. (2023), most farmers in the present study did not seem to be strongly motivated by animal welfare reasons in choosing CCC systems. On the other hand, they mentioned naturalness and health as important, and both can be seen as strongly related to animal welfare (Fraser, 2008). This could suggest that the term "animal welfare", which was used to introduce the last research question, is not a preferred or familiar term for the farmers. A discussion on the potential bias of the interviewer and interview guide in relation to the concept of animal welfare is given in Section 6.3.5.

Nonetheless, farmers did try to prioritize the flashcards with the three aspects of calf benefits while describing their ideas and perspectives. In general, it seemed that farmers agreed that the benefits for calves in a CCC system were covered by the three flashcards, as only one farmer utilized the "other" flashcard. This was Farmer H who specifically stated that natural behavior was the most important aspect of welfare benefits that calves could gain in a CCC system.

> *"(. . .) animal welfare is not the right word, it should have been called natural behavior... Like it says in the organic rules by the way, that's more important... it's just more correct"* [Farmer H]

Despite struggles to prioritize the three perspectives, *"care"* was always prioritized as the first or the second perspective. This was related to the care elicited by cows towards the calves such as licking and grooming,

> *"(. . .) I think that care from the cow is the most important thing... but I don't know why... it's because... they are like babies that need safety and... well, I am really surprised about how much the small calves are being licked—some of them are always wet! And we also had calves that couldn't figure out how to drink from their cow, but they were so fond of each other anyway, even though they got their milk from us (. . .). I don't know how it works, but there is a bond beyond the milk..."*[Farmer F]

One common perception was that from the calves' perspective, it was not important whether it was its own dam or a foster cow who took care of it, as long as it was cared for and allowed to suckle.

> *"Once the calves have a full belly, they are ready to go and lie down... then it's actually more the cow who is worried about the calf, rather than the calf worrying about the cow... then the cow isn't so important..."* [Farmer K]

Therefore, the care elicited by foster cows seemed to be considered equally as good for the calf as care from the dam,

> *"But the deal with letting dam and calf stay together, right, the whole mother-daughter feeling we are supposed to feel inside: The calf doesn't care one bit. To the calf, a cow is a cow."* [Farmer C]

This statement was supported by Farmer I, who focused on the welfare of the cow in choosing a *dam-calf* contact system.

> *"We need to keep in mind the cow's needs, too! (...) I think that for the calf, it doesn't matter so much welfare-wise [whether it is the calf's own dam] because for the calf it is about getting some milk and surviving."* [Farmer I]

Farmers also expected calves to benefit from a nutritional aspect such as having multiple smaller meals of milk at the right temperature, but most farmers felt that "caring for the calf" included nursing it and thus did not prioritize the nutritional aspect in itself. Only on the farm where calves were with the foster cows for 2 x 1 h a day (Farm C) did the farmer specifically state that the first prioritized benefit was nutritional because it ensured that the milk was delivered at the right temperature and had not been contaminated through the handling process.

Learning was prioritized quite differently among farmers. Farmers who prioritized this aspect described how when, and only if, the calf was allowed access to the same environment and resources as the cow, the calf had the opportunity to learn from the cow how to interact with the farm environment in the best way. Calves were mentioned to learn a variety of behaviors, such as eating solid feeds, navigating the barn and correctly lying in cubicles rather than on the slats.

> *"(...) well I believe it is crucial that the calf has free access to feed, I mean the natural development where they see the mother eat hay, silage, and concentrate.. so they also eat more and more of that, and that is also what the gut should develop toward... that's why it has four stomachs, that is not to drink milk, it just isn't..."* [Farmer I]

There is little literature on how calves learn from cows and more broadly the effect of CCC on dairy calves' social and cognitive skills. However, some studies have found that calves reared with the dam have more appropriate responses in social situations and cope better with the novelty of regrouping (Stěhulová et al., 2008; Zipp & Knierim, 2020) and calves housed in a complex environment with both cows and other calves performed better in a reversal learning task than calves reared individually (Meagher et al., 2015) and were more likely to eat when presented with a novel feed type (Costa et al., 2014).

In summary, farmers with different versions of CCC did not differ in how they described calves to benefit from their CCC system. There is a lack of research comparing the effects of different versions of CCC on the welfare of the calf, but also on the welfare of the cow. Even though farmers perceive calves to benefit equally from different CCC systems, as long as they were allowed to suckle, this does not take into account the welfare of the cows. The motivation of the cows (as demonstrated by Wenker et al. (2020)) to care for their offspring cannot be met, for all cows, in a *foster cow* system and only for a shorter period in a *hybrid* system, compared to *dam-calf* contact systems. This indicates that the calves' welfare is prioritized in CCC systems with hybrid or foster cows.

6.3.5 Methodological considerations

The nature of the present semi-structured qualitative interview study does not allow for generalizations, and care should be taken to understand the perspectives of the farmers in their contexts. The large diversity in types of CCC systems included in the present interview study allowed us to explore very different perspectives but also means that no strong, general conclusions can be drawn for each of the CCC systems. The diversity of farmers in the present study is strengthened by the inclusion of farmers that had tried to establish a CCC system, but for different reasons stopped after 4-12 months. All interviewed farmers from the 12 farms involved in this study were shareholders of one of two relatively small, organic dairy companies where CCC systems were not a part of the payment agreement within the company (at the time of the interviews). Even though their CCC systems were very different and had been established anywhere between 1 and 30 years ago, it cannot be excluded that their common backgrounds in the same dairy companies could have influenced their visions and perspectives, although this was not explored as part of the interviews.

One of the three research questions explored in the percent study was based on a previous study which had identified three main aspects relating to the benefits of a CCC system from the calves' perspective (Vaarst et al., 2020). In the present

study, these three aspects were included with the aim to investigate if there was a correlation between chosen CCC systems and which welfare benefits were prioritized. When introducing the research question during the interviews, the interviewer used the term "animal welfare" before introducing the flashcards which were used as prompts. However, farmers in the present study seemed unfamiliar with the use of the term "animal welfare" and did not recognize this as a main reason to choose a CCC system. Therefore farmers may have been uncomfortable with how to respond to this part of the interview. Nonetheless, farmers could recognize the three aspects and agreed that they were important elements of what the calf gained from a CCC system.

6.4 Conclusion

The present study gave a picture of an emerging practice of establishing CCC systems in Danish, organic dairy herds. The farmers' main motivations were related to practical considerations and a sense of rationality, and farmers described elements of naturalness and joy related to seeing a cow and calf together. Farmers also described major barriers to establishing CCC systems, and in particular dam-calf contact systems, such as financial constraints and structural challenges, for example having invested in housing systems that required major changes if they should provide space and facilities for CCC systems. Since the present study included farms with part-time *dam-calf* contact, *hybrid* systems, and *foster cow* systems, we were introduced to how and why these alternatives were seen as ways to manage these barriers. Part-time contact facilitated *dam-calf* contact systems by increasing the amount of saleable milk and allowing cows access to pasture during the day without having to calf-proof all fencing. *Foster cow* systems may be the most feasible CCC system to implement in current farm settings because it fully circumvents the two main barriers of *dam-calf* contact. However, none of the CCC systems seemed to solve the last main barrier; the weaning and separation stress, but in the present study farmers generally accepted some stress by the end of the milk feeding period, as it was weighted up against the positive effects of the contact period. Public image was only a primary driver for CCC for farmers with on-farm visitors, but some farmers showed consideration regarding their image relating to how they were perceived as competent and professional by their peers.

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Chapter 7

Paper II

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The behavior of calves reared with half-day contact to their dam

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Abstract

Dam-calf contact has been suggested to improve animal welfare in dairy calves, but practical and economical concerns have led to an interest in half-day contact between cows and their calves. However, little is known about the behavioral effects of half-day contact compared to whole-day contact. The present study investigated the behavior of 45 dairy calves housed with their dams either in a whole-day system (cows only away twice daily for milking) or a half-day system (cows away from afternoon milking until after morning milking the next day). Data were recorded during 24 h using video when calves were on average 3, 5, and 7 weeks old. Half-day calves spent less time suckling and received less grooming compared to whole-day calves, indicating that they received less maternal care. Half-day calves were quicker to reunite with their dam when the cows returned from morning milking compared to whole-day calves. Half-day calves also suckled alien cows more often though mainly shortly after the cows returned to the pen in the morning. This may indicate that they were hungrier than whole-day calves at this time of day. Half-day calves spent more time interacting with other calves and spent more time eating solid feeds, which may prepare them better for separation from the dam and weaning off milk. In conclusion, half-day dam-calf contact may affect calf welfare both positively and negatively, and further research focusing more directly on assessing affective states is encouraged.

Keywords: Dam-rearing; Mother-offspring bond; Maternal behavior; Repeated separation

7.1 Introduction

Animal welfare is an area receiving increased interest, especially in regard to the importance of animals experiencing positive emotional states (Lawrence et al., 2019). Studies have increasingly explored the behavioral effects of keeping dairy calves with their dam instead of the otherwise common practice of separation within 12 to 24 h of birth (reviewed by Meagher et al., 2019). A growing body of evidence indicates that cows and their calves are highly motivated to be together (Johnsen et al., 2015; Wenker et al., 2020; Wenker et al., 2021). Close contact and affiliative behaviors may be associated with positive experiences for both cow and calf (reviewed by Mellor, 2015). Further, calves appear to gain behavioral benefits such as improved social skills, enabling them to respond appropriately in challenging social situations such as regrouping (Buchli et al., 2017; Wagner et al., 2012; Zipp & Knierim, 2020) and to more readily accept novel feeds (Costa et al., 2014). This is also farmers'

impression; farmers that practice *dam-calf* contact (i.e. calves that suckle from their own dam, see Sirovnik et al. (2020) for terminology) reported in an interview study, that calves benefit from learning how to navigate the environment from the cow, as well as from suckling in a natural pattern and receiving maternal care (Paper I, submitted to Journal of Dairy Science: Bertelsen & Vaarst, 2023; Vaarst et al., 2020).

Challenges of cow-calf contact are 1) increased behavioral reactions to weaning and separation (Johnsen et al., 2018; Nicolao et al., 2022; Stěhulová et al., 2008), 2) a decrease in saleable milk due to the calf ingesting approximately twice as much as provided with standard artificial rearing (dam-rearing: 12 to 15L per day (Barth, 2020), artificial feeding: 4 to 6 L per day (reviewed by Whalin et al., 2021)) as well as 3) issues with cows not letting down milk completely in the parlor, possibly due to changes in hormonal sensitivity (Tancin et al., 2001). Further, interviewed farmers express practical difficulties related to keeping cow and calf together (Paper I, submitted to Journal of Dairy Science: Bertelsen & Vaarst, 2023; Hansen et al., 2023; Neave et al., 2022) such as having to increase fencing quality and have close-by pasture available if calves are to follow cows on pasture.

Part-time, or specifically half-day, contact systems have been suggested as an approach to mitigate these problems (Johnsen et al., 2016; Meagher et al., 2019). In half-day systems, cow and calf typically have contact between two milkings, either during the day or during the night, while the other half of the day, cows and calves are kept separate. Compared to whole-day contact, half-day contact has been suggested to 1) weaken the mother-offspring bond (Johnsen et al., 2016; Newberry & Swanson, 2008) and thereby promote a more gentle permanent separation, 2) to reduce calves' milk intake (both due to less time for suckling and by promoting solid feed intake) and thereby increase the amount of saleable milk (Johnsen et al., 2016), as well as 3) improve milk let down in the parlor (Barth, 2020). At the same time, half-day contact allows for more flexible housing and management, as well as more human handling, which may improve the human-animal relationship. However, there is little research on the effects of half-day contact compared to whole-day contact, where cows only are away for milking. Animal welfare concerns may be raised in regards to 1) The repeated daily separations, which may, at least during an initial period, be perceived as stressful, and 2) the lower daily duration of contact, which may reduce the quantity of maternal behavior, including nursing.

If the daily separation induces stress it may present as decreased resting in calves during the separation periods and cows may be difficult to herd to the milking parlor before the daily separation period. An important question is also whether responses to daily separation are reduced over time. A recent study by Roadknight

et al. (2022) found no decrease in response to separation over 10 days in dairy cows with either half-day or whole-day dam-calf contact but the response may have either waned before the observations started at 8 days of age or decrease over the following weeks. Increased social reinstatement behaviors after the daily separation period, such as shorter latency to reunite and to suckle, as well as a rebound of social behavior, may indicate a high motivation to be together. Reduced latency to nurse upon reuniting may also indicate increased hunger levels, as suggested by the results of Roadknight et al. (2022) who found shorter latency to reunite and suckle after the daily separation period in half-day contact calves than whole-day contact calves.

The mother-offspring bond, as defined by Gubernick (1981) is *"the preferential responding between parents and offspring as defined by various operational criteria. These include the preference for one individual over another, seeking and maintaining close proximity, a response to brief separation from the attachment figure, a response to extended periods of separation, a response to reunion with the attachment figure, and finally the use of the attachment figure as a secure base to explore the world."* The quality of the mother-offspring bond, as defined by Gubernick (1981) may thus be judged depending on the time spend in close proximity and performing grooming and suckling. Suckling in an inverse parallel position is expected to be indicative of a bonded pair (Sirovnik et al., 2020), while calves that are also suckling an alien cow may be less strongly bonded to the dam.

The present study compared the behavior of cows and their calves with respectively whole-day and half-day (day only) contact at weeks 3, 5, and 7 before any weaning occurred. The focus of the present study was on the calves unless otherwise specified. The hypotheses were as follows 1) That half-day contact results in fewer dam-calf interactions, 2) That half-day contact results in more daily separation-related stress as seen by reduced lying time, more social reinstatement behavior, and for the cows more reluctance to leave the calf and 3) That half-day calves spend more time eating solids, more time in calf creeps, and more time close to another calf, indicating less dependence of the dam.

7.2 Methods and materials

7.2.1 Animals, housing, and management

The study was conducted in the experimental barn at the Danish Cattle Research Centre at Foulum, Aarhus University, Denmark, from September 2020 to May 2021. Forty-eight purebred Danish Holstein *(Bos Taurus)* cows and their newborn calves were enrolled. For each of six consecutive blocks according to calving date, four cow-calf pairs were randomly chosen to be housed together in one group pen with daily whole-day contact (Whole-day) and four cow-calf pairs were housed in another group pen with daily half-day contact (Half-day), amounting to a total of 24 experimental cow-calf pairs on each treatment. The sample size was based on the availability of experimental animals in the resident herd and supported by post hoc power calculations to detect significant differences (at 5% significance) between treatments for suckling own dam with a power of 78%. Due to three disease incidences (two calves with diarrhea and fever and one cow with mastitis, blocks 3, 4, and 6, Whole-day treatment), data were analyzed from a total of 45 calves and cows (n = 21 for Whole-day and n = 24 for Half-day). To be enrolled in the experiment, cows had to have calved without complications, both cow and calf had to be clinically healthy and the calf should suckle independently within 24 h. Cows were in 1st to 5th lactation, and 1 primiparous cow was included per group (except in block 4 where each of the 2 groups had 2 primiparous and 2 multiparous cows). None of the cows had previously been kept with their calf for longer than 12 h after calving. Both male and female calves were included, and at least one of each sex was included in each group with the exception of two groups with only bull calves (Whole-day in block 2 and Half-day in block 5). The calves were not disbudded during the experimental period. The age difference between the youngest and oldest calf in a block was on average 13 days (SD ±7), ranging from 4 to 24 days. Cows and calves were separated permanently after the 8th experimental week.

After calving, the pair stayed in an individual calving pen for 20 to 36 h to establish suckling and bonding. All calves were fed the dams' colostrum (4 L) via a teat bottle within 6 h after birth. A dose (1 ml Cevivit®E-Selen) of E-vitamin was added to the colostrum. At the colostrum feeding the calf's ability to suckle the dam (filled calf stomach, milk foam around calf's mouth, saliva on the dam's udder) was assessed and if there were no signs of suckling, the calf was guided to the udder, i.e. suckling was assisted. If the calf did not suckle, suckling was assisted again 6 h later. If a calf was unable to suckle within the first 24 h of life, the cow-calf pair did not enter the experiment. If suckling was established the pair was moved to a deep-bedded group

pen (9 m x 7.5 m) for four cow-calf pairs on the same treatment. Each group pen had a feed trough for the cow's Total Mixed Ration (clover-grass and maize silage (65%) and concentrates (35%)) and two water bowls in the front of the pen, all of which were accessible to the calves as well. Calf creeps made from tubular metal bars were positioned in each of the two back corners of the pen (3 m x 3 m and 1.5 m x 1.5 m, respectively) and accessible to the calves only. In both calf creeps, calves had access to hay and calf concentrates (DLG: "Komkalv Start Valset" FEk/kg: 0.99 FEk; Raw Protein: 20%; Raw fat: 3.6%; Fiber: 5.4%; Raw Ash: 7.5%; Water; 13%) ad libitum, while only the largest calf creep contained a water bowl.

All cows were milked between 5:00 and 5:30 h and between 15:30 and 16:00 h in a milking parlor. Whole-day cows were thus separated from their calves for milking twice a day (i.e. 2 x 30 min/d (mean ±SD: 56 min ±8 min)). Half-day cows were further separated from their calves between afternoon and morning milking (i.e. 14 h a day (mean ±SD: 13 h 58 min ±8 min), where they were housed in a pen in an adjacent building with cubicles and slatted concrete floor in the alleys. In this pen, there were two cubicles per cow and ad libitum access to water, and the same Total Mixed Ration as in the cow-calf group pens.

7.2.2 Behavioral observations

The behavior was video recorded by cameras placed above each pen (Hikvision DS-2CD2143G2-I 4MP PoE). The behavior of all four calves in a pen was recorded using focal animal sampling and either continuous or instantaneous recording (Bateson and Martin, 2021) for 24 h (starting at midnight) using the BORIS software (Friard & Gamba, 2016). No blinding was possible. Three different datasets were collected from the video recordings by 2 to 3 observers per dataset and will be further described below. Calves were observed in experimental weeks 3, 5, and 7 (here forth: "week") at a mean age (SD = 7) of 22 days, 35 days, and 50 days, respectively. Inter-observer reliability was compared using the BORIS software's built-in Cohen's Kappa calculations. Lastly, cows were observed during the first and last two weeks of the experimental period on their way to afternoon milking, and Half-day cows were observed also during the first 20 min in their night pen, using direct focal animal sampling and continuous recording.

Data set 1: Calf behavior in home pen

Continuous recordings during 24 h were made on one day in weeks 3 and 7, respectively. The ethogram is presented in Table 7.1. All recordings were done by one of

three observers, and the inter-observer reliability was κ=0.875 between observers A and B and κ=0.789 between observers B and C.

Table 7.1: The ethogram describing the behavioral elements recorded continuously using focal animal sampling during 24 h in week 3 and 7, respectively.

Behavior	**Description**	**Subject**
Suckling from the side	The calf's head is positioned under the cow's abdomen in the udder area, accessed from either side of the cow, between a front and a hind leg. A break of less than 10 seconds does not interrupt the behavior.	Own dam, alien cow
Suckling from behind	The calf's head is positioned under the cow's abdomen in the udder area, accessed from behind the cow, between the two hind legs. A break of less than 10 seconds does not interrupt the behavior.	Own dam, alien cow
Cross sucking	The calf is sucking the head or any body part of another calf. The other calf's body part is in the mouth of the focal calf, typically ears, navel, scrotum, or udder base.	
Grooming	The calf's muzzle or tongue touches the head or body of another individual. Typically associated with licking movements as the tongue is moved over the fur of the other individual.	Own dam, alien cow, calf
Eating	The calf's muzzle is placed in a feeding trough, over feeding trough or next to the hay rack while the calf is chewing.	
Drinking	The calf's muzzle is placed in a drinking bowl.	
Lying	The calf is lying on its sternum or side. The legs may be stretched or bent and the head may be raised or resting on the body or the straw.	
Other activity	Any behavior of the calf not specified above, e.g. walking, trotting, exploring, self-grooming, no apparent activity.	
Locomotor play	The calf performs galloping, jumping, kicking up hind legs, leaps, turns, or body twists (as defined by Jensen et al., 1998).	
Social play	The focal calf is standing front to front with another individual while the two are mutually pushing their foreheads against each other without resulting in withdrawal or aggressive behavior (Jensen et al., 1998).	Own dam, alien cow, calf

Receiving grooming from cow	The calf receives grooming from a cow. The cow's muzzle or tongue touches the head or body of her calf. Typically associated with licking movements as the tongue is moved over the fur of the calf. Not mutually exclusive, e.g. the calf can be suckling/lying/etc.	Own dam, alien cow
Receiving agonistic behavior from cow*	The calf receives agonistic behavior from a cow. The cow either forcefully pushes on any body part of the calf with head or raises the hind leg and kicks any body part of the calf with the hoof. Also, if the cow threatens the calf with the head lowered towards the calf resulting in the withdrawal of the focal calf within three seconds.	Own dam, alien cow

*Point event. All other variables are recorded as states (Bateson & Martin, 2021)

Data set 2: Calves behavior upon being reunited after morning milking

Continuous recordings focusing on latency during the first 30 min after each of the cows returned to the group pens after the morning milking was made in weeks 3, 5, and 7, respectively. The observations started when the calf's dam had both front legs in the pen. The ethogram is shown in Table 7.2. The observations were stopped after 1800 s (30 min) and any calves that had not performed the behaviors within this time were allotted an 1800s observation and noted as censored. All recordings were done by one of two observers, and the inter-observer reliability was κ=0.921.

Table 7.2: The ethogram describing the behavioral elements recorded continuously upon cows reuniting with the calves after the morning milking where Half-day calves had been separated throughout the night, and Whole-day calves had been separated for the milking duration only. Observations were performed in weeks 3, 5, and 7, respectively.

Behavior	**Description**
Latency to reunite	The moment the calf's muzzle is less than 1 m from any body part of the cow
Latency to suckle alien cow	While standing, the calf's head is positioned under an alien cow's abdomen in the udder area. Any cow who is not the calves own dam, is defined as alien.
Latency to suckle own dam	While standing, the calf's head is positioned under the dam's abdomen in the udder area.

Data set 3: Calf creep use and proximity to the dam and the other calves

Instantaneous scan sampling was made during 24 h at 10 min intervals on one day in each of weeks 3, 5, and 7. The ethogram is shown in Table 7.3. All recordings were done by one of two observers, and the inter-observer reliability was κ=0.882.

Table 7.3: The ethogram describing the behavioral elements recorded using instantaneous recording (scan sampling) of calves at 10 min intervals during 24 h in weeks 3, 5, and 7, respectively.

Behavior		Description
Position	In creep	The calf is positioned with the head and both front legs inside the calf creep. The calf may be standing or lying.
	In main pen	The calf is positioned with the head and both front legs in the main pen. The calf may be standing or lying.
Posture	Standing	The calf's posture is upright, either standing still or walking, with at least 2 legs supporting the body.
	Lying	The calf is lying on its sternum or side. The legs may be stretched or bent and the head may be raised or resting on the body or the straw.
Distance to own dam	<1 m	The calf's muzzle is less than 1 m from any body part or head of the dam
	≥1 m	The calf's muzzle is at or more than 1 m from any body part or head of the dam
Distance to the nearest calf	<1 m	The calf's muzzle is less than 1 m from any body part or head of the nearest calf
	≥1 m	The calf's muzzle is at or more than 1 m from any body part or head of the nearest calf

Data set 4: Cow behavior when fetched for afternoon milking.

Continuous direct observations were made of all cows' behavior on the way to the milking parlor for afternoon milking and for Half-day cows also upon entering their night pen. Observations were made during the first 2 and last 2 weeks of the experimental period. All cows were observed at least twice (mean no. of observations/cow ±SD: 3.9 ±1.2. Number of days since calving ranged from 2 to 69). The cows were followed by one observer who walked 5 to 10 m behind the barn staff herding the animals to the milking parlor. The distance to the milking parlor was approximately 70 m. All parts of the walkway were wide enough for a cow to turn around (approximately 3.5 m), even if another cow was next to her. After milking, the Half-day cows were guided to the night pen where they were observed for 20 min. The ethogram is presented in Table 7.4. Any cows that had not performed eating or lying within the 20 min were allotted a 20 min observation and noted as censored.

Table 7.4: The ethogram used for observations on cows' behavior in relation to daily, repeated separation.

Behavior	Description
Turn around (Counts)	The cow changes faced direction (decided by the direction of the spine, not head) by at least 90 degrees after first having faced in the direction of the exit door. A subsequent event of the behavior may be recorded when the cow has again been facing in the direction of the exit door.
Vocalizations (Counts)	The cow emits an open-mouthed vocalization of any duration and pitch. A break of less than 3 seconds does not interrupt a vocalization.
Latency to eat*	The time span from the cow enters the pen until the first time the cow eats.
Latency to lie*	The time span from the cow enters the pen until the first time the cow lies down resting her sternum on the surface.
Head out* (Counts)	The cow places her head (at least the whole muzzle, i.e. both nostrils) over any side of the pen. Placing the head through a headlock is not counted as head out. A break of less than 10 seconds does not interrupt the behavior.

*Recorded for Half-day cows only

7.2.3 Statistical analysis

Statistical analysis was performed in R, using RStudio (Core Team, 2022). Generalized linear mixed models were analyzed with the package "glmmTMB" (Brooks et al., 2017) and mixed cox proportional models with the package "coxme" (Therneau, 2022). The assumptions of distribution and homoscedasticity were checked by graphical inspection of the model residuals. Statistical significance was decided at the $p<0.05$ level based on type II Chi^2 test (χ^2). Multiple pairwise comparisons were corrected using the Tukey or Sidak method. When less than 50% of animals performed a behavior, the variable was transformed to a binary variable (1/0) (see Table 7.5).

Table 7.5: An overview of response variables from each of the four data sets and the analyses performed

Data sets	Measure	Data type	Model
Data set 1: Calf behavior in home pen			
Grooming calf	Duration (min)[1]	Continuous (Gaussian, identity link)	GLMM
Grooming dam			
Eating (all)[2]			
Drinking			
Lying			
Receive grooming from dam			
Locomotor play			
Social play (all)[3]			
Suckling own dam (total)[4]			
Suckling own dam from behind	Number of calves	Binary (Binomial, logit link)	
Suckling alien cow from behind			
Suckling alien cow (total)[4]			
Cross sucking			
Groom alien cow			
Receive grooming from alien			
Suckling bouts (alien cow + dam)	Number of occurrences	Count (Poisson, log link)	
Receive agonistic behavior from dam			
Receive agonistic behavior from cow			
Date set 2: Calves behavior upon being reunited after morning milking			
Latency to reunite with dam	Latency (s)	Time to event	MCPH
Latency to suckle dam			
Latency to suckle alien cow			
Data set 3: Calf creep use and proximity to dam and other calves			
In creep	Proportion of scans	Continuous (Gaussian, identity link)	GLMM
Lying			
<1m from dam			
<1m from other calf			
Data set 4: Cow behavior when fetched for afternoon milking			
Turn around	Number of cows	Binary (Binomial , logit link)	GLMM
Vocalizations	Number of occurrences	Count (Neg. binomial, log link)	
Head out			
Latency to lie	Latency (min)	Latencies	MCPH
Latency to eat			

[1] Square root transformed for analysis

[2] Summed duration of eating hay, concentrate and total mixed ration

[3] Summed social play with dam, alien cow or other calves

[4] Summed suckling from behind and from the side

GLMM: Generalized linear mixed model, MCPH: Mixed Cox Proportional Hazards Model

For the continuous 24 h observations of calf behavior (data set 1), the total duration of each state behavior (see Table 7.5) and the total number of occurrences of point events (see Table 7.5) were calculated for each calf per 24 h, at each of the two observation weeks. For descriptive purposes, the data was also calculated for a day and a night period. The periods were defined as Day: from cows leaving for morning milking until leaving for afternoon milking (cows present except during morning milking). Night: from the beginning of afternoon milking until the next morning milking (cows not present for Half-day). The distribution of state variables was right-skewed, and before statistical analysis, the duration of all state variables was square root transformed to meet the assumptions of being normally distributed. Resulting estimates (means and confidence intervals (CI) were back-transformed for reporting.

For the data collected using 24 h instantaneous recording (data set 3), the number of recordings (scans) for respectively day and night, was used to calculate the proportion of recordings for each behavior, within each week and each period of the day. The periods of the day were defined as "day" when all cows were present and "night" when Half-day cows were not present. Further, lying less than one meter from own dam, lying less than one meter from another calf, and lying in the creep was computed for each week and period of the day.

Generalized linear mixed models (GLMM)

All continuous, binary, and count variables were analyzed with a GLMM, fitted with the appropriate distribution and link (See Table 7.5). All models included random effects of pen and block and a random effect taking into account the repeated measures on each calf.

The continuous variables in dataset 1 and dataset 3 were analyzed by a model including the categorical fixed effects of treatment (Whole-day, Half-day), week (3, 5, 7), and parity (primiparous, multiparous) as well as the interaction between treatment and week. Week 5 was included for data set 3 only.

For all binary and count data variables in dataset 1 and dataset 4, the model included the categorical fixed effects of treatment (Whole-day, Half-day), time [Week (3, 7) for data set 1 or the continuous fixed effect of days since calving (2-69 days) for data set 4] and parity (primiparous, multiparous) as well as the interaction between treatment and time.

Mixed Cox Proportional Hazards Model (MCPH)

latency in data set 2 and 4 were analyzed by an MCPH (Table 7.5). The model included the categorical fixed effects of treatment (Whole-day, Half-day), time [week (3, 7) for data set 1 or the continuous fixed effect of days since calving (2-69 days) for data set 4] and parity (primiparous, multiparous) as well as the interaction between treatment and time. The model further included random effects of pen and block and a random effect taking into account the repeated measures on each calf.

7.3 Results

7.3.1 Calf behavior in home pen

Calves on the Whole-day treatment spent more time suckling their dam than calves on the Half-day treatment (Table 7.6). There was a tendency for interaction for suckling the dam from behind and week since more Half-day calves than Whole-day calves suckled their dam from behind in week 7 (Probabilities and 95% CI: For week 3, Whole-day: 0.33 [0.17-0.5] and Half-day: 0.37 [0.2-0.59], for week 7, Whole-day: 0.09 [0.02-0.32] and Half-day: 0.46 [0.27-0.66], p = 0.07, χ^2 = 3.30, df = 1). There was also a tendency for more Half-day calves to suckle an alien cow than Whole-day calves (Table 7.6). Independent of treatment, fewer calves suckled on alien cows in week 7 than in week 3. There was an interaction between treatment and week for the frequency of suckling bouts (See Figure 7.1, p<0.001, χ^2=11.3, df = 1). Whole-day calves suckled more often in week 3 than in week 7, while Half-day calves suckled a similar amount of times in both weeks.

Table 7.6: The results from 24 h continuous observations of calf behavior in the home pen. Each of the response variables are presented as estimated mean durations, counts or probabilities for each of the levels of the categorical, explanatory variables week and treatment. Whole-day: n = 24, Half-day: n = 21.

	Treatment Estimates [95% CI]		**Weeks Estimates [95% CI]**		**Test Statistics**		
Behavior	**Whole-day**	**Half-day**	**Week 3**	**Week 7**	**Treat**	**Week**	**Treat x Week**
Suckling own dam	37.0	25.7	31.0	31.1	p<0.001	p = 0.77	p = 0.46
(min/24 h)	[30.6-44.0]	[20.5-31.5]	[26.11-36.2]	[26.3-36.2]	$\chi^2_1 = 9.60$	$\chi^2_1 = 0.97$	$\chi^2_1 = 0.79$
Suckling dam, from behind	0.18	0.41	0.23	0.35	p = 0.11	p = 0.58	p = 0.07
(probability)	[0.07-0.39]	[0.26-0.59]	[0.10-0.45]	[0.21-0.53]	$\chi^2_1 = 2.57$	$\chi^2_1 = 0.29$	$\chi^2_1 = 3.30$
Suckling alien cow	0.34	0.73	0.73	0.34	p = 0.08	p<0.05	p = 0.44
(probability)	[0.11-0.68]	[0.42-0.91]	[0.42-0.91]	[0.14-0.61]	$\chi^2_1 = 3.01$	$\chi^2_1 = 5.32$	$\chi^2_1 = 0.59$
Suckling alien cow, from behind	0.07	0.29	0.23	0.09	p = 0.11	p = 0.17	p = 0.56
(probability)	[0.009-0.42]	[0.08-0.65]	[0.006-0.57]	[0.02-0.43]	$\chi^2_1 = 2.60$	$\chi^2_1 = 1.92$	$\chi^2_1 = 0.33$
Groomed by own dam	16.9	8.45	14.1	10.6	p<0.001	p<0.05	p = 0.08
(min/24 h)	[10.9-24.1]	[4.53-13.7]	[9.42-19.8]	[6.53-15.7]	$\chi^2_1 = 8.19$	$\chi^2_1 = 5.02$	$\chi^2_1 = 2.99$
Grooming own dam	5.76	3.21	4.52	4.33	p<0.05	p = 0.84	p = 0.99
(min/24 h)	[3.56-8.71]	[1.62-5.33]	[2.76-6.68]	[2.52-6.64]	$\chi^2_1 = 4.40$	$\chi^2_1 = 0.04$	$\chi^2_1 = 0.00$
Grooming calf	2.78	4.91	3.44	4.08	p = 0.09	p = 0.24	p = 0.84
(min/24 h)	[1.2-4.9]	[2.7-7.6]	[1.9-5.2]	[2.5-6.2]	$\chi^2_1 = 2.79$	$\chi^2_1 = 1.38$	$\chi^2_1 = 0.03$
Agonistic from dam	0.03	0.13	0.05	0.07	p = 0.10	p = 0.69	p = 0.30
(count/24 h)	[0.004-0.21]	[0.03-0.64]	[0.009-0.31]	[0.015-0.36]	$\chi^2_1 = 2.65$	$\chi^2_1 = 0.16$	$\chi^2_1 = 1.07$
Agonistic from alien cow	3.32	2.41	2.98	2.70	p = 0.05	p = 0.46	p = 0.86
(count/24 h)	[2.39-4.55]	[1.74-3.34]	[2.29-3.91]	[2.01-3.58]	$\chi^2_1 = 3.54$	$\chi^2_1 = 0.54$	$\chi^2_1 = 0.87$
Resting	17.7	17.8	18.0	17.5	p = 0.72	p<0.05	p = 0.80
(h/24 h)	[17.1-18.3]	[17.2-18.4]	[17.5-18.5]	[16.9-18.0]	$\chi^2_1 = 0.13$	$\chi^2_1 = 5.26$	$\chi^2_1 = 0.06$
Eating	15.8	32.7	19.2	28.3	p<0.001	p<0.01	p = 0.46
(min/24 h)	[8.08-26.2]	[21.1-46.8]	[10.8-30.1]	[17.6-41.4]	$\chi^2_1 = 18.9$	$\chi^2_1 = 6.60$	$\chi^2_1 = 0.54$
Drinking	5.36	6.25	5.73	5.86	p = 0.44	p = 0.95	p = 0.16
(min/24 h)	[3.52-7.58]	[4.31-8.55]	[4.18-7.52]	[4.00-8.08]	$\chi^2_1 = 0.61$	$\chi^2_1 = 0.00$	χ^2_1=1.97

Subscripts indicate degrees of freedom for the Chi^2-test (χ^2_{df})

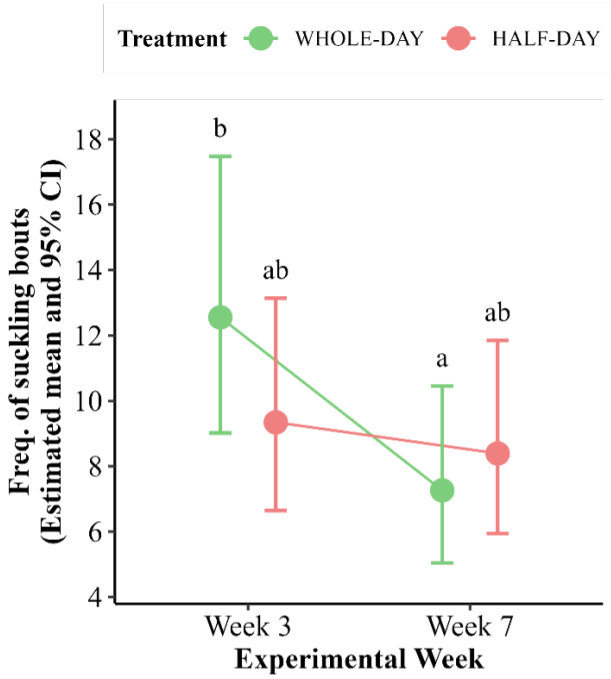


Figure 7.1: The interaction between treatment and week for the total number of suckling bouts (own dam + alien cows). Whole-day: n = 24, Half-day: n = 21

Calves on the Whole-day treatment received more grooming from their dam than Half-day calves and they also spend more time grooming their dam than Half-day calves (Table 7.6). Calves were generally groomed less by the dam in week 7 than in week 3, but the interaction between treatment and week tended to be significant, driven by a decrease in maternal grooming for Half-day calves in week 7 (Table 7.6). Calves of multiparous cows received more grooming than calves of primiparous cows (primiparous: 9.5 min [5.2-15.2], multiparous: 15.5 min [11.3-20.4]; $p<0.05$, $\chi^2 = 3.9$, df = 1). There was a tendency for more Half-day calves to groom other calves compared with Whole-day (Table 7.6).

There was also a tendency for calves of multiparous cows to spend more time grooming other calves, than calves of primiparous calves (primiparous: 2.6 min [1.0-4.9], multiparous: 5.0 min [3.5-6.9]; $p = 0.079$, $\chi^2 = 3.1$, df = 1). There was no difference in the number of calves grooming or being groomed by an alien cow across treatments.

There was no treatment difference found in the number of agonistic behaviors calves received from their own dam (Table 7.6). However, Whole-day calves tended to receive more agonistic behaviors from an alien cow than Half-day (Table 7.6).

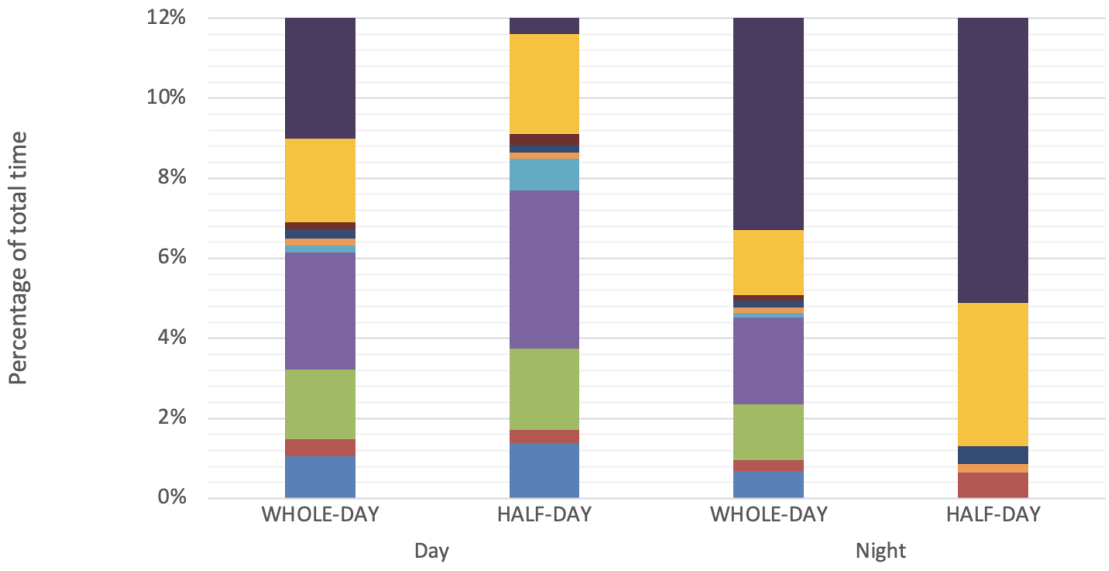
There was no effect of treatment on the daily time spent lying, but calves were lying for a longer duration in week 3 than in week 7 (Table 7.6). There was also no effect of treatment on the duration of time spent drinking water. There was however a treatment effect for the total time spent eating (hay, concentrate, and TMR). Half-day calves spend a longer duration eating solid feed compared to Whole-day (Table 7.6). Further, calves generally spend more time eating solids in week 7 than in week 3 (Table 7.6). A total of 5 calves showed cross-sucking behavior (Half-day: 3 and Whole-day: 2). For 2 of the Half-day calves, cross-sucking was observed in both weeks 3 and 7. The duration of cross-sucking for calves who performed the behavior ranged from 6.5 s/24 h to 253 s/24 h.

A detailed analysis of play behavior of two calves per pen is reported elsewhere (Bailly-Caumette et al., 2023), but general play categories including all calves are given in Figure 7.2. See Figure 7.2 for the descriptive distribution of the recorded behaviors between the day (cows present for both treatments) and night (cows only present for Whole-day).

7.3.2 Behavior when cows return after morning milking

Reuniting with dam after morning milking

There was a main effect of treatment for the latency to reunite with the dam ($p<0.001$, $\chi^2 = 28.4$, df = 1) with Half-day having a 65.9% probability of having shorter latency to reunite with their dam than Whole-day (Hazard Ratio and CI: 1.94 [0.99-3.80]). The median survival time (where half of the cow-calf pairs were reunited) was respectively 22.5 s for Whole-day and 3.9 s for Half-day. There was further a tendency for interaction between treatment and week ($p = 0.06$, $\chi^2 = 5.59$, df = 2). See Figure 7.3 for Kaplan-Meier Survival Curves for each week and each of the two treatments. The median survival time for reuniting with the dam as estimated from Kaplan-Meiers survival curves were respectively 9 s for Whole-day and 5 s for Half-day in week 3 (median ratio: 0.73), 27 s for Whole-day and 3 s for Half-day in week 5 (median ratio: 8.31), while for week 7 they were 31 s for Whole-day vs. 3 s for Half-day (median ratio: 10.3).



	Day		Night	
Resting	67.45%	65.36%	77.26%	78.72%
Other Activity	23.56%	23.03%	16.03%	16.39%
Eating	2.09%	2.51%	1.63%	3.59%
Social Play (Cow)	0.18%	0.26%	0.13%	0.00%
Social Play (Calf)	0.22%	0.21%	0.17%	0.45%
Locomotor Play	0.18%	0.16%	0.13%	0.20%
Suckling Alien	0.17%	0.79%	0.11%	0.00%
Suckling Own	2.93%	3.95%	2.18%	0.00%
Groomed by cow	1.74%	2.05%	1.39%	0.00%
Grooming calf	0.42%	0.32%	0.28%	0.64%
Grooming cow	1.06%	1.38%	0.68%	0.00%

Figure 7.2: Distribution of behaviors over 24 h in dairy calves with either Whole-day or Half-day contact to their dam, averaged across the third and seventh week. The plot is zoomed into the 12% of time, i.e. time spent on "resting" is not shown and not all time spent on "other activity" is shown. The percentage of total time spent on each of the behavioral elements recorded (including resting and other activity) is given for respectively the day period (all calves have access to their cow) and the night period (only Whole-day calves have access to their cow). Whole-day: n = 24, Half-day: n = 21.

Suckling dam after morning milking

There was an interaction between treatment and week for suckling the dam upon reuniting ($p<0.01$, $\chi^2 = 9.89$, df = 2). In week 3, calves on the Half-day treatment had a 90.6% probability of having shorter latency to suckle their dam than Whole-day calves (Hazard Ratio and CI: 9.67 [3.75-24.94], $p<0.001$). There was no significant difference in week 5 between treatments. Half-day calves had an 84.3% probability of having shorter latency to suckle the dam than Whole-day in week 7 (Hazard Ratios and CI: 5.36 [1.41-20.35], $p<0.01$). The median survival time for suckling the dam was respectively 724 s for Whole-day and 18 s for Half-day in week 3 (median ratio: 41.2), 429 s for Whole-day and 22 s for Half-day in week 5 (median ratio: 20.0), while for week 7, only 4 Whole-day calves suckled their dam at all within 30 min, not allowing for a median survival time, and the median survival time for Half-day was 16 s. See Figure 7.3 for Kaplan-Meier Survival Curves for each week and each of the two treatments.

Suckling alien cow after morning milking

There was an interaction between treatment and week for suckling an alien cow upon reuniting ($p<0.05$, $\chi^2 = 8.10$, df = 2). There was no significant difference in week 3 between treatments, but the probability of Half-day calves having shorter latency to suckle from an alien cow than Whole-day in week 5 was 94% (Hazard Ratio and CI: 15.95 [1.69-149.9], $p<0.01$). There tended to be a difference in week 7 with calves on the Half-day treatment having 90% probability of shorter latency to suckle an alien cow compared to Whole-day (Hazard Ratio and CI: 9.13 [0.96-87.18], $p = 0.055$). For Half-day the median survival time were respectively 1466 s, 727 s, and 1523 s for weeks 3, 5, and 7, while for Whole-day for each of the three weeks, respectively 7, 1, and 1 calf performed suckling of an alien cow within the 30 min observation period, not allowing for median survival times. See Figure 7.3 for Kaplan-Meier Survival Curves for each week and each of the two treatments.

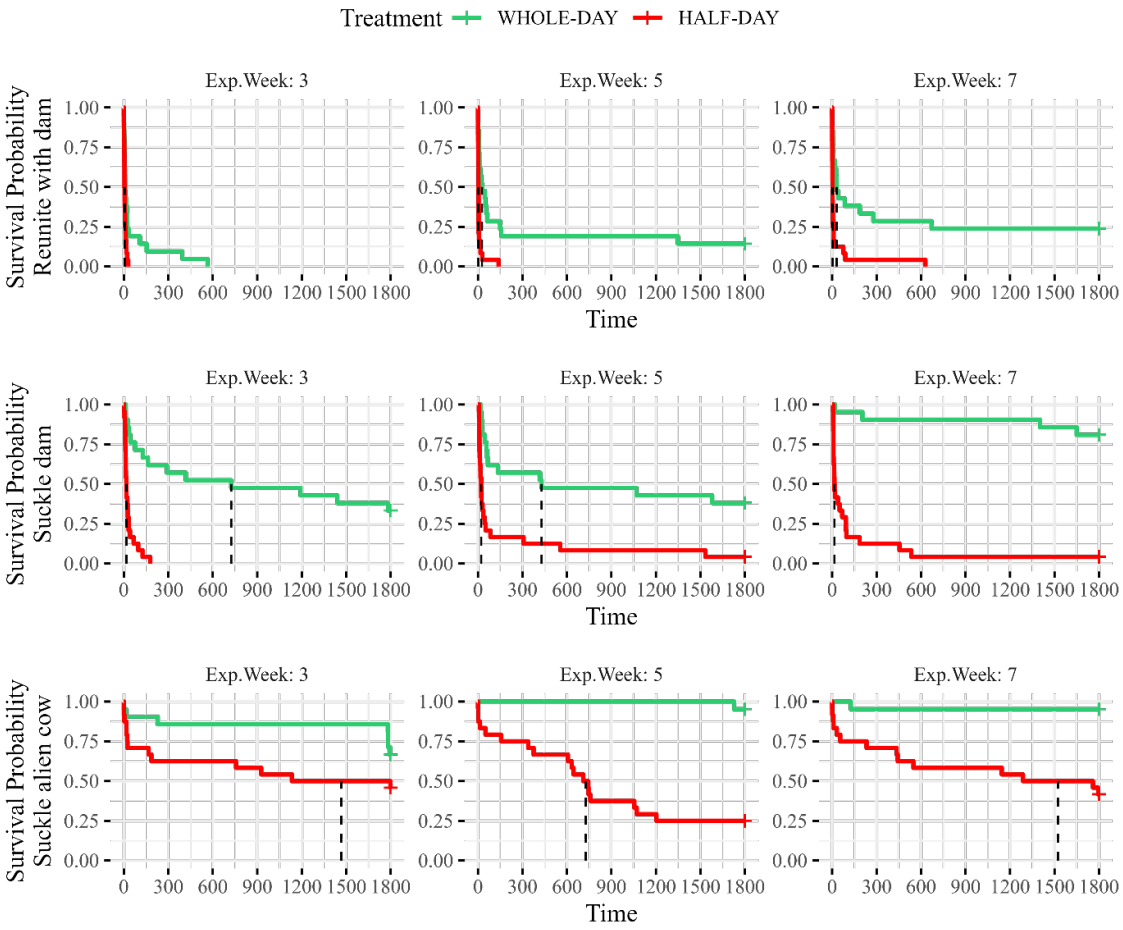


Figure 7.3: Kaplan-Meier Survival Plots with the survival probability against the time in seconds for the latency to respectively reunite with the dam, suckle the dam and suckle an alien cow for Whole-day (green line) and Half-day (red line) calves. Plots are shown for each of the three observed weeks (3, 5, and 7). The vertical, dashed lines indicate the median survival time where half of the calves have reunited and the other half has not, values are given in the text. Whole-day: n = 24, Half-day: n = 21.

7.3.3 Calf creep use and proximity to dam and other calves

Calf creeps were mainly used for lying (Lying in creep: 32% of all scans, Standing in Creep: 7% of all scans), however the use of creep differed between treatments. Whole-day calves used the creeps more during the night than during the day while Half-day calves used the creeps more during the day than at night (Figure 7.4, p<0.001, $\chi^2 = 78.0$, df = 1). For both treatments, the creeps were used less in week 7 than in weeks 3 and 5 (Table 7.7). Further, there was a tendency for calves of primiparous cows to use the creeps more than calves of multiparous (Percentage of scans [95% CI]: multiparous: 38.1% [33.7%-42.5%] and primiparous 45.4% [38.0%-52.7%], p = 0.09, $\chi^2 = 2.82$, df = 1).

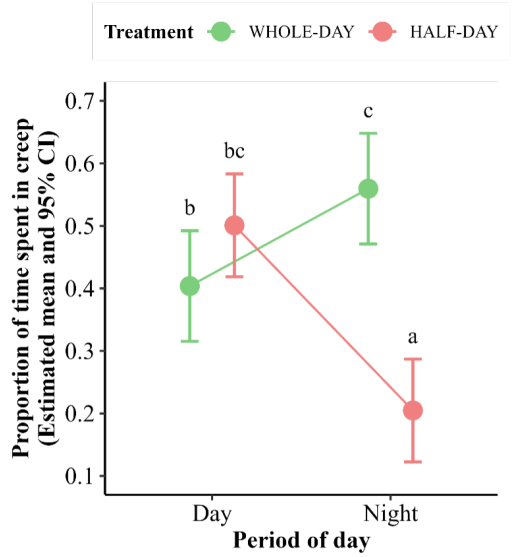


Figure 7.4: The interaction between the period of the day and treatment for the proportion of time spent in the creep. Whole-day: n = 24, Half-day: n = 21.

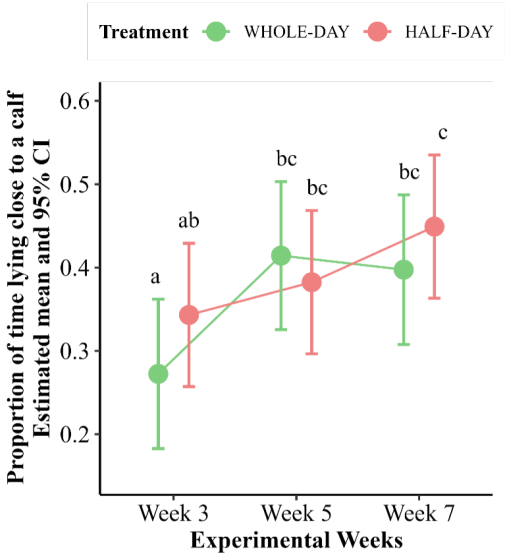


Figure 7.5: The interaction between week and treatment for the proportion of time lying close to another calf. Whole-day: n = 24, Half-day: n = 21.

During the day, when cows were present in pens of both treatments, there was no treatment difference in the proportion of time spent within 1 m of the calves' own dam (29.7% [24.4%-35.2%]). For both treatments, calves spent a larger proportion of their time within 1 m of another calf during the night, than during the day and the time spent close to another calf increased from week 3 to weeks 5 and 7 (Table 7.7).

Table 7.7: The results from 24 h scans at 10 min intervals of calf creep use and proximity to the dam and other calves. Each of the response variables of interest are presented as estimated mean percentage of scans for each of the levels of the categorical, explanatory variables week and period. Whole-day: n = 24, Half-day: n = 21.

Behavior	Experimental Week Estimates [95% CI]			Period Estimates [95% CI]		Test Statistics	
	Week 3	Week 5	Week 7	Day	Night	Week	Period
In creep (% of scans)	45.3^b [39.7-50.9]	45.3^b [39.8-50.9]	34.6^a [29.0-40.1]	45.2 [40.3-50.2]	38.2 [33.3-43.2]	p<0.001 $\chi^2_2 = 15.5$	p<0.01 $\chi^2_1 = 10.8$
<1m from other calf (% of scans)	39.3^a [32.0-46.6]	50.4^b [43.1-57.7]	54.0^b [46.8-61.3]	43.9 [37.5-50.4]	51.9 [45.4-58.3]	p<0.001 $\chi^2_2 = 41.2$	p<0.001 $\chi^2_1 = 17.2$
Lying <1m from calf (% of scans)	30.8^a [24.2-37.4]	39.8^b [33.3-46.4]	42.3^b [35.7-48.9]	33.2 [27.4-39.0]	42.1 [36.3-47.9]	p<0.001 $\chi^2_2 = 28.7$	p<0.001 $\chi^2_1 = 24.1$

$^{a-b}$ Within week, estimates in a row with different superscripts are significantly different (p<0.05). Subscripts indicate degrees of freedom for the Chi2-test χ^2_{df}

The proportion of time spent close together with another calf while lying down developed differently over time between treatments, showing an interaction (Figure 7.5, p<0.05, $\chi^2 = 5.99$, df = 2). Half-day calves had similar levels of lying close together in weeks 3 and 5, increasing further in week 7 (Figure 7.5). Whole-day calves had a tendency for a lower proportion of scans lying together in week 3 than Half-day but increased in weeks 5 and 7.

7.3.4 Cow behavior when fetched for afternoon milking

When being fetched for milking there was a higher probability of cows turning around and vocalizing, independent of treatment, with fewer days since calving (Table 7.8). There was no significant interaction between treatment and days since calving, but visual inspection of predicted probabilities for each treatment, when applied a smooth function, may indicate that Half-day cows were more likely to turn around until approx. 15 days after calving (See Figure 7.6). During the observed 20 min after Half-day cows had entered the night pen, there was a lower number of vocalizations and head out of the pen with more days since calving (Table 7.8).

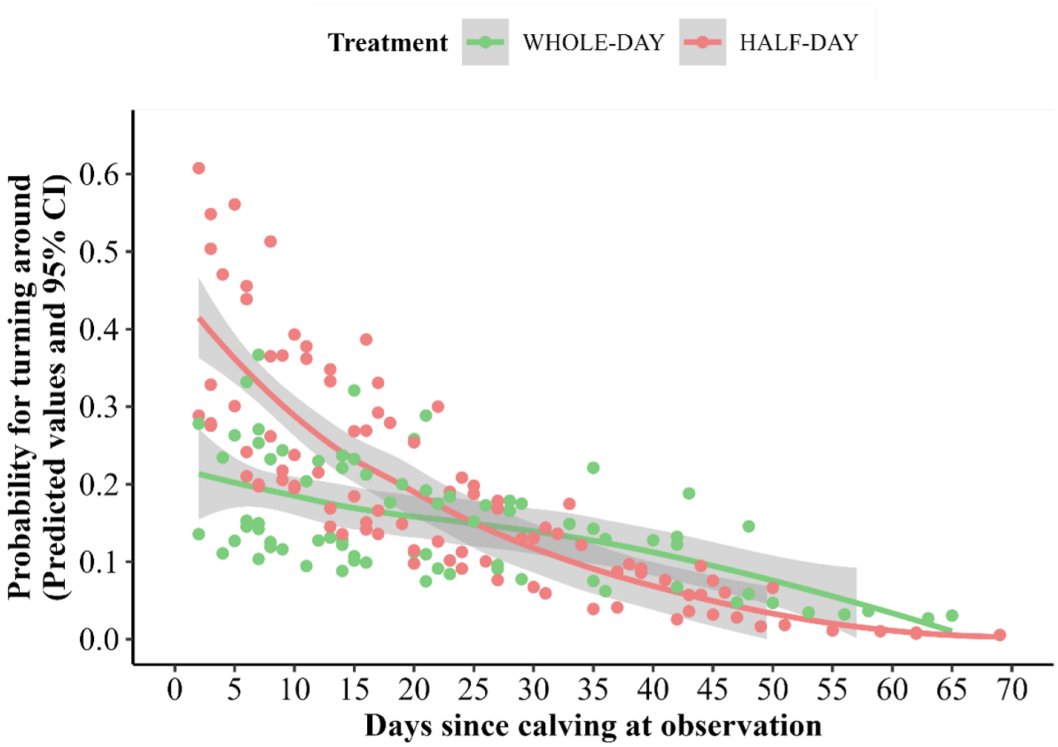


Figure 7.6: Predicted probability for Turning Around on the way to milking for Whole-day and Half-day cows respectively against the days since calving, plotted using a smooth function with 95% confidence intervals illustrated by shaded bands. Whole-day: n = 24, Half-day: n = 21.

Table 7.8: The results from continuous observations of cow behavior when fetched for afternoon milking and 20min after Half-day cows enter their night pen. Results are given as estimated mean counts or probabilities for the minimum and maximum number of days since calving. Whole-day: n = 24, Half-day: n = 21.

Behavior	**2 days since calving Estimates [95% CI]**	**69 days since calving Estimates [95% CI]**	**Test Statistics**
Turn Around	0.32	0.02	p<0.01
(probability)	[0.16-0.53]	[0.003-0.14]	$\chi^2_1 = 6.7$
Vocalizations	1.6	0.21	p<0.001
(Count/5 min)	[0.95-2.65]	[0.08-0.53]	$\chi^2_1 = 13.0$
Vocalizations in Night pen*	3.40	0.22	p<0.001
(Count/20 min)	[1.65-6.95]	[0.06-0.84]	$\chi^2_1 = 12.09$
Head out in Night pen*	1.35	0.08	p<0.01
(Count/20 min)	[0.69-2.66]	[0.02-0.39]	$\chi^2_1 = 9.23$

*Data on Half-day cows only.

Subscripts indicate degrees of freedom for the Chi2-test χ^2_{df}

7.4 Discussion

The present study compared the behavior of dairy calves housed in either a half-day or whole-day contact system with their dams in the pre-weaning period. In short, we hypothesized that 1) whole-day contact would result in more dam-calf interactions, 2) half-day contact would result in more daily separation-related stress, and that 3) half-day contact calves would show more dam-independent behavior. The three hypotheses will be discussed in mentioned order below.

7.4.1 Dam-calf interactions

The results showed that Whole-day calves were, as expected, involved in more dam-calf interactions over the 24 h period. Even though calves on the two treatments spent a similar amount of time close to their dam during the day hours, Whole-day calves spent additional time close to their dam during the night. Suckling and grooming are expected to be linked to positive emotional states for calves through the experience of highly motivated and positive social interactions which are suggested to improve animal welfare (Lawrence et al., 2019; Rault, 2019). From a more physiological view, this is also supported by the fact that higher oxytocin levels are measured in calves suckling their dam than from a bucket or teat bucket (Chen et al., 2015; Lupoli et al., 2001). Thus, since calves in the Whole-day contact system experienced more dam-related positive interactions, they may experience a better welfare state, compared to calves with Half-day contact.

For Whole-day calves, we saw an expected decrease in the number of suckling bouts from week 3 to week 7 (Fröberg & Lidfors, 2009). Half-day calves had a lower number of suckling bouts than Whole-day calves in week 3 and maintained this level in week 7, indicating that half-day contact restricted the level of suckling bouts compared to Whole-day contact during the first weeks. The number of suckling bouts in the present study was relatively high (ranging from 7.3 to 12.6 estimated mean occurrences) compared to Fröberg and Lidfors (2009), who reported 4.2 to 5 bouts per day for whole-day contact calves of similar ages. However, our ethogram allowed a new bout to be recorded after just 10 s break in suckling, similar to the study by Johnsen et al. (2021b) who allowed a new bout after 3 s and who reported mean suckling bout frequency around 13, more comparable to our levels. Fröberg and Lidfors (2009) used a bout criteria with at least 10 min between bouts which likely explains this difference.

Multiparous cows groomed their calf more, which is interesting, as they had no experience with their previous calves beyond the first 12 h after calving. Previous

studies have shown differences in maternal behavior for primiparous and multiparous cows, but most studies focus on the early hours after parturition, where multiparous cows show more intensive licking behaviors (reviewed by von Keyserlingk & Weary, 2007). Further research is needed to understand the longer-term effects of parity on maternal care in dairy cattle.

In summary, Half-day calves did not manage to compensate for the separation during the night period by sufficiently increasing time spent on suckling, being groomed, and grooming their dam during the day. This means that Whole-day calves likely experienced more positive dam-calf interactions. However, more knowledge is needed on whether this modulates any positive effects on social and cognitive skills based on dam contact and whether Half-day contact on the other hand improves welfare around weaning and separation (see also discussion Section 7.4.3). Compared to artificial rearing, where calves have either no, or very limited, social contact (individual housing), or only calf contact (pair or group housing) during the milk feeding period, Half-day contact still provides opportunities for suckling and maternal grooming. Due to Half-day contact showing promise in relation to increasing the amount of saleable milk compared to other CCC systems (Barth, 2020; Nicolao et al., 2022) and providing organic farmers, who prefer not to bring calves to pasture with the cows a practical solution, it may be a more feasible management system to implement in the current farm setting.

7.4.2 Stress from repeated night-time separation

There was no difference in total lying time between Whole-day and Half-day calves, which we had hypothesized. Thus, Half-day contact did not appear to lead to increased restlessness, as was suggested based on the period immediately before and after the daily separation period in the study by Roadknight et al. (2022). In accordance with other studies, we found that calves were lying a total of 72.6% of the time (Total time lying 67%-72,1% in Chua et al. (2002), Færevik et al. (2008), and Hänninen et al. (2005)).

However, the behavior of the Half-day and Whole-day calves differed greatly upon reuniting with the cows after the morning milking, where Half-day calves had been separated for the full night while Whole-day calves had been apart for approximately 30 min. All Half-day calves reunited with their dam in all three weeks, while for 11% of the opportunities Whole-day calves did not reunite within the 30 min. In addition, fewer Whole-day pairs initiated a suckling bout upon reuniting. In only approximately half of the opportunities, reunited Whole-day calves suckled their dam within the 30 min, while Half-day calves suckled their dam within 30 min

on more than 90% of the occasions. This is in accordance with the results found by Roadknight et al. (2022), also comparing half-day and whole-day contact. In addition, there was also an effect of the week, generally showing longer latency to reunite with the dam and suckling her, with increasing age for Whole-day, but not for Half-day calves. This indicates that especially during the first three weeks after parturition cows and calves are likely to reunite after even a short 30 min separation, illustrating the existence of maternal bonds on both treatments, but that with age, calves react less to approximately 30 min separation. Thus, it also shows that the motivation to reunite increases with time apart, overshadowing some of the age effects, probably partly due to hunger, as Half-day calves also were more likely to suckle upon reuniting.

Hunger may also explain why on a total of 63% of opportunities, Half-day calves suckled at least once from an alien cow during the 30 min after reuniting, while the equivalent number was 16% for Whole-day. When observing the video it was noted that often, for the Half-day treatment, the cow who entered the pen first was approached by multiple calves trying to suckle, as was also reported by Roadknight et al. (2022). Typically, attempts to suckle any available cow continued until each calf's dam was present in the pen.

When fetching cows for the afternoon milking, Half-day cows would have the opportunity to learn as the experimental period proceeded, that they would be separated from their calves for the full night until the next morning, while Whole-day cows would have the opportunity to learn that they would return after milking, 30 min later. We hypothesized that Half-day cows would be more reluctant to leave their calves, but we only found evidence of this based on a graphical inspection of the frequencies of the behavior 'turn around'. However, we found that the number of vocalizations during the walk to the milking parlor decreased with increasing days since calving. Possibly, cows stop responding to the separation, due to a decrease in maternal protection over time, as the calves got more independent. Indeed, earlier studies have shown that cows react less to permanent separation when calves are judged less dependent (Stěhulová et al., 2017). Using a different approach, aimed at measuring the same motivation, Roadknight et al. (2022) found that it took similar durations to separate whole-day and half-day cows from calves when fetching them for milking.

More studies are needed to further understand differences in the experience related to the daily separation of Half-day and Whole-day cows and their calves. We encourage future studies to record the cows' response to being fetched for milking in more detail. Whether Half-day cows are more unwilling to leave their calves than Whole-day is important information when evaluating the pros and cons of the two cow-calf

contact systems.

When Half-day cows entered their night pen, they vocalized more and placed their head out of the pen more with fewer days since calving indicated a higher level of stress. These behaviors are typical responses to separation from the calf (Flower & Weary, 2001), but it is not possible to interfere, from the present study design, whether these responses were due to the separation from their calf or general stress about being in a different environment. Multiparous cows were more vocal than primiparous, which could indicate a stronger maternal bond in multiparous cows, but as with the increased grooming shown by multiparous cows, more studies are needed in this area.

In summary, for Half-day calves, the shorter latency to reunite with the dam and the higher probability of suckling an alien cow at the time of reuniting indicate that these calves were hungry, and possibly stressed by the daily separation. However, if hunger plays a large role in the experienced stress, then artificial rearing with twice-a-day milk feeding should be questioned as well, as this results in similar intervals between milk feeding opportunities. A study by von Keyserlingk et al. (2006) found that calves reared with ad libitum milk allowance from an automatic milk feeder, but restricted to access during two daily periods of each 2 h, were able to consume slightly less, but similar amounts of milk as calves with all-day access. However, this does not necessarily mean that calves do not experience hunger between two daily feedings. Indeed, while calves under natural conditions seem to focus their suckling during two peaks respectively in the early morning and the late afternoon (Whalin et al., 2021), studies are reporting between 4 and 13 suckling bouts a day (Fröberg & Lidfors, 2009; Johnsen et al., 2021a) illustrating the preference for more than twice daily feeding. However, artificially reared calves are reported to have higher concentrate intake, which may reduce the hunger sensation between two daily milk feedings, especially in older calves. The basis for the lower concentrate intake in calves suckling a cow resulting in similar milk intake as an artificially reared group should be further investigated.

7.4.3 Dam-independent behavior

Half-day calves spend more time eating solids than Whole-day, which was especially due to more time spent eating during the night period. This supports the idea that Half-day indeed were hungrier during the daily separation period, and thus compensated by eating more solids. A similar effect on the solid feed intake was also shown when comparing twice daily suckling of 15 min to whole-day contact (Roth et al., 2009). Eating time (approximately 33 min a day for Half-day) was

comparable to pair-housed artificially reared calves of the approximately same age receiving large milk allowances (6 weeks of age, 11.8 L milk/day, and 30 min/d of eating solids reported by Miller-Cushon and DeVries (2015)). The increased intake of solid feed is promising for improving weaning off milk and separation from the dam, for Half-day calves. However, in our paper based on the same study (Paper III, submitted to Journal of Dairy Science Bertelsen et al., 2023) we found no decrease in the weaning and separation response for Half-day calves in the four days post-weaning and separation.

In general, calves spend more time close to each other as they grew older, in accordance with other studies (Kerr & Wood-Gush, 1987; Vitale et al., 1986), and in general calves spend much of their day within 1 m of another calf (approximately 40-50% of the day). We had hypothesized that Half-day calves would compensate for the lack of the dam during the night, by spending more time close to the other calves. Indeed, Half-day calves tended to groom each other for longer durations than Whole-day calves, suggesting that Half-day may direct more of their social behavior to other calves, when their dam is less present, thus showing indications of the earlier development of preferential relationships between calves compared to Whole-day. Bailly-Caumette et al. (2023) also showed increased social play in Half-day calves, based on the same experimental study as the present. Calves have been shown to prefer a known social partner (Lindner et al., 2022). If Half-day calves are more bonded to other calves, this may improve their social buffering capacity (Costa et al., 2015; Færevik et al., 2007) in situations like weaning off milk, separation from cow, and moving to a new environment, in the same way, pair-housed calves handle stressors better than individually housed calves (reviewed by Costa et al., 2016).

Creep use was different between the two treatment groups, which seemed to correspond closely to the presence of the cow in the main pen. Whole-day calves used the creep most at night and Half-day calves used the creep most during the day, while they used the main pen during the night when their cows were away. That Half-day calves chose to lie outside the creep, in the main pen, when cows were not present, could illustrate a preference for more space (calves show more lying on the side with stretched legs and less lying close in larger lying spaces (Færevik et al., 2008)). It could also suggest that calves did not feel the need for/or did not perceive the creep as a hiding place from outside factors. However, creeps seemed to be considered a safe space from the cows, but whether from agonistic interactions between cows, insisting grooming or fear of being stepped on cannot be known from the present study but warrants further investigation. The creep in the present study was designed to be "open" towards the main pen such that cows and calves remained in visual contact and access to the creep was along the closed outer wall.

Little research was found on creep or hide use in calves beyond either new-born hider behavior (Zobel et al., 2020) or isolation behavior related to pain (Gingerich et al., 2020). In the present study, we anecdotally noted that cows sometimes would intensely lick their calf, resulting in the calf leaving for the calf creep, seemingly to rest undisturbed.

7.4.4 Modified maternal-offspring bond

Though Half-day calves and cows experienced fewer daily dam-calf interactions, this does not necessarily mean that the bond between the dam and the calf is less strong as defined by Gubernick (1981). Indeed, we found evidence that Half-day cow-calf pairs had preferential bonds i.e. the comparable time spend close together during the day hours for both treatments and the short latency to reunite after the separation period in Half-day cows and calves. We did, however, see some indications towards a modification of the maternal-offspring bond, which warrants further investigation.

We saw a tendency for interaction between treatment and week for the grooming received from the dam, driven by a halving of the duration of grooming for Half-day from week 3 to 7, while there was no difference between weeks for Whole-day. Whether this is driven by a decrease in the cow's motivation to groom the calf or the calves' motivation to be groomed is not known from the present study.

Half-day calves tended to suckle more on alien cows than Whole-day (20% vs. 5% of all suckling), though they still showed a clear preference for suckling their dam and it appeared that it was mainly in the higher-stress reunite situation that suckling of an alien cow happened. Fröberg and Lidfors (2009) showed approximately 80% of all suckling bouts were on the calves' own dam in a whole-day contact system but in larger groups. In comparison, when looking at this measure, the calves in the present study were equally or more preferentially bonded to their dams. However, Half-day calves in the present study also showed a tendency for a higher inclination to suckle between the hind legs of their own dam, which could be interpreted as less bonded behavior (discussed by Sirovnik et al., 2020) but could potentially also be a result of the higher-stress reunite situation where calves were observed to scramble for access to a teat.

These differences suggest the possibility for a modification of the preferential bond between cows and calves with Half-day contact, however, the differences are minor, there is large individual variation and interpretations should be done carefully.

We had hypothesized that due to Half-day calves being more hungry after the separation period and potentially less strongly bonded to their dam, they would more

often try to suckle on an alien cow, and thus be more likely to receive agonistic behavior from her. This seemed to be the case in the study by Roadknight et al. (2022) who found half-day contact cows to show more agonistic behavior upon being reunited after the separation period than whole-day contact cows, and that the agonistic behavior was often aimed at alien calves trying to suckle. We did not find any support for this hypothesis, but rather a tendency that Whole-day calves received more agonistic behaviors from alien cows. Thus, further studies are needed to understand whether Half-day cows are less strict with only letting their own calf suckle and thus do not show agonistic behavior, or whether Half-day calves learn to suckle alien cows from behind and thus do not receive agonistic behaviors as often. However, it is hard to judge the biological significance of one additional daily occurrence of agonistic behavior, as is the present case.

7.5 Conclusion

Calves on a half-day dam contact system experienced fewer dam-related positive interactions than calves on a whole-day contact system. Together with increased reinstatement behaviors at the reunion and more calves suckling an alien cow, indicative of hunger and separation stress, this may affect the welfare level of half-day contact calves negatively, compared to whole-day contact. However, half-day contact calves showed indications of being able to compensate to some degree by having more positive, social interactions with other calves, and further half-day contact calves spend more time eating solid feed. Together, this may prepare half-day contact calves better for weaning and separation, which is known to be a stressor for whole-day contact calves. The present study also illustrates that with half-day contact, calves still prefer their own dam and spend similar or more time interacting with her than calves with whole-day contact, during the daily period where they have the opportunity. The daily separation periods may be associated with hunger, especially in younger calves with a low solid feed intake. Rearing dairy calves with half-day contact to their dam may be a feasible CCC system, especially if the farmer wish to practice summer grazing while keeping young calves inside.

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Paper II

Chapter 8

Paper III

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Comparing weaning methods in dairy calves with different dam-contact levels

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Abstract

It is common practice in the dairy industry to separate the calf from the dam within 24 h of birth. Allowing the dam to rear her calf is an alternative practice where cow and calf gain welfare benefits from performing natural and highly motivated behaviors. However, this system has been linked to reduced milk yield and an increased separation response. Reducing the daily dam-calf-contact time may be a way to reduce the amount of suckled milk, improve milk let-down and prepare the calf for weaning and separation. The first aim of the present study was to investigate the effect of 8 weeks of half-day dam-calf-contact on calves' response to weaning and separation, compared to calves reared with whole-day dam-calf-contact and an artificially reared, group-housed control. Weaning from milk and separation from the dam can be viewed as two independent stressors. By introducing each stressor separately, it may be possible to reduce the overall behavioral response. The second aim of the present study was to investigate the effect of one-week fence-line weaning before permanent separation. The study was conducted with a 3x2 factorial design with dam-contact treatments: "Whole-day", "Half-day" and "Control" and weaning treatments "Simultaneous" and "Stepwise". Whole-day calves were separated daily from their dams during milking while Half-day calves were separated daily from the afternoon milking and until the next morning milking. Simultaneous weaning and separation were done in week 9, while Stepwise weaning and separation started in week 8 with calves being fence-line weaned and permanently separated in week 9. Data were collected on 69 dairy calves in week 8 and week 9, and data were summarized over the two weeks for analysis. Stepwise weaning and separation decreased the number of high-pitched vocalizations and the activity level for dam-reared dairy calves while having little impact on control calves. There was no difference between Whole-day and Half-day calves in their separation response, but as expected, dam-reared calves reacted more strongly than the control group. This was also reflected in the average daily gains measured the week after weaning, with Control calves having a higher average daily gain than Whole-day, while Half-day calves were intermediate. In conclusion, one-week fence-line weaning may decrease the summed weaning and separation response in dam-reared dairy calves, but half-day dam-calf contact did not decrease calves' behavioral response to weaning and separation compared to whole-day contact.

Keywords: Maternal Behavior, Cow-Calf Contact, Weaning, Performance

8.1 Introduction

Most modern dairy farms separate the calf from the dam within 24 h of birth and artificially rear the calves on either whole milk or milk replacer. Rearing dairy calves with their dam has the potential to improve animal welfare through the opportunity to express natural and highly motivated behaviors by both the dam and the calf (reviewed by Meagher et al., 2019; Newberry & Swanson, 2008). Rearing calves with the dam also aligns better with consumer expectations (Boaitey et al., 2022; Sirovica et al., 2022; Weary & von Keyserlingk, 2017), especially to organic farms, where natural and ethical considerations are expected to a higher degree (Harper & Makatouni, 2002).

However, in recent studies, it has been shown that whole-day dam contact leads to reduced bulk tank milk (Barth, 2020) due to calves suckling a large amount of milk and issues with milk let-down (Tancin et al., 2001; Zipp et al., 2018). Further, compared to separation within 24 h of birth, later separation of the dam and her calf leads to an increased response to weaning, manifested as reinstatement behaviors such as vocalization, pacing, and standing with the head out of the pen (Johnsen et al., 2015b; Nicolao et al., 2022; Weary & Chua, 2000; Wenker et al., 2022), as well as reduced calf weight gain (Fröberg et al., 2011; Johnsen et al., 2015a).

Natural weaning age in cattle is expected to be earliest at 8 months of age (Reinhardt & Reinhardt, 1981b), and natural weaning is a gradual process where the cow produces less milk and eventually refuses the calf to suckle but continues to provide maternal care and to stay in close proximity of the calf (Reinhardt & Reinhardt, 1981a). Present dairy systems are usually based on weaning off milk at approximately 8 weeks of age (12 weeks for organic), and therefore a substantial behavioral response to weaning and separation is to be expected when cows and calves are strongly bonded and the calf is drinking large [12-15L (Barth, 2020)] amounts of milk.

Due to these challenges, part-time dam-calf contact, where the calf and the dam are kept together for some, but not all of the day, has been suggested (Johnsen et al., 2016; Meagher et al., 2019). Examples of part-time systems are restricted suckling (e.g. two short suckling opportunities either pre or post-milking) and half-day contact between two daily milkings, either during day hours or during night hours (e.g. Johnsen et al. (2015b), Nicolao et al. (2022), and Roadknight et al. (2022)). The practical aspects of half-day contact, compared to shorter or longer daily contact times, are that the caretaker is already handling the cows at the time of the daily separation and reunion of dam and calf due to milking management (Paper I, submitted to Journal of Dairy Science Bertelsen & Vaarst, 2023).

From a welfare perspective, half-day contact may prepare the calf (and the cow) better for permanent separation, due to extended daily periods of no contact where the calves may eat more concentrate and forage, while still gaining the welfare benefits of performing natural and highly motivated behaviors with the cow during the contact period. The first aim of the present study was to investigate the effect of half-day contact on dairy calves' response to weaning and separation.

The weaning and separation should be considered as two independent stressors from a farming perspective since they can be separated in time (Loberg et al., 2008; Weary et al., 2008). Weaning off milk can happen prior to separation from the dam, e.g. if the calf is prevented from suckling the dam's udder. This may be achieved by fitting the dam with an udder net, by fitting the calf with a nose-flap, or by placing the dam and calf on each side of a fence that allows relatively close contact, but prevents suckling (Wenker et al., 2022). Another option is weaning off milk after separation from the dam, by continuing milk feeding from another source, and then weaning off milk at a later age (Johnsen et al., 2015a). It has been shown that when calves are less dependent on the dam as a source of milk, they react less to separation from her (Johnsen et al., 2015a; Wenker et al., 2022). On the other hand, calves that were never allowed to suckle their dam, but had all other aspects of maternal contact, showed a negative bias upon separation (Daros et al., 2014), indicating that both weaning off milk and separation from the dam are stressful.

When milk feeds calves artificially, gradual weaning can be implemented. Here calves gradually receive less milk over an extended period, which stimulates them to increase their concentrate intake (e.g. Eckert et al. (2015)). Gradual weaning has been recommended especially for calves receiving large amounts of milk, as their pre-weaning concentrate intakes are much lower than calves fed low milk allowances, and thus they risk a substantial growth depression at weaning off milk (reviewed by Khan et al., 2011).

Knowing that especially calves fed large amounts of milk should be gradually weaned, there is a challenge in dam-calf contact systems where calves are reported to consume high amounts of milk and to eat only little concentrate, compared to artificially reared calves (Fröberg et al., 2011). Gradually weaning the calf from a high-yielding cow would require preventing the calf from suckling ad libitum. The use of automatic gates to reduce the daily duration of dam-calf contact has been investigated (Johnsen et al., 2021) and may combine the benefits of gradual weaning off milk and gradual separation from the dam. However, calves that had access to restricted suckling of the dam for 30 min twice daily managed to suckle approximately 10 L/d in the study by Fröberg et al. (2008) which may suggest that gradual weaning calves off milk, while they continue to have even short periods of full contact with the dam,

may be a challenge. A simpler approach, which may be more feasible, is fence-line weaning. Fence-line weaning has been used and researched especially in beef cattle. Here, the calves are first weaned off milk but remain in close contact with their dam, and then subsequently are separated from the dam (Enríquez et al., 2011; Taylor et al., 2020). The second aim of the present study was to investigate the effect of fence-line weaning before separation of dam-reared dairy calves on their response to weaning and separation.

Firstly, we hypothesized that calves on the half-day contact treatment would react less strongly to weaning and separation than calves with whole-day contact, while control calves were expected to react the least. Secondly, we hypothesized that calves weaned and separated by use of a fence line would react less overall, i.e. compiling the response from the first and the second step, compared to calves subjected to simultaneous weaning and separation.

8.2 Methods And Materials

8.2.1 Animals, housing, and management

The experimental study was based on a 3x2 factorial design repeated in 6 blocks. Animals were enrolled in blocks of 12 cow-calf pairs and within block allocated to one of three dam-contact treatments on a rotation basis: whole-day contact except at milking [Whole-day], part-time contact between morning and afternoon milking [Half-day] and separation at birth and artificial rearing [Control], balancing for dam parity, calf sex, and calf age. This amounted to a total of 72 calves, which were observational units. The sample size was based on the availability of cows in the resident herd and supported by post hoc power calculations to detect significant differences (at 5 % significance level) of high-pitch vocalizations between the cow-contact and weaning treatments and with a power of at least 80 %.

Due to illness, 3 cow-calf pairs were excluded from the study. The experimental timeline began when the block was full and no further interventions, except weekly weighing and health scoring, were made until the time of weaning and separation. All references to “week” are the experimental week, while calf age varied due to calves being enrolled over a period: mean age (95% CI) at first weaning intervention, week 8; Whole-day: 54.9 (53.1-56.6) days; Half-day: 59.3 (58.2-60.5) days; Control: 55.7 (54.4-56.9) days). Calves were further randomly allocated to one of two weaning and separation treatments using an online random generator (one simultaneous step [Simultaneous] or two separate steps [Stepwise]). No blinding was possible.

All calves were born in individual calving pens and fed 4 L of their dams' colostrum within 6 h of birth using a teat bottle. From the 2nd day of life, all calves had access to ad libitum calf-starter concentrate, hay, water, and cows' total mixed ration.

8.2.2 Dam-Contact treatments

Whole-day and Half-day (collectively: dam-reared)

Dam-reared calves stayed in the calving pen with the dam for approximately 24 h and were assisted in suckling if necessary. The cow-calf pair was housed in a deep-straw-bedded group pen from the second day after birth, together with three other cow-calf pairs on the same dam-contact treatment. The group pens were 9 m x 7.5 m in size and had two calf creeps where calves had access to hay, concentrate, and water (1.5 m x 1.5 m and 3 m x 3 m, respectively) in the back corners. The creeps were made from tubular metal bars with narrow enough gaps to prevent calves from sticking their head through the fixture. Calves had access to the creeps along the wall on each side (see Figure 8.1). Calves received all of their milk from suckling.

Figure 8.1: A picture showing the larger calf creep, which was used for fence-line weaning of two calves. Calves could not suckle through the bars.

Calves on the Whole-day treatment were with their dam throughout the day and night except during milking time (5:00 h to 5:30 h and 15:30 h to 16:00 h) while calves on the Half-day treatment were housed with the dam between the morning milking and the afternoon milking, but cows were housed in a separate barn from after the afternoon milking until after next morning milking (15:30 h to 5:30 h).

Control

Control calves were separated from the dam 12 h after birth and managed largely according to standard farm procedure. Upon separation from the dam, they were moved to individual straw-bedded pens (1.5 m x 3 m) with sides made from tubular bars allowing visual and tactile contact with neighboring calves of the same treatment. As each calf reached an age of seven days, the partitions between pens were removed resulting in four control calves of a block who were housed together as a group. During the first 7 days, calves were fed daily amounts of milk gradually increasing from 6 L to 8 L in 2 daily feedings. For the rest of the milk-feeding period, they were fed to satiation twice daily at 06:30 h and 17:00 h with milk available for 20 min (mean daily intake per calf ±SD ranged from 7.9 L ±0.93 in week 2 to 11.1 L ±1.7 by week 8).

8.2.3 Weaning and separation treatment

Simultaneous

In week 9, calves on the Simultaneous treatment were abruptly and simultaneously weaned off milk and moved from their home pen to a new environment (group pens for 4 calves of 3 m x 3 m) at 11:00h, in the other end of the barn, together with the calves from the same dam-contact treatment and block. This effectively also separated the dam-reared calves from their dams, who moved away to a separate barn at the same time. Although Control calves were already separated from their dam and thus only moved to a new environment, the described procedure will for simplicity be referred to as separation (or, being separated) throughout (see Figure 8.2).

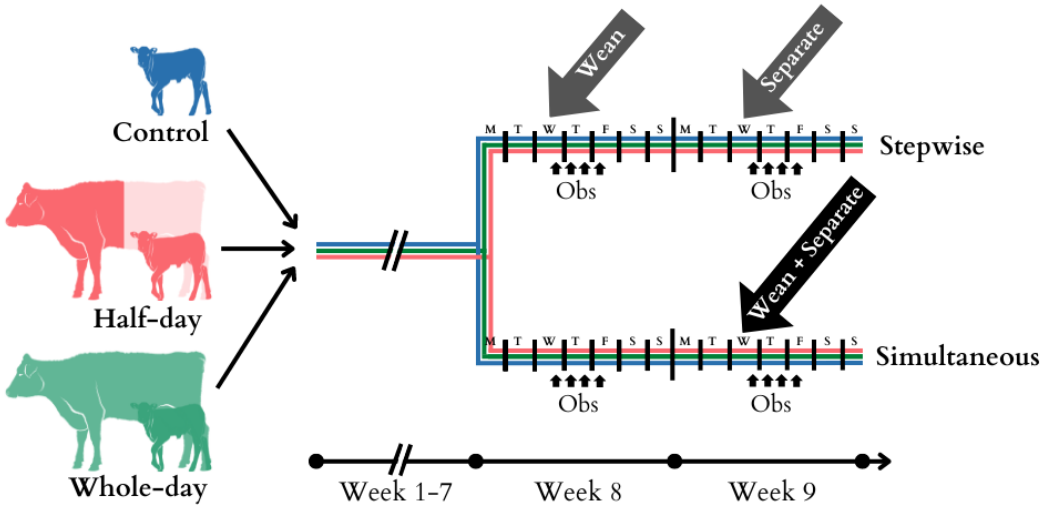

Figure 8.2: A graphical illustration of the experimental timeline. Calves were housed according to their allocated dam-contact treatment throughout the experimental period [Control, Half-day or Whole-day]. From week 8, half of the calves started a Stepwise weaning and separation while the remaining calves were simultaneously weaned and separated in week 9. Behavioral observations on three days post-weaning and separation interventions are indicated by arrows. Observations were carried out 4 h, 21 h, 29 h, and 45 h after interventions. Simultaneous calves were also observed in week 8, giving a baseline measure, before any intervention.

Stepwise

For calves on the Stepwise treatment, weaning off milk started in week 8, at 11:00h, where dam-reared calves were confined in the larger calf creep (two calves, 9 m^2), abruptly weaning the calves off milk. The other two calves remained with their dams (and the dams of the Stepwise calves) in the main pen, with no change. At the same time, the control pen was divided into two equally sized pens, each holding two calves. Control calves on the Stepwise weaning treatment were also abruptly weaned off milk but stayed in the familiar environment. One week later, in week 9 and at the same time and way as for calves on the Simultaneous treatment, calves were moved to a group pen with the calves from the same dam-contact treatment and block, and the dams were moved to a separate barn (see Figure 8.2).

8.2.4 Observations

We carried out behavioral observations on all calves at each of the two weaning interventions (weeks 8 and 9, see Figure 8.2). We used focal animal sampling and continuously counted high-pitched and low-pitched vocalizations and recorded the behaviors "activity" and "cross-sucking" (see Table 8.1 for ethogram) at 1-minute intervals using one-zero sampling [did the behavior occur 'yes' or 'no', (Bateson & Martin, 2021)). Observations were made at 4-time points after the interventions had taken place: after 4 h (d 0, 15:00 h), 21 h (d +1, 08:00 h), 29 h (d +1, 16:30 h), and 45h (d +2, 8:00 h), respectively. At each observation time point, the 4 calves on each of the 3 dam treatments were observed for 3 * 5 min at 10 min intervals within a 45 min observation period. Thus, observations amounted to 15 min of observation per calf per observation time point, and a total of 2 h observations per calf for weeks 8 and 9 combined. For Simultaneous calves, we expected week 8 to correspond to a baseline level, as they did not experience any weaning and separation yet.

Table 8.1: The description of vocalizations and behavior of dairy calves upon weaning and separation (modified from Johnsen et al. (2015b)).

Behavior	Description	Recording rule
High-pitched vocalizations	The calf gives a high-pitched (loud), open mouth sound. Taking a breath interrupts a vocalization.	Continuous recording
Low-pitched vocalizations	The calf gives a low-pitched (muffled), close mouth sound. Taking a breath interrupts a vocalization.	Continuous recording
Activity	The calf took more than two steps in any direction	One-Zero sampling*
Cross-sucking	The calf is sucking on another calf's body parts e.g. ears, muzzle or scrotum.	One-Zero sampling*

*1min intervals

8.2.5 Growth and Health measures

All calves underwent weekly health scoring and weighing. The health score was based on the procedure suggested by McGuirk and Peek (2014) and involved scoring nasal discharge, ocular discharge, navel inflammation, coughing, and fecal consistency on a scale from 0 (perfectly normal) to 3 (heavy clinical signs of illness). Lastly, the rectal temperature was measured. Calves were also weighed on a walk-on calf scale weekly.

8.2.6 Statistical Analysis

Statistical analysis was performed in R, using RStudio (Core Team, 2022) and the package "glmmTMB" (Brooks et al., 2017) for generalized linear mixed models. The assumptions of distribution and homoscedasticity were checked by graphical inspection of the residuals. Statistical significance was decided at the $p<0.05$ level and pairwise comparisons were corrected using the Tukey or Sidak method.

Experimental units

The number of experimental units were: Control-Stepwise: n = 12, Whole-day-Stepwise: n = 10, Half-day-Stepwise: n = 12, Control-Simultaneous: n = 12, Whole-day-Simultaneous: n = 11, Half-day-Simultaneous: n = 12.

Vocalizations

Vocalization counts (high-pitched and low-pitched, respectively) were summed across weeks 8 and 9 within each observation time point (e.g. Obs 1 from week 8 + Obs 1 from week 9; See Figure 8.2). The summed vocalization counts were analyzed with a generalized linear mixed model with log link and a negative binomial (linear parameterization) distribution. The fixed effects were: weaning and separation treatment [Stepwise; Simultaneous], dam-contact treatment [Whole-day; Half-day; Control], observation time point relative to intervention [4 h, 21 h, 29 h, 45 h] and their possible interactions, as well as a random effect taking into account the repeated measures on each animal and the random effect of block and pen.

Activity

The activity, recorded as successes and failures (number of minutes where the calf moved and number of minutes where this behavior did not happen), were analyzed with a generalized linear mixed model with a logit link and a binomial distribution. The fixed effects were: weaning and separation treatment [Stepwise; Simultaneous], dam-contact treatment [Whole-day; Half-day; Control], and observation time point relative to intervention [4 h, 21 h, 29 h, 45 h] and all their possible interactions, as well as a random effect taking into account the repeated measures on each animal and the random effect of block and pen.

Cross sucking

Due to low levels of cross sucking this variable was transformed into a binary variable and the number of calves on each treatment combination that performed cross-sucking at least once was analyzed using Fishers' Exact test.

Growth

The last weighing before any weaning interventions was in week 8. Body weight in week 8, as well as the average daily gain for the period from birth to week 8 (before weaning), for the week after weaning off milk (differing between weaning and separation treatments: week 9 for Stepwise and week 10 for Simultaneous) and (for calves on the Stepwise weaning and separation treatment only) ADG in the week after separation from the dam, two weeks after weaning of milk were analyzed with a generalized linear mixed model with identity link and a Gaussian distribution. The fixed effects in the model were: weaning and separation treatment [Stepwise; Simultaneous], dam-contact treatment [Whole-day; Half-day; Control], dam parity [primiparous; multiparous], calf sex [heifer; bull] as well as two-way dam-contact interactions (dam-contact treatment*weaning and separation treatment, dam-contact treatment*dam parity, dam-contact treatment*calf sex) and the random effect of block and pen in the model. For ADG two weeks after weaning off milk we could only compare dam-contact treatments because we only had this measure for stepwise weaned and separated calves.

Health

For health scores, no formal statistical analysis was made, but group-wise frequency distributions are reported. Body temperature was analyzed with identity link and a Gaussian distribution with the fixed effects: weaning and separation treatment [Stepwise; Simultaneous], dam-contact treatment [Whole-day; Half-day; Control], week [1 to 9], and all their possible interactions, dam parity [primiparous; multiparous] as well as a random effect taking into account the repeated measures on each animal and the random effect of block and pen.

8.3 Results

8.3.1 Vocalizations

For both high- and low-pitched vocalizations, there was a three-way interaction between dam-contact treatment, weaning, and separation treatment, and the observation time point (High-pitched vocalizations: $\chi^2 = 14.8$, $p<0.01$, See Figure 8.3A, Low-pitched vocalizations: $\chi^2 = 22.1$, $p<0.01$, See Figure 8.3B).

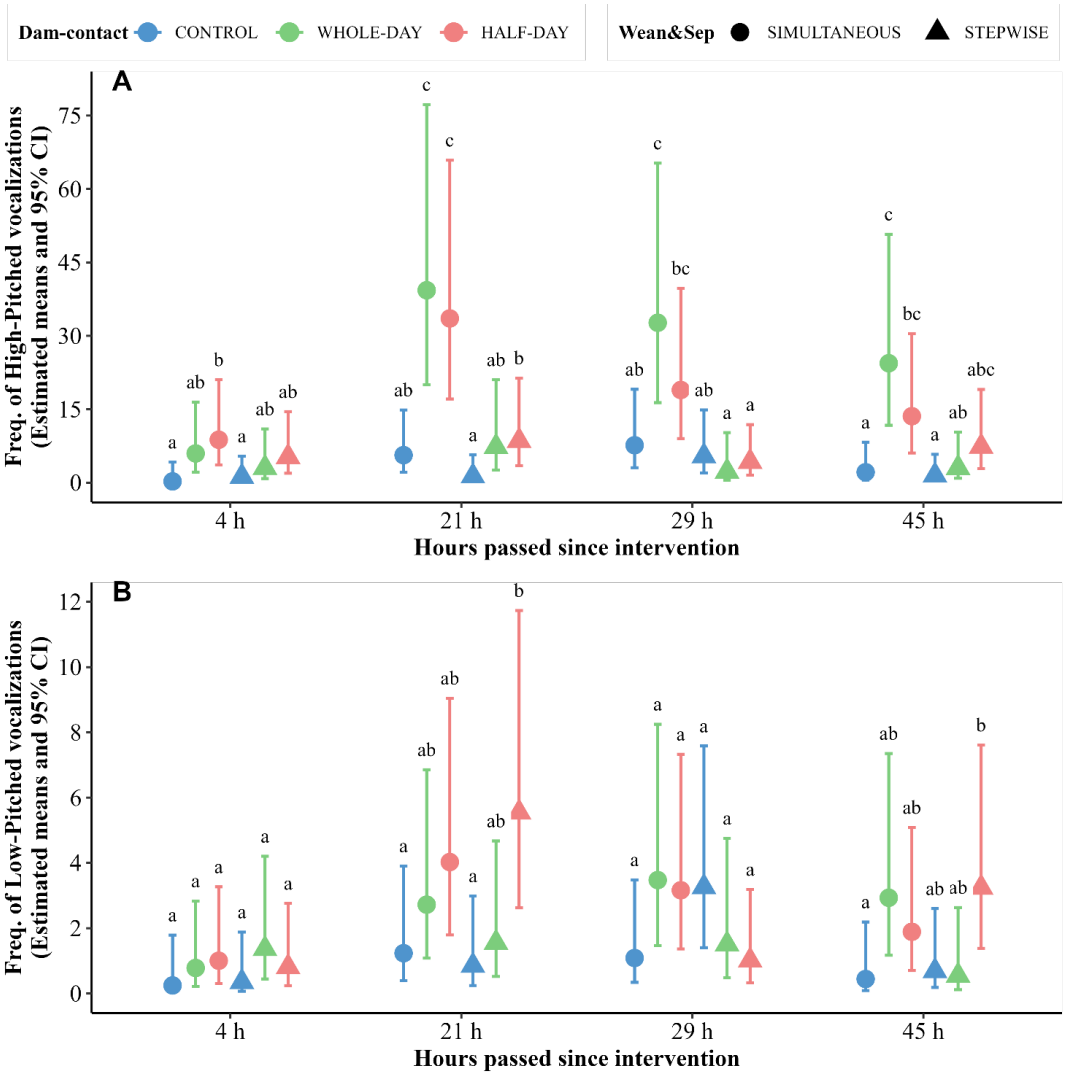

Figure 8.3: The estimated mean number and 95% confidence interval of the summed A) high-pitched vocalizations and B) low-pitched vocalizations of dairy calves after weaning and separation intervention, at each of 4 observation time points, each estimate is based on 30 min of observations. Statistical, pairwise comparisons are made between all 6 treatment combinations within each observation time point. Within time point, means that share the same superscript letter are not significantly different at the $p<0.05$ level.

The effect of weaning and separation treatment

For Control calves, the number of high-pitched vocalizations of control calves on the two weaning treatments was similar (Figure 8.3A). For Whole-day calves, the number of high-pitched vocalizations was lower for Stepwise weaning and separation than for Simultaneous weaning and separation 21 h, 29 h, and 45 h after the intervention (Figure 8.3A). For Half-day calves, the number of high-pitched vocalizations was lower at 21 h and 29 h after the intervention for Stepwise weaning and separation than for Simultaneous weaning and separation (Figure 8.3A). Regarding low-pitched vocalizations, there was no difference for any of the dam-contact treatments when comparing the Stepwise and Simultaneous weaning and separation within treatment (Figure 8.3B).

The effect of dam-contact treatment

Under the Simultaneous treatment, the number of high-pitched vocalizations was higher for both Whole-day and Half-day than for Control 21 h and 45 h after the intervention (Figure 8.3A). After 4 h only Half-day had a higher number of high-pitched vocalizations than the Control while after 29 h only Whole-day did. There was no difference between the Whole-day and Half-day treatment at any of the time points. Under the Stepwise treatment, the only difference in the number of high-pitched vocalizations was at 21 h where Half-day had higher numbers than Control (Figure 8.3A). Again, there was no difference between the Whole-day and Half-day at any of the time points. For low-pitched vocalizations, there was no difference under the Simultaneous weaning and separation (Figure 8.3B). Under the Stepwise weaning and separation there was a difference 21 h after the intervention with Half-day calves emitting more low-pitched vocalizations than Control calves (Figure 8.3B).

8.3.2 Activity

There was a three-way interaction between dam-contact treatment, weaning, and separation treatment and the observation time point for the response variable "activity" ($\chi^2 = 22.6$, $p<0.001$, See Figure 8.4). The activity response was higher under the Simultaneous weaning and separation than the Stepwise for Whole-day calves at 21 h, 29 h, and 45 h (Figure 8.4). For Half-day calves, a higher activity response under the Simultaneous weaning and separation was seen at 21 h and 29 h and for Control only at 21 h (Figure 8.4).

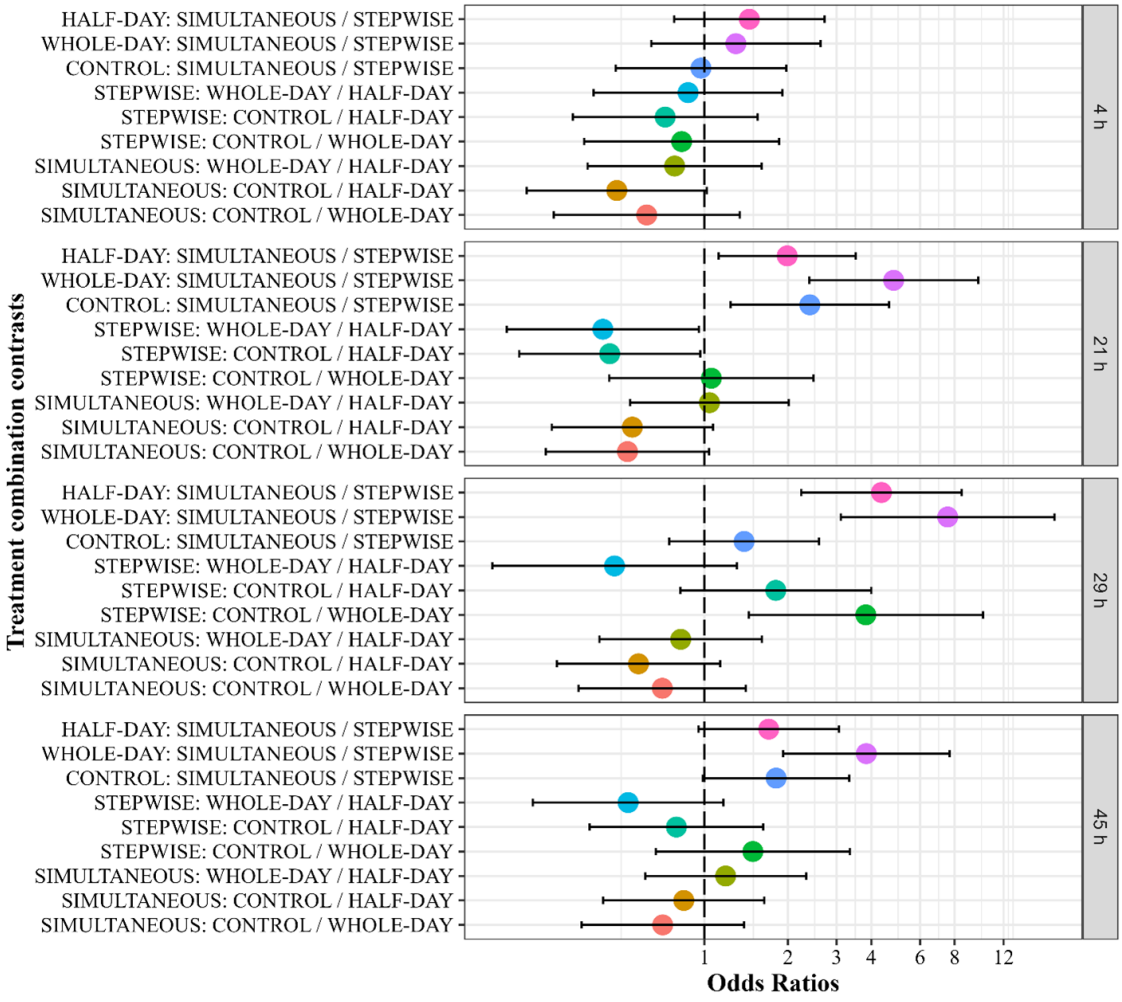

Figure 8.4: The odds ratios and the 95% confidence interval for dairy calves being active for each minute of a 30 min observation period, at each of 4 observation time points (4 h, 21 h, 29 h, and 45 h), after a weaning and separation intervention. Each point represents the odds ratio between two treatment combinations. Odds ratios are shown on a log10 scale to ease visual interpretation (odds ratios of 0.5 and 2 show the same magnitude). Statistical, pairwise comparisons were made within each observation time point. Odds ratios between two treatment combinations whose confidence interval transects the vertical dashed line at "1" are not significantly different at the alpha = 0.05 level.

For calves on the Simultaneous treatment, there were no dam-contact treatment differences in the activity response. However, for calves on the Stepwise treatment, Half-day calves showed a higher activity response after 21 h than Whole-day and Control, while Control calves showed a higher activity response than Whole-day after 29 h (Figure 8.4)

8.3.3 The timing of the response

The above results are based on the summed behavioral reactions from weeks 8 and 9. To get a sense of the timing of the behavioral response in relation to the weaning and separation interventions, the raw data for high- and low-pitched vocalizations, respectively, are plotted in Figure 8.5A and 5B for each of the two weeks and each of the two weaning and separation treatments.

Simultaneous calves did virtually not vocalize in week 9, which was expected as no change happened in week 8. For Stepwise calves, the response appeared to be fairly evenly distributed between the two weeks, but with numerically more high-pitched vocalizations after the weaning step in week 8 (Figure 8.5A). The same pattern appeared for low-pitched vocalizations.

8.3.4 Cross sucking

The occurrence of cross-sucking was low, but numerically more Control calves performed cross-sucking during at least one of the 30 min observations per observation time point (See Table 8.2). A Fishers' exact test revealed no difference in the number of calves observed performing cross-sucking between any of the treatment combinations ($p = 0.874$).

Table 8.2: The number of calves on each treatment combination performing cross sucking at least once during 2 h of observations, in dairy calves on three different dam-contact treatments and two different weaning and separation treatments

	Control	**Whole-day**	**Half-day**
Simultaneous	8 (n= 12)	3 (n = 11)	3 (n = 12)
Stepwise	9 (n = 12)	1 (n = 10)	5 (n = 12)

8.3.5 Growth

At 8 weeks of age, just before any weaning interventions, there was no difference between treatments in body weight (Estimated marginal means [95% CI]; Control: 89.6 [83.0-96.2] kg, Whole-day: 91.2 [84.2-98.1] kg, Half-day; 88.0 [81.0-94.9] kg). There was, however, an effect of both actual calf age ($\chi^2 = 30.1$, $p<0.001$), calf sex ($\chi^2 = 6.4$, $p<0.001$), and the dams' parity ($\chi^2 = 13.4$, $p<0.05$) on body weight. Older calves were 1.7 (SE: 0.39) kg heavier for each extra day of age, calves of

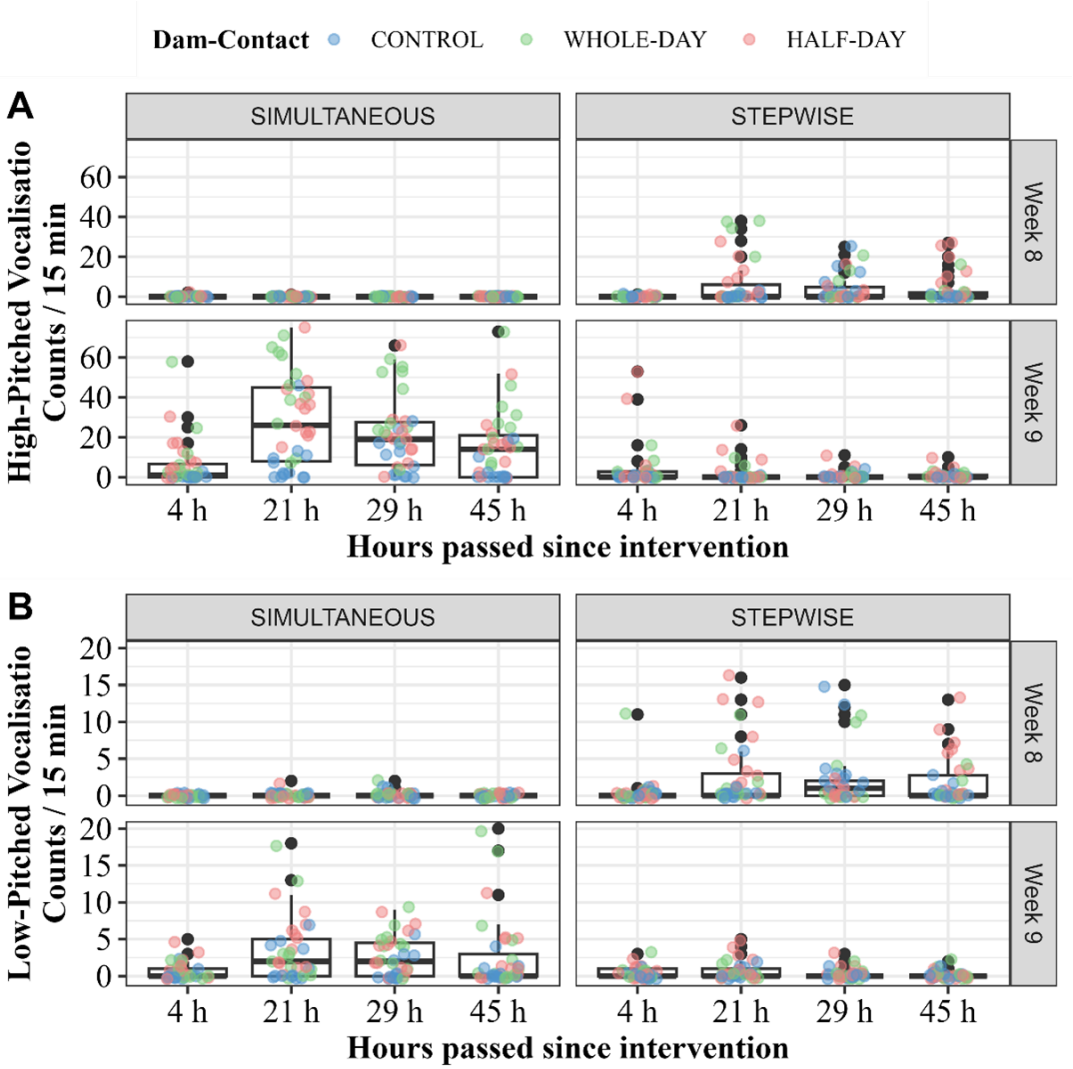

Figure 8.5: Descriptive plot of behavioral responses to the weaning and separation interventions. The number of A) high-pitched and B) low-pitched vocalizations for each of the two weeks of observations (week 8 and week 9) and each of the two weaning and separation treatments (Simultaneous and Stepwise). Each calf's vocalization count is illustrated with a point filled in a corresponding color (Control = blue, Whole-day = green, and Half-day = red). Box plots show the medians (mid-line within the box) with 25th and 75th percentiles (outside edges of the boxes) with whiskers going out to the upper and lower adjacent values (the most extreme values within 1.5 of the interquartile ranges of the nearer percentile) and black dots are outside values > 1.5 of the interquartile ranges.

multiparous cows (95.2 [89.6-100.8] kg) were heavier than calves of primiparous cows (84.2 [77.3-91.1] kg), and bull calves (93.2 [87.2-99.1] kg) were heavier than heifer calves (86.1 [79.8-92.5] kg).

There were also no treatment effects for the ADG from birth to 8 weeks of age (estimated marginal means [95% CI]; Control: 930 [800-1060] g, Whole-day: 918 [783-1050] g, Half-day; 883 [752-1010] g), but calves of multiparous (993 [888-1099] g) cows had a higher ADG than calves of primiparous cows (827 [702-953] g), across dam-contact treatments.

When comparing the ADG during the first week after weaning off milk, (week 9 for calves on the Stepwise treatment and week 10 for calves on the Simultaneous treatment) there was a main effect of the dam-contact treatment (χ^2 = 10.83, p<0.01) with Control calves (estimated marginal means [95% CI]; 230 [33 to 428] g) having a higher ADG than Whole-day calves (-230 [-447 to -14] g), while Half-day were intermediate (7 [-19 to 21] g). There was also a tendency for an interaction between dam-contact treatment and weaning and separation treatment (χ^2 = 4.8, p<0.09) for the ADG after weaning, likely driven by Control calves (estimated marginal means [95% CI]; 402 [127 to 676] g) having higher ADG than Whole-day (-316 [-610 to -21] g) and Half-day (-86 [-37 to 192] g), under the Simultaneous weaning and separation but not under the Stepwise weaning and separation (estimated marginal means [95% CI]; Control: 59 [-222 to 341] g, Whole-day: -145 [-451 to 161] g and Half-day: 101 [-177 to 379] g).

The ADG for the second week after weaning for the Stepwise weaned and separated calves was also calculated. Here, there was an effect of dam-contact treatment (χ^2 = 12.0, p<0.01), with Control calves (estimated marginal means [95% CI]; 1136 [753-1519] g) having higher growth rates than both Whole-day (497 [11-888] g and Half-day (380 [1-759] g). In addition, bull calves (estimated marginal means [95% CI]; 894 [612-1176] g) had higher ADG at this point in time than heifers (448 [73-875] g, χ^2 = 5.2, p<0.05).

8.3.6 Health

For the observations on health, the frequency distribution is shown in Figure 8.6, summed across the experimental period.

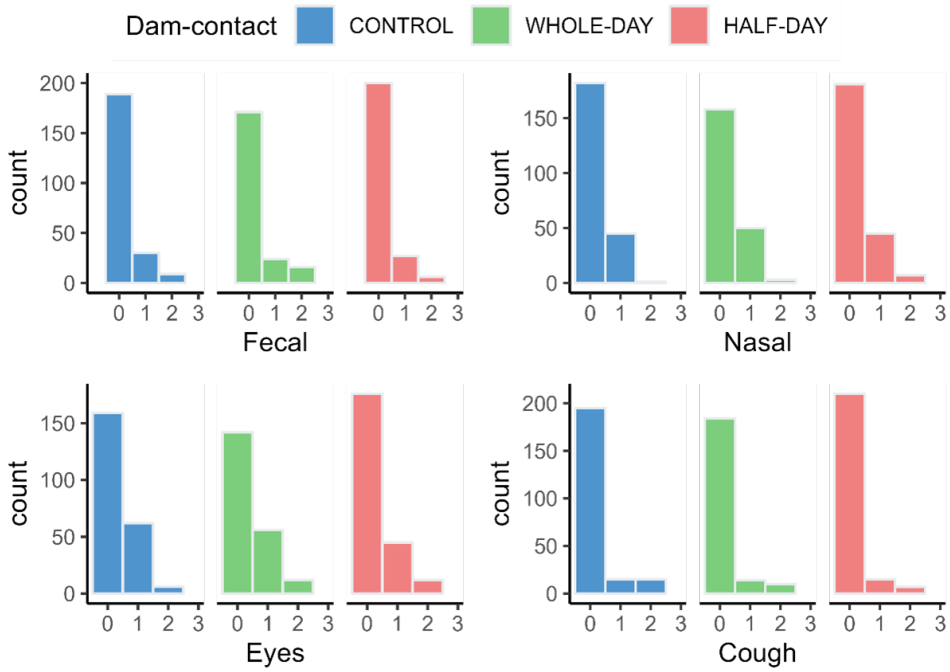

Figure 8.6: Frequency distribution of health scores related to fecal consistency, nasal discharge, ocular discharge and coughing summed across the 10 weekly health checks. A score of zero indicates no signs of disease and a score of three is the highest possible, indicating severe clinical symptoms of the disease.

For the rectal temperature, there was an interaction between the experimental week and the dam-contact treatment ($\chi^2 = 32.6$, $p<0.05$), as well as between the experimental week and weaning and separation treatment ($\chi^2 = 20.2$, $p<0.05$). In week 1 Control calves had a lower temperature (estimated marginal means [95% CI]; 38.4 [38.1-38.74] °C) than Whole-day (38.8 [38.5-39.2] °C) and Half-day calves (38.9 [38.6-39.2] °C) when averaging over weaning and separation treatment. In week 9, there was a difference between Simultaneous (estimated marginal means [95% CI]; 38.8 [38.6-39.0] °C) and Stepwise (38.4 [38.1-38.7] °C), when averaging over dam-contact treatments, due to a drop in temperature for Stepwise. Post-hoc analysis revealed a similar drop in temperature for Simultaneous the week after weaning off milk. See Figure 8.7.

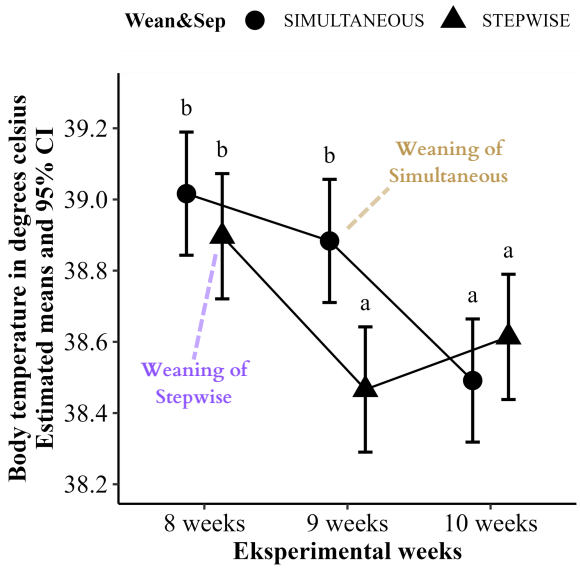

Figure 8.7: Post-hoc analysis of temperature drop around weaning. Estimated marginal mean temperature and 95% confidence interval for dairy calves weaned and separated either simultaneously (dot, weaning in week 9) or stepwise (triangle, weaning in week 8). Statistical, pairwise comparisons were made between all treatments, combinations, and experimental weeks. Means that share a letter are not significantly different at the alpha = 0.05 level

8.4 Discussion

The present study compared the response to weaning and separation of dairy calves that were housed either with whole-day or half-day contact with their dam to a control group of artificially reared calves. Dam-calf contact calves were either weaned off milk and separated from the cow simultaneously at nine weeks of age, or weaned off milk at eight weeks of age, but were continuously allowed physical contact with the dam until being separated from the dam in a second step at nine weeks of age. Control calves were also either weaned off milk in week 8 or week 9. This experimental design allows us to ask two main questions: 1) Does half-day contact result in a lower behavioral response to weaning and separation compared to whole-day contact, and is this comparable to the behavioral response observed among artificially reared calves when they are weaned off milk? 2) Does a stepwise weaning and separation reduce the summed behavioral response, compared to simultaneous weaning and separation?

8.4.1 The effect of dam-contact treatment

Comparing the three dam-contact treatments, the general picture is that Control calves had a lower response to weaning and separation than dam-reared calves, but only under the Simultaneous weaning and separation treatment. This was evident from Control calves showing fever high-pitched vocalizations after weaning and separation and a higher ADG after weaning which is in line with the literature (Fröberg et al., 2011; Johnsen et al., 2015a; Wenker et al., 2022). This may be because Control calves had a higher daily intake of solids before weaning and/or were less affected by being weaned and moved to a new environment than dam-reared calves, who in addition were separated from their dam at this point.

The differences were less clear under the Stepwise treatment, where response levels were generally lower across dam-contact treatments. On one hand, Control calves had fewer high- and low-pitched vocalizations than Half-day calves at 21 h, but on the other hand, they were more active than Whole-day calves at 29 h (See discussion in Section 8.4.3 below). It thus seems that the difference between treatments was less pronounced when calves were weaned and separated in a stepwise, fence-line manner. This is also supported by the measures of ADG: in week 8, dam-reared calves on the Stepwise treatment were housed inside the group pen in the familiar calf creep and during this week had similar ADG as Control calves. Whether this is caused by dam-reared calves being in the known environment and with the dam present and thus allocating time to eating solids is unclear. However, one week later, two weeks after weaning off milk and one week after being moved to the weaning pens, permanently away from the cow, Control calves on the Stepwise treatment had regained pre-weaning ADG while dam-reared calves on the Stepwise treatment had not, indicating that dam-reared calves were more strongly affected by the separation step.

Contrary to expectations, there was no difference between Whole-day and Half-day under any of the two weaning and separation treatments, except that Half-day calves were more active than the Whole-day calves on the Stepwise weaning and separation treatment, 21 h after interventions. Thus, we found no support for the hypothesis that half-day rearing reduces the behavioral response to weaning and separation as suggested by Veissier et al. (2013). Spending 14 h apart every night for the first 2 months of life did not appear to prepare Half-day calves better for weaning and separation, although this management could be expected to stimulate calves to eat more solids. However, Fröberg et al. (2008) showed that during one daily hour of restricted suckling calves ingested approximately 10 L of milk, suggesting that calves are able to ingest a high amount of milk during a short period of dam-

contact. Additionally, studies found that calves suckling their dams for even short daily periods had a low concentrate intake (Hepola et al., 2007; Roth et al., 2009). Nevertheless, in the present study, numerically, Half-day did have a higher ADG than Whole-day calves under both weaning and separation treatments and less high-pitched vocalizations than Whole-day calves under the Simultaneous weaning and separation treatment. We encourage future research to explore the effect of further reducing the daily dam-contact duration prior to separation as a way to stimulate solid feed intake before weaning.

8.4.2 The effect of weaning and separation treatment

The summed behavioral response (as measured by vocalizations and activity) to the Stepwise weaning and separation was as expected, based on studies in beef cattle (Enríquez et al., 2011), lower than the Simultaneous weaning and separation, but to varying degrees depending on the dam-contact treatment.

For dam-reared calves, the Stepwise treatment consistently resulted in a lower number of high-pitched vocalizations at the 21 h, 29 h (and for Whole-day also 45 h) observation time points compared to Simultaneous. The largest mean difference in the number of high-pitched vocalizations between weaning and separation treatments was seen after 21 h, which is in accordance with peak vocalization latency found in literature (Fröberg et al., 2011; Loberg et al., 2008). Under the Stepwise weaning and separation, dam-reared calves did not differ from Control calves except at 21 h after the intervention. The found differences support our hypothesis that Stepwise weaning and separation result in an overall lower behavioral response, which is supported by studies on dairy (Johnsen et al., 2015a; Taylor et al., 2020) and beef cattle (Price et al., 2003). In contrast, Enríquez et al. (2010) and Solano et al. (2007) found that the summed response to fence-line weaning of beef calves was similar, or higher, than the control, but extended over a longer time. This will be further discussed in Section 8.4.3.

Not surprisingly, it appeared that Control calves benefitted the least from the Stepwise treatment. Due to Control calves already being separated from their dam within 24 h of birth, there was no separation happening in weeks 8 and 9 for Control calves. Control calves were however still weaned off milk in one of two ways, either weaned at week 8, but staying one week further in the familiar environment, or being moved to an unfamiliar pen at the same time as being weaned off milk at week 9. The only indication that being moved and weaned simultaneously was more stressful for Control calves was more activity under the Simultaneous weaning and separation 21 h after intervention.

Regarding low-pitched vocalizations, the effect of weaning and separation treatments are less clear, and these vocalizations appear to be more influenced by the time of day (see Section 8.4.3).

Concerning the distribution of behavioral responses between weeks 8 and 9, we recorded few vocalizations for Simultaneous calves in week 8 (high-pitched: 2, low-pitched: 3), i.e. before they had experienced any weaning or separation, which was expected. We consider this level of vocalization illustrative of a close to baseline vocalization level for the calves in the study. One should keep in mind, however, that these calves were disturbed by calf creeps being closed off for them and by the vocalization of the calves undergoing Stepwise weaning and separation during week 8. For Stepwise calves, high-pitched vocalizations appeared similar in each of the two steps (week 8 and week 9, not statistically tested), which indicates that weaning off milk (while staying in fence-line contact to the dam) and being separated from the dam one week later constitute two individual stressors of similar strength. However, further studies that control for calf age are needed to investigate if they are indeed similar in strength.

There was a large variation in both high-pitched and low-pitched vocalization frequency for dam-reared calves and especially among calves on the Simultaneous treatment. Neither calf sex, calf age nor dam parity could explain these. Future research is encouraged to investigate how personality traits play a role in the vocalization response to weaning.

8.4.3 Timing of observations

Padilla et al. (2015) suggested high-pitched vocalization to be aimed at long-distance communication to reinstate contact and opportunity to suckle, while low-pitched vocalizations are used for signaling intent to suckle when the dam is within visual contact. Indeed, among Half-day calves on the Stepwise treatment, low-pitched vocalizations peaked during those two observation time periods where the dam is present in the pen during week 8 (dams had recently returned to the pen at 21 h and 45 h) and was at its lowest when Half-day calves were alone in the pen at night (29 h). Similarly, Stepwise Control calves' low vocalizations and activity peaked during milk delivery to the calves in neighboring pens at 29 h. The fact that calves were influenced by either the time of day, the physical presence of the cows, or milk feeding warrants a discussion of the best time to do observations in relation to weaning and separation interventions. Had we e.g. not included the afternoon time point where Control calves were normally fed, we would have observed very little response in Control calves. When comparing weaning and separation in calves with

different housing, feeding, and timing of management, future studies should carefully choose when to record and preferably have many repeated observation points, or an automatic recording of vocalizations throughout the 24 h of the day. In relation to the choice of observation time periods, the response should reach baseline levels at the time of the last observation. Based on previous studies, we expected the weaning response to have ceased by the last observation at 45 h (Johnsen et al., 2015b), but we recorded a mean of 15 high-pitched vocalizations for Simultaneous and 4 high-pitched vocalizations for Stepwise during the 15min observation window 45 h after weaning off milk (and separation from the dam, for Simultaneous). Compared to our own "baseline" level (Simultaneous, week 8, before any interventions, mean = 0.0), these are still elevated levels. We might thus have missed responses to weaning and separation between the last observation from week 8 and the first in week 9 and again after the last in week 9. This is an important limitation of the present study. It also further illustrates the need to develop reliable, automatic detection of vocalizations when comparing responses that are expected to last over several days. Lastly, the present study is also limited by the number of animals in each treatment combination (n = 10-12).

8.4.4 Health

Health was monitored to ensure that calves' behavior was not influenced by ill health, and the data set is too small to make statistical interferences on dam-calf contact's effects on the health score. However, it was interesting to note that rectal temperature dropped approximately half a degree the week after weaning off milk, for both Stepwise and Simultaneous treatments, and that for Stepwise it started increasing again after two weeks, mirroring the ADG pattern. Indeed, Silva et al. (2021) also found an effect of larger colostrum intake on the immediate rectal temperature, which they attribute to increased metabolized energy. We also found lower body temperature for Control calves in week 1, compared to the other treatments. It can be speculated whether this was caused by a lower daily milk intake than dam-reared calves, at this age. This indicates that rectal temperature may be used as a proxy for energy uptake in dairy calves, and caution should be taken when interpreting temperature differences for calves on different milk allowances.

8.5 Conclusion

Dairy calves reared by the dam had a higher response to weaning (a higher number of high-pitched vocalizations and a higher level of activity) than artificially reared calves when calves were weaned and separated simultaneously. The response of dam-reared calves that had been with the dam daily from morning to afternoon milking only (Half-day) was similar to the response of dam-reared calves that had been with the dam all day, except for milking twice daily (Whole-day). Thus, we found no support for the hypothesis that half-day rearing reduces the behavioral response to weaning and separation. Among dam-reared calves, the summed response to stepwise weaning and separation using a fence line was lower than the response to simultaneous weaning and separation at 21 h, 29 h, and 45 h after the intervention. Therefore, using a stepwise, fence-line weaning, and separation method shows promise as a way to reduce the response to weaning and separation in dairy calves reared by the dam, but further studies on gradual weaning methods for dam-reared dairy calves are needed.

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Chapter 9

Paper IV

Applied Animal Behaviour Science

The effects of part-time dam-contact and stepwise weaning and separation on the voluntary human approach behaviour of dairy calves

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Abstract

Dairy calves are commonly reared without contact with their dam, which facilitates a human-animal relationship based on close human contact and feeding. Dam-contact may negatively affect calves' relationship with humans. The current study investigates the effect of dam-contact and weaning methods on calves' response to humans. A total of 69 dairy calves were allocated to one of three dam-contact treatments [Control (separated from dam after 24h), Whole-day (housed with dam for 23h/d), and Half-day (housed with dam for 10h/d)]. Within each treatment, calves were allocated to one of two weaning treatments [Stepwise (weaning off milk at eight weeks, dam-separation/pen change at nine weeks) or Simultaneous (weaning off milk and dam-separation/pen change simultaneously at nine weeks), i.e Control were weaned in the same manner but only the pen change was possible at the separation step, as calves were already separated from the dam]. All animals received a similar amount of human contact, except Control calves who were additionally fed milk by teat bucket twice a day. Calves were tested in a random order within the block using a human approach test followed by an animal approach test conducted in a 2.5m x 10m arena at 10 weeks of age. Stepwise-Control calves had shorter latency to first approach the test person than Stepwise-Whole-day ($p < 0.05$, median survival time of Stepwise-Control: 11s, Stepwise-Whole-day: 111s and Stepwise-Half-day: 52s). Among Simultaneous calves, no contact treatment differences were detected for the latency to first approach. Similarly, Stepwise-Control calves had an odds ratio (95% CI) of 24.2 (1.6-365.9, $p < 0.05$) for coming within 1m of the test person vs Stepwise-Whole-day calves and 12.5 (1.1-141.1, $p < 0.05$) vs Stepwise-Half-day calves. Throughout the test period Simultaneous-Control vocalised less [estimated mean no. of vocalisations (95% CI), 3.6 (2.1-6.4)] than both Simultaneous-Whole-day [18.2 (12.8-25.9), $p < 0.01$] and Simultaneous-Half-day [15.7 (11.0-22.5), $p < 0.01$] while there was no difference under Stepwise. As expected, Control approached faster and was more likely to come close to the test person than dam-reared calves, but exclusively after the Stepwise weaning and separation. For calves tested one week after simultaneous weaning and separation no effect of the contact treatments was found, except a higher frequency of vocalisations for dam-reared calves. This implies that Controlling for the stress level related to weaning and separation from the dam is important when interpreting human-animal relation tests, as contact treatment effects appeared to be affected by high levels of weaning stress.

Keywords: Cow-Calf Contact, Human-Animal Relationship, Stepwise Weaning, Weaning Stress.

9.1 Introduction

A possible way of improving dairy cow and calf welfare is by allowing prolonged contact between a cow and her calf, referred to as dam-rearing of calves. This allows for the expression of highly motivated, natural behaviours and positive experiences such as affiliative behaviours and social play between a dam and her calf (reviewed by Meagher et al., 2019). This differs from conventional dairy calf rearing in most parts of the world where the calf is separated from the dam within 24h of birth and reared artificially by humans.

However, there is a concern that dam-rearing leads to a low level of human contact due to the lack of human handling during milk feeding, and that this will result in calves – and subsequently cows – that have a poorer human-animal relationship (HAR) (Boivin et al., 1992; Jago et al., 1999; Johnsen et al., 2016; Krohn et al., 2003; Waiblinger et al., 2020). Measuring the HAR has classically been done with 1) the human approach test (measuring mainly animal avoidance distance), and 2) the animal approach test (measuring mainly animal latency to first approach and time spend with the test person) (reviewed by Waiblinger et al., 2006).

Studies have shown that dam-rearing affects the HAR negatively, i.e. the HAR was judged to be more positive for artificially reared calves than for dam-reared calves (Duve et al., 2012; Mogensen et al., 1999). Dairy cows and calves should at least accept and perhaps even enjoy aspects of interactions with humans to ensure their welfare in production systems where daily handling and routine procedures such as moving the animals and milking require human contact. If animals are more fearful of humans and more difficult to handle, this can lead to stress and the animals having more negative experiences (reviewed by Mota-Rojas et al., 2020; Waiblinger et al., 2006). The difference in the HAR between dam-reared and artificially reared calves may be explained by the importance of the type of human contact for the development of the HAR and in extension hereof the association between humans and milk feeding. Indeed the positive effects on the HAR were stronger when calves visually associated milk feeding with humans than when curtains blocked any visual contact between humans and animals during milk feeding (Jago et al., 1999). Further, a more positive HAR was found in multiple studies for calves that received gentle handling [(Breuer et al., 2003) (Holstein Frisian heifers, 5-14 months old); (Lensink et al., 2000) (Holstein bulls, 2-21 weeks old); (Lürzel et al., 2015) (Holstein-Friesian heifers and bulls, 17-86 days old)]. This effect of gentle handling, however, was not found in a study where calves were housed right next to the dam during handling, which may be a contributing factor to the more positive HAR in artificially reared calves, who experience human contact separate from their dam ((Krohn et al., 2003)

(Holstein Frisian heifers and bulls, tested 50-55 days old)). It has also been shown that pair-housing results in a poorer HAR compared to individual housing in pre-waened calves, suggesting an effect of available social partners on the development of the HAR (Doyle et al., 2022).

Part-time contact has been suggested as a more feasible option for dam-contact for practical and production economic reasons (reviewed by Johnsen et al., 2016) and would at the same time allow the calves to experience human handling and interference without the dam being present. This could possibly improve the HAR, if indeed the presence of the dam inhibits the socialisation towards humans (Krohn et al., 2003).

In the present study, we compared dam-reared calves with either whole-day or half-day contact (terminology: Sirovnik et al., 2020) with their dam (all milk supplied by the dam, for both treatments) to control calves that were separated shortly after birth and artificially reared using standard farm procedures. In regards to the two different levels of contact time between dam and calf, Boivin et al. (2009), found no difference in handleability between half-day and whole-day contact in beef calves who all received forced stroking for 5min, 5 days a week over 3 weeks while separated from the dam. However, in the present study, we investigate the HAR of calves reared either with whole- or half-day dam-contact, in a setting where human contact involved less invasive, standard management procedures such as the provision of straw, cleaning, and filling of the feed troughs across a longer total period. For half-day calves, they would experience some of these management procedures with human presence, without the presence of the dam. Based on the above literature, we hypothesised Control calves approach a test person more readily during an animal approach test and allow the test person to come closer during a human approach test compared to whole-day calves and with half-day calves being intermediate. Stepwise weaning and separation have been found to reduce the reaction to weaning and separation, which is likely due to calves not experiencing the combined stress response from two stressors at one point in time (reviewed by Newberry & Swanson, 2008). In the present study, either a stepwise weaning and separation or a simultaneous weaning and separation strategy was applied as a second treatment. We thus expected that simultaneously weaned and separated calves would be hungrier and more affected by weaning stress at the time of testing than stepwise weaned and separated calves. To the best of our knowledge, there are no studies investigating how weaning stress and hunger affect the HAR as measured by human- or animal approach tests. On one hand, it could be that animals show faster approach behaviour and less fear of humans if a human is regarded as a potential source of milk or social contact. On the other hand, it could be argued that hunger and

weaning stress leads to calves being in a more negative affective state (e.g. negative judgement bias after weaning (Daros et al., 2014)) and thus less explorative, though interpreting inactivity in a testing setting must be done with caution (Fureix & Meagher, 2015). Based on this, we hypothesised that simultaneously weaning and separating calves would lead Control calves to show a more positive HAR, as they associate humans with milk feeding, while dam-reared calves to show no change, as they do not associate humans with milk compared to calves on the stepwise weaning and separation treatment.

9.2 Material and Methods

9.2.1 Animals, housing, and management

The study was conducted at the cattle Research facilities at Aarhus University, Foulum, Denmark, from November 2020 to May 2021. A total of 72 pure-bread Danish Holstein calves and their dams were allocated to six blocks of 12 cow-calf pairs according to the calves' birth date. Within a block, animals were allocated to one of three calf-dam contact treatments: Control, Whole-day, and Half-day (4 cow-calf-pairs per group). The treatment groups were to the best extent balanced for sex (at least one calf of each sex in each group in all treatment pens), except for two pens with only bull calves (Whole-day in Block 2 and Half-day in Block 5, i.e. a total of 29 heifer calves and 40 bull calves). The groups were also balanced for dam parity with either one or two first parity cows in each group (4 groups had two first parity and two multi parity cows (Control in Block 2 and Whole-day, Half-day and Control in Block 4), i.e. in total 50 multi parity and 22 first parity cows). Due to three disease incidences (2 calves with diarrhoea and fever and 1 cow with mastitis), data was collected on a total of 69 calves. Calves were tested in six sessions corresponding to the six blocks.

All calves were fed the dams' colostrum (4L) via a teat bottle within 6h after birth. A dose (1ml Cevivit®E-Selen) of E-vitamin was added to the colostrum. From day 2 and onwards, the calves were housed in deep bedded pens with or without their dams depending on the treatment. All calves had ad libitum access to calf-starter concentrate (DLG: "Komkalv Start Valset" FEk/kg: 0.99 FEk; Raw Protein: 20%; Raw fat: 3.6%; Fiber: 5.4%; Raw Ash: 7.5%; Water; 13%), hay, water and the cows' total mixed ration (TMR; clover-grass and maize silage (64.6%) with concentrate (35.3%).

Calves experienced human contact during daily and weekly standard care procedures such as feeding, bedding replenishment, weekly weighing, and weekly experimental health checks. Half-day calves specifically experienced evening farm-procedure health checks and refilling of hay and concentrate in the calf creep during the period when their dams were not present. The calves were not disbudded during the experimental period.

9.2.2 Treatments

Whole-day and Half-day

After calving, the cow and calf stayed together in the calving pen for 24h (range: 20h – 36h) to establish suckling and bonding. At the colostrum feeding within 6h of birth, the calf's ability to suckle the dam (filled calf stomach, milk foam around calf's mouth, saliva on the dam's udder) was assessed and if there were no signs of suckling, the calf was guided to the udder, i.e., suckling was assisted. If the calf did not suckle, suckling was assisted again 6h later. Calves not being able to suckle within the first 24h did not enter the experiment (n = 6 out of 78 calves).

The cow-calf-pair was moved to a deep-bedded group pen (9m x 7.5m) for four cow-calf pairs on the same treatment. There were four treatment group pens in the experimental barn, allowing a new block to start while the proceeding block was still running. All four pens had the same, but mirrored, layout (see Figure 9.1). Treatment groups were allocated to the different sides of the barn in a balanced matter, across the six blocks. There were two calf creep areas with sides of tubular metal bars, one in each back corner, of each pen; one sized 3m x 3m with concentrate in bowls, a hayrack, and a water cup and one sized 1.5m x 1.5m with concentrate in a bowl and a hayrack (see Figure 9.1).

Whole-day calves were kept with their dam at all times, except for approx. 30min (mean ±SD: 28 ±8min) twice a day, while the cows were away for milking in a milking parlour in an adjacent building. Half-day calves were kept with their dam, except for approx. 14h (mean ±SD: 13h 58 ±8min) during the night (from when the cows were taken out of the pen for afternoon milking (15:30h) until they returned from morning milking (5:30h).

Weaning treatment started at the eighth treatment week [mean age (95% CI) and mean weight (95% CI); Whole-day: 54.9 (53.1-56.6) days and 93.2 (86.3-100) kg; Half-day: 59.3 (58.2-60.5) days and 93.8 (88.4-99.2) kg]. Two randomly selected calves in both Whole-day and Half-day treatments were at this time confined in

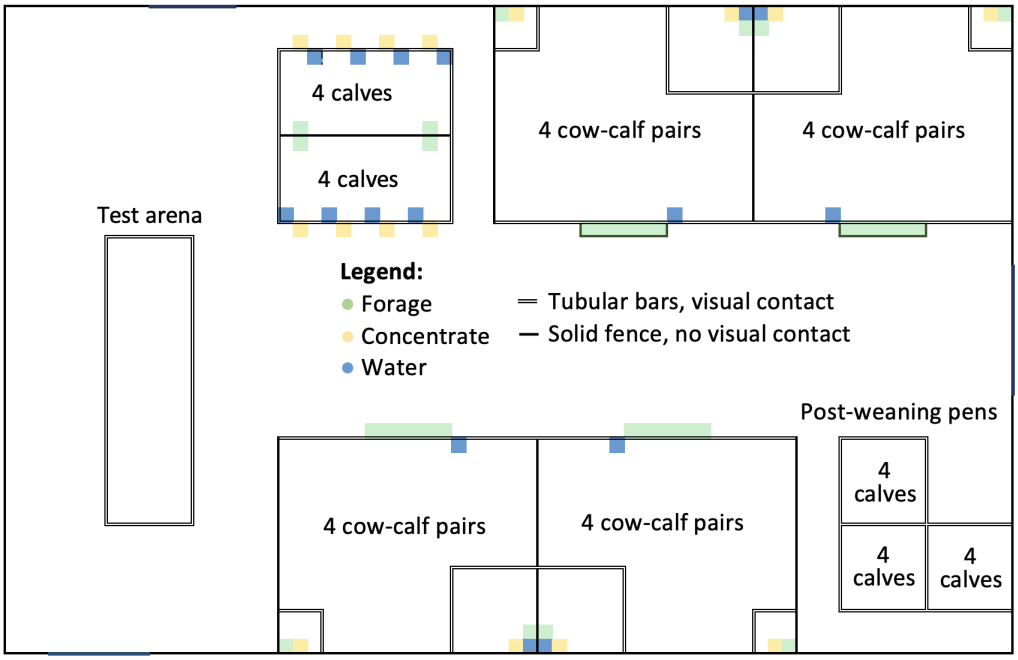

Figure 9.1: Graphical illustration of the experimental barn and housing environment. Calves on the contact treatments Whole-day and Half-day are housed with their dams in straw-bedded pens in groups of four cow-calf pairs. Control are housed in groups of four without their dam. There was room for two simultaneous blocks at a time. Calf creeps are provided in the dam-rearing treatment pens and the larger creep is used for fence-line weaning at week eight for calves on the Stepwise weaning and separation treatment. The weaning pens in the corner are used for all calves in a block at week nine. The location of the test arena is indicated.

the 3m x 3m calf creep, closed with pen fixtures made from tubular metal bars (Stepwise). The cow and calf pair could maintain olfactory, visual and some tactile contact, but nursing was not possible, effectively weaning the calves off milk. The two remaining calves stayed in the main part of the pen with full access to their dams for another week (Simultaneous). There was one block (Block 2) were the enrolment time for the two last calves (one Whole-day and one Control) of the block was prolonged due to either twin birth or disease. For this block, the treatment weeks followed the third youngest calf. The two youngest calves were allocated to the Simultaneous weaning to allow them an extra week of milk intake, thus in Block 2 an exception from random allocation of calves to weaning treatment was made.

All dam-reared calves were permanently separated from the dams one week later, after nine weeks of contact treatment. The dams were moved to an adjacent building but within auditory reach. The calves were moved to straw-bedded weaning pens of 3m x 3m in the corner of the experimental barn and followed for seven days. During this period, calves were still housed with the calves from their previous groups, in groups of four.

Control

Control calves were managed largely according to standard farm procedure and separation from dams took place after 12 h to 24 h. During the first seven days after the separation from the dam, the calves were housed in individual straw-bedded pens (1.5m x 3m) with sides made from tubular metal bars allowing visual and tactile contact with neighbouring calves on the same treatment and within the same block. After seven days, they were grouped in groups of four (by removing partitions), resulting in a group pen for the four Control calves (3m x 6m) in each block.

During the first week of life Control calves were first offered 6L/d of whole milk in two daily feedings, which was gradually increased over seven days to 8L/d in two daily feedings. From seven days old and throughout to weaning off milk they were offered milk to satiation twice daily at 06:30 h and 17:00 h. The calves had 20min to drink milk before any leftovers were removed (mean daily intake per calf ±SD ranged from 7.9L ±0.93 in the second week to 11.08L ±1.7 in the eighth week).

Weaning began at the eighth treatment week [mean age (95% CI) and mean weight (95% CI) 55.7 (54.4-56.9) days and 90.3 (82.7-97.9) kg]. For Control, true Stepwise weaning and separation were not possible, due to the obvious decoupling of milk and dam. However, a version of the Stepwise weaning was achieved as described below: The group pen was split into two equally sized adjacent pens (3m x 3m), each housing two calves. The two calves in one pair of pens were randomly allocated to be Stepwise weaned and separated by first removing milk, but only one week later moving the calves away from the known environment (Stepwise). The remaining two calves continued to be fed milk for one week and then weaned from the milk and moved on the same day (Simultaneous). On the moving day, all four calves were moved to a common weaning pen (3m x 3m) in the corner at the opposite end of the experimental barn and observed for seven days post-weaning. See Figure 9.2 for a graphic timeline of treatments.

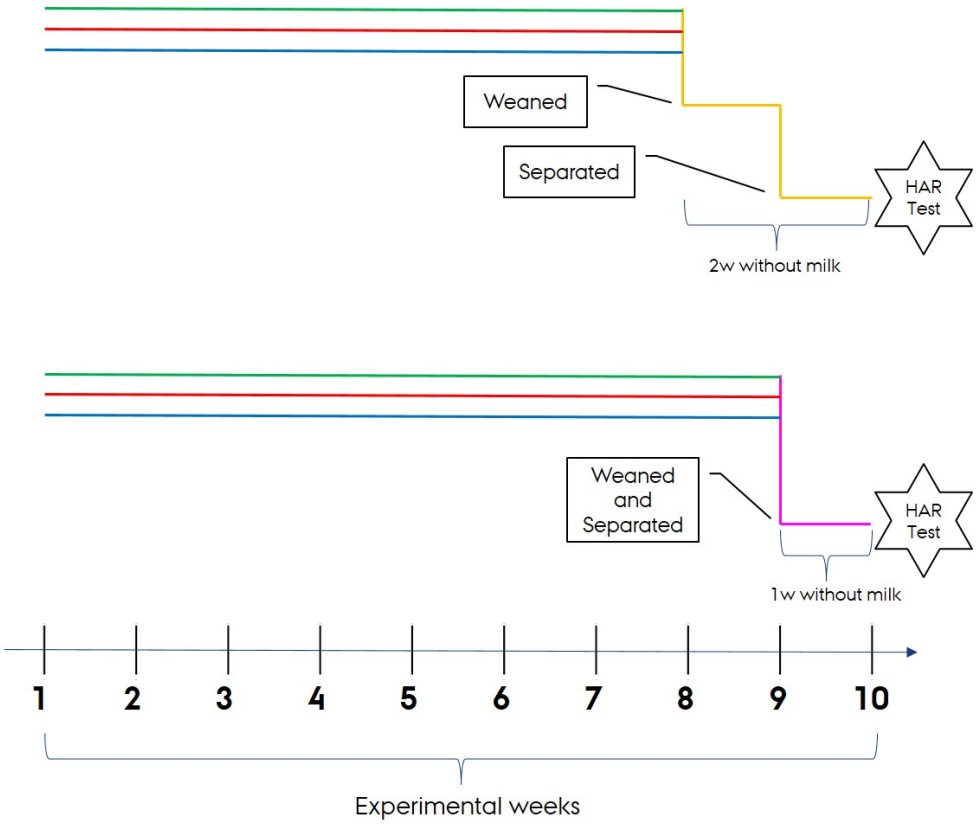

Figure 9.2: Timeline of the experimental treatment of the present study. The contact treatment is initiated immediately after birth (Control, Whole-day, and Half-day, each represented by blue, green, and red lines) while the weaning treatments start at either eight (Stepwise, orange) or nine (Simultaneous, pink) weeks of age. The 3x2 factorial design yields six treatment combinations.

9.2.3 Test procedures

For all calves, behavioural tests described below were performed at 10 weeks (mean age ±SD; 68.5 ±7.0 days). After testing, the calves were moved to the main calf herd and no longer included in the experimental study.

We measured the calves' HAR by assessing their reactions towards a test person in a human approach test (HAT) and an animal approach test (AAT), adapted from previous studies (e.g. Krohn et al., 2003). Two people, an observer and a test person conducted the tests. The same observer did all behavioural observations, but three different test persons were included, in an unbalanced manner (Test person A: Block 1 + 2, Test person B: Block 3 + 6, Test person C: Block 4 + 5). The test people were not involved in daily management and care for the animals but assisted (in a similar degree and way) in other behavioural observations and weekly weighing. Behaviours were recorded directly by the observer. All calves were tested individually in an unfamiliar test arena placed at the far end of the experimental

barn. During testing, the calf could have visual contact with the cows from othe ther blocks if cows had their head out of the pen, but not with their pen mates or own dam. The arena consisted of ten galvanized steel fences attached to each other and enclosing a rectangular space measuring 10m x 2.5m (See Figure 9.3).

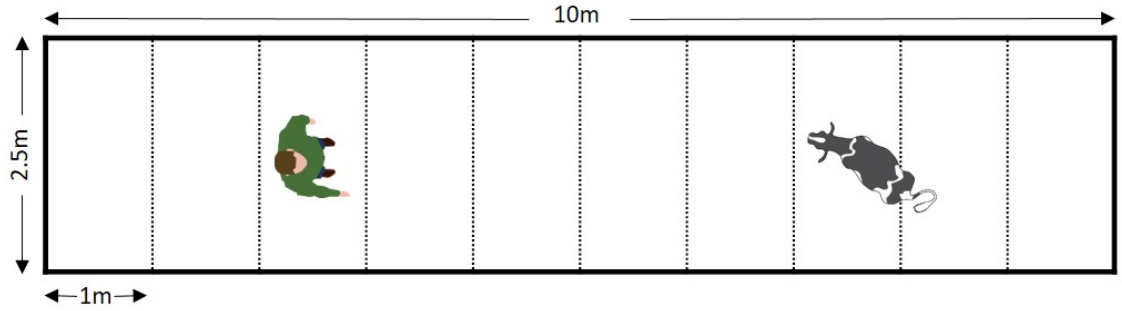

Figure 9.3: Illustration of the test arena used on dairy calves for both a human approach test and an animal approach test. For both tests, the test person entered and started the test at a four-zone (equal to 4m) distance.

A coloured spray marker on the floor, just outside of the test arena, was used to indicate distance increments of 1m. The calves were tested in a random order according to a list generated before the test session. Test sessions started approximately at 12:00 h and ended before 15:30 h. The test calf was gently guided from the home pen to the arena; it was first tested in the HAT (45 ±15s) followed by the AAT (180s). Before the HAT, calves were habituated to the test arena for 3min and the calves were left undisturbed in the arena for 3min between the two tests. Disturbances during the testing were kept at a minimum and any unforeseen disturbances were minimal but noted. The order of the tests was chosen to prioritise the test with the highest repeatability, thus starting with the HAT (Lensink et al., 2003; Waiblinger et al., 2006). The total time in the arena including habituation, testing, and pause was 8min and 45 ±15s.

Human Approach Test

After the three-minute habituation period, the test person entered the arena. The HAT test started once the calf was standing still and at least 1.5m from either of the two ends of the arena (to ensure space to allow for a withdrawal) and the test person was positioned at four zones distance from the calf (see Figure 9.3). The test person could access the arena by moving any of the fences. In case the calf started moving, the test person re-positioned it according to the calf's new location before the test was initiated. To start the test, the test person said, "Hey you, I am here" to catch the calf's attention and started to approach, one step per sec, with one arm, stretched at 45 degrees angle. No abrupt or sudden moves were made. When the

test person's hand was within the calf's reach, the approach was stopped. If the calf sniffed the test person's hand, the test person tried to touch the calf on the cheek. The test ended whenever the calf moved one of its forelegs backwards or when the test person touched it. After the HAT, the test person left the test arena and the calf was left alone in the arena for 2min.

Behaviours were observed continuously, and the following measures were recorded: distance from the test person at withdrawal (m, in 0.5m increments), whether the calf sniffed the hand (yes, no), and whether the calf allowed touch by the hand (yes, no).

Animal Approach Test

After 2min of pause, the test person re-entered the test arena. The test person again entered and positioned at a four zones distance from the calf. The test person stood motionless, gaze lowered, with one arm stretched at 45 degrees angle, and waited for the calf to approach. If the calf sniffed the test person's hand, the test person tried to touch the cheek of the calf. If the calf withdrew, the test person stayed motionless. The test lasted 3min from when the test person was correctly positioned.

Behaviours were observed continuously, and the following measures were recorded: latency to first approach the test person (s) (more than one step in the direction of the test person), duration of time spent within 1m of the test person (s); duration of sniffing and touching the test person (s); the total number of lines crossed. The frequency of vocalisation and defecation (n) was recorded throughout the test session from when the calf entered the arena for habituation until the AAT finished.

After the AAT finished, the calf was gently guided back to the home pen.

9.2.4 Statistical analysis

From the HAT, we analysed only the variable "avoidance distance" statistically due to low response on "sniffing the test person" and "allowing touch" (Sniffing: 7 out of 69 calves, 4 Control, 2 Half-day, 1 Whole-day; Allowing touch: 3 out of 69 calves, 1 Control, 1 Half-day, 1 Whole-day). Due to low behavioural durations the variable "latency to first approach within 1m of the test person" from the AAT was changed into a binary variable: "calf approaching within 1m of test person (yes/no)" and due to high collinearity with response variables "sniffing the test person" the analysis of sniffing duration was omitted.

Statistical analysis was performed in R, using RStudio (Core Team, 2022) and the package "glmmTMB" (Brooks et al., 2017) for generalised linear mixed models (GLMM) or Survival Analysis using "Coxme" (Therneau, 2022) for a mixed cox proportional hazards model. The choice of distribution was based on an initial visual inspection of raw data histograms and following model comparison using the residual investigation tool from the "DHARMa" package in R.

For "avoidance distance" from the HAT, the Normal Distribution was used (family = Gaussian in glmmTMB, R, treated as continuous data after inspecting residual plots). For the AAT, "latency to the first approach" was analysed using a mixed cox proportional hazards model. The binary response variable "calf approaching within 1m of test person (yes/no)", was analysed with logistic regression (family = binomial in glmmTMB, R). Count data ("number of vocalisations", "number of defecations", and "number of lines crossed") were fitted using a Quasi-Poisson distribution (family = nbinom1 in glmmTMB, R). The model included contact treatment, weaning treatment, and their interaction as fixed effects, age as covariate, and block as random effect.

Significant effects were found using the type II Wald Chi^2 test and when relevant, pairwise comparisons within each of the weaning treatments using the package emmeans in R with the Sidak adjustment.

9.3 Results

9.3.1 Human Approach Test

Avoidance Distance

We did not find any significant differences in avoidance distance between contact or weaning treatments. There was however a significant effect of age on the day of testing, with older calves having larger avoidance distances (slope estimate ±SE: older calves had a 4.1 ±1.7cm increase in avoidance distance per extra day of age, between 57-83 days of age, Chi^2 = 5.58, df = 1, $p < 0.05$).

9.3.2 Animal Approach Test

Latency to First Approach

For the latency to first approach, there was a significant interaction between contact treatment and weaning treatment ($Chi^2 = 11.7$, df = 2, $p < 0.01$, see Figure 9.4A). The interaction was driven by no significant differences between contact treatments among simultaneously weaned and separated calves, while there were significant differences for Stepwise weaned and separated calves. Stepwise-Control had a 90.3% probability of having shorter latency to first start approaching the test person than Stepwise-Whole-day (Hazard Ratio (95% CI): 0.106 (0.028-0.412), $p < 0.01$), and an 82.35% probability of having shorter latency than Stepwise-Half-day (Hazard Ratio (95% CI): 0.214 (0.064-0.722), $p < 0.05$) to first start approaching the test person. There was no significant difference between Stepwise-Whole-day and Stepwise-Half-day. The median survival time (where half of the animals "at risk" had performed the behaviour and half had not) as estimated from Kaplan-Meier survival curves were respectively 11 s for Control, 53 s for Half-day and 111 s for Whole-day under Stepwise. There was no effect of calf age.

Approaching within 1m of the test person

There was also a significant interaction between contact treatment and weaning treatment for the probability of calves approaching within 1m of the test person ($Chi^2 = 10.13$, df = 2, $p < 0.01$, see Figure 9.4B). Within Stepwise, the odds ratio of Control for coming within one meter of the test person was 24.16 (95% CI: 1.59-365.97, $t = 2.82$, $p < 0.05$) vs Whole-day and 12.47 vs Half-day (95% CI: 1.10-141.07, $t = 2.50$, $p < 0.05$). There was no significant difference between Stepwise-Whole-day and Stepwise-Half-day. Within Simultaneous there were no significant differences between contact treatments and overall, there was no effect of age.

Activity

For the number of lines crossed, there was an interaction between contact treatment and weaning treatment [$Chi^2 = 7.69$, df = 2, $p < 0.05$, results given as back-transformed estimated mean no. of lines crossed (95% CI)] with Stepwise-Control [10.5 (6.9-15.9)] crossing significantly more lines than Stepwise-Whole-day [5.5 (3.2-9.5)] and Stepwise-Half-day [4.8 (2.7-8.2)]. There was no significant difference within simultaneously weaned and separated calves [Simultaneous-Control 7.4 (4.7-11.6), Simultaneous-Whole-day: 8.4 (5.1-12.6), Simultaneous-Half-day: 9.1 (6.1-14.1)].

9.3.3 Across test period

Vocalisations

Vocalisations were recorded from when the calf entered the test arena until both tests were finished. There was a significant interaction between the contact treatment and weaning treatment ($Chi^2 = 12.6$, df = 2 $p < 0.001$, see Figure 9.4C). For this variable, the interaction was caused by significant differences within the simultaneous weaning and separation (Simultaneous-Whole-day and Simultaneous-Half-day were vocalising more than Simultaneous-Control), while there were no differences between contact treatments for Stepwise weaning and separation. Simultaneous-Full-day and Simultaneous-Half-day were vocalising more than calves on the other treatment combinations.

Further, heifers vocalised more than bulls independent of contact treatment and weaning treatment [estimated mean no. of vocalisations (95% CI) averaged across contact treatment and weaning treatment: heifers: 9.02 (6.47-12.59), bulls: 5.66 (4.02-7.96), $Chi^2 = 8.21$, df = 1, $p < 0.01$]. There was no effect of age.

Defecations

No differences in the number of defecations were found for any of the treatments, sex, or age (mean ±SD: 0.39 ±0.88)

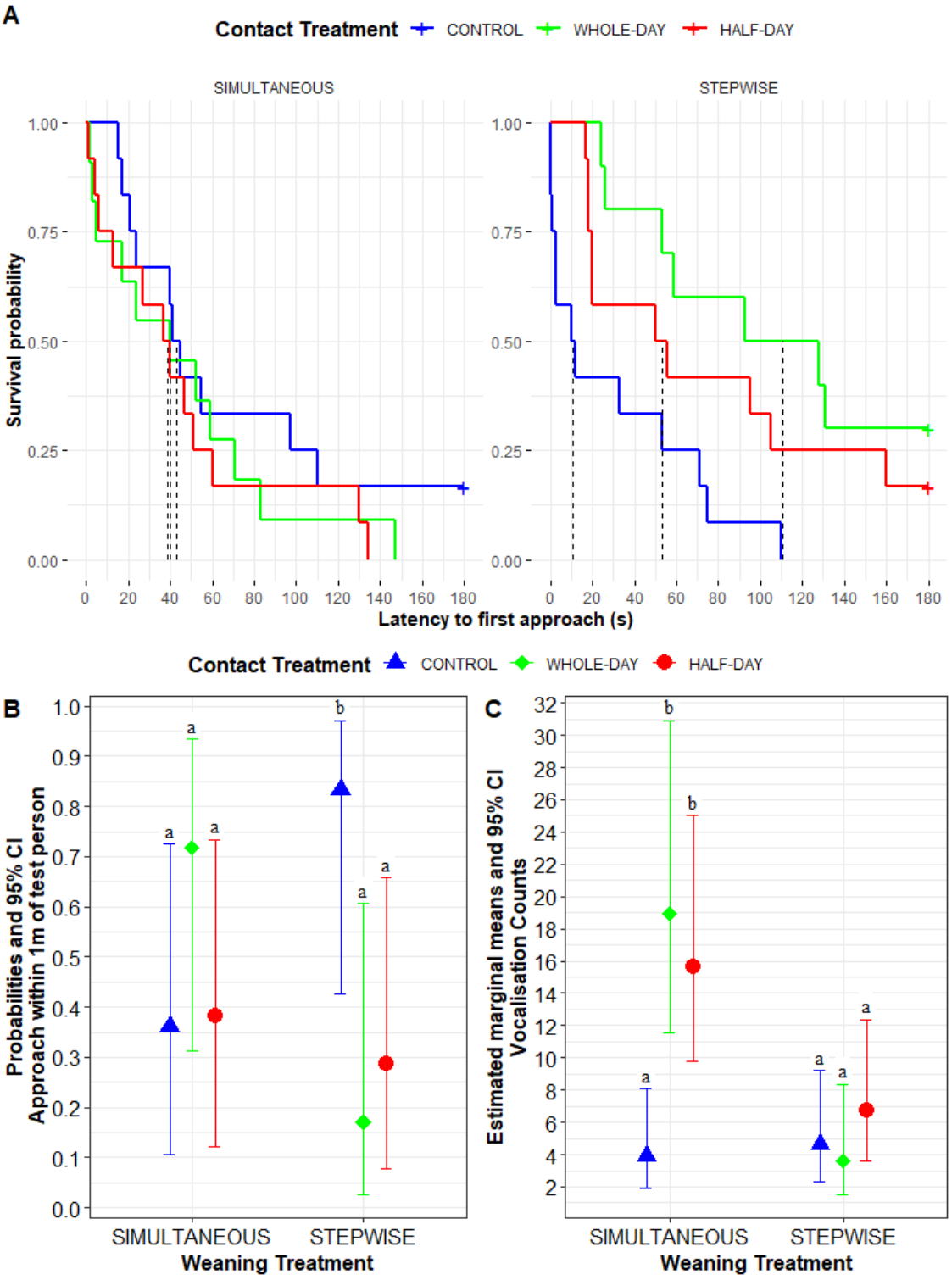

Figure 9.4: Behavioural responses from an animal approach test for either artificially-reared (Control) or dam-reared (Whole-day and Half-day) dairy calves on one of two weaning treatments (Stepwise or Simultaneous). A) Kaplan-Meier survival curves for the latency to the first approach. Vertical, dashed lines are median survival times. Crosses on the line are where data is censored. B) Probability of approaching within 1 m of the test person and 95% CI. C) Vocalisation counts back-transformed estimated means, and 95%CI during a 9-minute test period. Pairwise comparisons are made within each weaning treatment. Points that share a letter are not significantly different at the $p < 0.5$ level.

9.4 Discussion

In the present study, we compared the human-animal relation as measured by a human approach test and an animal approach test in dairy calves with three different contact levels to their dams and undergoing two different weaning methods.

In summary, we found that exclusively under the Stepwise weaning and separation treatment, Control calves had a shorter latency to first approach the test person and were more likely to go within one meter of the test person. Following, we found no differences among any of the contact treatments on the simultaneous weaning and separation treatments, except that calves on Whole-day contact and Half-day contact treatment were vocalising more frequently than Control calves.

9.4.1 The interaction between treatments

For most response variables, we found an interaction between contact treatment and weaning and separation treatment. This interaction was based on differences between contact treatments' HAR under Stepwise, but not under Simultaneous weaning and separation. It is highly likely, that weaning stress and/or hunger affected the results of the HAR test which is supported by the increased frequency of vocalisations observed under Simultaneous for both dam-reared treatments. High-pitched vocalisations are interpreted as either hunger or reinstatement behaviour in cattle (Green et al., 2020; Johnsen et al., 2015). Calves on the simultaneous weaning and separation treatment were tested one week after weaning off milk and simultaneously being moved to a new environment (and for dam-reared, separated from the dam), whereas calves on the Stepwise weaning and separation had gone two weeks without milk before testing and one week in a new environment (for dam-reared the new environment equaled being separated from the dam). The effect of weaning on ADG, and thus likely hunger levels, differs greatly from study to study depending on e.g. the age of calves, previous milk allowance, and any Stepwise reduction of milk allowance. Some studies report calves losing weight during the first week post-weaning (Budzynska & Weary, 2008), others no weight gain (Eckert et al., 2015), and others again show maintained ADG (Roth et al., 2008). However, e.g. Eckert et al. (2015) found calves to have regained pre-weaning ADG two weeks after weaning so based on the above studies it is likely that artificially reared calves are back to pre-weaning weight gains approx. two weeks after weaning abruptly from milk. Thus it is also likely that the weaning stress and/or hunger levels are at least less at the time of testing Stepwise than for Simultaneous. We acknowledge that the abrupt weaning off milk applied to all calves of the present study will induce high levels

of weaning stress, especially due to the high milk consumption up until weaning. The choice was made to make weaning comparable to the Control group since it is difficult to reliably match a gradual step-down weaning schedule when calves have access to suckle their dams since calves with just 2x15 min access to suckle their cows can consume 10 L of milk a day (Fröberg et al., 2008). The higher number of vocalisations given by dam-reared calves than Control calves, under Simultaneous may have several causes. It could indicate an increased hunger in dam-reared calves, a response to being separated from the dam, or a different expectation to the benefit of vocalising. Control may have had a higher intake of solid feed pre-weaning, since they had longer periods without milk access daily, leading to an easier transition from milk to solid feed (Eckert et al., 2015; Roth et al., 2008). However, since Control, at the time of abrupt weaning, had a mean milk intake of approx. 11 L/day, which is close to the expected ad libitum intake of 10-12L by both dam-reared and artificially reared calves (reviewed by Khan et al., 2011), we also expected Control to be hungry the week following weaning (Budzynska & Weary, 2008). Thus, it is plausible that at least some of the increased calling in dam-reared calves is not due to higher hunger levels than Control but reflects calling for the dam to be reunited with her either to reinstate the social contract, the milk resource or both. Studies separating the nutritional dependency from the dam from the social aspect do show that there is a bond beyond milk, but depending somewhat on the opportunity for full contact or only partial contact (Johnsen et al., 2018; Wenker et al., 2022), thus we cannot know whether calling is for the dam, milk or both.

In any case, the results illustrate how the timing of weaning or other similar stressful events, which may affect treatment groups differently, should be taken into account when designing studies comparing the human-animal relation using human and animal approach tests. Had we only tested and analysed data from our calves being simultaneously weaned and separated a week before testing we would not be able to confirm the previously found results of a better HAR for artificially reared calves. Completely avoiding the confounding effect of timing and weaning and separation treatments is not possible, but allowing more time after weaning and separation before testing would have allowed us to Control for hunger levels between contact treatments e.g. by ensuring similar average daily gain for all calves at testing. In the present study, this was not possible, due to the calves only being available for experimentation until 10 weeks of age.

For both of the HAR-related measures analysed from the AAT (latency to first approach and the probability of coming close to the test person), the lack of dam-contact treatment related differences for Simultaneous seems to be driven by a poorer HAR for Control and a better HAR for Dam-reared, compared to Stepwise, opposite

to our hypothesis. We had hypothesised that under increasing weaning stress and/or hunger, as expected under the simultaneous weaning and separation, Control would react with a shorter approach latency and more often coming close to the test person, due to the calf associating humans with milk feeding, while we had hypothesised that dam-reared calves, who do not associate humans with milk feeding, would show the opposite trend. This interaction warrants further investigation to understand the driving mechanisms. It seems the lower stress levels at the time of testing for Stepwise calves allowed the experiences of the different contact treatments to influence the calves' behaviours in accordance with their HAR (Waiblinger et al., 2006).

As mentioned, when looking at Stepwise only, Control seemed to have a more positive HAR (significantly faster to approach the test person and were more likely to come up close to the test person) than dam-reared calves. This was as expected based on results from other studies (Krohn et al., 2001; Waiblinger et al., 2020; Wenker et al., 2022). Control calves had been milk fed by humans and thus had more close contact and opportunity to develop a positive association with humans. However, with regard to the effect of Half-day vs Whole-day, we did not find any significant differences. Wenker et al. (2022) compared calves with partial contact to the dam (no suckling, housed individually inside the cow pen) to full contact and a Control group with a two minute HAT two weeks after weaning and found no treatment effects, although possibly due to statistical power issues as discussed by the authors. Although at present we cannot show that merely providing dam-reared calves with more experiences with humans during the first 8 weeks of life, while the dam is not present, improves the HAR, studies addressing this aspect are few and the effect of duration of cow-calf contact in dam-reared calves on HAR deserves further study.

9.4.2 Technical side note

A technical side note to the performance of the animal approach test is that the author regretted implementing the 'try to touch/scratch calf' after the calf had sniffed. In most cases, the movement, however gentle, by the test person led to the calf backing away and focusing its attention elsewhere, leading to very short sniffing durations, hard to analyse. This might have been avoided had the test person just remained still.

9.5 Conclusion

Artificially reared dairy calves showed indications of a more positive human-animal relationship with a shorter latency to first approach and a higher probability to come close to and sniff the test person, compared to dam-reared calves, when tested upon a Stepwise weaning and separation period of two weeks. However, this difference was not found when testing upon a one-week simultaneous weaning and separation. Upon one week of simultaneous weaning and separation, dam-reared calves vocalised more during the test session, but this was the only difference between simultaneously weaned and separated calves. Overall, this implies that Controlling for the hunger and/or stress levels related to weaning off milk is important when interpreting human-animal relation tests, as contact treatment effects were affected by high levels of weaning stress.

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Chapter 10

Discussion

The present dissertation aimed to advance understanding of the challenges that hinder the implementation of cow-calf contact practices in Danish organic dairy farming, through the exploration of various management strategies. In this chapter, I will provide a general discussion based on the findings presented in the four research papers, presented in this dissertation, by discussing the broader implications and suggesting ways to move forward. Moreover, I will highlight areas that require further investigation, as well as the limitations of the experimental designs and approaches utilised in this research. Finally, I will reflect on how we can compare the welfare of calves in different versions of cow-calf contact systems, using the concept of "affective animal happiness" proposed by (Webb et al., 2019).

Through the interview study presented in Paper I, knowledge has been developed on the factors which shape the choices made when Danish, organic farmers are developing a CCC system. Practical and economic considerations were the most common factors mentioned, but for farmers choosing *dam-calf* contact systems, where each cow rears her own calf, an ethical component was also especially important. Half-day contact between the cow and her calf was chosen to try and reduce economic and practical barriers in *dam-calf* contact systems. We need to know how half-day contact is perceived by cows and calves and thus how it affects animal welfare. In the experimental study, I investigated the benefits as well as problematic behavioural effects of choosing a half-day contact system compared to a whole-day contact system while comparing them to an artificially reared control group.

10.1 Welfare Implications of Half-Day Contact

Half-day contact has been proposed as a viable option for balancing feasibility and improved animal welfare in dairy cows raising their calves (Johnsen et al., 2016; Meagher et al., 2019). In this section, I will discuss the findings from the experimental study included in this dissertation with particular attention to the implications for animal welfare.

10.1.1 Dam-Calf Interactions

Results from Paper II showed that calves with half-day contact with their dam were overall receiving less maternal care in the form of suckling and grooming, compared to whole-day contact. This may not be surprising, given that cows and calves on the Half-day treatment had less time to perform these behaviours. During the day, when all calves had access to their cows, Half-day calves spent relatively more time suckling the dam than Whole-day calves, to some extent compensating for the nightly separation period. It is interesting, however, that time spent on "other activities" such as standing or walking did not decrease during the day hours in favour of mother-offspring interactions. However, a prioritisation of suckling could explain why there was a slightly lower percentage of time allocated for resting, during the day, in Half-day calves, compared to Whole-day calves.

The reason that Half-day calves did not fully compensate for the time apart was not clear from the present study. Possibly, the reason could be a lower availability of milk in the udder, due to better udder emptying in the milking parlour, in Half-day cows (Barth, 2020; Nicolao et al., 2022). Alternatively, both suckling and grooming durations could also be affected by the diurnal pattern of calves. Based on the review by Whalin et al. (2021) we expect most of the suckling to happen in the day hours between 05:00 and 18:00. However, in the present study, we observed that for Whole-day calves, only a slightly larger proportion of time was spent suckling during the day (05:00-15:30, ∼3%) than during the night (15:30-05:00, ∼2.2%). Thus, a large proportion of Whole-day calves' daily suckling happened during the time period when Half-day calves did not have access to their cows. However, calves with 2 x 2 h access to *ad libitum* milk from an automatic milk feeder (around 06:00 in the morning and 18:00 in the evening) did not alter their diurnal pattern in regards to lying and drinking, compared to calves with all-day access (von Keyserlingk et al., 2006). Further, time-restricted calves were able to quite closely match (∼10L vs ∼11L) milk intake with the all-day access group, indicating they adapted largely to the time restriction (von Keyserlingk et al., 2006). In the present study, daytime

contact was chosen for practical reasons, as the pen used for Half-day cows during the separation period was only available during the night. The interviewed farmers who practised half-day contact used mainly night-time contact, either because they hope to reduce the amount of milk calves drank, hoping they suckled less during the night, or because they put the cows out to pasture during the day, without the calves.

In any case, if participation in positive, social interactions such as suckling, and grooming is linked to positive affective states and thus improves welfare, Half-day calves had less opportunity to gain from this relation, as shown in the present study. Comparing half-day contact during respectively night and day may provide insights towards the effect of the diurnal rhythm on mother-offspring interactions. Had we chosen nighttime contact, cows and calves would only have been separated for 10 hours, instead of 14 hours, which may have decreased hunger, increased the duration of positive interactions and thus increased the positive effects of half-day contact. A shorter separation period could thus potentially also lower the occurrence of calves suckling on alien cows since this seemed to be driven by hunger. However, unless calves are at a higher risk of injury, due to alien cows refusing them, there does not seem to be any immediate welfare risk involved in calves suckling an alien cow, but it may be an indicator of hunger.

Though half-day contact does not allow for the same amount of positive social interactions between cow and calf as whole-day contact, Half-day calves in the present study did not show more abnormal behaviours, such as cross-sucking, and they still had a clear preferential relationship with their dam. Having half-day contact during the pre-weaning period thus still substantially improves the opportunity for a range of highly motivated and natural behaviours, not possible in artificially reared calves, which can contribute to good animal welfare (Bracke & Hopster, 2006; Lawrence et al., 2019)

It is, however, not known whether potential welfare benefits, resulting from the suggested improvements, to cognitive and social skills (Buchli et al., 2017; Meagher et al., 2015; Stěhulová et al., 2008; Wagner et al., 2012; Zipp & Knierim, 2020) in dam-reared calves develop differently in half-day contact systems. This was not investigated in the current study. However, in horses, foals observing their mares' calm reaction to otherwise fear-eliciting stimuli (Christensen, 2016) or human handling (Henry et al., 2005) appeared to have reduced fear reactions themselves. Performing social interactions with the dam, eating together, seeing her reactions to outside stimuli and when interacting with other cows, may all be important components in the suggested improved cognitive and social function of dam-reared calves, and the minimum time required to gain these benefits needs further investigation. I suggest

future studies compare the coping capacity of dairy heifers reared with different levels of dam-contact in practical, farm-related settings such as introduction to new social groups (e.g. Zipp & Knierim, 2020), being herded, introduction to the milking parlour, or undergoing restraint for veterinary check-ups, as well as more experimental conditions focusing on social facilitation in both fear-eliciting (Morozov & Ito, 2019) and problem-solving settings (Bailey et al., 2000).

10.1.2 Stress due to Repeated Half-Day Separation

Because the separation period in our half-day contact treatment was approximately 14 h we expected that cows and calves, at least until they were familiar with the system, would react to this separation as if it was a permanent separation (peak response 9-18 h after separation as seen in the studies on weaning of young calves by Chua et al. (2002) and Flower and Weary (2001)). However, the only measures recorded in the present study regarding the stress induced by the daily separation period, for Half-day cows, were respectively; lying time for the calves, the cows' willingness to leave the calves for milking before the separation period, and the response to being let into the separation pen, for Half-day cows.

Lying time did not differ between Whole-day and Half-day calves over the 24 h period, so there were no indications of increased restlessness in Half-day calves, due to the nightly separation. However, supporting evidence from physiological measures such as heart rate variability, faecal cortisol metabolites or (automatic detection of) 24 h vocalisation observations (Ntalampiras et al., 2020) are needed before concluding that Half-day calves were not stressed by the repeated separation.

For both Whole-day and Half-day cows, there was a habituation-like effect to both the number of vocalisations and turnarounds, which decreased over time, when being fetched for the afternoon milking. This could be due to cows getting used to the system, or it could be that as calves get older, the cows judge them as less dependent (Stěhulová et al., 2017) and thus were less stressed about leaving them. There was some indication that Half-day cows actually were more reluctant to leave for milking during the first two weeks, but further studies should look more systematically into the stressors related to the repeated separation for both whole-day and half-day contact, and for both calves and cows. In the study by Roadknight et al. (2022) they did not find differences in milk cortisol between half-day and whole-day cows but they did see more restless behaviour in the milking parlour, prior to cows and calves being reunited. Behaviour such as vocalisations and turnarounds during the separation process and restlessness during the separation period seem to be useful behaviours to record in cows, to access any separation-related stress.

Since calves exhibit hider-behaviour during their first days of life, when cover is available (reviewed by Rørvang et al., 2018), cows and their calves may be relatively well-suited for periodic separations compared to more pronounced follower species (Rails et al., 1987), making the introduction to a half-day system relatively gentle. This may be why no pronounced stress responses were found in relation to the repeated separation in the present study and in Roadknight et al. (2022). Nonetheless, this area deserves more attention.

Though we saw no clear indications of increased stress in Half-day calves immediately at or during the nightly separation period, there were clear differences in behaviour upon reuniting in the morning, when compared to the Whole-day calves. When reuniting in the morning, Half-day calves seemed hungry and highly motivated to reunite with their cow, but would also try to suckle at any cow until its own dam was available. These behaviours persisted through weeks 3 to 7. It thus seemed that 14 h without milk resulted in a substantial sensation of hunger in calves also at 7 weeks of age. Calves fed *ad libitum* milk during restricted time windows of 2 x 2 h, (10 h between milk access) showed no increase in unrewarded visits, or change in the diurnal pattern, indicative of hunger (von Keyserlingk et al., 2006). However, it is hard to compare to the present study, where the main response variable indicating hunger was the short latency to reunite and suckle own and alien cows. In the present study, the period without access to milk was, however, also somewhat longer for Half-day calves (14 h compared to 10 h (von Keyserlingk et al., 2006)) which may be why calves showed signs of hunger. However, in the study by Roadknight et al. (2022), where the separation period was only 9 h, they also reported short latency to reunite and attempts to suckle alien cows, upon being reunited, for calves with half-day contact. Actually, calves and cows were also observed to reunite quickly (latency of ∼25 s) after the daily separation period (12 h), even if the cows were wearing udder nets, and calves obtained their full milk allowance from an alternative source (Johnsen et al., 2015b). This makes the interpretation of the short latency to reunite in the present study somewhat difficult, though the short latency to not only reunite but also suckle indicates a clear sensation of hunger. Further studies are needed to disentangle the relative effects of hunger and social motivation in the high motivation to reunite with the dam, as seen in calves reared with half-day contact.

Along the lines of the studies by Johnsen et al. (2018) and Johnsen et al. (2015b) it has been suggested to give calves access to an alternative milk source, while they are reared by the dam. This allows firstly for part-time contact calves to obtain milk during separation periods and secondly facilitates the opportunity for a gradual weaning process. Indeed this has been shown to work well in reducing the weaning and separation stress (Johnsen et al., 2018; Johnsen et al., 2015a). However, as

seen in Paper I, some farmers have expressed concerns or negative experiences with trying to teach calves, with cow contact, to drink from an alternative milk source, though one farmer, on the other hand, stated it was no problem. In any case, having an alternative milk feeding scheme would increase labour, which to some extent, as perceived by the interviewed farmers, would defy the main motivation to have CCC, being practicality and ease of management.

So far, this section has shown that half-day contact decreases the occurrence of mother-offspring interactions and induces higher levels of hunger when compared to a whole-day contact system. However, half-day contact may also have positive welfare implications, compared to whole-day contact systems, which will be discussed in the next section.

10.1.3 Social peers

A difference between Half-day and Whole-day calves in the present study was the higher level of social play behaviour seen in Half-day calves. This data is presented in the paper by Bailly-Caumette et al. (2023) and is not included in the present dissertation. However, a descriptive mention of play behaviour duration is included in Paper II. The increase in social play behaviour in Half-day calves was seen during the night period, when the cows were away, and was probably related to the large space available when cows were not present (Jensen et al., 1998). The performance of play has been linked to an experience of positive emotions and thus positive affective states (Boissy et al., 2007). Not only did Half-day calves play more together, but results from paper II also showed indications of Half-day calves grooming each other more and spending more time lying together from an earlier age. However, these effects were rather slight and should be interpreted with caution. If the Half-day calves do have stronger relationships with each other, this is interesting in relation to weaning and separation, since social buffering may decrease stress responses, and it is expected that more familiar animals provide a better buffering capacity (Rault, 2019). Future studies may investigate more directly whether Half-day calves have a stronger attachment to each other than Whole-day calves e.g. using preference or motivational testing (Duve & Jensen, 2011; Ede et al., 2022).

The use of play as an indicator of positive welfare is interesting but difficult, due to play being modulated strongly by both rebound effects and changes in space allowance, and further that play is both perceived as an indicator of, and an inducer of, positive affective states (Burghardt, 2005) In any case, in the present study, while Half-day calves performed more frontal pushing with each other, there was no difference between Half-day and Whole-day calves in total play over 24 h (Bailly-

Caumette et al., 2023). There are thus no indications, that the performance of play behaviour reduced welfare in half-day contact systems compared to whole-day contact. One benefit of cow-calf contact systems more generally, could be that calves often would be housed in larger spaces, with the opportunity to engage in both locomotor and social play behaviour (Waiblinger et al., 2020a).

10.1.4 Solid feed intake

In the present study, Half-day calves spent more time eating solid feed than Whole-day calves. Looking at each individual feed type this was mainly driven by concentrate uptake, though the same was seen for hay and TMR.

In artificially reared calves, a strong relationship has been established between milk allowance and solid feed uptake in pre-weaned dairy calves, indicating that young calves only eat measurable amounts of concentrates when they, due to restricted milk feeding, are feeling hungry (Eckert et al., 2015; Khan et al., 2016; Khan et al., 2011). The increased time spent eating, in the present study, was mainly during the night period when Half-day calves did not have access to their cows, which may support the notion that Half-day calves were getting hungry during the night.

The fact that there was no weight difference between calves on the Whole-day and Half-day contact treatment at 8 weeks of age nor a difference in ADG from birth to 8 weeks, even though Half-day calves spent less time suckling, may be due to Half-day calves compensating with a higher uptake of solid feeds.

However, in a study by Miller-Cushon and DeVries (2015) they reported that in six weeks old calves with *ad libitum* milk allowance, a daily eating time of approximately 30 min translated to 190 g of concentrate intake per day. While no strong interference can be made regarding the concentrate uptake in our study, we did have very similar daily eating times for Half-day calves (33 min/d) and may thus speculate that the calves in the present study had a similar concentrate uptake. Weaning of milk is not recommended until calves have a daily concentrate intake of at least 500g/day or 1% of body weight (discussed by Eckert et al., 2015). This can explain why, even with the above-mentioned differences between Half-day and Whole-day calves, Half-day calves are reacting equally strongly to weaning and separation.

10.1.5 Weaning and Separation Response

Indeed, Paper III showed that half-day contact did not reduce the behavioural response to weaning and separation as expected; if anything, based on the low-pitched

vocalisations, Half-day calves were reacting more to the separation and weaning than Whole-day calves. However, the higher level of low-pitched vocalisations was only observed when Half-day calves were weaned and separated in a stepwise manner using one week of fence-line weaning.

Indeed, looking at the data for each of the two steps of respectively weaning of milk, and separation from the dam, Half-day calves were emitting low-pitched vocalisations during the fence-line weaning step, but only during the observations in the morning at 08:00 h where cows were present in the pen. This is quite interesting because, at a first glance, Whole-day calves are experiencing the same; they are also housed behind the fence line, with the cows present in the pen. I thus suggest that the anticipation of the Half-day calves to the daily routine of being reunited in the morning, including the stimuli of the cows returning after milking, renders them more frustrated by not being able to satisfy the motivation to reunite and suckle. Indeed, the Control calves on the Stepwise treatment, also show a peak in low-pitched vocalisations during the observation period in the afternoon when they would normally be fed milk, and they could see the other calves receive milk.

It indicates that calves who expect specific, daily patterns with regard to milk access have increased stress responses during weaning. However, 24 h observations of weaning and separation responses are needed to confirm these results. Even though Half-day calves did not show a reduced behavioural response, they did appear to do better than Whole-day calves when looking at ADG the week after weaning, especially under the Stepwise treatment. However, possibly due to large individual variations, the effects were minor.

The suggested effect of anticipation both underlines the importance of the time of day that the behavioural observations are conducted, but also how they are not necessarily a direct mirror of the animal hunger state, as sometimes could seem the case (Thomas et al., 2001). Due to the timing of the observations, in the present dissertation, where two out of four observation points were in the morning, we may have overestimated the vocalisation response of Half-day calves. Alternative ways of testing hunger levels, based on motivational tests, where calves work for access to milk (or the dam) during the weaning and separation step, would be of great value, to support inferences based on vocalisations. Of course, in order to tease apart the motivation to reunite with the dam and satiate hunger, an experimental treatment controlling hunger levels should be applied to dam-reared calves. Using technical aspects of recorded vocalisations also seems like an interesting area to develop to further understand the basis of calf and cow vocalisations (Green et al., 2020; Schnaider et al., 2022; Watts & Stookey, 2000).

Summing up, it is hard to say whether Half-day calves to some extent benefitted from being used to daily separations when it came to weaning and separation. The possible overestimation of vocalisations, based on the time of day we conducted the observations as well as the fact that calves had not reached baseline levels of vocalisations at the last observation, warrants careful interpretation. In any case, Half-day contact did not substantially reduce the behavioural response to weaning and separation.

10.1.6 Human-Animal Relationship

The effects of the stress related to weaning and separation were also evident in the human-animal relationship tests conducted. While the main aim of Paper IV was to investigate if half-day contact could improve the HAR compared to whole-day contact, the weaning and separation treatments were influencing the results greatly, which made inferences based on the dam-contact treatments hard. When tested upon the Stepwise weaning and separation the expected pattern of a better HAR in Control calves than dam-reared calves was evident, but there was no difference between Half-day and Whole-day calves. Nonetheless, it would be interesting to repeat this study without the confounding effect of weaning and separation stress.

When tested upon the simultaneous weaning and separation the were no differences between Control, Whole- and Half-day calves except the dam-reared calves were vocalising more. The lack of difference between dam-contact treatments was driven by a relatively better HAR in dam-reared calves and a relatively poorer HAR in Control calves, on the Simultaneous vs the Stepwise treatment. Paper IV raises questions as to why weaning stress seems to be influencing artificial and dam-reared calves differently and what motivations or emotions were actually measured during the arena test. Further studies are encouraged to look into this. Paper IV also illustrates that all calves were still affected strongly by the simultaneous weaning and separation beyond the period of our observations in the home pens (last observation after 45h) as HAR-tests were performed one full week after the weaning and separation and future studies are encouraged to look into longer periods after weaning and separation until baseline response levels are reached.

In the present study, the only difference in human contact experienced by Whole-day and Half-day calves was that Half-day calves experienced more human presence without the dam's concurrent presence. This may not have been enough to drive a change. However, in Paper I, farmers who were interviewed emphasised the benefit of having a daily separation period to facilitate their focus on calf care. One of the farmers intentionally spent time in the calf pen, during the day, while the cows were

grazing on the pasture. During the daily reunion of the cows and calves, the farmers paid particular attention to the calves' health, as this situation made it easier to spot a weak calf. These potential benefits of a part-time contact system, such as half-day contact, may aid in ensuring a better HAR and timely detection of diseases, which are both conductive to maintaining good welfare.

A side note: Are Control Calves not Hungry at Weaning?

In paper III, the primary outcome measure was vocalisations, and the results showed that Control calves vocalised substantially less than dam-reared calves during the Simultaneous treatment, despite all calves consuming a high milk allowance (Khan et al., 2011). The twice-a-day milk-to-satiation feeding, applied in the control group, may have induced hunger sensations between feedings, prompting Control calves to eat more concentrate and thus reduce hunger during weaning. Using automatic milk feeders in the Control group would have provided a more comparable milk-feeding pattern. However, other factors could explain the lower levels of calling in Control calves, the main one being concurrently losing contact with their dam. Moreover, differences in communication strategies between the two groups could also account for the discrepancy in vocalisation levels. Dam-reared calves may have learned to use vocalisation to communicate with their cows during the first eight weeks of life (Padilla de la Torre & McElligott, 2017). In contrast, artificially reared calves did not have the opportunity to communicate with an adult cow and obtain milk. As a result, the strategy of calling to reunite with the dam and access milk may not have developed equally in the artificially reared Control calves. If vocalisations potentially are not fully representative of the weaning response, it would have been valuable to use additional measures of the stress response, such as physiological indicators like pooled faecal cortisol metabolites or heart rate variability, to compare all three dam-contact treatments.

10.2 Suggestions for Weaning and Separation

While the one-week fence-line weaning before separation substantially reduced dam-reared calves' combined weaning and separation response it should be noted that all calves in the present experimental study suffered a substantial reduction in ADG after weaning, indicating that the abrupt weaning off milk carried out on both of the

weaning and separation treatments were very hard on the calves. This is of course not a recommendable approach, but in the present study, it ensured comparable weaning situations across the three dam-contact treatments. However, while artificially reared calves can undergo step-down or gradual weaning processes, which induce higher pre-weaning concentrate uptake (Eckert et al., 2015; Khan et al., 2011), we still need better ways to improve weaning in dam-reared calves.

10.2.1 Prolonged Fence-Line Weaning

In order to further increase the solid feed intake in dam-reared calves, it is tempting to suggest reducing the daily contact time further. However, keeping in mind that both Roth et al. (2009) and Fröberg et al. (2008) reported a high milk intake (>10 L/d), and a low concentrate intake, in calves with a maximum of 1 h of daily cow contact, it may not be a feasible solution. In other words, further improving the pre-weaning daily concentrate intake for calves in cow-calf contact systems is a challenge. It could be speculated whether housing pre-weaning half-day contact calves with older, weaned calves during the daily separation period could facilitate higher concentrate intake through social facilitation (De Paula Vieira et al., 2012b). However, this would come with the increased risk of infectious disease in mixed-age groups (Svensson & Liberg, 2006).

During the first week of the Stepwise treatment calves were abruptly weaned of milk but remained in the known environment. For dam-reared calves, this included continuous, partial contact with the dam. During this first week of the stepwise weaning and separation, dam-reared calves achieved similar (though low) ADG as Control calves. After the initial week of being weaned, calves were moved to new calf group pens and cows left the barn. At this point, after one week in the new pens (two weeks without milk), Control calves had surpassed pre-weaning (birth to week 8) weight gains resulting in approximately 1.1 kg/d. Yet, the dam-reared calves were still gaining only half as much as they did pre-weaning, at this point. It thus seems that the ”second step” of being separated from the dam and/or being moved to a new environment was adding another substantial layer of weaning-related stress to dam-reared calves while Control calves were not additionally affected.

Based on this, a suggestion to reduce the weaning and separation response, in acknowledgement of the difficulty in increasing concentrate intake before weaning, would be to extend the duration of the fence-line weaning step. Suckling through the fence could possibly be allowed during an initial period like in the study by Wenker et al. (2022), which may reduce milk intake some, though this has not been studied in detail. Afterwards, designing housing such that calves can stay with

fence-line access to the cows until concentrate intake is high and ADG has stabilised, possibly well beyond that, may work well.

10.2.2 Increasing Weaning and Separation Age

The calves in the present study were weaned off milk at either 8 or 9 weeks of age, around the time of conventional practice in Denmark. However, the present PhD project was part of a larger project which intended to produce knowledge relevant to the implementation of CCC in organic farms especially. The choice of using the weaning age applied on conventional farms was due to time constraints. In Danish, organic farms, calves are usually weaned off milk at 12 weeks of age. A later weaning age may have improved the overall weaning and separation response. Indeed, in the study by De Passillé et al. (2011) delaying the weaning of calves fed high milk allowances (12 L/d) via an automatic milk feeder to 12 weeks rather than 8 weeks improved step-down and post-weaning ADG, indicating that calves were more ready to be weaned at 12 weeks. The later-weaned calves on the high milk allowance even had ADG during and after weaning comparable to a traditionally fed and weaned group (6 L/d and weaning at 8 weeks) (De Passillé et al., 2011).

However, the calves in the study by De Passillé et al. (2011) were not concurrently separated from their dam. Studies on the weaning and separation of beef calves at later ages generally also report substantial weaning and separation stress (Enríquez et al., 2010; Stěhulová et al., 2017). Beef calves weaned and separated at 6 months of age were still showing a pronounced vocalisations response, though less so at 8 months of age (Lambertz et al., 2015), indicating that even a much later weaning and separation still results in some stress. It is hard to imagine implementing natural or close-to-natural weaning ages in the current dairy industry context, even though some few farms are doing it (Thompson, 2022), based on strong ethical principles. Further, due to the large volumes of milk produced in modern milking cows, compared to beef or more native breeds (which are the basis of the commonly used literature on natural weaning age (Reinhardt & Reinhardt, 1981b; Veissier et al., 1990)), it is hard to know when the dairy calf would actually be weaned, in a natural manner, if left with the cow for a prolonged period. In other words, is a dairy cow producing too much milk for the calf to be weaned naturally by the cow? Holstein cows produce around 40-45 kg/d at peak lactation around 4-8 weeks (Dematawewa et al., 2007). In comparison, while recent studies on the lactation of beef cows are scarce, beef breeds such as Angus and Hereford *(Bos Taurus)* and Nellore *(Bos Indicus)* produce somewhere around 3-11 kg/d during peak lactation (peaking around 3-6 weeks) (Ferreira et al., 2021; Iewdiukow et al., 2020; Sapkota

et al., 2020). It thus seems likely that non-separated dairy calves would have access to much larger volumes of milk for a longer period than beef calves. While direct comparisons cannot be made due to differences in genetic growth potential between beef and dairy breeds (Sapkota et al., 2020) it still seems reasonable to suggest that only pushing the weaning and separation age to later will not suffice to wean calves of milk, with no weaning stress, but studies are greatly needed on this. While pushing the weaning age alone may not achieve a close-to-natural level of weaning and separation stress, I still suggest that choosing the latest possible weaning time will improve the overall response to stress and weaning (De Passillé et al., 2011; Lambertz et al., 2015; Stěhulová et al., 2017). However, it seems likely that measures to actively promote a gradually lower intake of milk and a higher intake of solid feed are still necessary for dairy calves if they are to be weaned gently.

While striving to reduce the negative experiences of husbandry animals is generally the main approach to ensuring good welfare (Lawrence et al., 2019), it should also be kept in mind that natural weaning most likely also includes some element of stress for both the cow and the calf (Weary et al., 2008). A short period of lower-valence stress related to a natural weaning process may not compromise overall welfare. However, this situation differs greatly from 8-12 week old calves being weaned abruptly off milk and separated from the dam concurrently.

10.3 Adding up the Positives and Negatives

Summing up from the four included papers and the above discussion, there are aspects of respectively artificial rearing, whole-day *dam-calf* contact, half-day *dam-calf* contact, *foster cow* systems and *hybrid* systems which can be expected to influence the affective state of the animals in either a positive or a negative direction. Based on the five domains model (Mellor et al., 2020), the affective state of the animal ultimately decides its welfare. However, the five domains model does not conceptualise directly how welfare is experienced over time and thus how to access the overall welfare of an individual that generally experiences a wealth of respectively positive and negative affective states over time. Webb et al. (2019) suggested, based on human psychology research, a framework for assessing "animal happiness". They define animal happiness as a long-term, typically stable, state covering "how an animal feels most of the time", affected by the balance of moods with positive or negative valence, which in turn are the result of more fluctuating emotions, see Figure 10.1.

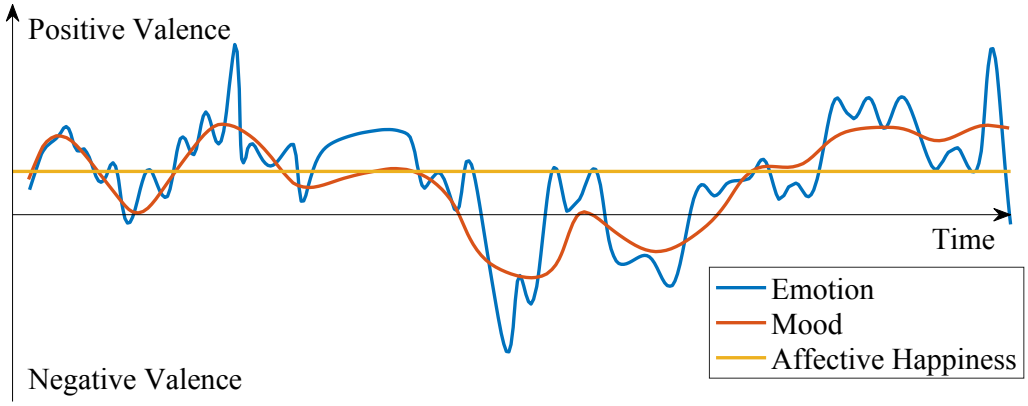

Figure 10.1: The framework of Animal Happiness. The figure is adapted from Webb et al. (2019).

The term *affective state* (different from *affective happiness*) which has been applied throughout this dissertation is used to cover both emotions and moods (Trimmer et al., 2013). In this section, I will use the term "mood" as used in the animal happiness framework (Webb et al., 2019), as an affective state, typically lasting hours to days, which is longer than distinct, short-lived emotions.

10.3.1 Comparing Calf-Rearing Systems

In the following, I compare the different calf-rearing systems investigated in this dissertation by applying the animal happiness framework, which was summed up in Figure 10.1. Each CCC system and artificial rearing will be represented by the expected, corresponding "mood line" in Figure 10.2. It should be noted that this comparison is a schematic best guess based on the knowledge I have acquired on the subject during the work with this dissertation and should be regarded as hypothetical and as a basis for further discussion and hypothesis generation. I have not added affective happiness lines to the figure, to illustrate that more research is needed before concluding more definitely on the overall effect on animal happiness in different CCC systems. Figure 10.2 thus illustrates the hypothetical mood in dairy calves from birth to a few weeks after weaning. Weaning is chosen to be at a hypothetical 12 weeks of age independent of the rearing system, by "best practice" within each rearing method. No other management procedures such as for example ear tagging, castration or dehorning are taken into consideration.

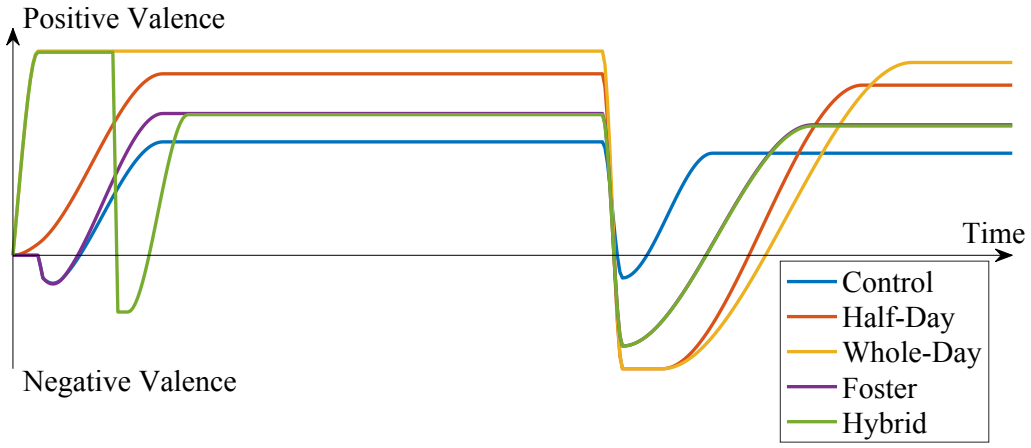

Figure 10.2: Hypothetical mood lines as seen from the calve during the pre-weaning and immediate post-weaning period in different calf-rearing systems.

Artificial Rearing System

Artificially reared calves ("Control", see the blue line in Figure 10.2) experience early separation from the cow which is expected to induce some negative moods initially. Further, artificially reared calves do not have the opportunity to experience the daily, positive experiences related to maternal care such as grooming and suckling a cow, and are thus judged to have a less positive mood during the milk feeding period, than dam-reared calves. The negative moods related to weaning, when applying a gradual/step-down approach at 12 weeks of age, are judged to be proportionally minor, compared to dam-reared calves, but the lack of a more complex social environment could result in calves that have continuous sub-optimal welfare levels due to reduced social and cognitive competences.

Half-Day Contact System

Half-day contact calves (see the red line in Figure 10.2) experience what could be seen as repeated, early, and prolonged separations. These separations likely induce daily fluctuations in emotions related to a sensation of hunger and separation stress, which in turn will affect the mood negatively, until they get used to the system, and reach an age where they can take larger meals and thus are less impacted by the daily separation period. However, calves in a half-day contact system also experience daily periods of maternal care and the opportunity to suckle their cow, and when they are fully used to the system they are judged to only experience minor stress related to the daily separation period. At the time of weaning and separation, they show a marked stress response, more pronounced than artificially reared calves and equal to calves with whole-day contact, due to the concurrent loss of the dam.

However, the mood improves slightly faster than in calves with whole-day contact due to a higher concentrate intake leading to slightly less hunger and a stronger social buffering capacity of the stronger bond to peers. After recovering fully from the negative effects of weaning and separation, the positive social and cognitive effects of dam-rearing are judged to increase the mood to higher levels compared to artificially reared calves, but not quite to the level of calves with whole-day contact, which potentially experiences more pronounced benefits to their social and cognitive abilities.

Whole-Day Contact System

Whole-day contact calves (see the yellow line in Figure 10.2, partly overlain by the green *hybrid* line) have an uncompromised start to life and experience almost unrestricted, self-controlled, access to the dam, thus receiving higher amounts of maternal care and suckling than calves with half-day contact. However, at weaning, they experience the biggest drop in mood and they take longer to recover due to low solid feed intake, which results in higher hunger levels, for a longer time. However, once they recover, the social and cognitive benefits are expected to lead to a more positive mood than artificially reared calves, slightly higher than that of half-day calves.

Foster Cow System

Foster cow calves (see the purple line, Figure 10.2, partly overlain by the green *hybrid* line) are shortly after birth separated from the dam and paired with the foster cow. This induces some negative experiences, both due to the separation from the dam and to the foster cow typically being somewhat unwilling to accept the calves in the beginning. If the calf is adopted by the cow it will receive maternal care and be able to suckle from a cow. However, the maternal care will be shared between calves and milk allowance most likely not be *ad libitum*, but that depends on the foster cow's yield and the number of calves paired with the cow. Based on this, the foster calf is not expected to quite reach the positive mood levels of whole-day and half-day contact calves. At the time of weaning the foster calf is expected to respond more than artificially reared calves, but less than half-day and whole-day contact calves, due to being less strongly bonded to the foster cow, potentially having higher concentrate intakes and potentially a strong social buffering from the peer calves.

Hybrid System

Hybrid calves (see the green line in Figure 10.2) experience the same uncompromised start to life as calves with whole-day contact. They receive maternal care and can suckle freely from their dam during the first few weeks of life. Then the calf is separated from the dam, which at this point in time causes a more negative mood compared to earlier separation as the calf is strongly bonded to the dam and highly dependent on the cow and her milk at this age. Nonetheless, as the calf is experienced in suckling, it quickly manages to suckle from the provided foster cow, and after they have been paired, the calf experiences positive moods at the same level as foster calves until weaning and separation. At this point, hybrid calves experience the same level of negative moods as foster calves.

10.3.2 A Complex Comparison

In summary, many different aspects complicate the comparison of different CCC systems from an animal welfare perspective, even with this relatively simplistic focus. In reality, a range of other factors such as group size, health, barn type, pasture access, milking system, staff, climate and much more will affect the balance between positive and negative moods. I suggest the choice of the management system should be based on maximising "animal happiness" (Webb et al., 2019), and whether the positive affective states (emotions as well as moods) experienced during the time cow and calf have together can outbalance the negative affective states experienced around weaning and separation remains a key question in judging the "animal happiness" in each CCC system. Nonetheless, the above comparison highlights the areas where most research is needed to be able to give knowledge-based recommendations on both which system to choose and how to manage the chosen system in the best possible way. Future studies should employ methods aimed at directly comparing the affective state of cows and calves managed in different CCC systems both pre-weaning, at weaning and in the long term, such as judgement bias tests (Lagisz et al., 2020).

The above discussion focused on the calf only and the welfare of the cow should be included and prioritised equally when comparing calf-rearing systems. For example, calves in *hybrid* systems may relatively quickly recover from the separation from the dam due to the access to a foster cow, but the dam is separated right at a time when research is generally pointing towards pronounced separation stress (Flower & Weary, 2001), without having a prolonged period of positive affective states to somewhat weigh up for it.

The present dissertation has focused on half-day contact as one version of CCC, which has been suggested to be a potentially feasible compromise between practical, economic and ethical considerations (Johnsen et al., 2016; Meagher et al., 2019). However, half-day contact as compared to whole-day contact did not benefit the calves around weaning and separation, as had otherwise been hypothesised, while it carried side effects such as increased hunger. Nevertheless, if the increase in saleable milk and the opportunity to turn cows out on pasture without the calves is what facilitates implementation in Danish organic farms then half-day contact may still be considered a viable rearing method, which improves welfare in dairy calves during the milk feeding period, and potentially beyond, compared to artificial rearing. However, if dam-rearing systems are to improve overall animal welfare levels it is crucial to ensure that the milk-feeding period is as long as possible to prepare for weaning and to balance out the negative effects of weaning and separation. Weaning and separation should be carried out using a stepwise approach that separates the loss of milk and the loss of the dam over time.

Chapter 11

Perspectives

The implementation of CCC systems depends on a range of different factors which motivate, enable, or discourage farmers. These can be internal, such as the characteristics of the individual farm, but can also be external such as pressure from society. Utilising themes brought up in the discussion of the included interview study I will provide perspectives towards answering the question: Is the implementation of cow-calf contact realistic in organic, Danish farms?

11.1 Implementation of Cow-Calf Contact

In the background chapter (see page 11), I presented three main barriers to the implementation of *dam-calf* contact systems as identified through four interview and survey studies with farmers (Eriksson et al., 2022; Hansen et al., 2023; Neave et al., 2022; Vaarst et al., 2020). These main barriers were economic concerns, animal welfare concerns and human welfare concerns. In the interview study included in the present dissertation (Paper I), farmers largely echoed these barriers, though they appeared to be less concerned about separation stress and labour. In the following section, I will elaborate on four specific barriers identified in Paper I, which belong to respectively the economic main barrier (decreased saleable milk and having free stall cubicle housing) and the human welfare main barrier (having a larger farm size and farmer image). Each of the four barriers to implementation will be considered below, ending with perspectives on how they apply to different versions of CCC systems.

11.1.1 The Broader Economic Perspective

The main barrier influencing the implementation and choice of which CCC system to implement, in a Danish organic farm setting, seems to be the economy of such systems, as seen from Paper I. This is the case mainly because of the decrease in saleable milk which at the time of the interviews was not compensated economically in any of the cooperative dairies in Denmark (however, since then one dairy has added a premium for farmers delivering cow-calf contact milk, *foster cow* and *dam-calf* systems both). However, while there was a very strong focus on the amount of saleable milk, other effects on the farm budget were less often brought up. I will explore the economics of CCC systems in a broader way, by drawing on the work by Knierim et al. (2020), who presented a socio-economic framework for CCC systems (see Figure 11.1.)

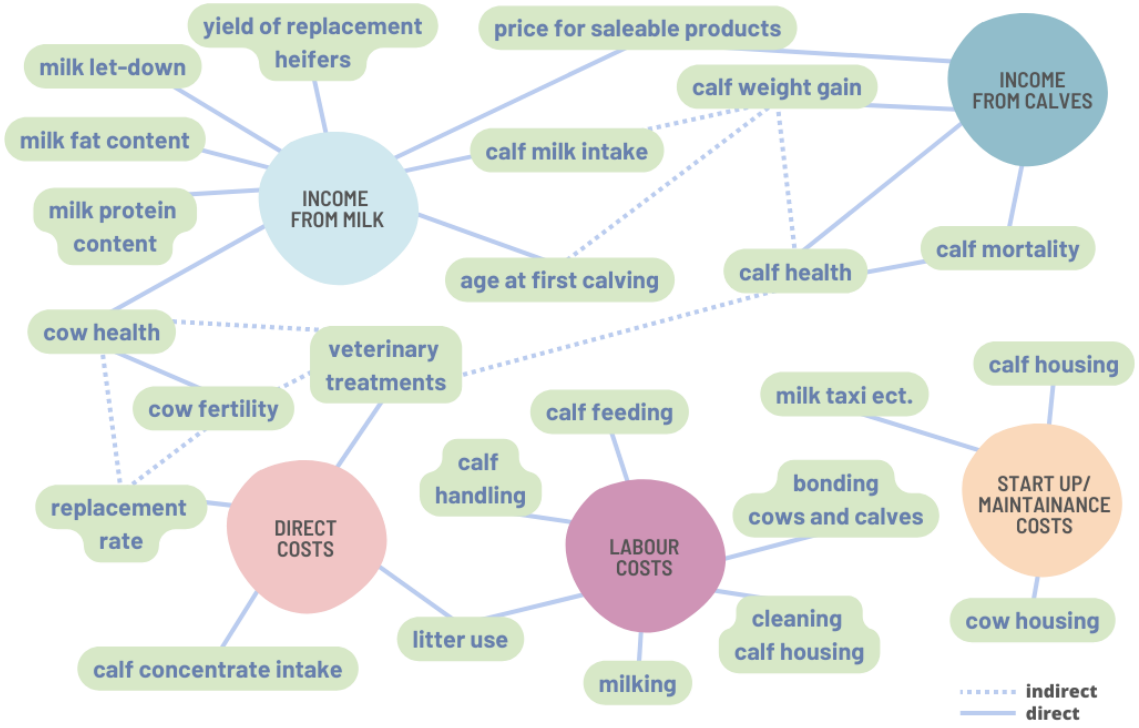

Figure 11.1: The socio-economic framework adapted from Knierim et al. (2020), here only presenting the monetary effects.

In the study by Knierim et al. (2020), they presented a socio-economic framework for calf-rearing systems either with or without cow-calf contact. In addition to the impact on saleable milk, this framework includes a more complete overview of both costs and income related to the calf-rearing and dairy enterprise on the farm as shown in Figure 11.1. Based on this framework Knierim et al. (2020) further provided an enterprise-budget case comparison between an average-sized (44 cows) organic farm in Germany with 12 weeks of either artificial rearing or *dam-calf* contact. They

conclude that the net profit is quite similar between the two systems. Actually, the net profit of the *dam-calf* contact system is better in their case comparison, after taking into account positive effects in the *dam-calf* contact system such as: selling heavier calves due to increased growth, feeding less concentrate and forage due to increased milk intake, using less litter due to calves housed in cow barn with solid floors, reduced labour, and decreased cost of housing as no calf hutches were needed.

While this sounds promising for implementation, the authors also highlight that more research is needed on the actual extent of the monetary effects and how they relate to the chosen version of a CCC system (Knierim et al., 2020). In any case, it is important when farmers evaluate the feasibility of a CCC system on their farm that the complete enterprise budget is considered.

11.1.2 Farm Size

The average, organic dairy farm in Denmark has 210 milking cows (conventional 254) (RYK-fonden/Viking Danmark, 2023). This is much larger than the farm sizes reported in the study by Hansen et al. (2023) (average of ∼33 cows/farm with CCC) on Norwegian farms and in the German economic case study by Knierim et al. (2020) (average of 44 cows/farm). Indeed, larger farm sizes are identified in multiple survey and interview studies as a barrier to CCC (Eriksson et al., 2022; Hansen et al., 2023; Neave et al., 2022). Thus, the implementation of CCC systems in Denmark may indeed be hindered by relatively large average (organic) farm sizes. However, little is known about why CCC is perceived to be more difficult on larger farms and this should be further investigated. One farmer in the interview study presented in this dissertation (Paper I) stated that being able to keep an eye on every calf in a large CCC system would take someone very skilled, which may be one of the reasons why large farm size is perceived as a barrier. In more general terms it seems obvious that trying out something majorly different on a larger scale operation will demand more planning, intitial investment and management e.g. since more staff needs to be involved in the process.

11.1.3 Housing Type

One other suggestion, as to why larger farm size is a barrier to CCC systems, may correlate with the typical type of housing systems on larger dairy farms. Larger farms in Denmark typically have free-stall cubicle housing while smaller farms more often have deep-bedded barns (Larsen, 2021). As seen from Paper I, farmers generally perceive free-stall cubicle housing as unfitting for calves, and thus that they would need substantial adjustment of buildings to facilitate a CCC system, which at the same time was practical and located well in relation to milking management.

Figure 11.2: Free-stall cubicle housing with dairy calves. The picture is taken with permission from one of the interviewed farmers.

Figure 11.3: Calves navigating steps from slats to deep bedding. The picture is taken with permission from one of the interviewed farmers.

However, examples from Scotland and the Netherlands (Lehmann et al., 2021) provide some evidence that cow-calf contact in free-stall cubicle housing is indeed possible. Farmers with no CCC experience, who visited a range of farms with CCC systems, reported that they were surprised at how well calves handled very different types of housing as was described by Vaarst et al. (2020). However, while experimental studies on CCC have been conducted in free-stall cubicle barns (e.g. Fröberg & Lidfors, 2009; Wenker et al., 2021) no research has directly aimed at investigating the effects of different housing systems on the welfare and practicality in a CCC system. Thus, research aiming at investigating the advantages and disadvantages of having calves with cows in free-stall cubicle barns is needed to ensure safe and practical environments for animals as well as staff.

11.1.4 Farmers Image: The Law of Jante

Another barrier to implementation, which is suggested based on Paper I, was that farmers potentially shy away from being seen as ”trying to do better than others” in the eyes of their peers. This perspective may be linked to the Nordic concept or

"code of conduct" commonly known as "The Law of Jante" (similar to "tall poppy syndrome") (Cappelen & Dahlberg, 2018) which is believed to be deeply embedded in Danish culture. The Law of Jante dictates, in general terms, that no one should think themselves better than others. I suggest, based on the results and discussion of Paper I, that the farming community may be especially sensitive towards someone promoting their farm based on "soft values" such as animal welfare or naturalness, rather than economic or practical perspectives. This mindset can be a barrier to farmers who would like to try a CCC system. However, the data to support this suggestion was slight and future research is encouraged to explore the theme further.

11.1.5 Cow-Calf Contact on Danish, organic farms

The feasibility of implementing CCC in Danish, organic dairy production largely depends on the version of CCC. I will here distinguish between *foster cow* systems and *dam-calf* contact systems.

Dam-Calf Contact Systems

Implementation of *dam-calf* contact systems in Danish, organic farms, on a broader scale, seems less realistic under current conditions, as *dam-calf* contact systems both are affected by economic concerns, the concerns of where to house cows and calves together and the suggested concern regarding "the law of jante". However, as suggested in the discussion on the larger economic perspective (Section 11.1.1), there may be some easy-to-miss economic benefits to *dam-calf* contact systems when taking into account the full picture, which might make a *dam-calf* contact system feasible on some farms. Nonetheless, for all farms which already have invested in calf housing, equipment for calf rearing, and housing for the lactating herd (which do not have space for or may not be suitable for calves), it seems that a higher income from the products sold is needed to compensate for the reduced amount of saleable milk. Thus, it is interesting that one of the cooperative dairies in Denmark is now paying a premium for CCC milk, and it will be interesting to follow whether this will drive any further implementation of CCC. On the other hand, if recommendations or legislation on milk allowances for young dairy calves are increased, in the years to come, towards 20% of body weight as increasingly suggested in the scientific community (Heinrichs & Heinrichs, 2011; Khan et al., 2011; Reedman et al., 2022), this may change the perspective on the economic barrier, as the difference between milk fed artificially and milk intake by calves would diminish (Lehmann et al., 2021). Further, if research or experience starts to convincingly show that calves

can be reared with cows in existing or mildly modified versions of free-stall cubicle barns, this could also increase the likelihood of implementation on a broader range of farms and farm types. If farmers choose a *dam-calf* contact system, it seems likely that they will choose a part-time contact system, due to the practical and economic benefits such as increased saleable milk and the opportunity to let cows on pasture without the calves. Further, rearing both replacement heifers and bull/meat bread calves in this system once again may be unrealistic unless a premium can be earned when selling these calves.

Foster Cow Systems

A *Foster cow* system may be implemented without direct reductions to the level of saleable milk and utilising buildings that are not suitable for the milking herd, while at the same time providing the farmer with a management tool to handle undesirable milking cows, and thus seem like a largely realistic system to implement on many Danish, organic farms. However, large farm sizes can still be a barrier to *foster cow* systems. Further, labour related to the process of pairing foster cows and calves could also pose as both an economic and a practical barrier, especially on larger farms. Including both replacement heifers and bull/meat breed calves in the *foster cow* system may be less realistic under current conditions, due to constraints on space and the need for a larger proportion of cows to be foster cows which may lead to a reduction of saleable milk. If a premium can be gained when selling the calves this may, however, not be an issue.

Whether *foster cow* and part-time *dam-calf* contact systems live up to the expectations and demands of society and consumers is a question still to be answered.

11.1.6 Who Should Drive the Change?

As evident from the considerations above, the implementation of CCC systems under present conditions depends on various factors, including consumer demand and willingness to pay (Grethe, 2017). This raises the question of who should drive a potential change towards CCC implementation. Should it be farmers, consumers, or policymakers? While 40% of EU citizens believe that the government should handle animal welfare, only 12% believe that the market alone should be responsible (TNS opinion & social, 2016) and it is a long-standing argument whether animal welfare is a public or a private good, and thus who should take the responsibility for improving animal welfare (Grethe, 2017).

On the one hand, if the government puts down stricter animal welfare legislation, e.g. banning early separation of dairy cows and calves, this may negatively affect consumers' willingness to pay for increased-value products, as some consumers may believe that animal welfare problems have already been addressed (Grethe, 2017). Further, implementing legislation before proper solutions are developed risks compromising animal welfare, such as implementing CCC without addressing weaning and separation stress adequately or having a period of CCC that is too short to outweigh negative experiences. On the other hand, consumers do not always follow up on their ethical demands when buying products (Bozzo et al., 2019). Allowing farmers and researchers to develop more knowledge and disseminating this knowledge to citizens and consumers, before legislating, is thus important to ensure improved animal welfare in the long term.

Another important consideration in regard to the implementation of CCC is sustainability. One of the UN's sustainable development goals is to promote responsible production and consumption (Keeling et al., 2019), and CCC aligns with this goal from a social sustainability perspective. However, it may not align with environmental sustainability due to the decrease in saleable milk, which lowers system efficiency (Mogensen et al., 2022). Therefore, if CCC is to be implemented on a large scale, major structural changes to our farming systems, such as producing more food and less feed (Schader et al., 2015) are needed to achieve sustainable farming goals.

Therefore, further comparisons of the effects of different CCC systems are needed to develop feasible and sustainable recommendations for future calf-rearing systems.

Perspectives

Chapter 12

Conclusion

This dissertation employed a multi-disciplinary approach to investigate various cow-calf contact practices with respectively a qualitative interview study and a behavioural experiment. The interview study showed that practical considerations and a sense of a more natural and rational system were the most commonly mentioned drivers for farmers choosing cow-calf contact systems. Foster cow systems were used on some farms to overcome two main barriers of dam-calf contact, which were a decrease in saleable milk and providing suitable housing for calves in the lactating herd's barn. However, some farmers chose dam-calf contact systems out of a sense of ethical responsibility and managing it as a half-day contact system mitigated some of the challenges associated with this approach, by increasing saleable milk and providing a simple solution for having cows on pasture without their calves. The experimental study showed that compared to whole-day contact, half-day contact reduced the duration of positive social interactions between the cow and calf, and while it improved some aspects of dam independence before weaning, it increased calf hunger and did not alleviate the substantial weaning and separation stress experienced by dam-reared calves. The effects of weaning and separation carried over to the human-animal relationship test, where artificially reared calves did not show a better human-animal relationship than dam-reared calves when calves were experiencing weaning and separation stress. However, a one-week fence-line weaning before separation reduced weaning stress in dam-reared calves to levels comparable to the control group. Nonetheless, weaning and separation stress was still substantial and future research should continue to improve methods to prepare dam-reared calves for weaning and separation. From an animal welfare perspective, half-day contact is not advantageous to whole-day contact, but half-day contact offers some advantages over artificial rearing systems and is more likely to be implemented than whole-day contact, under current dairy farming conditions.

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The separation of the dairy cow and her calf within hours of birth is a common management practice, criticised from an animal welfare perspective. Cow-calf contact systems are an interesting alternative which can be organised in different ways depending on the farmer's prioritisation of practical, economical, ethical and image-related considerations. Half-day contact between the cow and her calf reduces the amount of positive social interaction compared to whole-day contact, without substantially improving the weaning and separation. Using a fence-line weaning approach does however improve the weaning and separation of dam-reared calves.