Behaviour of Foster Cows and Calves in Dairy Production

Acceptance of Calves, Cow-Calf Interactions and Weaning

Jenny M. Loberg
Faculty of Veterinary Medicine and Animal Science
Department of Animal Environment and Health
Skara

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Abstract

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By using foster cows to raise calves in dairy production the calves are given the possibility to perform more of their natural behaviours, such as suckling, playing and having social contact. In this thesis the acceptance of calves by foster cows of different breeds and stages of lactation, the development of an attachment between foster cows and calves and the possibility to reduce stress at weaning and separation was investigated.

In paper I cows of the breeds Swedish Red (SR) and Swedish Holstein (SH) from early to late lactation were tested with regard to their ability to accept four alien calves. There were no differences between the breeds or the different stages of lactation. SR cows were more social towards their calves and SR calves suckled and tried to suckle more than the SH calves.

In paper II foster cows having four foster calves each were observed for 24 hours at three different occasions. All social interactions between the foster cow and individual calves, along with sucklings were recorded. In all groups the foster cows directed more social behaviour to one or two calves, and those calves were interpreted to have the closest attachment to the cow, but the identity of the preferred calves was different during the different weeks. The attachment was not correlated with either the suckling duration or the weight gain of the calves.

In the third study two different ways of weaning foster cows and calves after 9 weeks of free suckling was tested. Either the calves were prevented from suckling by separating them from the cow (control), or they were prevented from suckling by a nose-flap that was fitted in the nose of the calves and kept with the cow for another two weeks after which they were separated (two-step). Both cows and calves in the two-step treatment vocalised and walked less than the cows and calves in the control treatment both when comparing the time of weaning and the time of separation. The heart rate was lower in the two-step calves and they had a decrease in the level of saliva cortisol compared to the control calves.

In conclusion, cows of both SR and SH breed and from early to late lactation accept being foster cows, foster cows seems to attach to one or two of her foster calves, and the two-step weaning process reduce the stress for both foster cows and calves after a long period of suckling.

Keywords: foster cows, acceptance, attachment, separation, weaning, breed differences, stress

Author's address: Jenny Loberg, Department of Animal Environment and Health, Swedish University of Agricultural Sciences, P.O. Box 234, SE-532 23 Skara, Sweden,
E-mail: Jenny.Loberg@hmh.slu.se

”Forskning har visat att män och kvinnor inte är lika.
Så nu undrar forskarna varför kvinnorna är olika.”

”Research has found that men and women are not alike.
So now the researchers wonder why women are different.”

Gunilla Dahlgren, Lilla fruntimret rymmer hemifrån, 1995

To my mother and father for your love and support

To Johan, Judith and Jesper for being in my life

Contents

Appendix

Paper I-IV

The present thesis is based on the following papers, which will be referred to by their Roman numerals:

I Loberg, J. & Lidfors, L. 2001. Effect of lactation and breed on dairy cows' acceptance of foster calves. *Applied animal behaviour science 74*, 97-108.

II Loberg, J.M. & Lidfors, L. Do foster cows develop an attachment to one or more foster calves? (Manuscript)

III Loberg, J.M., Hernandez, C.E., Thierfelder, T., Jensen, M.B., Berg, C. & Lidfors, L. 2007. Reaction of foster cows to prevention of suckling from and separation from four calves simultaneously or in two steps. *Journal of animal science 85*, 1522-1529.

IV Loberg, J.M., Hernandez, C.E., Thierfelder, T., Jensen, M.B., Berg, C. & Lidfors, L. 2007. Weaning and separation in two steps – A way to decrease stress in dairy calves suckled by foster cows. *Applied animal behaviour science*, doi:10.1016/j.applanim.2007.06.011.

Introduction

Background

Milk production in Sweden

Dairy production in Sweden has been moving towards fewer cows and larger farms. In 1980 the mean herd size was 15 and the number of cows in Sweden was 655 700 (Anon., 2007). In 2006, the mean herd size was 48 and the number of cows was 387 600 (Anon., 2007). Today cows are kept in loose-housing systems to a larger extent than before, and a higher number of calves are raised on each farm as herd size increases. A large inquiry to dairy herds in Sweden showed that the usual way of raising calves in conventional dairy production was to remove the calves immediately or a few hours after birth and house them in single pens (68 %) and during the milk period feed them either milk replacer or whole milk in a bucket without a teat (77 %, Pettersson, Svensson & Liberg, 2001). Since then, the farms have increased further in size (Anon., 2007) and this might have resulted in more farms with group housing of calves. When calves are kept in groups and fed milk in buckets it often results in problems with cross-sucking (de Wilt, 1985; Lidfors, 1993), i.e. calves sucks on different body parts of other calves. To prevent this problem the milk should be offered through a teat in order to satisfy the calves' motivation to suckle (de Passillé, 2001; Jensen, 2003).

In ecological dairy farming in Sweden the statutes postulates that calves should be kept in groups after one week of age and that they should be able to suck whole milk from its own species in a natural position (KRAV, 2007). One of the aims in this type of production is to fulfil more of the calf's natural behaviours. Methods where calves can be fed milk so that they can suck are through teat buckets or permanent teats that have to be placed high enough, through an automatic milk feeder or by the use of a cow. There are farmers that use cows as foster mothers, letting them nurse two to four calves, instead of milking them (Hartmann, 1994). In an enquiry that was made to all dairy farms that were members of KRAV 1999, it was found that to let the calves suckle either their own mother or a foster cow during the milk period was the second most common way of distributing the milk (26%, Anderberg, 2001). The most common way were to give the calves milk with teat buckets or floating teats (44%) and the third and fourth most common way were to use permanent teats (7%) or to use an automatic milk feeder (7%).

Why use foster cows in dairy production?

There are both behavioural and physiological advantages of using foster cows to raise calves during the milk feeding period. Since modern dairy cows produce enough milk to feed 3-5 calves at a time, the calves can be kept in groups. This gives them opportunity for social contact and gives them space to play. Studies have shown that both social contact and locomotor play behaviour is essential for calves (Jensen, 1999; Holm, Jensen & Jeppesen, 2002). It also gives them opportunities to have social contact with an adult animal. They can suckle milk several times per day and the milk always has the right temperature and hygienic

standard provided that the cow is healthy and has a clean udder. For the foster cow, the suckling several times per day may be beneficial for the udder in terms of massage, more frequent emptying and the saliva from the calves might promote a better udder health (Vaarst *et al*., 1997). The use of foster cows in dairy production may also save labour and calf rearing costs (Everitt, Phillips & Whiteman, 1968; Vaarst *et al*., 1997). There are farmers that use this system and all have their own way of putting the groups together, letting the calves stay with the same foster cow or changing foster cow during the 12 weeks the calf suckles, keeping the foster cows separated or in larger groups (Lidfors & Berg, 2004). There are also farmers that have tried to use foster cows but have abandoned it because of problems perceived.

Which cows are used as foster cows?

In a Swedish study on ecological dairy farms, the main criteria for choosing a cow as a foster cow were high somatic cell count and good maternal behaviour (Anderberg, 2001). In my own contact with private farms using foster cows these criteria are often mentioned as important. On one of the study farms they also use cows that are about to be culled at the end of the present lactation period as foster cows. In a study by Vaarst, Jensen and Sandager (2001) the aim was to use late lactating dairy cows that were 8 weeks before expected drying off. The purpose was that the calves would dry the cows off. Carlo & Velez (1974) used dairy cows to be culled for the purpose of suckling both their own and alien calves.

Acceptance of and attachment to alien young

Acceptance vs attachment

A foster cow can have different levels of relationship to her fostered young. In cattle the cow has been considered to accept or tolerate a fostered calf if the calf has been allowed to suckle in any position except the inverse parallel (Le Neindre & Garel, 1979). Cows have been considered to adopt the calf if it has been allowed to suckle in the inverse parallel position and the foster cow has been licking the calf at least once per day (Le Neindre & Garel, 1979). According to these definitions, calves that are accepted or adopted are allowed to suckle but the difference between them is the suckling position and the presence of friendly social interactions with the foster cow. However, the definitions suggested above are not sufficient to analyse any differences in the relationship between the foster cow and the foster calves that are adopted. If the foster cow occasionally licks one of the calves but spend much time licking and grooming another calf it may indicate that there is a difference in her relationship to those calves. The higher frequency of licking can be interpreted as a stronger relationship, i.e. an attachment.

Attachment between mother and infant is not present in all mammals. The ultimate function of an attachment is to provide ones own young with necessary resources and not to provide for alien young. In species where the offspring does not come in contact with anyone but the mother, such as solitary species or species

with altricial young that can not leave the nest, the development of an attachment is not necessary (Gubernick, 1981). This makes cross-fostering easy. For example cross-fostering of rats and mice is widely used in laboratory settings and captive environments to investigate the significance of genetic and environmental influence on different traits (Gomez-Serrano *et al.*, 2001; Schwaibold & Pillay, 2001). Attachment is predicted to have evolved in species where there is a possibility for the mother to accidentally nurse or care for alien young, as in larger groups where the young is precocial (Gubernick, 1981). In these types of species attachment between mother and offspring prevents the mother from nursing other than her own young, and allosuckling is rare. However, in matriarchal herds where the females are related, caring for other young than ones own may increase the mother's inclusive fitness and therefore a combination of attachment and cooperative care of young might have evolved (Gubernick, 1981). In such species we may find allosuckling.

Allosuckling in wild and domesticated species

The term "allosuckling" has been used to describe a suckling bout in which a non-filial mother and young is involved (Víchová & Bartoš, 2005). It has been observed in many wild ungulate species such as red deer (*Cervus elaphus*, Kelly & Drew, 1976; Bartoš *et al.,* 2001a; Bartoš *et al.*, 2001b), mouflon sheep (*Ovis gmelini musimon,* Réale, Boussès & Chapuis, 1999), bighorn sheep (*Ovis canadensis*, Hass, 1990), Saharan arrui (*Ammontragus lervia sahariensis*, Cassinello, 1999), fallow deer (*Dama dama*, Birgersson, Ekvall & Temrin, 1991; Ekvall, 1998; Pélabon *et al*., 1998) and muskox (*Ovibos moschatus,* Tiplady, 1990). There are also observations of allosuckling in domesticated ungulates, for example cattle (*Bos taurus*, Špinka & Illman, 1992; Illman & Špinka, 1993; Waltl, Appleby & Sölkner, 1995) and water buffalo (*Bubalus bubalis,* Murphey *et al.,* 1991, 1995; Paranhos da Costa *et al.*, 2000). Allosuckling is more common in taxa producing large litters (Packer, Lewis & Pusey, 1992) and the authors suggest that in species that usually only give birth to one young, allosuckling often involves females that have lost their own offspring. However, in cattle this does not always seem to be the case. Frequent allosuckling has been observed in cattle and involved almost all calves and cows in a herd of beef and dairy beef crosses (Víchová & Bartoš, 2005) and cows have also been observed to accept sucklings from orphan calves even when their own calf has been present (Špinka & Illman, 1992). In an attempt to find out what factors influence allosuckling in cattle, Víchová & Bartoš (2005) found that allosuckling was mostly performed by the calves with low birth weight and with a low maternal suckling rate. Calves with a mother of beef breed performed more allosuckling than calves with a mother of dairy-beef cross. This suggests that allosuckling is a strategy for calves to compensate for low intake of nutrition, but still the calves that had the highest frequency of allosuckling also had the lowest weight at weaning (Víchová & Bartoš, 2005). What we do not know is if they would have done even worse if they would not have been able to allosuckle, so there might still have been some positive effects of performing allosuckling. This is supported by previous suggestions that allosuckling in red deer is a response to compensate for a reduced maternal milk supply (Landete-Castillejos *et al.*, 2000).

Is there an effect of domestication on allosuckling?

In the domestic guinea pig (*C. porcellus*) there is minimal female intrasexual aggression and females will nurse the young of other females, while in the wild guinea pig (*C. aperea*) there is a high level of female aggression and the females only nurse their own young (Rood, 1972). Possibly the difference in the nursing behaviour is accounted for by the difference in aggressiveness by the females, and domestication might have made the females less aggressive and therefore nursing of other young is made possible. High aggression might have made the evolution of attachment unnecessary in the wild species, since it might minimize contact between females with pups. In the wild water buffalo (*Bubalus bubalis*), which live in groups of unrelated females, allosuckling has not been observed (Eisenberg & Lockhart, 1972). However, there are many observations of allosuckling in the domestic water buffalo (Murphey *et al.*, 1991, 1995; Paranhos da Costa *et al.*, 2000). This difference might be due to domestication (a genetic difference) or a result of keeping domestic animals in captivity with small possibilities for the animals to withdraw from the rest of the herd. Allosuckling may also be affected by a higher supply of food in captivity, making the mothers less defensive of their milk. However, cross-suckling in the domestic pig have been observed both in group housing (Olsen, Dybkjær & Vestergaard, 1998; Maletínská & Špinka, 2001) and in a semi-natural environment (Newberry & Wood-Gush, 1985). Also, there are observations of allosuckling in both wild and enclosed non-domestic fallow deer (Birgersson, Ekvall & Temrin, 1991; Ekvall, 1998) where the extra food supply has not increased the frequency of allosuckling.

Effects of suckling on the cow and calf

Behaviour, hormones and weight gain

If the cow is allowed to keep her calf after calving and nurse it both the cow and the calf are more active and are lying down less than if they are separated directly (Metz, 1984; Lidfors, 1996). It has been found that there is a high release of oxytocin in both the cow and the calf during suckling (Lupoli *et al.*, 2001). The level of oxytcin during suckling is higher than during machine milking for the cows and drinking from a bucket for the calves (Lupoli *et al.*, 2001). Oxytocin is a hormone that is connected to calmness (Uvnäs-Moberg, 1997) and a decrease in blood pressure (Petersson *et al.*, 1996). Oxytocin has also been suggested to influence the anabolic processes and growth (Lupoli *et al.*, 2001). Even if the calves do not suckle, the pure presence of the mother during colostrum intake of the calves has been shown to have a positive effect on the weight gain (Krohn, Foldager & Mogensen, 1999). Suckling on a cow, compared with sucking on an artificial teat or drinking from a bucket, results in higher milk consumption, and therefore in higher weight gain (Metz, 1987). This higher weight gain during a short suckling period was still present at 2 months of age (Metz, 1987).

Body condition and milk production of the cow

Since milk production is energy demanding (König, Riester & Markl, 1988) it affects the cow's body condition. Cows that had been allowed to suckle their own calf along with being milked during 10 days post-partum lost more weight than cows that only had been machine milked during the same period (Metz, 1987). Weight loss might not solely depend on milk production. Cows that had been machine milked and suckled by their own calf lost more weight and body condition than cows that had been machine milked and suckled by alien calves, although the cows produced the same amount of milk (Margerison, Preston & Phillips, 2002). In dairy production the calf is removed to increase the amount of milk to be sold. It is therefore a concern that suckling negatively affects the production of the cow, in that way that if not enough milk is withdrawn during the suckling the cow is decreasing its production. It has been shown that suckled cows do produced less milk than non-suckled cows after 10 days of suckling, but this difference was no longer present at day 16 (Metz, 1987). The same is true when comparing the milk yield for cows either suckled for one day or two weeks (Flower & Weary, 2001). On the other hand, there are studies comparing identical twin cows, where the suckled cows did not reach the same level of production as their machine milked twins until 6 weeks after weaning (Swanson, 1956). In a review on the effect of different suckling systems, Krohn (2001) conclude that free suckling can stimulate the post-weaning milk production by means of a better evacuation of the udder, better udder health and maybe also by a higher release of lactogenic hormones.

Udder health

One of the major causes of culling in Swedish dairy herds is high somatic cell count and mastitis (Swedish Dairy Association, 2007). On one of the farms used in this study suckling calves are often used to reduce the somatic cell count in newly calved cows. Suckled cows have been shown to have a larger reduction of the somatic cell count than machine milked cows (Margerison, Preston & Phillips, 2002) and to have lower CMT (Californian Mastitis Test) values and fewer treatments of sub-clinical mastitis than machine milked cows (Everitt, Phillips & Whiteman, 1968). Suckling can also reduce the incidence of clinical mastitis (Walsh, 1974). Even when combining suckling and machine milking in early lactation it can have a positive effect on the incidence of sub-clinical mastitis (Krohn, Jonasen & Munksgaard, 1990a) and as short as 5 days of suckling post-partum has been shown to reduce the risk of mastitis (Krohn, Jonasen & Munksgaard, 1990b).

Oestrus interval

Suckled cows, especially those that suckle their own calf, have been shown to have a longer interval to first oestrous compared to machine milked cows (Kaiser, 1975; Krohn, Jonasen & Munksgaard, 1990a; Margerison, Preston & Phillips, 2002). On the contrary, in a study by Metz (1987), the cows suckling their own calf for 10 days had a shorter interval to next oestrous than cows that were

machine milked during the same period. These contradictory results could partly be explained by the length of the different suckling periods. In the studies where the oestrus interval was prolonged the calves suckled the cow for 6-14 weeks, as opposed to Metz's study with a much shorter suckling period.

Previous studies on the use of foster cows

Weight gain of foster calves

There have been several earlier studies on the practice of using foster cows. Many of them have focused on the weight gain of the fostered calves and the reason for fostering has been to increase the production of calves per cow (Kilgour, 1972; Smith, Callow & McSweeney, 1973; Hudson, 1977; Wyatt, Gould & Totusek, 1977; Rosencrans & Hohenboken, 1982). Suckling a cow, compared with sucking an artificial teat or drinking from a bucket, results in higher milk consumption, since artificially fed calves are normally on a restricted milk allowance, and as a result of that to a higher weight gain (Everitt, Phillips & Whiteman, 1968). The number of calves suckling the same foster cow has an effect on the weight gain of the calves (Kaiser & O'Neill, 1975), with the highest weight gain for pairs and the lowest for quadruplets. The number of calves suckling each cow and the number of weeks suckling has no affect the post-weaning weight gain (Kaiser & O'Neill, 1975). The relationship between the foster cow and calf has an effect of the weight gain of the calf. If the foster calf is adopted, i.e. is allowed to suckle in a parallel position and is licked by the cow, it has the same weight gain as the cows own calf, but the poorer the relationship with the cow the lower the growth rate for the foster calf (Le Neindre, Petit & Garel, 1978).

Techniques for fostering

In the beginning the cow recognises her calf by licking and smelling (Lidfors, 1994; von Keyserlingk & Weary, 2007) and in many studies on foster cows, knowledge of this has been used to facilitate the process of fostering. The calves has been smeared with amniotic fluids from the presumed foster cow before introduction (Hudson, 1977), the legs of the calf have been tied to make it resemble a newborn calf unable to stand (Rosencrans & Hohenboken, 1982), or the alien calf has been covered with a sack that has previously been worn by the cows own calf (Herd, 1988). Another technique is to tether the foster cow to prevent her from kicking and butting the calves (Kaiser, 1975; Hudson, 1977; Kent, 1984). Allowing the foster cow and calf to interact freely has also been used (Smith, Callow & McSweeney, 1973; Vaarst, Jensen & Sandager, 2001). In order to utilize the increased maternal responsiveness of the cow after parturition several researchers have aimed at introducing the foster calves as soon as possible post-partum (Hudson & Mullord, 1977; Le Neindre, Petit & Garel, 1978; Nicoll, 1982a).

Milk production and oestrus interval

Several previous studies have been focused on the milk production and oestrus interval of foster cows. Studies on cows and heifers suckled by two to four calves have been shown to produce more milk than cows and heifers that are machine milked (Everitt & Phillips, 1971; Walsh, 1974; Peel, Robinson & McGowan, 1979; Margerison, Preston & Phillips, 2002). Probably because of the higher milk production, cows that suckle two to four foster calves have been shown to have a lower weight gain than machine milked cows (Everitt & Phillips, 1971; Kaiser, 1975). In an old study cows and heifers used as foster cows showed no visible signs of being in heat until 5-7 days after weaning (Everitt, Phillips & Whiteman, 1968) and a later study have pointed in the same direction (Wettemann *et al.*, 1976). Although oestrus interval does not seem to be affected by the number of calves suckling (Kaiser, 1975) it does seem to be affected by an increased period of suckling (Kaiser, 1975).

Behaviour of foster calves

There is a lot of information on how the behaviour of the calves is affected by the presence of the cow during the first hours and days after calving (Metz & Metz, 1986; Krohn, Jonasen & Munksgaard, 1990b; Jonasen & Krohn, 1991; Lidfors, 1996), but there is to my knowledge no publications on the difference in behaviour between calves fostered by a cow and calves fed milk artificially. Studies on foster calf behaviour have been focused on the foster calves ability to suckle or not (Rosencrans & Hohenboken, 1982; Vaarst, Jensen & Sandager, 2001). It seems that experience of suckling the mother during the colostrum period is important when introduced to a foster cow (Vaarst, Jensen & Sandager, 2001). In my studies all calves had been sucking their mothers prior to fostering. The rearing conditions might also affect the behaviour of the animal later in life. Le Neindre (1989a) has found that calves reared with foster cows are more "maternal" as cows than calves reared artificially in isolation.

Stress at weaning and separation

In nature, weaning is a process that not only involves the termination of milk for the young. It is a gradual process which prepares the animal for adult life and involves both transition from milk to solid feed but also to achieve adult behaviour and social independence from the mother (Galef, 1981; Martin, 1984). The process of terminating the suckling period is often a gradual process where the young is allowed to suckle more and more seldom and the rate of solid food intake increases. Martin (1984) uses the concept "parental investment" when describing the process of weaning. Parental investment is defined as a biological resource invested by the parent in its current offspring that increases the offspring's chance of surviving and reproducing, and at the same time reduces the parent's ability to invest in future offspring (a cost). The theory predicts the mother to terminate the suckling earlier than the offspring would want, and the offspring to try to prolong the suckling over the point where the mother would have terminated it. This conflict of interest is often referred to as the "parent-off-spring conflict" (Trivers,

1974), and is thought to impose some levels of stress in the young (Rheingold, 1963). In group-living animals the mother still has a relationship with the young after the suckling is terminated (Douglas-Hamilton, 1973; Reinhardt & Reinhardt, 1981; Green, Griswold & Rothstein, 1989; Veissier, Le Neindre & Garel, 1990). When domestic animals in captivity are weaned it is often directly associated in time with the separation between mother and young and the suckling is often terminated before the natural age of weaning in that species. This type of weaning causes a lot of stress to both mother and young that is expressed both in their behaviour and their physiology.

Behaviour

Behaviours usually associated with weaning and separation under commercial production conditions are an increase in vocal behaviour and activity. In some mammals, inactivity and depression has been observed (Reite *et al.*, 1981). There are a number of reports on calves and cows showing an increase in vocalising and walking as a response to separation (Hudson & Mullord, 1977; Lidfors, 1996; Stookey *et al.*, 1997; Weary & Chua, 2000; Flower & Weary, 2001; Haley *et al.*, 2001; Price *et al.*, 2003; Haley, Bailey & Stookey, 2005; Stehulová, Lidfors & Špinka, 2007). An increase in vocal behaviour and activity has also been observed in foals (McCall, Potter & Kreider, 1985; Moons & Zanella, 2001; Moons, Laughlin & Zanella, 2005). Piglets vocalise as a response of being separated from the sow (Weary & Fraser, 1995). In these studies the weaning and separation has been between the mother and offspring. However, these types of reactions have also been reported upon separation between foster cows and their calves (Vaarst *et al.*, 1997). In that study the calves refused to eat or ate minimal ration for 1-7 days after separation. Foster cows and calves vocalised and seemed to search for each other in up to 7-10 days after the separation.

Physiology

There are different ways to handle stress, and this is often described as active or passive coping. In animals which adopt an active coping strategy the sympathetic system is activated while in animals which adopt a passive coping strategy the pituitary-adrenocortical system is activated (Toates, 1995). When animals adopt an active coping strategy when stressed, behaviours such as startle response, jumps and vocalisations can be observed, while the behaviours of an animal adopting a passive coping strategy can be immobility and lack of vocalisation (Broom & Johnson, 1993). This lack of activity and vocalisation may falsely be interpreted as “no stress”, however, it is possible to detect a physiological response in the passive animals and therefore behaviour and physiological measures can act as complementary when assessing the level of stress an animal is exposed to. In cattle it has been shown that the removal of the calf gives a short increase in heart rate of the cow (Hopster, O’Connell & Blokhuis, 1995). Unfortunately, the authors only measured the heart rate during 10 minutes after the removal of the calf. An increase in plasma cortisol and noradrenaline has been found as a response to weaning and social disruption in beef calves (Hickey, Drennan & Early, 2003). Also in foals and mares there is an increase in plasma

cortisol concentration following weaning (McCall *et al.*, 1987; Malinowski *et al.*, 1990). Cows can lose weight and milk production as a consequence of not eating their normal quantity of feed as a response to weaning (Metz, 1987).

Weaning and separation are two stressors

Even if the process of weaning in nature is thought to cause some stress to the young, it is a gradual process where most of the young still have the opportunity to have contact with the mother. In commercial production, however, the weaning often includes the physical separation from the mother and at a much younger age than in nature. If we believe that stopping to drink milk from one day to the other is stressful for the animals we also add the stress of being removed from the mother. Weaning with fence line contact has been studied in sheep but there it was not compared with abrupt weaning (Galeana *et al.*, 2006). There have been several studies where the two events have been separated in time in cattle (Stookey *et al.*, 1997; Haley *et al.,* 2001; Price *et al.*, 2003; Haley, Bailey & Stookey, 2005), in wapiti (Haigh *et al.,* 1997) and in horses (McCall, Potter & Kreider, 1985; McCall *et al.*, 1987). The results show that the offspring seems to react less to separation when they still have the possibility for social contact with the mother. Therefore I wanted to investigate if this two-step method could be used when ending the suckling period for calves and cows in a foster-cow system.

Aims of the thesis

The aim of this thesis was to investigate which dairy cows can be used as foster cows, if they form an attachment to one or more of the calves and if a two-step method of weaning them decreases the stress response in both foster cows and their calves. Hopefully, the results from this thesis can improve the use of foster cows. The specific questions of this thesis were:

- At what time after separation from her own calf is a dairy cow most willing to accept four foster calves?

- Is there a difference between the two most common Swedish dairy breeds, Swedish Red cattle (SR) and Swedish Holstein cattle (SH), in their ability to accept four foster calves?

- Does a foster cow establish a stronger attachment to one or two out of four foster calves, and if so, does this attachment have an effect on the weight gain of the calves?

- Do four foster calves increase their synchronisation of suckling with age and how are the social interactions between foster cow and calves distributed over the day?

- Does splitting the prevention of suckling and the separation of cow and calves in two steps reduce stress-related reactions in foster cows after 9 weeks of suckling?

- Does splitting the prevention of suckling and the separation of cow and calves in two steps reduce stress-related reactions in foster calves after 9 weeks suckling?

Material and methods

Farms

Two of the studies (Papers I, III, IV) were carried out on a private ecological farm situated in the southwest of Sweden. When the studies were conducted the farm had around 300 dairy cows in the herd. The farm consisted of two major buildings, one for cows and heifers and the other one for calves, foster cows and sick cows. The two major buildings were connected by a smaller building where the milking parlour and calving pens were located. The cows were housed in a loose-housing system with cubicles, and the heifers on deep straw bedding with a concrete alley in front of the feeding manger. Both cows and heifers had ad libitum access to a Total Mixed Ration and water in water bowls. Shortly before calving the cows were moved to individual calving pens. All calves were allowed to stay with the mother during the colostrum period (approx. 4 days), and after that they were usually put to a foster cow together with other calves. The farm used foster cows as a routine to raise calves during the entire milk period, which was 12 weeks. After weaning the calves were housed in groups with 4-8 calves and fed a Total Mixed Ration and ad libitum water in water bowls. During all studies the foster cow-calf groups were kept in the building where the calves and foster cows were normally kept. They were kept in pens of 10 m^2 (Paper I) or 14.4 – 26 m^2 (Paper III-IV).

The study in Paper II was carried out on an ecological research- and demonstration farm owned by the Rural Economy and Agricultural Society of Gothenburg and Bohuslän on the west coast of Sweden. When the study was conducted the farm had around 50 dairy cows in the herd. The cows and heifers were housed in a loose-housing system with deep litter, were given a Total Mixed Ration twice a day and had ad libitum access to water in water bowls. The cows calved outdoors on pasture or in a group calving pen with deep straw bedding. Like on the first farm the calves stayed with the mother during the colostrum period. After the calves had been separated from the mother they were moved to group pens and fed whole milk in teat buckets until 10 weeks of age. During the study, the foster cows and their calves were kept in pens of 16 m^2.

Paper I

Forty-eight cows and 55 calves were used in this study. Twenty-four cows and 28 calves were of the Swedish Red breed (SR) and 24 cows and 27 calves were of the Swedish Holstein breed (SH). The cows were tested as foster cows at different times after the separation from their own calf (Table 1). Between separation and testing the cows were kept in the loose-housing system and milked as usual. All cows were put in a pen where there were four alien calves waiting, 2 SR and 2 SH. No attempts were made in order to ease the foster cows' acceptance of the four foster calves other than to tie the cow if she behaved too aggressively. The group was observed with direct observation 0-2 hours and 27-29 hours after being put together. Directly after the second observation the cow was taken back to the

loose-housing system and the calves were moved to a group pen. All calves were weighed before and after the 29 h testing. Since I only had access to a limited number of calves, each calf group was used for 4 different cows of the same breed but from the 4 different times after separation. If the cow let the calves suckle during the first two hours she was left loose in the pen. If the cow moved around and kicked the calves when they tried to suckle or if she attempted to butt them during the first two hours she was tied in-between observation periods. If the cow started to kick and butt the calves directly after entering the pen even if the calves did not approach her she was immediately tied, and kept tied through out the whole test. Focal animal sampling was used and the behaviours were recorded with 1-0 sampling where the cow was observed for 1 min and the calves for 15 s each. Then there was a 1 min break and the observation on the cow started again. All groups were also video filmed during the 29 h test, and from the videos the suckling frequency and suckling duration was recorded.

Table 1. *The number of cows tested of each breed and in each stage of lactation (n=48)*

No of cows per breed	No of cows per lactation stage
24 cows of SH breed	6 cows directly after separation from own calf 6 cows 4 days after separation from own calf 6 cows 26 days after separation from own calf 6 cows 178 days after separation from own calf
24 cows of SR breed	6 cows directly after separation from own calf 6 cows 4 days after separation from own calf 6 cows 26 days after separation from own calf 6 cows 178 days after separation from own calf

Fig. 1. One of the foster cows of Swedish Red breed used in paper I, together with two of her calves, one of Swedish Red breed and one of Swedish Holstein breed. (Photo: Jenny Loberg)

Paper II

Seven cows and 28 calves were used, all but one calf of the Swedish Holstein breed. The groups, consisting of one foster cow and four calves, were put together in a pen when the cows had been separated from their own calf for on average 11 days (range 1-32 days). The groups were filmed with cameras placed in the ceiling for 24 hours every week from week 1, when the calves were about 1 week of age, until week 10. From week 8, half of the groups were only together during daytime, since they were weaned gradually. The behaviour of the groups at week 2, 5 and 7 were recorded. From the videos, I recorded all social interactions between the foster cow and individual calves and all sucklings with start time, end time and identity of the calf. A suckling was recorded when the calf had its head under the cows belly close to the udder for at least one minute. A suckling bout was defined as the time during which the cow was nursing one or several of the calves with no pause between the calves, starting when the first calf started to suckle and ending when the last calf stopped suckling. During a bout, one to four calves could suckle. I also recorded the exact time of the day when the social interactions and sucklings took place, along with how many calves were suckling at the same time. The calves were weighed once a week and from those weighings the average daily gain (ADG) was calculated.

Paper III-IV

In this study, 12 dairy cows (5 SR and 7 SH) and 47 calves (15 SR and 32 SH) were used. They were put together in groups with one cow and four calves (except for one group with 3 calves) each, when the calves were around one week old. All calves had been with their own mother during the colostrum period, and most of them stayed with the mother until the formation of the group. If they could not stay with the mother, they were put on another foster cow in the mean time. All foster cows were tied during the first 12 hours and then let loose in the pen. They were observed during the first hour upon their release to make sure that they were not aggressive towards the calves. All groups were allowed free suckling until the calves were 10 weeks old. At that time the calves were prevented from suckling either by separating the calves from the foster cow (control, n=6 groups) or fitting the calves with a nose-flap (Fig. 2a) and letting them stay with the foster cow for another two weeks, where after they were separated (two-step, n=6 groups). The calves in the control groups were also fitted with the nose-flap (Fig. 2b) after separation, in order to be able to compare weight gains between the two treatments. During week 10 (both treatments) and week 12 (two-step treatment only) direct observation of the behaviour, heart rate measures and saliva sampling was done (for details of the sampling schedule see Papers III and IV). The recording of the behaviour of foster cow and calves in the same group was done simultaneously by two different observers using focal animal sampling and continuous recordings. The heart rate was measured on the cow and three of the four calves with the Polar Horse XTrainer. Saliva was collected using a cotton swab that was held in the animals' mouths until enough saliva was collected. The samples were centrifuged at 4500 x g for 15 min just after collection and then frozen at -20^{o}C until analysis. The saliva cortisol concentration was measured using a solid phase RIA. The calves were weighed before the groups were formed, at 5 weeks of age and twice a week at 10, 11 and 12 weeks of age.

a)  b) 

Fig. 2. The nose-flap (a, Quiet-Wean) used in study three (Paper III-IV) and a calf wearing it (b). The calf is also equipped with the Polar Sports heart-rate measuring device that is covered with an elastic black belt to protect the equipment from other calves. (Photo: Jenny Loberg (a) and Carlos Hernandez (b))

Statistical analyses

The behavioural processes that are studied as frequencies can not be considered normally distributed. On several occasions we have tried to use parametric statistics by first transforming the data into a normal distribution. Sometimes this is successful, but many times the fit is poor. There are many factors in an experimental set-up that may affect the behaviour in focus of the study, and therefore the possibility to take all these factors in to account in a model is desirable. Behavioural data, even if they are not normally distributed, may be normal approximated if the sample size is big enough. However, in many studies the sample sizes are too small for practical reasons. In these cases non-parametric statistics can be used, but they have their limitations when a researcher wants to take many factors into account. There are, however methods of analysing non-normally distributed data in a more sophisticated way by using generalised linear models where the actual distribution can be stated. In this thesis I have used non-parametric statistics and normal approximations in papers I and II, and taken the step into using generalised linear models with Poisson distributions in papers III and IV. The statistical analyses are described in detail in each paper. Here follows a short summary of the statistics used in each paper.

Paper I

The behavioural data was transformed to fit a normal distribution and then analysed with a general linear model. The behaviours of the foster cows were analysed with a model including breed (SR and SH), time after separation (0, 4, 26 and 178 days) and treatment (if they were loose or had to be tied due to aggression). The behaviours of the calves were analysed with a model including group (n=12), time after separation and order of cow (1, 2, 3 and 4). To analyse if the cows behaved differently towards calves of their own breed compared to calves of the other breed, and if there was a breed difference in the suckling behaviour and social behaviour of the calves, a Wilcoxon signed rank test was used. Pearsons correlation was used to analyse if there was a correlation between total suckling time and weight gain of the calves.

Paper II

This paper was more of a descriptive study. The frequencies of licking and rubbing between the cow and calves, together with the recordings of if the calf had been allowed to suckle by itself or not, were used to create a rank sum. High frequencies of a behaviour resulted in a low rank. The calf in each group with the lowest rank sum was considered the calf with the strongest attachment to the foster cow. I used a Spearman rank correlation to test correlations between ADG, suckling duration, licking received and rank sum during each week. Both the ADG calculated from the week prior to the observation and the ADG calculated from the week after the observation was used in the analyses.

Paper III-IV

In this study the behavioural data was observed as frequency counts following a Poisson distribution. Therefore they were analysed with a generalised linear model using a log-linked Poisson regression model. To compare the cows' and calves' reactions to the prevention of suckling the observations during week 10 for both treatments were used, and to compare the reaction to separation the observations during week 10 for the control groups and the observations during week 12 for the two-step groups were used. The behaviours were analysed using a model that included treatment (control and two-step), observation time (0-2, 8.5-9.5, 24-26 and 72-74 h after the prevention of suckling), breed (SR and SH) and all second degree interactions. Since the behaviour of both foster cow and calves were repeatedly observed over equidistant time, quasi likelihoods were used to estimate first-order autoregressive correlation structures within the repeated subjects, 'observation × cow' in foster cows and 'group' in calves.

The heart rate was measured every 15^{th} second and therefore there was strong auto-regression within the data. Therefore, each heart rate series was filtered. The mean, median, inter-quartile range, slope and standard deviation were calculated from each heart rate series. The resulting heart rate characteristics were analysed with a general linear model including treatment, observation time, breed and all second degree interactions. As a post hoc test, planned comparisons of LS Means were used.

The effect of treatment on the cortisol concentration, the increase in cortisol compare with baseline, and the difference in cortisol between two consecutive measures was analysed with a generalised linear model specified with a normal distribution and an identity link function. Since the measurement were repeated every day auto-regression structures were addressed by using 'cow' and '(calf)group' as repeated statements when analysing the data from the foster cows and calves respectively.

Summary of results

Acceptance of foster calves (Paper I)

There was no difference between the times after separation from the cow's own calf on any of the behaviours performed by the foster cows. The numbers of cows that were kept loose with the calves during the whole test period, that were tethered in between observation periods and that were tethered immediately, respectively, are shown in table 2. Cows of the SR breed sniffed the calves more than cows of the SH breed. During the first two hours of observation, the cows that later had to be tied sniffed the calves less and butted the calves more than cows that could be kept loose during the test. The cows did not treat calves of the two breeds differently. The calves suckled on average 37 times per test period (29 h) on cows that were tested 178 days after separation from their own calf compared to on average 58 times per test period on cows directly or 4 days after separation. Cows that were tested 4 days and 26 days after separation from their own calf had higher milk production than cows tested directly or 178 days after separation. Calves vocalised more when they were tested with the cow 178 days after separation and also when tested for the first time with their first cow. None of the other behaviours were affected by the lactation stage of the cow. Calves of the SR breed suckled and tried to suckle more often than the calves of the SH breed. On the other hand the SH calves ate more Total Mixed Ration than the calves of the SR breed. There was a positive correlation between total suckling time recorded from the video and weight gain during the 29 hours.

Table 2. *The number of cows per breed and time after separation that were loose during the test, loose during observations and tied in-between observations, and tied during the 29 h test period*

Breed	Days after separation	Loose	Loose & tied	Tied
SR	0	5	1	
	4	5	1	
	26	5	1	
	178	4	2	
SH	0	6		
	4	6		
	26	5		1
	178	3	2	1
Total		39 (81%)	7 (15%)	2 (4%)

Attachment to foster calves (Paper II)

In all groups one, and at one occasion two, of the calves received more lickings and rubbings than the other calves in the group. This resulted in the lowest rank sum for these calves. But only one of the foster cows licked and rubbed the same calf more during all three weeks of observation. In the other groups the calf

receiving the most licking and rubbing differed between weeks. The received rank sum for the different calves did not correlate with the total suckling duration, nor was there any correlation between ADG and suckling duration. There was a positive correlation between the ADG prior to week 7 and the licking received at week 7. The frequency of licking by the cow and her calves were positively correlated at week 2 and 7 but not at week 5. There were more sucklings with 3 calves at week 5 (26 % of the sucklings) than at week 2 (8 % of the sucklings) or week 7 (13 % of the sucklings). There were more sucklings with all four calves at week 7 (48 % of the sucklings) than at week 5 (23 % of the sucklings) or at week 2 (9 % of the sucklings). The number of suckling bouts were highest at week 2 (18.6 suckling bouts) compared to week 5 (10.6 suckling bouts) and 7 (10.4 suckling bouts). Looking at the distribution of the suckling bouts and social interactions between foster cow and calves, there seemed to be two peaks of activity during the day (Fig. 3). In the morning the foster cows started by licking the calves before suckling while the calves licking and rubbing towards the foster cow occurred after suckling. In the afternoon the social interactions between cow and calf took place mainly after suckling.

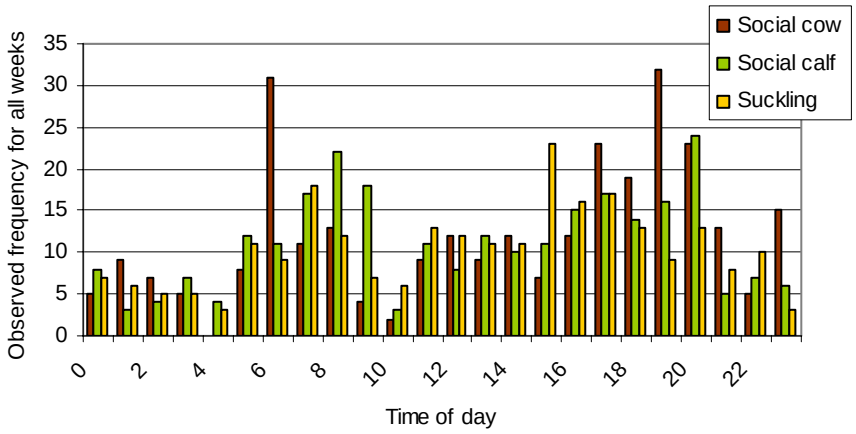


Fig. 3. The observed number of lickings and rubbings by the cow (brown) and by the calves (green) and the observed number of suckling bouts (yellow). The social behaviours and the suckling bouts are summarised for each hour and for all three weeks of observation.

Response by foster cows and calves to two-step weaning (Paper III-IV)

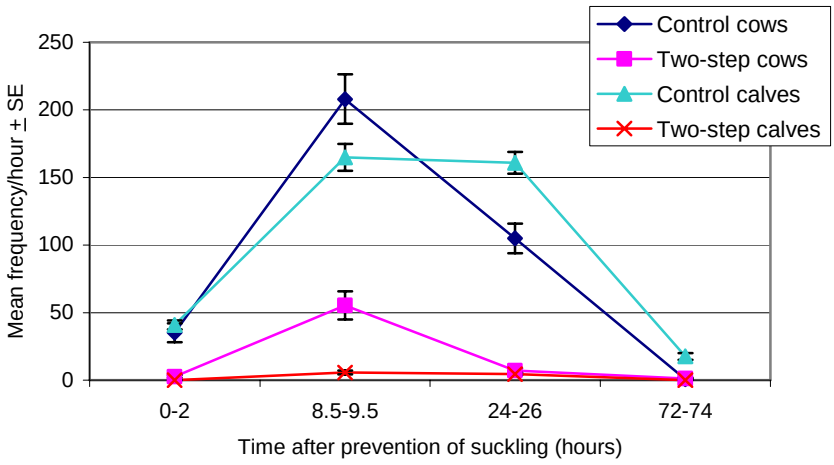
Reaction to the prevention of suckling

Both foster cows and calves in the control treatment vocalised more than foster cows and calves in the two-step group after the prevention of suckling (Fig. 4a). The highest frequency of vocalisations in the control group occurred around 9 hours after the prevention of suckling in both cows and calves, but while the cows

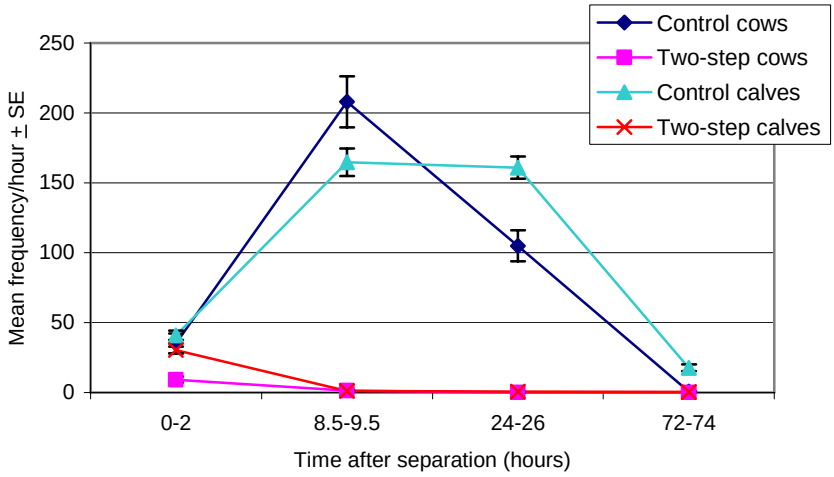
had decreased the frequency after 24 hours (still vocalising more than two-step cows) the calves continued to have a high frequency of vocalisations through out the third observation (24-26 h after prevention of suckling, Fig. 4a). The cows of SR breed vocalised more than the cows of SH breed. In both cows and calves the control animals walked more after the prevention of suckling than the two-step groups. Two-step calves were lying down more and ruminated more than control calves. The control calves that were moved to a new pen sniffed the interior of the pen more than two-step calves, and the foster cows decreased their sniffing on the interior with time since prevention of suckling. The mean heart rate of the foster cows was not affected by the treatments. In the calves the mean heart rate was higher for the two-step calves than for the control calves during the first two hours after prevention of suckling, where after the heart rate of the two-step calves decreased and the heart rate for the control calves increased. At 24 h after prevention of suckling the control calves had a higher mean heart rate than two-step calves. There were no differences between treatments in the increase in concentration of saliva cortisol in either foster cows or calves.

Reaction to separation

Both foster cows and calves that were separated two weeks after the prevention of suckling vocalised less than cows and calves that were separated and prevented from suckling simultaneously (Fig. 4b). There was no increase in vocalisation in the two-step cows and calves after 9 hours of separation (Fig. 4b). Two-step cows and calves walked less after separation than control cows and calves, and the SR cows walked more than the SH cows. Calves in the two-step group had more recordings of eating after separation than control calves and foster cows had more recordings of eating during the first and second observation period compared to the third and fourth observation period. Both cows and calves in the control treatment decreased their lying behaviour after the first observation period, whereas the cows and calves in the two-step treatment increased their lying with time since separation. The frequency of sniffing the interior decreased with time since separation in both cows and calves. SR cows sniffed the interior more than SH cows, and SR calves performed more social behaviours than SH calves. Cows in the control group stood with their head outside the pen more often and calves in the control group tended to stand with the head outside the pen more often than animals in the two-step treatment. After separation the calves in the two-step treatment had a lower mean heart rate than the calves in the control group. This difference was true between 24 and 50 hours after separation. In the foster cows the median heart rate was higher 24 hours after separation than later. After separation the salivary cortisol in the two-step calves decreased compared to baseline level while it increased in the control calves. No difference was found between the treatments in the foster cows.



a)



b)

Fig. 4. Mean frequency per hour (± SE) of vocalisation for both cows and calves in control and two-step treatment for the different times after the prevention of suckling (a) and for the different times after separation (b). The prevention of suckling was done either by separation (control) or by applying the nose-flap (two-step).

General discussion

This thesis has investigated different aspects of the possibility to use foster cows as a way of raising calves during the milk period in dairy production. According to the results most of the cows do accept being used as foster cows, even though some of them need some time to do so. The question on attachment needs further investigation, but the weaning and separation becomes less stressful if the two-step weaning method is practiced.

Success in putting the cow and calves together

In the long term studies (Paper II-IV), none of the foster cows had to be replaced due to not accepting the calves. In a study including two private farms and one research farm, some calves had to be taken away 1-7 days after introduction to the foster cow because the calves were not allowed to suckle (Vaarst *et al.*, 1997). This only happened when the calves had not been able to suckle the mother before introduction to the foster cow. Hence, previous experience of suckling seems to be crucial for the calves, and for the system to work. All calves in my studies had previous experience of suckling their own mother, and sometimes also another foster cow. At one occasion in the first study (Paper I) one of the calves had to be replaced by a calf that had been given milk from a teat bucket some weeks before. Although being only anecdotal evidence, it is interesting to notice that this new calf had to be "taught" how to suckle, in the sense that she did not seem to connect the cow with milk. When the other calves in her group started suckling she stood looking at the observer, and vocalised. This calf had suckled her mother during the colostrum period, so she had previous experience of suckling, but after that she had been fed milk with a teat bucket for 3-4 weeks. What probably had happened was that she had learned to connect humans with feeding and no longer connected cows with feeding. This is supported by Hudson (1977) where calves fed with an artificial teat for two days after suckling the mother had to be re-taught to suckle from a cow when introduced to a foster cow.

The foster cow-calf groups in this study was always put together after the morning milking before the calves had been fed with milk, to increase their motivation to suckle upon introduction to the foster cow. This way of putting hungry calves onto foster cows was used already in a study in 1968 by Everitt, Phillips & Whiteman. In that study, however, to confuse the foster cows oil was smeared over her muzzle and on the tops of the heads, along the backs, and on the tail-heads of the foster calves. Other techniques that have been used in order to get the foster cows to accept alien calves are to smear the calves with amniotic fluids (Hudson, 1977; Rosecrans & Hohenboken, 1982), or by using a jacket for odour transfer (Dunn, Price & Katz, 1987; Herd, 1988). No odour transfer was used in any of the studies in this thesis. Instead, I have used both the procedure of leaving the foster cow and calves free to interact while observing them, and tethering the foster cows during the first hours to facilitate suckling by the calves.

Possibility to accept and to attach to alien calves

The behavioural and physiological signs of stress that were shown when the cows were separated from their foster calves indicate that some form of bond or attachment had formed between the cow and the calves. The ability to accept foster calves could be a sign of a relaxation in the rejection behaviour towards alien young that is often seen in many ungulates (Rudge, 1970; Gubernick, 1981). Suckling attempts made by alien calves in free-ranging beef cattle is often refused by the cow (Lidfors, Jensen & Algers, 1994). It has also been reported that a larger proportion of beef cows having twins allow cross-suckling from alien calves (Wyatt, Gould & Totusek, 1977; Price, Thos & Anderson, 1981), at least temporarily. Maternal behaviour is generally thought of as a trait that is relatively resistant to modification during the domestication process since it is of high importance in animal production systems (Price, 2002). For example, studies have shown that domestic sows and crosses between domestic and wild boar only have minor differences in their maternal behaviours (Gustafsson *et al*., 1999; Spinka *et al*., 2000). However, in species where the caretaker removes the offspring and serve as a surrogate mother there may be a relaxed selection on maternal behaviours (Price, 2002). In beef cattle with a much lower milk production than the dairy breeds, one can assume that the milk is a highly valued resource that is protected by the dam for the own young. In dairy cattle, however, there is usually milk enough for three to five calves, but does the cow know that? The breeding for high milk production, which increases the energy available for the calves, could be one component in the relaxation. There is also evidence in natural populations that mothers that produce more milk than their offspring can consume are more willing to nurse alien young, and it has been called "the milk evacuation hypothesis" in relation to the occurrence of allosuckling (Roulin, 2002). In dairy production, the long history of removing the calf immediately after parturition might have favoured cows that have a low reactivity towards this loss. Cows reacting by vocalising and that were difficult to milk after calf removal, might have been culled earlier, leaving fewer offspring to the population. If this has been the case, the maternal behaviour of today's population of dairy cows might have become more relaxed than in beef cattle, where the maternal behaviour is essential for the survival of the calf. The relaxation may have lowered the threshold of some of the behaviours necessary for a successful motherhood, such as rejection of alien calves.

The idea of a possible formation of an attachment between foster cow and calves was formed during the first study (Paper I) when some of the cows used as foster cows showed a strong behavioural response when they were separated after only 29 hours together with the calves. This reaction had also been reported by farmers (Vaarst *et al*., 1997). In an old study Walsh (1974) has described the difficulties with fostering, and the problem was not to foster calves onto cows immediately post-partum but to foster new calves onto the same foster cow after 50 days of suckling. This might have been caused by the lower maternal responsiveness in later lactation, although it was not present in this study (Paper I), or by the possible formation of an attachment to the first calves suckling. The attachment between cow and calf is thought to be strengthened by the cow licking the calf

(von Keyserlingk & Weary, 2007). All the cows in this thesis had the possibility to lick their own calf and possibly attach to them before they were used as foster cows. Still they accepted alien calves after the possible attachment to and separation from the own calf. According to the definition of adoption presented in the introduction (Le Neindre & Garel, 1979) all but four calves in paper II were adopted by their foster calves. However, as pointed out previously this definition does not allow any differentiation in the relationship between a foster cow and her four calves. Therefore I have used the term "attachment" to define the calf/calves that receives and performs more frequent licking and rubbing with the foster cow than other calves in the group.

If there has been a relaxation in the maternal behaviour of dairy cows, the cows might need longer time to form a strong attachment to the calf. It would be interesting to investigate if they would still accept alien calves if they had a longer time together with their own calf before being used as foster cows. In this thesis, all foster cows were introduced to the four calves at the same time, and this might have made it more difficult for the cow to attach to one or two of them. Previously, cows having twins have been showed to be less discriminative towards alien calves (Price, Thos & Anderson, 1981) indicating a lower level of attachment when having more than one calf. In the private farms used in this thesis, calves are often used to improve the udder health of cows that have recently calved. Alien calves are put on the cow when she still has her own calf present for a few days, before the cow is separated from all calves and is moved back to the loose-housing system and milked. In all studies in this thesis the foster cows have been kept alone with their foster calves. In other studies foster cows and calves has been kept in group housing, either directly after the calves have been taken from their own mother (Brouček *et al*., 1995) or after a short period of keeping one foster cow with calves in a pen (Everitt, Phillips & Whiteman, 1968; Everitt & Phillips, 1971; Kilgour, 1972; Hudson, 1977; Dunn, Price & Katz, 1987). Group housing might influence the possibility to form an attachment since many different calves can suckle the same cow. On the other hand if this is true then it might lead to a less stressful situation at weaning and separation.

For the same reason the mother should be restrictive in her nursing and only give the milk to the own offspring, the offspring should try to get as much milk as possible to increase its own chance of survival. Studies also mention that calves try to suckle other cows than their mother the first days of life before they learn that they are often rejected by others than their mother (Edwards, 1983; Murphey, Ruiz-Miranda & de Moura Duarte, 1990; Illman & Špinka, 1993). In this study none of the calves seemed to care about if the cow was its own mother or not. If given the possibility the calves were very social with the foster mother and many of the calves were actively contact seeking. It was observed, although not systematically, than most of the calves when taken directly from the own mother to the foster cow and if they were allowed to suckle, did not show signs of distress because of the separation from the mother. Gubernick (1981) suggests that foster mothers might reduce the stress of being separated from the own mother. However, studies on separation have shown that the reaction of the calf is usually delayed by several hours and is probably partly caused by hunger (Weary & Chua,

2000; Flower & Weary, 2001; Paper IV). The calves did not seem to react to the separation from their own mothers; instead they seemed to adjust well to the situation of being fostered on an alien cow as long as they were allowed to suckle. A study on maternal recognition (Murphey, Ruiz-Miranda & de Moura Duarte, 1990) in *Bos indicus* calves showed that calves 8 months of age made numerous errors when trying to find their own mother. The authors suggests that the "errors" may be an adaptive behaviour, in that way that calves given the opportunity should suckle from any cow that allows them to. The attachment of the calf to the mother is probably partly based on that she is the cow that is most willing to be nursed.

Milk production and weight gain

Since dairy cows are selected for high milk production, the calf's weight gain when suckling has been reported not to be correlated with the production of the cow (Metz, 1987). In several trials with 2-4 calves per foster cow there was no relationship between calf growth and lactation performance of the cows (Everitt & Phillips, 1971). The dairy cows always produce more than a single calf can consume. However, in one study single suckling calves gained more weight than double suckling calves (Nicoll, 1982b). When using a dairy cow as foster cow, letting 3-5 calves suckle her, the milk production becomes important. In my studies, the production of the foster cows was always at least 25 kg ECM (Energy Corrected Milk), leaving at least 6 l of milk per calf and day, but usually the cows produced more. If the foster cow produces too little milk the calves will not gain as much weight as they have the potential to do. Also they would try to suckle more frequently during a day to try to extract additional milk, leading to many short sucklings and no rhythm in the foster cow-calf group. This was actually observed on one of the videos that I did not use (Paper II).

Response at weaning and separation

Most of the previous studies done on foster cows and calves have focused on the methods of fostering and the weight gain of the calves (Everitt, Phillips & Whiteman, 1968; Hudson, 1977; Dunn, Price & Katz, 1987). The problems that occur after the long period of suckling when the foster cows and calves are to be separated has not rendered much attention, although it has been mentioned as a major problem when farmers use foster cows (Vaarst *et al*., 1997). Previous studies on weaning and separation have been focusing on the separation between mother and calf (Hopster, O'Connell & Blokhuis, 1995; Lidfors, 1996; Weary & Chua, 2000; Flower & Weary, 2001; Haley, Bailey & Stookey, 2005; Stěhulová, Lidfors & Špinka, 2007). In this thesis (Paper III and IV) the technique of splitting two stressful events in time, which previously have been used when weaning mother and calf (Stookey *et al.*, 1997; Haley, 2006), has been tested to reduce the stress at weaning and separation after 9 weeks of suckling of foster cows.

The response to weaning and separation may have been affected by the fact that each cow had four calves, which never happens in nature, and that none of the

calves were her own offspring. It seems that the number of calves a cow receives does have an affect on their relationship. In a study by Price *et al.* (1986) it has been shown that cows with twins are less likely to approach their young when the calves are removed than cows with singles, and they are also less likely to approach, sniff and lick their calves after reunion. Furthermore, cows having twins spend less time licking each calf than cows with singles (Price, Thos & Anderson, 1981). But being single or twin does not seem to affect the distress of the calves when separated from the mother (Price *et al.*, 1986).This may indicate that when a cow has more than one calf, the attachment is less robust and therefore the separation is less stressful. In the study by Price *et al.* (1986) this difference was only evident in the contact and contact-seeking behaviours and not in the general response to separation like walking and vocalising, which was in focus in my study.

In the third study (Paper III-IV) the frequency of vocalisation was used as a measure of distress. Vocal behaviour at separation is thought to function as a way for the cow and calf to reunite. It has been shown that cows have a higher rate of following their calves when the calves are removed if the calf vocalise than if the calf is silent (Price *et al.*, 1986). However, the vocal behaviour of the calf when returned to the mother has not been shown to affect the mother's rate of approaching (Price *et al.*, 1986). The function of vocalising at separation seems to be different for the cow and the calf. Flower and Weary (2001) showed that cows vocalise directly after separation whereas the calves vocalised several hours after separation. Possibly the cows react on the actual separation, trying to find the calf while the calves probably respond to the level of hunger they feel after 12 hours without suckling. In my studies vocal behaviours of the calves could not be explained by the level of hunger, since the calves that remained with the cow being deprived of milk did not vocalise, but rather a sign of distress. In the study by Flower and Weary (2001) there was a second peak of vocalisations by the cows around the time of milking when the udder hadn't been emptied for 12 hours, and their explanation for that was udder discomfort. In my study the peak of vocalisation around 9 hours after weaning and separation in both treatments could partly be explained by udder discomfort. Cows from both treatments were milked in the milking parlour in the afternoon after the calves were prevented from suckling and thereafter twice a day. During their first milking more foster cows kicked and vocalised than control cows that were taken from the loose-housing system and they had a lower milk yield (Hernandez, 2004), indicating that they did not let down the milk properly. However, if udder discomfort was the only explanation to the peak in vocalisations I would not expect the difference between treatments that I found. A similar peak in the behavioural reaction to separation has previously been found by Weary and Chua (2000).

Breed differences

There were some differences in the cows' and calves' behaviour between the two breeds SR and SH. In paper I the SR cows were more social towards their calves than SH cows and the SR calves suckled and tried to suckle more than the SH

calves. In paper III the SR cows vocalised, walked and sniffed the interior more after weaning and separation than the SH cows and in paper IV the SR calves performed more social behaviours after separation than the SH calves. The differences between the two breeds are probably due to genetic differences since all cows and calves in these studies were kept under the same conditions at the same farm. Previous studies on behaviour have shown differences between beef and dairy breeds. When comparing calves from a hardy breed (Salers) with calves from a dairy breed (Friesian) it has been found that Friesian calves learned to drink from a bucket quicker than Salers (Le Neindre, Menard & Garel, 1979), that Salers calves make more suckling attempts before the first suckling than Friesian calves, and that Salers cows licks their own calf and other calves more often than Friesian cows (Le Neindre, 1989a). Salers calves has also been shown to have more social interactions than Friesian calves (Le Neindre, 1989b). The authors discuss this difference in terms of different selection pressures brought about by the different husbandry conditions. To minimise the influence of rearing conditions both Friesian and Salers calves have been brought up by Salers cows and still there are breed differences in the calves' behaviour (Veissier, Le Neindre & Trillat, 1989). There is a big difference in the breeding of beef and dairy breeds where the maternal behaviour is essential in beef cattle but not so essential in dairy cattle. To find breed differences when comparing two different dairy breeds is more surprising but also in this case there have been slightly different aims with the breeding of Swedish Red and Swedish Holstein. The Swedish Holstein population is, to a large extent, based on high yielding US imports (M. Håård, Svensk Avel, personal communication, 2006). Once in Sweden, the selection criteria applied in the breeding program for both breeds has been focused at both production and health status (M. Håård, Svensk Avel, personal communication, 2006). However, these different targets might have resulted in differences in behaviour between the two dairy breeds.

The effect of foster cow rearing system on the calf-human interaction

Keeping calves individually in small pens and feeding them milk with an open bucket or a teat bucket gives the farmer many opportunities for close contact with the calves and a good chance to check the health. With an increasing group size and more automatized feeding, or the use of foster cows, the opportunity for contact between the stockperson and the individual animal decreases. Both the frequency of contact with the stockperson and the housing has been shown to affect the propensity for calves to seek contact with an unknown person (Webster *et al.*, 1985; Lensink *et al.*, 2001). Even the presence of a stockperson during feeding has been shown to shorten the time taken for a calf to interact with an unfamiliar person (Jago, Krohn & Matthews, 1999). Calves housed in pairs took longer to load and unload during transport than individually housed calves, but when the pair-housed calves had been subjected to additional contact they became easier to load and unload (Lensink *et al.*, 2001). Besides the extra effort that has to be put in when handling less handled animals it also has an effect on the heart rate, where calves with additional contact had lower heart rate than non-handled calves

(Lensink *et al.*, 2001). To ease the handling and decrease the stress at handling for the animals later in life, it is important to make the calves used to human contact even when housing them in groups with foster cows where the daily routine does not involve feeding.

Methodological considerations

In the first study (Paper I) all calves were used four times when testing four cows from the different stages of lactation. This may have affected the results as a difficult cow may have been more successful in keeping the calves away from her if the calves were tested for the first time and thereby were young and inexperienced. If a difficult cow was tested with a group as that groups' fourth cow, the calves were older and had more experience, which may have led to the cow being less successful in keeping the calves away from her udder. This may have affected the interpretation of the results in such a way that more cows were considered accepting alien calves, than if all cows were tested with inexperienced calves. In the study I tried to compensate for this by testing the cows of different stages of lactation in a balanced order for each calf group and I also included the order of testing in the model.

The data in paper II was actually taken from the first study on foster cows conducted in Sweden, and that study was designed to investigate the differences in behaviour of calves raised either by foster cows or in groups of four feed milk with permanent teats or teat buckets. I used the video recordings made every week on the foster cow-calf groups to look at the attachment between cows and calves. If I was to design a study exclusively to investigate a possible attachment I would combine more frequent observations in the home pen with short separation tests to observe the reaction at separation and reunion of cow and calf. In the existing material I would like to analyse videos from every week and concentrate on the mornings and afternoons where most of the social interactions were concentrated.

In the third study (Papers III and IV) I would have liked to have more animals but there were practical constraints on the farm and we could only use four pens at a time. The number of cows used (6 in each treatment) were too small to detect the same differences as were found when analysing the behaviour of the calves. When you do studies on just one private farm, you always take the risk that this material is not representative for the population that you want to make inferences to (dairy cows in Sweden). Farms differ in the housing conditions and the management. If you in the model of your statistical analysis include "farm", this factor usually comes out as significant, meaning that there are either large differences in the husbandry routines or that there is a genetic difference between the animals at different farms. In Swedish dairy production, however, there are probably not large variations in genetic material between farms since most of the cows are inseminated with semen from the same company. A study conducted with the same design on a number of farms that shows no interaction between treatment and farm would suggest that the treatment effect is a general one. Nevertheless, I

do believe that the study on separation is reasonably representative since earlier studies on different farms in Canada have come to the same conclusion.

An evolutionary perspective

The results from the four papers included in this thesis point in somewhat different directions if one should try to explain them from an evolutionary point of view. The function of a mother-offspring attachment is, as pointed out in the introduction, to assure that enough resources are allocated to the offspring as opposed to alien young, and the absence of an attachment facilitate acceptance of alien young (Gubernick, 1981). One way of testing the presence of an attachment is to observe the reaction to separation between mother and young (Gubernick, 1981; Price *et al.*, 1986). The result from the first study (Paper I) showed that dairy cows easily accept alien young, even when taken directly from the own calf, and that would imply a low level of attachment between mother and offspring. In the second study (Paper II), the possible attachment between foster cow and calves seemed to change over time, and could support the idea of a reduced attachment in dairy cows. On the other hand, the results of the third study (Paper III-IV) were strong reactions to separation was observed do imply that there was an attachment between the foster cows and their calves. The switch in attachment between different calves that was observed in the second study might reflect that the foster cows attached to several of the calves. Since the social behaviours used as signs of attachment was unevenly distributed in time, observing the group for only 24 hours per week may result in an incorrect interpretation of the relationship within the group. Observing the animals during several consecutive days around the most active times of day may give a truer picture. If dairy cows have been subjected to a relaxed selection pressure on maternal behaviour, they may still attach to calves if given sufficient time to do so. The lower level of maternal behaviour can explain the readiness in which they accept alien young, but with time they do attach, as shown by the reactions at separation after 9 weeks of suckling.

Allosuckling is thought to occur when there is a low level of attachment or if the mothers living together are relatives; in these cases it is explained by kinship and inclusive fitness theories. If dairy cows have a lower level of attachment or if the attachment takes longer time to develop this might explain why they so easily accept alien calves. On the other hand, when discussing allosuckling in other ungulates the mother often has her own offspring as well and in this study all foster cows had been separated from their own calf before being introduced to alien calves. How the acceptance and possible attachment to alien calves would function if the foster cow is also allowed to keep her own calf has not been investigated in this thesis.

Future research

If I was to continue my research on foster cows I would like to concentrate my efforts in two directions. First I would like to continue investigating the possibility of foster cows to form an attachment with their foster calves. To do that I would

like to test the attachment with short and long separation tests to find out to which calves an attachment has been formed or if the reaction to separation only is evident when you remove all calves and not just only one. Possibly the formation of an attachment is confused by the fact that four calves were introduced simultaneously. It would be interesting to study the development of attachment if one calf or two calves at a time were introduced to the foster cow. In all studies involved in this thesis the foster cows were not allowed to keep their own calf. I would like to study the possibility to accept foster calves and the formation of an attachment to these calves in a case where the cow is allowed to keep her own calf in the group. One question that has been asked is if there is a difference in the strength of attachment between mother-calf and foster cow-foster calf. This needs further investigation. I would also like to conduct a study on group housing of foster cows and calves and look at the reaction of the cows when a small number of calves are weaned and separated. It is possible that in group housing the reaction to separation is reduced because of a lower level of attachment and if so, this type of housing would be preferred by farmers. In such a study, it is important to make sure that all cows in the group are suckled to prevent the cows from developing mastitis. This can be done by keeping each foster cow together with a few calves in a smaller enclosure for some days before introduction to the larger group.

Secondly, in the two studies where both the Swedish Red breed and the Swedish Holstein breed were used I found behavioural differences. To my mind this indicates that SR is more active and social than SH. I would like to continue to investigate these breeds and also include two old Swedish dairy breeds (Rödkulla and Fjällko) that are lower yielding than both SR and SH. My idea is that breeding for high milk production may be somehow linked to maternal behaviour. For this type of research both behavioural studies and genetic studies will be required.

Conclusions

In this thesis it has been shown that dairy cows can accept and probably also attach to alien calves that suckles them in a foster-cow system. Furthermore the problems with stress in both foster cows and calves at weaning and separation after a long period of suckling can be lowered by the use of a two-stage weaning procedure. The main conclusions drawn from each paper are:

- Cows of both Swedish Red and Swedish Holstein breeds can be used as foster cows.
- Cows can be used as foster cows during different stages of lactation, at least up till 6 months.
- Even if foster cows form a stronger attachment to one or two of her foster calves this does not affect the weight gain of the different calves in the group.
- Four foster calves suckling a foster cow do synchronise their suckling with increasing age.
- The use of a two-step weaning method reduces the behavioural stress response in foster cows both at weaning and at separation.
- The use of a two-step weaning method reduces the behavioural reaction in foster calves both at weaning and at separation, as well as the physiological reaction at separation.

Practical applications

Based on the studies in this thesis and results from previous research on foster cows and their calves the following practical applications may be recommended:

- To facilitate a successful introduction to the foster cow the calves need experience from suckling their own mother.
- Remove the cows own calf before introduction of the foster calves in order to get an even weight gain within the group.
- If you do not have time to observe the group after introduction, tie the cow during the first hours and if the calves still can't suckle change foster cow.
- To get the calves used to human contact spend time touching the calves for example when the pen is cleaned.
- To reduce stress at weaning and separation, let the cow and calves have contact without suckling a few days before the separation. The weaning with contact can be made by using a nose-flap or by putting the calves in a pen next to the cow with possibility to physical contact.

Svensk sammanfattning

Inom konventionell svensk mjölkproduktion tas kalven ofta bort direkt eller några timmar efter födelsen och placeras i en ensambox där den mjölkutfodras med hink. För kalven innebär detta att den inte får möjlighet att suga i sig mjölken, att den inte får kontakt med andra kalvar eller kor och att den inte har utrymme att springa, hoppa och leka. I studier på kalvar har man visat att dessa beteenden är något som kalvarna är mycket motiverade att göra. Inom ekologisk mjölkproduktion i Sverige har man försökt att gå ett steg längre för att försöka tillgodose delar av kalvarnas beteendebehov. Där måste kalven få suga i sig mjölken i en naturlig ställning och kalvarna får inte hållas ensamma längre än till en veckas ålder. För att tillgodose kalvarnas sugbehov kan man använda sig av olika typer av spenhinkar, fasta gummispenar eller gummispenar på automatiska ammor, s.k. kalvammor. Ett annat sätt är att låta kalven dia en ko, antingen den egna mamman eller en amma, en s.k. amko. Fördelarna med att använda sig av amkor är att kalvarna hålls i grupper, vilket tillfredsställer deras sociala behov, de får alltid mjölken i rätt temperatur och genom att suga i sig den, mjölken är av en god hygienisk kvalitet och kalvarna kan dia fler gånger per dygn vilket gör att de ofta har en bättre tillväxt. Dessutom har det framhållits att detta system sparar tid och arbete för lantbrukaren. I tidigare studier av amkohållning har man inriktat sig på tillväxten på kalvarna och mjölkproduktionen hos korna. Man har visat att tillväxten inte är beroende av kons mjölkproduktion, troligen för att mjölkkor producerar tillräckligt för 2-4 kalvar. Det verkar inte heller som att kornas mjölkproduktion efter att ha varit amko har påverkats negativt av detta. Man har däremot funnit att om kon får behålla sin egen kalv när hon ska dia 2-4 kalvar så ökar den egna kalven mer i vikt än de kalvar som inte är kons egna. I den här avhandlingen har jag fokuserat på beteendet hos amkor och kalvar, dels när amkogruppen bildas, under deras tid tillsammans och vid avvänjningen och separationen.

Syftet med avhandlingen var att undersöka vilka kor som kan användas som amkor, om amkor skapar ett band till en eller flera kalvar och om en två-stegsavvänjning kan minska stressen hos både amkor och kalvar när digivningsperioden är slut.

I den första studien (Artikel I) ville jag undersöka om det var någon skillnad mellan våra två vanligaste mjölkkoraser i deras benägenhet att acceptera främmande kalvar. Jag ville också undersöka om det var svårare för kor som togs direkt från sin egen kalv eller sent i laktationen att acceptera främmande kalvar än kor som var tidigt i laktationen men ändå hade haft möjlighet att glömma sin kalv. Här användes 24 kor av Svensk röd och vitbrokig ras och 24 kor av Svensk Holstein. Korna från de båda raserna användes som amkor antingen direkt, 4 dagar, 26 dagar eller 178 dagar efter separation från den egna kalven. Jag studerade beteendet hos både kor och kalvar under de första två timmarna och ytterligare två timmar när de varit tillsammans i 27 timmar. Om kon var snäll och lät kalvarna dia fick hon vara lös under hela testet, om hon inte var aggressiv men sparkade så att kalvarna inte kunde dia under de första två timmarna så bands hon

mellan de två observationerna och om kon var aggressiv och stångade kalvarna bands hon direkt och hölls bunden under hela testet. När den andra observationen var avslutad separerades gruppen. Jag fann inga skillnader mellan raserna eller de olika laktationsstadierna i hur väl korna accepterade att bli amkor. 39 av 48 kor kunde hållas lösa, 7 bands mellan observationerna och endast 2 kor hölls bundna under hela testet. Slutsatserna från denna studie är att kor av båda raserna Svensk röd- och vitbrokig och Svensk Holstein kan användas som amkor och att de kan användas både i tidig och sen laktation.

I den andra studien (Artikel II) ville jag undersöka om amkor skapade ett starkare band till någon av sina amkalvar och om detta band i så fall påverkade kalvarnas möjlighet att dia och därigenom öka i vikt. Här användes 7 amkor som hade fyra kalvar var. Dessa grupper filmades under 24 timmar vid tre olika tillfällen, när kalvarna var 2, 5 och 7 veckor gamla. Från filmerna registrerades alla sociala interaktioner mellan amkon och de olika kalvarna, samt alla digivningar med start- och sluttid. De kalvar som mottog och utförde flest vänliga sociala beteenden med amkon och dessutom fick dia ensamma ansågs vara de som hade starkast bindning till amkon. Vid alla observationer kunde en till två kalvar urskiljas som verkade ha en starkare bindning till amkon än de övriga i gruppen. Däremot verkade det som att det varierade vilken kalv som kon hade mest kontakt med. Det fanns ingen korrelation mellan att ha en stark binding till kon och kalvens viktökning. När kalvarna var 8 veckor skedde fler digivningar där alla kalvar deltog än när kalvarna var yngre vilket tyder på att de synkroniserade sitt digivningsbeteende med ålder. Slutsatsen från denna studie är att även om amkon binder starkare till en eller två av sina amkalvar så påverkar inte det viktökningen i gruppen.

I den tredje studien (Artikel III och IV) ville jag undersöka om avvänjningen och separationen kunde underlättas genom att dela dessa två händelser i tiden. Här ingick 12 kor som hade fyra amkalvar vardera. Grupperna fick vara tillsammans tills kalvarna var 10 veckor gamla då alla kalvar avvandes från mjölk. I hälften av grupperna avvandes kalvarna genom att de separerades från kon (kontroll) och resterande grupper avvandes kalvarna genom att en nosplatta av plast sattes i nosen och de fick stanna kvar hos kon i ytterligare två veckor innan de separerades från kon (två-steg). Nosplattan förhindrade digivning men kalvarna kunde äta fullfoder och dricka ur en vattenkopp. Både kor och kalvar observerades vid fyra tidpunkter efter avvänjning och separation. Dessutom mättes hjärtfrekvensen två timmar per dag under fyra dagar efter avvänjning och separation och salivprov för kortisolmätning togs under fem dagar. Observationerna av djurens beteende i samband med avvänjning och separation visade att kor och kalvar som avvandes med nosplatta men fick stanna hos varandra råmade mindre och var mindre aktiva än kalvar och kor som avvandes och separerades samtidigt. Även när två-stegsgruppen separerades råmade kor och kalvar mindre och var mindre aktiva än kontrollgruppen. Dessutom hade kalvarna som separerades två veckor efter avvänjning en lägre hjärtfrekvens och en lägre koncentration av kortisol i saliven jämfört med kalvar som avvandes och separerades samtidigt. Slutsatsen från denna studie är att två-stegs metoden vid avvänjning och separation minskar stressen för både amkorna och deras kalvar.

Med denna avhandling hoppas jag kunna öka kunskapen om hur amkor kan fungera i mjölkproduktionen och inspirera lantbrukare till att pröva amkosystem. Jag anser att detta är det bästa sättet för kalven att växa upp på om den inte kan få tillgång till sin mamma. Dessutom vittnar många lantbrukare som använder systemet om att det finns kor som trivs bättre som amkor än att vara med flocken och bli mjölkade, och därför används dessa kor endast som amkor. Det kan också vara ett sätt att minska antibiotika användningen då flera studier har visat att kor som blir diade har lägre celltal och färre mastiter. På en av de gårdar som ingått i dessa studier är det just kor med höga celltal som används som amkor. Kalvarna står för de täta urmjölkningarna som krävs för att komma till rätta med problemet.

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