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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.

Research Reflection

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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

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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 suckling/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).

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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 Unrestricted contact Natural 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	
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 Unrestricted contact Natural 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	
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*)

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Table 1. (*Continued.*)

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 process of permanent deprivation of nursing milk from the mammary gland of the mother (called udder for most mammals) or any other artificial source of milk	
Separation	Preventing the physical and often other types of contact between the dam/ foster cow and her own or foster calf	
A. Temporary	The cow and calves will reunite	
B. Permanent	Indefinitive separation of cows and calves (third phase animals in CCC systems experience)	
C. Total separation	Cows and calves have no physical contact	
D. Abrupt separation	Sudden prevention of all physical contacts between cows and calves	
E. Gradual separation	Gradual reduction in the daily amount of the CCC prior to permanent total separation	
F. Partial separation	In the case of partial cow-calf contact system when cows and calves have some physical contact through a fence-line	
G. Two-step separation	When suckling is prevented with a nose-flap prior to permanent total separation	
H. Fence-line separation	Limited amount of physical contact is allowed through a fence-line	
Artificial rearing system	Calves are separated from the dam in the first days after calving and have no physical contact to the dam or foster cow	Conventional rearing
Semi-natural rearing	Management of cows and calves where interference by humans is minimal and CCC is possible into adulthood	

CCC, Cow-calf contact.

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

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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 (Loberg, 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

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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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