Methodological terminology and definitions for research and discussion of cow-calf contact systems

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Abstract

Due to increasing public concern regarding separation of the dairy cow and calf within the first days after birth, alternative systems, where cows and calves stay in contact for an extended period, are receiving increasing interest from a broad array of researchers and other stakeholders. With more research in the area, there is a risk of inconsistencies emerging in the use of terminology. To create a better consensus in further discussions, the aim of this Research Reflection is to provide definitions and propose a common terminology for cow-calf contact in dairy production. We also suggest definitions for various systems allowing cow-calf contact and describe the distinct phases of cow-calf contact systems.

Concern from the public regarding the practice of separating cow and calf within the first days after birth is growing (Agenäs, 2017; Busch et al., 2017). Alternative systems, where cows and calves stay in contact for an extended period, are receiving increasing interest from a broad array of stakeholders (Busch et al., 2017; Beaver et al., 2019). From an animal welfare perspective, research on cow-calf contact systems is needed (von Keyserlingk and Weary, 2017). Cow-calf contact systems vary considerably in terms of the type and duration of physical contact allowed between dams and calves (reviewed by Johnsen et al., 2016). These systems probably have distinct welfare implications for cows and calves, which need to be investigated (von Keyserlingk and Weary, 2017; Meagher et al., 2019). The state of knowledge on the effects on welfare and production has been reviewed elsewhere (e.g. Johnsen et al., 2016; Beaver et al., 2019; Meagher et al., 2019). However, there are inconsistencies in the use of terminology regarding cow-calf contact that make comparisons of outcomes difficult and carry the risk of misconceptions (Meagher et al., 2019). For instance, weaning has been used to describe weaning off milk as well as separation from the mother.

Experimental and observational methodology to study cow-calf contact systems is described by de Oliveira et al. (2020) and methodology to study human attitudes and behaviour in relation to cow-calf contact systems is described by Ferneborg et al. (2020). This Research Reflection provides a communal suggestion for terminology to be used in cow-calf contact systems coming from a consortium of scientists studying these systems. We decided to use already established terminology if it was unambiguous. When introducing a novel term, we refer to the natural behaviour or the common dairy production practice. However, the scientific knowledge to support these definitions is sometimes insufficient. For instance, the minimum duration of daily cow-calf contact, and the minimum age at permanent separation in a cow-calf contact system are not clear. Thus, we expect that the terminology will develop alongside with more research in this field. Further, we also describe different phases of cow-calf contact management: milk-feeding, weaning, and permanent separation (sometimes including milk-feeding). Our aim of proposing a common standard set of
terminologies is to improve communication and facilitate creation of a common knowledge base among researchers and other stakeholders. To improve knowledge transfer we urge the stakeholders to clearly describe the terms and definitions they refer to in their work.

**Rearing systems in dairy production**

**Artificial rearing systems**

We propose the term *artificial rearing* (Table 1) to describe calf rearing in which calves are separated from the dam in the first days after calving and not introduced to a foster mother, such that calves consume (suck) milk or milk replacer from an artificial source and cannot suckle from an udder.

**Cow-calf contact systems**

With *cow-calf contact* is meant physical contact between a dam and her own calf, or between a foster cow and her foster calf, allowing behaviours such as licking, sniffing, suckling/nursing, and playing (Newberry and Swanson, 2008; Johnsen et al., 2015a). We define *cow-calf contact rearing* as any system allowing physical contact between a dam and her own calf, or between a foster cow and her foster calf. Little research has been done to determine the age at which the cow and the calf receive the most benefit from the contact in terms of health, behaviour, and psychological support. However, we expect these benefits to accrue over some weeks or months of cow-calf contact. Future research may better define how many weeks or months of the cow-calf contact relationship are needed to provide more significant benefits to both cows and calves and to outweigh stress associated with separation from the cow. Therefore, depending on total time-span of cow-calf contact before permanent separation, we currently propose to clearly state the duration, for instance, a 2-week or 3-month (time-span) cow-calf contact.

If permanent separation of calf and cow after a period of cow-calf contact rearing happens before the end of the milk-feeding period, and thus calves obtain milk from an artificial source after having suckled their dam or a foster cow, this rearing may be called *combined rearing*.

We suggest the term *dam-calf contact rearing* for a system allowing physical contact between a dam and her own calf (Hillmann et al., 2019). The *foster cow rearing* is defined as a system in which one or more alien calves are nursed by one cow. However, a combination between these systems is possible, when the cow’s own calf is reared together with foster calves. A foster cow is commonly not milked, but it may be milked depending on the stage of lactation and number of calves per cow (reviewed by Johnsen et al., 2016).

In terms of type of physical contact, cow-calf contact can be described as either full or partial. *Full cow-calf contact* allows unrestricted physical contact between the cow and her calf/foster calves. For instance, the calf can suckle and lick the cow, and the cow can nurse and lick the calf (Kiley-Worthington and de la Plain, 1983). Full cow-calf contact implies a possibility for the cow-calf pair to perform natural behaviours. If the physical contact is limited, the term *partial cow-calf contact* with detailed information of the type of contact can be used. For instance, fence-line contact hinders suckling, but allows auditory, visual, olfactory, and some physical contact. The use of nose-flaps prevents or limits the calf’s ability to physically interact with the cow (and other herd members), particularly affecting suckling and licking. Udder nets prevent nursing, thus, when nose-flaps or udder nets are used, we recommend that this be defined as partial contact.

The duration of daily contact can be described as either whole day or part-time contact. *Whole day cow-calf contact* implies that the cow and the calf have the possibility to have physical contact for almost 24 h daily; the possible exception is a period when the cow is in the milking parlour or feeding alley. Whenever the separation exceeds milking and feeding times and is enforced by a human, our recommendation is to call this a *part-time cow-calf contact* (previously also called restricted sucking/contact system). For instance, cow-calf contact can be allowed during two (or more) short periods daily (i.e. *short-time cow-calf contact*), often around milking time, e.g. 2 × 15 min (Roth et al., 2009), or 2 × 30 min (Fröberg et al., 2008). It is also possible that the cow is directed by selection gates into the calf area after milking and, in principle, is free to choose the duration of her stay, but that she has to leave to access food. For the rest of the day, the cow and calf are separated. Another type of part-time contact system allows contact either during the night or during the day, usually between the milking sessions (Veissier et al., 2013; Johnsen et al., 2015a, 2015b, 2015c). Since dairy cattle have a distinct diurnal activity rhythm (Haley et al., 2000), it is necessary to report if *day-time or night-time cow-calf contact* is allowed. Even when the contact between the cow and calf is possible only during certain times of day, some systems additionally prevent calves from entering the feeding alley or provide areas to retreat.

Some cow-calf contact systems with whole day or part-time contact allow animals to choose when contact can occur. Specifically, the use of creep areas or automated selection gates can create areas where either the cow or calf cannot enter and thus allow either animal to separate from the other (reviewed by Johnsen et al., 2016). We propose to call this type of system *cow-driven or calf-driven*, depending on whether the cow or the calf can take the initiative to make contact. Additionally, in a barn with an automatic milking system there are three main cow-driven traffic systems: (1) *pre-milking cow-calf traffic* (the cow can move through a one-way gate from the feeding or resting area to the calf, but has to go through the milking robot to get back to those resources), (2) *post-milking cow-calf traffic* (the cow has to pass through the milking robot to access the calf, and through a one-way gate from the calf back to the resources), (3) *free cow-calf traffic* (the cow can move freely between all resources and the calf). All three traffic systems can be combined with both whole day and part-time cow-calf contact, as well as full or partial cow-calf contact.

While in some cow-calf contact systems, cows and calves share resources, such as feeding or resting areas, in other systems these resources are in physically separated locations (Roth et al., 2009; Johnsen et al., 2015a, 2015b, 2015c). The possibility to share resources may influence the total amount of physical contact between the cow and calf as well as the calf’s ability to learn to use the resources from cows (Fröberg et al., 2011). Hence, we suggest that authors describe which resources cow and calf share in the cow-calf contact system studied.

**Cow-calf contact phases**

Three more or less distinct phases can be distinguished in cow-calf contact systems: milk-feeding, weaning, and permanent separation (sometimes including milk-feeding).
Table 1. List of suggested terms and definitions on cow-calf contact systems

| Term                        | Definition                                                                                                                                                                                                 | Older terms                      |
|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| **Cow-calf contact system** | Any housing or management where calves have contact to either the dam or a foster cow; cow-calf pairs either bond with or tolerate each other; they may or may not be able to suckle/nurse                                   |                                  |
| **Cow-calf contact (CCC)**  | Any physical contact and behavioural interaction between a dam and her own calf or a foster cow and her foster calf                                                                                          |                                  |
| A. Dam-calf contact system  | A system allowing any physical contact and behavioural interaction between a dam and her own calf                                                                                                          |                                  |
| B. Foster cow system        | A system allowing any physical contact and behavioural interaction, including suckling/nursing between a cow and an alien calf or calves. The cow's own calf may or may not be one of the calves                         | Multiple suckling/fostering Long-term suckling without additional milking |
| In terms of type of physical contact |                                                                                                                                                                                                 |                                  |
| A. Full CCC                 | Unrestricted CCC between a cow and her calf/foster calves is allowed; i.e. both suckling/nursing and affiliative interactions without any hindrance                                                    | Free contact/suckling            |
| B. Partial CCC              | Limited CCC between a cow and her calf/foster calves, for instance, fence-line contact and/or prevention of suckling with a nose-flap or an udder net; in terms of daily duration of contact it can be whole-day or part-time | Natural suckling                |
| In terms of duration of daily contact allowed |                                                                                                                                                                                                 |                                  |
| A. Whole-day CCC            | The cow and the calf are managed together with CCC for almost 24 h daily with a possible exception of being temporarily separated during milking and feeding and with a possibility to retreat | Free contact/suckling            |
| B. Part-time CCC            | The cow and the calf are managed with CCC during specific periods of the day only, that is when temporary cow-calf separation exceeds milking and feeding times                                                   | Natural suckling                |
| a. Several short times a day | CCC allowed during two (or more) short periods daily, e.g. 2 × 15 min, 2 × 30 min, 2 × 60 min                                                                                                               | Restricted contact/suckling/nursing X-times daily contact/suckling/nursing |
| b. Daytime/night time CCC   | CCC allowed only during daytime or only during night time                                                                                                                                               | Half-day contact Partial suckling |
| In terms of possibility to choose physical contact and cow traffic |                                                                                                                                                                                                 |                                  |
| A. Calf-driven CCC          | The calf takes the initiative to contact or leave the cow and is allowed to choose when the contact occurs                                                                                               |                                  |
| B. Cow-driven CCC           | The cow takes the initiative to contact or leave the calf and is allowed to choose when contact occurs                                                                                                  |                                  |
| a. Pre-milking traffic      | The cow can move through one-way gate from resources such as feeding and resting areas to the calf area, but has to go through the milking robot to get back to those resources                             |                                  |
| b. Post-milking traffic     | The cow can move through one-way gate from the calf area to access resources such as feeding and resting areas, but has to go through the milking robot to get back to the calf                                 |                                  |
| c. Free traffic             | The cow can move freely between the calf area and resources                                                                                                                                              |                                  |
| In terms of shared resources |                                                                                                                                                                                                 |                                  |
| A. With shared resources    | Cows and calves can share resources (e.g., feed, water, resting area). It needs to be specified which resources are shared.                                                                            |                                  |
| B. Without shared resources | Cows and calves have contact in areas without shared resources (e.g., CCC allowed in the walkway)                                                                                                        |                                  |
| In terms of time until permanent separation |                                                                                                                                                                                                 |                                  |
| A. Whole lactation period   | CCC is allowed over the whole lactation period                                                                                                                                                         |                                  |
| B. Limited time-span        | Total time-span of cow-calf contact is timely limited                                                                                                                                                  |                                  |
| Cow-calf contact phases     |                                                                                                                                                                                                 |                                  |
| Milk-feeding                | A phase during which a calf is allowed to suckle milk either from the dam (i.e. suckling) or by means of a milk feeder (suckling prevented contact or maternal visits after milking), or both.                        |                                  |
| A. Nursing                  | The behaviour of a cow which allows calves to suckle her udder                                                                                                                                            |                                  |
| B. Suckling                 | The behaviour of calves while consuming milk from the udder                                                                                                                                             |                                  |

(Continued)
Milk-feeding

Milk-feeding is a phase during which a calf can obtain milk either from the cow (by suckling), artificially (from a milk feeder, teat buckets, or buckets), or both (suckling in combination with artificial milk feeding). The possibility of the cow nursing a calf may differ during the different phases of a cow-calf contact system and between different systems. In a cow-calf contact system, we suggest the term *nursing* for cows allowing the calves to suckle their udder, and *suckling* for the behaviour of the young while consuming milk from the udder. For feeding from a milk feeder, we propose the term *sucking*. On the other hand, foster mothers are suckled by calves that are not their biological offspring, for which the term *allonursing* and *allosuckling*, respectively, is appropriate (Mills and Marchant-Forde, 2010). It should be recognized that in the literature and in most dictionaries the term *suckling* is used both for the act of a mother providing milk and of the young consuming it, hence our definitions need to be regarded as a specific clarification relevant to cow-calf contact research. A similar situation exists with *nurse*, a term that is often applied by farmers specifically to describe foster cows (*nurse cows*). More precise definitions are needed for obvious reasons, a simple example being a calf that might wish to suckle a cow, but she refuses to nurse it.

### Establishment of a cow-calf bond

A *bond* is defined as a mutual, affiliative relationship between two individuals (between mother and infant, for example) that lasts for a long time and survives temporary separation (Newberry and Swanson, 2008). Characteristics of a bond are mutual affiliative behaviour, synchronized behaviour, maintaining proximity, reinstatement behaviour when separated and greeting behaviour after a period of separation (Newberry and Swanson, 2008). Further, bonded pairs may provide each other with social support in challenging situations and their affiliative interactions are accompanied by specific physiological reactions (Newberry and Swanson, 2008; Rault, 2012). In contrast, attachment theory developed by Bowlby (1958) and Ainsworth (1979) to describe

| Term                              | Definition                                                                 | Older terms                                                                 |
|-----------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|
| C. Sucking                        | The behaviour of calves while feeding from a milk feeder                   |                                                                            |
| D. Allonursing                    | Foster mothers suckled by calves that are not their biological offspring   |                                                                            |

| Bonding                           |                                                                           |                                                                            |
|-----------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|
| A. Bonded calf                    | Expresses affiliative behaviour to the cow, and shows distress behaviour when separated from the dam over many hours, which subsides after reunion with the cow |                                                                            |
| B. Bonded cow                     | A cow that expresses maternal behaviour and shows behavioural reaction to separation, which reduces after reunion with the calf |                                                                            |
| C. Maternal behaviour indicating bonding | The pattern of behaviours given by the mother to her dependent offspring: affiliative behaviours, nursing in inverse parallel position, protecting the calf. |                                                                            |
| D. Tolerance or acceptance of a calf | Nursing in any position expect in inverse parallel position, no affiliative behaviours, no behavioural response to separation |                                                                            |

| Weaning                           |                                                                           |                                                                            |
|-----------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|
| A. Bonded calf                    |                                                                           |                                                                            |
| B. Bonded cow                     |                                                                           |                                                                            |
| C. Maternal behaviour indicating bonding |                                                                           |                                                                            |
| D. Tolerance or acceptance of a calf |                                                                           |                                                                            |

| Separation                        |                                                                           |                                                                            |
|-----------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|
| A. Temporary                      |                                                                           |                                                                            |
| B. Permanent                      |                                                                           |                                                                            |
| C. Total separation               |                                                                           |                                                                            |
| D. Abrupt separation              |                                                                           |                                                                            |
| E. Gradual separation             |                                                                           |                                                                            |
| F. Partial separation             |                                                                           |                                                                            |
| G. Two-step separation            |                                                                           |                                                                            |
| H. Fence-line separation          |                                                                           |                                                                            |

| Artificial rearing system         |                                                                           |                                                                            |
|-----------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|
| A. Bonded calf                    |                                                                           |                                                                            |
| B. Bonded cow                     |                                                                           |                                                                            |
| C. Maternal behaviour indicating bonding |                                                                           |                                                                            |
| D. Tolerance or acceptance of a calf |                                                                           |                                                                            |

| Semi-natural rearing              |                                                                           |                                                                            |
|-----------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|

CCC, Cow-calf contact.
differences in emotional ties of human infants towards their caregivers, relates to the perspective of one individual (the infant) which may or may not be returned by the attachment figure (the mother, for instance: Nowak and Boivin, 2015). To simplify the use of terminology, we suggest to use the term bonding including one-sided as well as mutual selective relationships between a dam or foster cow and calf. Besides, for the purpose of aligning future research into cow-calf contact systems, it may be important to create a functional definition of the cow-calf bond based on behavioural indicators within a cow-calf pair. Instead of using a predefined time period of isolation of the dam-calf pair from the herd, behavioural indicators of the bond may be used to decide when a dam-calf pair is ready to be introduced into the herd.

**Bond formation between the dam and calf under free-range or semi-natural conditions vs. in dam-calf contact systems**

In free-range or semi-natural conditions, a cow separates herself from the herd before calving (see Rørvang et al., 2018 for review). The calf hides for some days (Reinhardt et al., 1977; Vitale et al., 1986) and the dam prevents the members of the herd from interacting with her calf (Reinhardt, 1980). With increasing age of the calf, the dam’s distance from the calf increases (Vitale et al., 1986). After the dam brings the calf to the herd, the calf joins other calves to form a crèche group or kindergarten, which is under the supervision of an adult animal (Reinhardt et al., 1977; Vitale et al., 1986). Calves spend the greatest proportion of the day in crèches at ages of 2–4 weeks. At this point of the calf’s development, the cow-calf contact truncates to regular visits for nursing and other forms of maternal care (von Keyserlingk and Weary, 2007).

Rather than the dam deciding when to introduce the calf to the herd, in farming it is a decision by humans. Bonding between dam and offspring is not automatically established. There is a sensitive period after birth when bonding is more likely to occur (Hudson and Mullord, 1977; Kiley-Worthington and de la Plain, 1983). Thus, in most dam-calf contact systems, the dam and her calf are kept separated from the herd during the first few days of the milk-feeding period. This period is considered necessary for the bond between the dam and her calf to form (Vitale et al., 1986). Thereafter, dam-calf pairs are integrated with the rest of the dairy herd until weaning and separation.

**Behaviours indicating a dam-calf bond**

A dam starts the process of bonding with her calf within minutes to hours after calving (Hudson and Mullord, 1977; Kiley-Worthington and de la Plain, 1983), while the offspring may need days until it recognizes the mother, as shown in lambs (Mora-Medina et al., 2016). However, Marchant-Forde et al. (2002) observed that calves were able to selectively respond to their own mother’s calls if separated at an age of 24 h. In a bonded dam-calf pair, the dam shows maternal behaviour towards the calf. Maternal behaviour indicates a bond and includes affiliative behaviours such as licking, sniffing, and vocalizations directed towards the calf, nursing the calf, and a stress response to separation from the calf. Nursing and suckling likely ease bond formation through physiological processes stimulated (Nowak and Boivin, 2015). There is some indication that the dam and calf may form a bond independent of nursing and suckling (Johnsen et al., 2015a). However, a recent study suggests that nursing increases the motivation to reunite (Wenker et al., 2019).

Little is known about indicators of calf’s bonding with its dam. A bonded calf will show a preference for its dam as indicated by licking the dam, lying in physical contact, sniffing, or playing (Reinhardt, 1980; Jensen, 2012; Santo et al., 2018). A bonded calf will also show distress behaviour when separated from the mother over many hours (Flower and Weary, 2001), though this might also be a reaction to social isolation. Further, a bonded calf will suckle its dam, however, suckling alone is not a sufficient indicator of a bond.

**Acceptance/tolerance vs. bonding in foster cows**

Foster cows nurse and tolerate the foster calves, but although some do, not all foster cows bond with their foster calves (Løberg, 2007). The prepartum rise of oestrogen and vaginocervical stimulation caused by foetus expulsion as well as licking of the neonate trigger further hormonal and neurophysiological processes in the dam contributing to dam-calf bond formation (reviewed by Lévy and Keller, 2009). Therefore, it is more likely that a foster cow bonds with an alien calf immediately after parturition, especially if the odour of the alien calf is covered with the cow’s amniotic fluid (Waltl et al., 1995). While most dams form a bond with their own calves, the relationship between foster cows and calves is less easily formed sometime after birth. Bonding and tolerance in foster cows is not well researched, but Le Neindre and Garel (1979) suggested that if the cow assumes the inverse parallel position during nursing, this indicates bonding. We therefore propose that a foster cow is regarded as bonded with a calf if the calf is allowed to suckle in the inverse parallel position and if she licks the calf daily. A foster cow is considered to accept/tolerate a foster calf if the calf is allowed to suckle in any other position.

**Weaning**

Weaning entails weaning off milk. Weaning is ‘a process of permanent deprivation of nursing milk from the mammary gland of the mother or any other artificial source of milk’ (Mills and Marchant-Forde, 2010). At weaning, the calf must make the transition from dependence on milk or milk replacer to nutritional independence of milk. Under semi-natural conditions, a dam usually nurses her calf for 8–12 months, that is to say, until shortly before her next calving (Reinhardt and Reinhardt, 1981). In cow-calf contact systems, weaning may occur concurrently with separation from the dam/foster cow (weaning by separation), but can also happen before separation (as when a nose flap is used), or after separation (Johnsen et al., 2018). In commercial (artificial and cow-calf contact systems) systems, dairy calves are commonly weaned at 8–12 weeks of age, but sometimes as early as six weeks of age (Kehoe et al., 2007; Marcé et al., 2010; Rey et al., 2014).

**Separation**

The term separation describes the total or partial prevention of physical and other types of contact between the cow and calf. The physical contact allowed during the separation process can be partial (such as fence-line housing; partial separation) or none (total separation). As separation can be temporary or permanent, authors should provide additional information on the
duration of separation. For instance, animals in part-time cow-calf contact systems repeatedly experience temporary separation. If separation is indefinite, permanent total separation is the recommended term, and it represents the third phase experienced by animals in the cow-calf contact systems. In cow-calf contact systems, permanent total separation typically occurs before 12 weeks of cow-calf contact. If calves are nutritionally independent of milk at separation, behavioural and physiological stress responses may be reduced, as well as negative effects on growth rate (Johnsen et al., 2018). Abrupt separation, where all physical contacts between cows and calves are suddenly prevented, is still the most commonly used in dairy production. Effort has been made to reduce negative effects of permanent total cow-calf separation. For instance, preventing suckling with a nose-flap prior to permanent separation (we define this as two-step separation) reduces stress reactions once the calf and the dam are permanently separated (Loberg et al., 2008). Allowing some physical contact through fence-line separation may alleviate the behavioural response to separation in calves (Johnsen et al., 2015b). Another possibility to reduce stress experiences at separation may be to gradually reduce the amount of daily contact between cows and calves prior to permanent separation (defined as gradual separation), though this has not been studied in cattle.

**Behavioural reactions to separation**

**Separation distress** is recognized by increased vocalization, locomotion (reviewed by Flower and Weary, 2001), and searching behaviour (Stěhulová et al., 2008). Separation distress vocalizations, which have been recorded up to 48–72 h after separation (Johnsen et al., 2015b), probably express the motivation of the calf to re-join the mother and function as a signal for the mother to return and increase maternal care (provide food or protection; Nelson and Panksepp, 1998; Padilla de la Torre et al., 2015). After permanent separation, calves perform less play behaviour, but this behaviour may reflect reduced energy intake (Rushen et al., 2016). Further, calves express negative cognitive judgement bias after a prolonged (e.g. up to 60 h) separation from the mother (Daros et al., 2014).

**Conclusion**

In this Research Reflection we have proposed terminology to be used in future studies on calf rearing systems allowing contact between cow and calf. Common use of terminology will facilitate comparability among studies. Nevertheless, studies should always describe details of the contact allowed, such as time and quality of contact from birth to permanent separation, housing facilities and feeding. We also urge the scientists and practitioners working with cow-calf contact systems to clearly describe the terms and definitions they refer to in their work. Further, we expect that the terminology suggested in this paper will evolve alongside with more research and experience in the field.

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**References**

Agenäs S (2017) We need to bring the calves back to the dairy cows. *Journal of Dairy Research* 84, 239.

Ainsworth MS (1979) Infant–mother attachment. *American Psychologist* 34, 932.

Beaver A, Meagher RK, von Keyserlingk MAG and Weary DM (2019) Invited review: a systematic review of the effects of early separation on dairy cow and calf health. *Journal of Dairy Science* 102, 5784–5810.

Bowlby J (1958) The nature of the child’s tie to his mother. *The International Journal of Psychoanalysis* 39, 350–373.

Busch G, Weary DM, Spiller A and Von Keyserlingk MAG (2017) American And German attitudes towards cowcalf separation on dairy farms. *PLoS One* 12, e0174013.

Daros RR, Costa JHC, von Keyserlingk MAG, Hötzell MJ and Weary DM (2014) Separation from the dam causes negative judgement bias in dairy calves. *PLoS One* 9, e98429.

de Oliveira D, Barth K, Haskell MJ, Hillmann E, Jensen MB, Fosse Johnsen J, Mejdell C, Waiblinger S and Ferneborg S (2020) Methodology for experimental and observational animal studies in cow-calf contact systems. *Journal of Dairy Research* 87S1, Special Issue: DairyCare husbandry for wellbeing 115–121.

Ferneborg S, Napolitano F, Vaarst M, Mejdell CM, Waiblinger S and de Oliveira D (2020) Methodology for studying human attitudes and behaviour to cow-calf contact systems. *Journal of Dairy Research* 87S1, Special Issue: DairyCare husbandry for wellbeing 122–127.

Flower FC and Weary DM (2001) Effects of early separation on the dairy cow and calf: 2. Separation at 1 Day and 2 weeks after birth. *Applied Animal Behaviour Science* 70, 275–284.

Fröberg S, Gratte E, Svennersten-Sjauña K, Olsson I, Berg C, Orihuela A, Galina CS, Garcia B and Lidfors L (2008) Effect of suckling (‘restricted suckling’) on dairy cows’ udder health and milk let-down and their calves’ weight gain, feed intake and behaviour. *Applied Animal Behaviour Science* 113, 1–14.

Fröberg S, Lidfors L, Svennersten-Sjauña K and Olsson I (2011) Performance of free suckling dairy calves in an automatic milking system and their behaviour at weaning. *Acta Agriculturae Scandinaevica Section A* Animal Science 61, 145–156.

Haley DB, Rushen J and de Passillé AM (2000) Behavioural indicators of cow comfort: activity and resting behaviour of dairy cows in two types of housing. *Canadian Journal of Animal Science* 80, 257–263.

Hillmann E, Bruckmaier R and Buchli C (2019) Calf-cow contact during rearing improves health status in dairy calves – but is not a universal remedy, in: Proceedings of the 53rd Congress of the ISAE, p. 84

Hudson SJ and Mullord MM (1977) Investigations of maternal bonding in dairy cattle. *Applied Animal Ethology* 3, 271–276.

Jensen MB (2012) Behaviour around the time of calving in dairy cows. *Applied Animal Behaviour Science* 139, 195–202.

Johnsen JF, Beaver A, Mejdell CM, Rushen J, de Passillé AM and Weary DM (2015a) Providing supplementary milk to suckling dairy calves improves performance at separation and weaning. *Journal of Dairy Science* 98, 4800–4810.

Johnsen JF, de Passillé AM, Mejdell CM, Boe KE, Grondahl AM, Beaver A, Rushen J and Weary DM (2015b) The effect of nursing on the cow–calf bond. *Applied Animal Behaviour Science* 163, 50–57.

Johnsen JF, Ellingsen K, Grondahl AM, Boe KE, Lidfors I and Mejdell CM (2015c) The effect of physical contact between dairy cows and calves during separation on their post-separation behavioural response. *Applied Animal Behaviour Science* 166, 11–19.

Johnsen JF, Zipp KA, Källber T, de Passillé AM, Knieiri U, Barth K and Mejdell CM (2016) Is rearing calves with the dam a feasible option for dairy farms? – current and future research. *Applied Animal Behaviour Science* 181, 1–11.
Johnsen JF, Mejdell CM, Beaver A, de Passillé AM, Rushen J and Weary DM (2018) Behavioural responses to cow-calf separation: the effect of nutritional dependence. Applied Animal Behaviour Science 201, 1–6.

Kehoe SI, Dechow CD and Heinrichs AJ (2007) Effects of weaning age and milk feeding frequency on dairy calf growth, health and rumen parameters. Livestock Science 110, 267–272.

Kiley-Worthington M and de la Plain S (1983) The Behaviour of Beef Suckler Cattle. Burkhauser Verlag, Basel, Switzerland.

Le Neindre P and Garel J-P (2007) Behaviour of foster cows and calves in dairy production. Acta Universitatis Agriculturae Sueciae 122, 1–50.

Lévy F and Keller M (2009) Olfactory mediation of maternal behavior in selected mammalian species. Behavioural Brain Research 200, 336–345.

Loberg J (2007) Behaviour of foster cows and calves in dairy production. Applied Animal Behaviour Science 111, 222–234.

Marcé C, Guatteo R, Bareille N and Fourichon C (2010) Dairy calf housing systems across Europe and risk for calf infectious diseases. Animal 4, 1588–1596.

Marchant-Forde JN, Marchant-Forde RM and Weary DM (2002) Responses of dairy cows and calves to each other’s vocalisations after early separation. Applied Animal Behaviour Science 78, 19–28.

Meagher RK, Beaver A, Weary DM and von Keyserlingk MAG (2019) inviting review: a systematic review of the effects of prolonged cow-calf contact on behavior, welfare, and productivity. Journal of Dairy Science 102, 5765–5783.

Mills DS and Marchant-Forde JN (2010) The Encyclopedia of Applied Animal Behaviour and Welfare. CAB, Wallingford, UK.

Mora-Medina P, Orihuela-Trujillo A, Arch-Tirado E, Roldan-Santiago P, Terrazas A and Mota-Rojas D (2016) Sensory factors involved in mother-young bonding in sheep: a review. Veterinarni Medicina 61, 595–611.

Nelson EE and Panksepp J (1998) Brain substrates of infant–mother attachment: contributions of opioids, oxytocin, and norepinephrine. Neuroscience and Biobehav Reviews 22, 437–452.

Newberry RC and Swanson JC (2008) Implications of breaking mother–young social bonds. Applied Animal Behaviour Science 110, 3–23.

Nowak R and Boivin X (2015) Filial attachment in sheep: similarities and differences between ewe-lamb and human-lamb relationships. Applied Animal Behaviour Science 164, 12–28.

Padilla de la Torre M, Briefer EF, Reader T and Mceligott AG (2015) Acoustic analysis of calf (Bos Taurus) mother–offspring contact calls from a source–filter theory perspective. Applied Animal Behaviour Science 163, 58–68.

Rault J-L (2012) Friends with benefits: social support and its relevance for farm animal welfare. Applied Animal Behaviour Science 136, 1–14.

Reinhardt V (1980) Untersuchung zum Sozialverhalten des Rindes: Eine Zweijährige Beobachtung an einer Halb-Wilden Rinderherde (Bos indicus). Springer, Basel, Switzerland.

Reinhardt V and Reinhardt A (1981) Natural suckling performance and age of weaning in zebu cattle (Bos indicus). The Journal of Agricultural Science 96, 309–312.

Reinhardt V, Reinhardt A and Mutiso FM (1977) Cow-calf relationship in Masai cattle, in: 28th Annual Meeting of the European Association of Animal Production. Brussels, Paper M/1.04/1–7.

Rey M, Enjalbert E, Combes S, Caquill L, Bouchez O and Montells V (2014) Establishment of ruminal bacterial community in dairy calves from birth to weaning is sequential. Journal of Applied Microbiology 116, 245–257.

Rorvang MV, Nielsen BL, Herskin MS and Jensen MB (2018) Prepartum maternal behavior of domesticated cattle: a comparison with managed, feral, and wild ungulates. Frontiers in Veterinary Science 5, 45.

Roth BA, Barth K, Gygax I and Hillmann E (2009) Influence of artificial vs. Mother-bonded rearing on suckling behaviour, health and weight gain in calves. Applied Animal Behaviour Science 119, 143–150.

Rushen J, Wright R, Johnsen JF, Mejdell CM and de Passillé AM (2016) Reduced locomotor play behaviour of dairy calves following separation from the mother reflects their response to reduced energy intake. Applied Animal Behaviour Science 177, 6–11.

Santo N, König von Borstel U and Sirovnik J (2018) Preliminary investigation of the influence of maternal contact on behavioural patterns indicative of emotionality in calves, in: 50. Internationale Tagung Angewandte Ethologie 206, 263–266.

Stěhulová I, Lidfors I and Špinka M (2008) Response of dairy cows and calves to early separation: effect of calf age and visual and auditory contact after separation. Applied Animal Behaviour Science 110(144), 165.

Veissier I, Caré S and Pomés D (2013) Suckling, weaning, and the development of oral behaviours in dairy calves. Applied Animal Behaviour Science 147, 11–18.

Vitale AF, Tenucci M, Papini M and Lovari S (1986) Social behaviour of the calves of semi-wild Maremma cattle, Bos primigenius taurus. Applied Animal Behaviour Science 16, 217–231.

von Keyserlingk MAG and Weary DM (2007) Maternal behavior in cattle. Hormones and Behaviour 52, 106–113.

von Keyserlingk MAG and Weary DM (2017) A 100-year review: animal welfare in the Journal of Dairy Science–The first 100 years. Journal of Dairy Science 100, 10432–10444.

Walit B, Appleby MC and Sknner J (1995) Effects of relatedness on the suckling behaviour of calves in a herd of beef cattle rearing twins. Applied Animal Behaviour Science 45, 1–9.

Wenker ML, Bokkers E, Verwer C, van Reenen CG, von Keyserlingk MAG and Weary DM (2019) Effect of cow-calf contact on motivation of dairy cows to access their calf, in: WIAS Science Day 2019: Trade-Offs in Science. Wageningen University and Research 47.