Behaviours Related to Milk Intake in Dairy Calves

The Effects of Milk Feeding and Weaning Methods

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Abstract

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Dairy calves are usually raised by artificial milk feeding systems where their need to perform sucking is not fulfilled. This thesis investigated the effects of various milk feeding and weaning methods on the calves' behaviour, intake and weight gain.
In paper I calves were fed from an automatic milk feeder. It was found that gradual weaning over 14 days reduced the occurrence of cross-sucking immediately after weaning and it stimulated the calves to eat more concentrate during weaning compared to abrupt weaning. A high milk allowance (9.2 vs. 4.8 litres) reduced the number and duration of unrewarded visits and thus reduced individual calves' occupancy of the feeder.
In paper II calves were fed milk from teat-bars with either a common milk compartment for all teats or a separate milk compartments for every teat. The teat-bar design did not affect the variation in milk intake within the groups, but a teat-bar with separate compartments increased the teat switching while there was still milk left in one or more of the compartments. Gradual weaning over 10 days stimulated the calves to eat more concentrate during weaning as compared to weaning by diluting the milk. The occurrence of cross-sucking was low with this milk feeding system.
In paper III calves were fed from automatic milk feeders and it was found that a large portion size (2.0 vs. 1.0 litres) increased the mean duration of rewarded visits. In combination with a slow flow (300 vs. 600 ml/min) it increased the number and daily duration of visits where the calves did not drink milk even though they could. The treatments did not influence the percentage of calves performing cross-sucking, but a large portion size or a slow milk flow reduced the percentage of calves performing cross-sucking 60 min or more after a visit.
In paper IV calves were fed milk ad libitum from either one teat or five teats per group. Five teats per group increased the time manipulating the teats but lowered the time waiting for access to a teat, access to concentrate and the time eating concentrate. Five teats per group also increased the occurrence of cross-sucking directed towards the head of another calf.
The conclusion of this thesis is that calves should be fed milk in large portions to provide an out-let for their sucking motivation and they should be weaned gradually over 10-14 days to stimulate the concentrate intake and reduce cross-sucking after weaning.

Keywords: dairy calves, cross-sucking, behaviour, weaning, milk allowance, meal allowance, milk flow, feeding method, concentrate intake, weight gain

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”I may not have gone where I intended to go, but I think I have ended up where I needed to be.”
Douglas Adams

Contents

Appendix

Paper I-IV

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

I Nielsen, P.P., Jensen, M.B. & Lidfors, L. 2008. Milk allowance and weaning method affect the use of computer controlled milk feeder and the development of cross-sucking. *Applied Animal Behaviour Science*, *109*, 222-236.

II Nielsen, P.P., Jensen, M.B. & Lidfors, L. 2008. The effects of teat-bar design and weaning method on behaviour, intake and gain of dairy calves. *Journal of Dairy Science*. Doi:10.3168/jds.2007-0666.

III Nielsen, P.P., Jensen, M.B. & Lidfors, L. Effect of portion size and milk flow on the use of a milk feeder and development of cross-sucking in dairy calves. (Manuscript).

IV Nielsen, P.P., Häggström, L. & Thierfelder, T. Effect of teats-per-calf ratio on feeding behaviours, competitive behaviours and cross-sucking in group housed calves. (Manuscript).

Introduction

In the modern dairy production the majority of calves are separated from their dam within the first 24 hrs after birth. This type of management does not allow for any sufficient bonding to occur between calf and dam and furthermore, the calf is prevented from performing natural sucking behaviours. Various methods of feeding milk to the calves have been used and tested throughout the years, as discussed later, but there are problems with artificial milk feeding. One of the problems of artificial milk feeding of dairy calves is cross-sucking, due to an insufficient out-let of the sucking motivation. Another problem is variation in milk intake among group-housed calves due to competition for milk.

Natural suckling behaviours of calves

Under natural conditions the cows walk away from the herd before calving in order to isolate themselves from herd mates and to find an appropriate place to give birth (Lidfors *et al.*, 1994; von Keyserlingk & Weary, 2007). After birth the dam spends a significant amount of time licking the newborn calf (Edwards & Broom, 1982; Lidfors*, et al.*, 1994). One of the functions of this licking is to stimulate calf activity and thereby facilitate the first sucking attempt (Figure 1).

Fig 1. Cow licking her calf. (Photo: Per Peetz Nielsen)

When the calves are raised by the dam the majority of the suckling occurs during three periods of the day; early morning (5:00 – 8:00), midday (10:00 – 13:00) and late afternoon (16:00 – 20:00; Odde, Kiracofe & Schalles, 1985; Day *et al.*, 1987). In between these periods the calves lie in groups or 'crèche' whilst the cows are grazing (Vitale *et al.*, 1986; Sato, Wood-Gush & Wetherill, 1987; Phillips, 1993). After some time, one or two calves will start calling their dam, the dams will return and a suckling session, typically including all calves, will occur (Kilgour & Dalton, 1984).

Under semi natural conditions beef calves suckle their dam three to 11 times per day with a higher frequency when the calves are younger than three months (Wagnon, 1963; Hafez & Lineweaver, 1968; Sato & Wood-Gush, 1988; Paranhos da Costa *et al.*, 2006). The frequency of suckling is related to the cows stage of lactation and declines as lactation progresses (Vitale*, et al.*, 1986; Day*, et al.*, 1987) probably because the calf take larger meals as it grows older. The average duration of a suckling bout is about 10 minutes, and does not seem to decline with increasing age of the calf (Day*, et al.*, 1987) until late in lactation (Vitale*, et al.*, 1986). All in all the total suckling time sums up to around 40 - 60 minutes per day (Hafez & Lineweaver, 1968; Odde, Kiracofe & Schalles, 1985; Paranhos da Costa*, et al.*, 2006). The daily milk intake from free ranging beef calves varies, but it is often around 6 to 7 kg per day (Boggs *et al.*, 1980; Holloway, Worley & Butts, 1983; Ansotegui *et al.*, 1991) and together with the sucking frequency described above the natural meal size for beef calves can therefore be estimated to 1-2 kg per meal. Dairy calves have the ability to consume more milk than what is normally available in beef cattle and when they are fed whole milk *ad libitum* they consume from 8 to 14 litres per day (Appleby, Weary & Chua, 2001).

During a nursing bout the calf starts with performing non-nutritive sucking (sucking without receiving milk) interrupted by frequent teat switching and butting behaviour, which probably function as a pre-stimulation of the udder (Lidfors, Jensen & Algers, 1994). After about one minute the calf starts sucking the same teat for an extended time, and this is regarded as nutritive sucking (Lidfors, Jensen & Algers, 1994). During the nutritive sucking the butting behaviour increases towards the end of the session, and the nutritive sucking is replaced with another session of non-nutritive sucking (Lidfors, Jensen & Algers, 1994). The stimulation of the udder before milk let-down may be a type of begging behaviour as shown for pigs (Špinka & Algers, 1995). Stimulation of the udder after milk let-down by non-nutritive sucking and butting may serve as a regulation of future milk production (Algers & Jensen, 1985; Sederström, Mayntz & Sender, 2002) which is strengthened by the observations that butting increases with decreased milk availability (Hafez & Lineweaver, 1968; Haley *et al.*, 1998a; de Passillé & Rushen, 2006a). However, even *ad libitum* fed calves perform butting towards the teat supporting that butting is always a natural part of suckling (Appleby, Weary & Chua, 2001).

The natural weaning time in a semi wild herd varies from 7 to 14 months and male calves are nursed for a longer time than female calves (Walker, 1962; Sato & Wood-Gush, 1988; Reinhardt, 2002). This is substantially later than under commercial conditions where the weaning time varies from 6 to 10 weeks. Under natural conditions weaning is a gradual process where the cow allows the calf fewer and fewer meals over a period of time and thereby forces the calf to increase the intake of solid feed (de Passillé, Rushen & Weary, 2004; von Keyserlingk & Weary, 2007).

Motivation for sucking behaviour

Calves fed from bowls and buckets have been observed to perform apparently irrelevant feeding behaviours such as sucking on fixture or cross-sucking after a milk meal (Hammell, Metz & Mekking, 1988; Lidfors, 1993; Loberg & Lidfors, 2001) indicating that calves have a high motivation to perform sucking behaviour in relation to milk ingestion. Toates & Jensen (1991) describe this as a need, because the animal has to perform the behaviour that would normally lead to the goal, in this case ingestion of milk and elimination of hunger. In calves cholecystokinin (CCK), a hormone involved with satiety, and insulin increase more rapidly after milk feeding if the calves are allowed to suck on a dry rubber teat after ingesting milk from an open bucket (de Passillé, Christopherson & Rushen, 1993), suggesting that the performance of the behaviour has physiological consequences. According to the original Lorenzian motivation model the motivation levels are strengthened as a function of time since the behaviour was last performed for any behavioural pattern.
However, when examining how a simple feedback model fits with the motivation for sucking behaviour, de Passillé and Rushen (1997) discovered that sucking motivation does not only arise from the stimulation of hunger and sensory stimuli (seeing mother or watching other calves drink) but that it is also regulated via negative feedback from the ingestion of milk. They concluded that sucking motivation is affected by several negative and positive feedback loops (de Passillé & Rushen, 1997). In their model sucking motivation is affected by the stimulation of hunger and sensory stimuli as in the more simple feedback model. However, the sucking motivation is elicited from the ingestion or taste of milk (positive feedback loop) and sucking itself reduces sucking motivation (negative feedback loop). On the other hand there is no evidence that sucking motivation increases with time since it was last performed (de Passillé & Rushen, 1997). Some of the factors in this model are discussed separately below.

Taste of milk and its components

Several studies have shown the effect of the taste of milk on the sucking motivation in calves (de Passillé *et al.*, 1992; Rushen & de Passillé, 1995; Jung & Lidfors, 2001) and in a preference test it has been shown that calves prefer to suck on a teat which taste of milk rather than a clean teat (Jung & Lidfors, 2001). Whole milk and commercial milk replacer stimulate the non-nutritive sucking equally well and for a similar amount of time, and even 14 days after weaning 75 ml of milk replacer stimulates sucking behaviour (de Passillé, Rushen & Janzena, 1997). Lactose has been found to be the main ingredient in milk that stimulates sucking behaviour and removing it from the milk reduces the duration of non-nutritive sucking (de Passillé & Rushen, 2006b).

Prevention from sucking

Ad libitum fed calves that are prevented from drinking their milk through an artificial teat have a high motivation to suck on a dry teat after the meal, indicating that the sucking motivation is independent of satiety (Hammell, Metz & Mekking, 1988). Rushen & de Passillé (1995) found that when calves were prevented from

sucking after one feeding event this did not have a strong effect on the sucking behaviour during the following feeding events, suggesting that motivation to perform sucking behaviour does not build up over time.

Hunger

Hunger is a strong motivation for feeding and several experiments have shown that restrictively fed calves perform behaviours that can be associated with hunger; e.g. they spent longer time standing (De Paula Vieira *et al.*, 2008), had a higher rate of unrewarded visits to an automatic milk feeder (Jensen, 2006; Nielsen, Jensen & Lidfors, 2008) and vocalized more (Thomas, Weary & Appleby, 2001). Furthermore, Rushen and de Passillé (1995) found that when calves were deprived of a meal they would perform more non-nutritive sucking after the next meal, indicating that hunger can increase the calves sucking motivation. However, reducing the milk offered in one meal does not affect the occurrence of non-nutritive sucking after the meal as much as skipping a meal did (Rushen & de Passillé, 1995).

Social factors

As described earlier under natural conditions the calves lie in a 'crèche' while the dams are grazing and when the dams return to the group of calves the calves immediately start to suckle (Kilgour & Dalton, 1984; Phillips, 1993) which indicates that suckling behaviour may be subject to social facilitation.

Non-nutritive sucking

Non-nutritive sucking occurs both under natural and artificial conditions when the calves are not reared with their mother or a foster cow (a cow taken out of production; Loberg et al., 2007), they may direct a considerable level of non-nutritive sucking towards for instance objects in the pen (de Passillé, et al., 1992). It is mainly performed in relation to a milk meal where the calf is not provided with a teat to serve as outlet for sucking motivation (Jung & Lidfors, 2001). The performance of non-nutritive sucking on a dry teat reduces the sucking motivation (de Passillé, 2001). The level of non-nutritive sucking is related to the meal allowance (De Paula Vieira, et al., 2008), the flow with which the milk is delivered (Jung & Lidfors, 2001) and the time since the last meal (de Passillé & Rushen, 1997). Non-nutritive sucking can be reduced by prolonging the meal by a low milk flow and by providing hay right after the milk meal (Haley et al., 1998b). Even small amounts of milk can stimulate non-nutritive sucking on a dry teat suggesting that it is a rather inflexible response (Rushen & de Passillé, 1995). It is, however, not a consistent response since preventing the calves from sucking on a dry teat after a meal for as little as 10 min reduces the occurrence of sucking and butting (de Passillé, et al., 1992). This is because the motivation declines spontaneously 10-15 minutes after the milk meal (Rushen & de Passillé, 1995).

Abnormal behaviours in calves

When animals are not able to perform a normal behaviour for which they are motivated, they may start to perform abnormal behaviours which are behaviour patterns from the normal behavioural repertoire that are performed inappropriately (Fraser & Broom, 1997). This could either be performances of normal behaviours that differ in form or frequency from the normal occurrence, behaviours that do not occur under natural conditions or natural behaviours that the animal redirected towards itself, pen mates or the environment (Fraser & Broom, 1997).
The occurrences of abnormal behaviours in animals are regarded as an indication of poor welfare (Wiepkema, 1985). Others, however, suggest that the performance of abnormal behaviours may also have some beneficial effects on the animals although clear evidence is lacking (Duncan, Rushen & Lawrence, 1993; Mason & Latham, 2004). Wiepkema et al. (1987) found that veal calves performing tongue-rolling had no abomasal damage whereas the calves that did not perform tongue-rolling all had ulcers or scars. On the other hand, the occurrences of abnormal behaviours may be seen as evidence that the animals may have experienced negative feelings at some stage and the occurrence of abnormal behaviours should always be taken as an indication that the welfare of the animal is jeopardized (Duncan, Rushen & Lawrence, 1993).

Cross-sucking

Cross-sucking is defined as sucking on ears, tail, prepuce, udder area and other body parts of another calf (Figure 2; Haley*, et al.*, 1998b; de Passillé, 2001) and it is a redirection of the calves' normal sucking behaviour. Cross-sucking mainly occurs within the first 10 minutes after a milk meal (Lidfors, 1993; Margerison *et al.*, 2003) and is related to the milk feeding method (Jensen, 2003). When calves are fed milk from an open bucket they perform more cross-sucking (Hoyer & Larkin, 1954; Jensen & Budde, 2006) and especially prepuce sucking (de Wilt, 1987) than calves fed milk from a teat bucket. This effect of feeding method is mainly related to a prolonged meal and an out-let of the calves' sucking behaviours both through the ingestion of milk and the performance of non-nutritive sucking after the meal (de Passillé, 2001). This has been shown in single housed calves fed with teat buckets (Veissier *et al.*, 2002) and in group housed calves (Jensen & Budde, 2006). When the calves are fed milk from a computer controlled milk feeder the time they perform non-nutritive sucking after a meal can be prolonged by closing the rear end of the feeder with a gate and thereby preventing other calves from displacing the calf occupying the feeder (Weber & Wechsler, 2001). As a consequence of this, the calves fed by the modified feeder performed less cross-sucking compared to the calves with a non-modified feeder (Weber & Wechsler, 2001). Allowing artificially reared calves to suckle their dam or a nurse cow for 15 minutes after milking reduces the occurrence of cross-sucking compared to calves that did not have the opportunity to perform natural sucking behaviours (Margerison, Phillips & Preston, 1999; Margerison*, et al.*, 2003).

a)  b) 

Fig 2. Calves performing cross-sucking by sucking the prepuce of another calf. a) Paper I; b) Paper III (Photo: Per Peetz Nielsen)

Inter-sucking

Inter-sucking is an abnormal oral behaviour seen in heifers and cows and it is defined as a heifer or cow sucking the udder region of another heifer or cow with the purpose to drink milk (Keil, Audige & Langhans, 2001). Inter-sucking has been found to be highly related to the occurrence of cross-sucking in calves (Keil & Langhans, 2001) and even though the occurrence of cross-sucking and inter-sucking declines with the age of the animal (Maity & Tomer, 1998) it is still of high importance to prevent the development of cross-sucking in calves. If the behavioural problem is not solved, inter-sucking can lead to increased risk of mastitis, udder damage, milk loss or culling of otherwise healthy animals (Sambraus, 1985; Keil, Audige & Langhans, 2000). There are several ways to prevent the animal from sucking, the most commonly used is putting a bull ring in the nose of the sucking animal (Lidfors & Isberg, 2003). However, up to 20% of farmers asked in a survey in Sweden was sending the inter-sucking animal to slaughter (Lidfors & Isberg, 2003).

Other abnormal behaviours

Dairy calves may also engage in other abnormal oral behaviours, such as tongue-rolling, where the animal is curling and uncurling its tongue inside or outside the mouth with no solid material present (Sambraus, 1985; Redbo, 1992), excessive licking of itself, another calf or fixture and bar biting where the animal opens and closes its mouth around fixtures in the pen (Fraser & Broom, 1997). All these abnormal behaviours are seen as being related to an insufficient feed provision or an insufficient stimulation and outlet of feeding behaviours (Sambraus, 1985; Sato, Nagamine & Kubo, 1994; Redbo & Nordblad, 1997). Furthermore, when heifers are fed a short cut silage, especially when harvested at an early maturity stage, they perform more excessive licking of fixtures than when they are fed a long and late harvested silage (Gustavsson, 2007; Lidback, 2007).

Housing and management of calves

In commercial milk production, calves are a necessity to maintain the milk production, both by initiating new lactation periods and by replacing culled cows (Lawrence *et al.*, 2005). On most dairy farms, the calf is removed from the dam within the first 24 hrs after birth and moved to a single pen. The producers justify

this early separation by economical considerations and by the stress inflicted by separation of the cow and calf once they have bonded (Flower & Weary, 2003). Studies show that separation within the first 24 hours is associated with less stress related behaviours of both the calf and the dam as compared to separation after several days or weeks (Lidfors, 1996; Weary & Chua, 2000; Stěhulová, Lidfors & Špinka, In Press, Corrected Proof). However, a later separation may reduce the medical treatment of the calves for diarrhoea (Weary & Chua, 2000).

Dairy calves are often housed in single pens or hutches during the entire milk feeding period but some calves are moved to group pens or hutches at the age of about two to four weeks. Calves that are introduced to the milk feeder at an earlier age (six days) than at two weeks have more difficulties in getting access to the milk feeder and they consume less milk during the first two weeks after introduction (Jensen, 2007). Group housing enables the calves to develop and perform social behaviours (Chua *et al.*, 2002; Bøe & Færevik, 2003) and it may improve the calves' overall welfare by enabling them to perform a larger part of their behavioural repertoire e.g. lying on the side, social interactions and play (de Wilt, 1986; Jensen, Vestergaard & Krohn, 1998; Chua*, et al.*, 2002). However, group housed calves perform more abnormal oral behaviours in the form of cross-sucking than individually housed calves (Veissier, Ramirez de la Feb & Pradel, 1998; Babu, Pandey & Sahoo, 2004). Even though group housing has a positive effect on the calves' behaviours, a large group size increases the competition for access to a computer controlled milk feeder amongst the calves (Jensen, 2004). However, some of the competition may be overcome by increasing the teat per calf ratio (von Keyserlingk, Brusius & Weary, 2004a). In groups of 15 calves (Stephens, 1974) the lighter subordinate calves were disturbed more often when drinking and as a consequence of this they used less time drinking than heavier dominant calves. They compensated for this lower milk intake by eating more solid feed but even in total they had a lower daily weight gain (Stephens, 1974). Several studies have examined the effect of housing on calves' health and even though group housing may have a beneficial effect on the calves' health (Kung Jr *et al.*, 1997; Terré, Bach & Devant, 2006) a large group size has the opposite effect (Maatje *et al.*, 1993; Svensson *et al.*, 2003). Svensson & Liberg (2006) suggest a maximum group size of 10 calves from a health and growth perspective.

Milk feeding methods

Types of feeding

There are a number of ways to artificially feed milk to calves during the milk feeding period. These range from feeding in a simple common trough or separate bowls to a more technically complicated computer controlled milk feeder where the calves drink milk through an artificial teat (Figure 3). In between there are different teat based buckets, either single buckets or common teat-bars, where the teats are connected to either a shared milk compartment or each teat is connected to a separate compartment. Finally, there is simple bucket with a floating nipple as described in Loberg & Lidfors (2001). The teat-based system allows the calves to perform natural sucking behaviours and provide an outlet for the suckling motivation. Additionally, teat based systems have been found to reduce the risk of

diarrhoea compared to when they are fed milk from a bucket without a teat (Wise & LaMaster, 1968; Perez *et al.*, 1990). Despite these advantages of using teat based systems for milk feeding only around 20% of the farmers in Sweden used teat based systems in 2001 and 75% of the calves were fed milk from a bucket without a teat (Pettersson, Svensson & Liberg, 2001). However, as described earlier, calves may want to drink at the same time due to social facilitation and a higher ratio of teats per calf will reduce the competition of getting access to a teat and increase the individual milk intake in *ad libitum* fed calves (von Keyserlingk, Brusius & Weary, 2004a).

Fig 3. Calf drinking milk from an automatic milk feeder (Calvex) while another calf is standing waiting to get access to the milk feeder. The automatic concentrate feeder is visible in the upper part of this picture. Paper I (Photo: Per Peetz Nielsen)

When calves are fed milk from a computer controlled milk feeder they show the same diurnal milk feeding pattern as under natural conditions and have the majority of their meals in the early morning and late afternoon (Ferrante *et al.*, 1991; Jensen & Holm, 2003). It is therefore of high importance that the calves are given the opportunity to get access to the milk feeder when they are motivated to ingest milk.

Milk allowance

During the milk feeding period the calves can be fed with whole milk, commercial milk replacer or a mixture of the two. The daily milk allowance varies a lot among countries. In North America it is common to feed the calf 10% of its bodyweight in milk every day which means that a 40 kg calf gets 4 litres of milk per day (Jasper & Weary, 2002), whereas calves in Europe, and especially calves in Scandinavia, receive a slightly higher milk allowance ranging from 4 to 7 litres per day from birth until weaning (Pettersson, Svensson & Liberg, 2001).
The daily milk allowance influences the calves' behaviour and it has been shown that increasing the daily milk allowance increases nutritive sucking (Jensen, 2006) and consequently reduces the occurrence of cross-sucking (Nielsen, Jensen & Lidfors, 2008). Even though a higher milk allowance fed from a computer

controlled milk feeder increases the time the calves' spend on visits where they receive milk, the total occupation of the milk feeder is lower mainly due to a lower occurrence and duration of visits where the calves are not receiving milk (Hammon *et al.*, 2002; Jensen & Holm, 2003). These are an indication of hunger and will increase the competition for access to the feeder, other things being equal. Furthermore, a high milk allowance also reduces the competition for getting access to the milk feeder and thereby reduces the number of times the calves will have to wait for access to the milk feeder (Jensen & Holm, 2003).
Solid feed intake is highly related to milk intake and calves receiving a low daily milk allowance are eating more solid feed than calves receiving a high daily milk allowance, both when they suckle a dam (Ansotegui*, et al.*, 1991) and when fed artificially (Jensen, 2006; Huuskonen & Khalili, 2008; Nielsen, Jensen & Lidfors, 2008). However, this difference in solid feed intake between high and low milk allowance is rapidly eliminated within the first weeks after weaning (Jasper & Weary, 2002; Nielsen, Jensen & Lidfors, 2008).

Portion size

When calves receive their daily milk allowance in many small portions from a computer controlled milk feeder, they occupy the milk feeder for a longer time per day than when they get fewer and larger portions (Jensen, 2004). This is mainly due to a prolonged duration of milk intake and of non-nutritive sucking after a milk meal (Jensen, 2004).

Milk flow

The flow with which the milk is delivered to the calf has a profound influence on its sucking behaviour (Jung & Lidfors, 2001; Loberg & Lidfors, 2001). Calves fed milk with teat buckets with a reduced flow reduced non-nutritive sucking after a milk meal (Jung & Lidfors, 2001) and a slow milk flow reduced cross-sucking in bucket fed calves (Loberg & Lidfors, 2001). Reducing the milk flow in a computer controlled milk feeder results in a longer duration of visits where the calves consume milk (Jensen & Holm, 2003) and does thereby increase the probability of the calf getting a sufficient outlet of its sucking motivation.
A sudden drop in milk flow increases the occurrence of butting towards artificial teats (Haley*, et al.*, 1998a) and under natural conditions calves are observed butting the udder towards the end of the milk feeding phase of the suckling bout when the milk flow presumably drops (Hafez & Lineweaver, 1968; Lidfors, Jensen & Algers, 1994).

Weaning

The recommended time for weaning calves off milk varies a lot. Some argues that with excellent calf management calves can be weaned as early as at four to five weeks of age (Hill, Aldrich & Schlotterbeck, 2005) whereas others suggest that weaning should occur much later in life and in accordance to the calf's concentrate intake (Roth *et al.*, In Press, Corrected Proof). The median age of weaning in Sweden is eight weeks (Pettersson, Svensson & Liberg, 2001).

Weaning should induce as little stress for the calf as possible and it is therefore important that the weaning procedure mimic the natural weaning as much as possible. Weaning can be performed in several ways; abrupt weaning where the calf is weaned off milk from one day to another without an acclimatization period, gradual weaning where the calf is gradually weaned off milk by gradually reducing the milk allowance over a period of time and water weaning where the calf is weaned by gradually diluting the milk with water over a period of time.
Abruptly weaned calves at about 10 weeks of age show an increased stress response (e.g. higher frequency of calls, standing with head out of pen and more movements) immediately after weaning (Jasper, Budzynska & Weary, In Press, Corrected Proof). This stress response was reduced by allowing the calves to drink warm water from the teat system the first three days after weaning (Budzynska & Weary, In Press, Corrected Proof).
Gradual weaning can be performed by either reducing the number of portions per day and maintaining the same portion size, by reducing the portion size and maintaining the same number of portion, or a mixture of both (Jensen, 2006). Weaning by reducing the portion size resulted in a lower number and daily duration of unrewarded visits to the milk feeder compared to reducing the number of milk portions (Jensen, 2006). When the calves are fed milk from a computer controlled milk feeder, that also monitors their concentrate intake, weaning can be performed in accordance with the calves individual concentrate intake. This type of weaning has been shown to reduce the occurrence of cross-sucking compared to calves gradually weaned over a period of three weeks beginning at eight weeks of age (Roth*, et al.*, In Press, Corrected Proof). However, almost 50% of the farmers in Sweden used age as the criteria for weaning time and only about 20% used concentrate intake as the criteria (Pettersson, Svensson & Liberg, 2001).
Weaning the calves by gradually increasing the dilution of the milk offered with water enable the calves to slowly adapt to the lower level of energy from the milk by increasing the intake of solid feed (de Passillé, Rushen & Weary, 2004; Jasper, Budzynska & Weary, In Press, Corrected Proof). With this weaning procedure the calves remain on the same duration of nutritive sucking whilst they are encouraged to switch to a solid feed based diet.

After weaning

When the calves are weaned they are exposed to new types of challenges. During the milk feeding period the calves are normally fed with hay *ad libitum* and a calf starter concentrate, but after the weaning most calves are moved to another pen and are fed another concentrate type and often also silage. In addition to this change in diet the calves are also regrouped and might have to settle in a totally new group of animals and find their place in the social hierarchy. The management of the calves during the milk feeding period can ease this transition for the calves and it is, therefore, of a high relevance to find the appropriate housing, milk feeding and weaning method for the calves.

Motivation for this thesis

As outlined the method with which the milk is being fed to the calves has a profound effect on calves' behaviours and especially on the development of cross-sucking. Furthermore, the weaning method influences the level of stress the calf is exposed to due to a change in diet and does thereby affect the calf's behaviour. However, further research is needed in order to be able to describe the influence of milk feeding method, milk allowance, feeding frequency, milk flow, and weaning method on the calves' behaviour. The present thesis is a contribution to a more thorough understanding of the effects of milk feeding and weaning methods on calves' behaviours and especially the development of cross-sucking.

Aim of thesis

The aim of this thesis was to study the effects of different milk feeding and weaning methods on behaviour, feed intake and weight gain of dairy calves during and immediately after the milk feeding period. For the studies conducted, the following questions were aspired to be answered:

- How does the interactive effect of milk allowance (high or low) and weaning method (abrupt or gradual) affect the development of cross-sucking, use of milk- and concentrate feeder and energy intake in dairy calves fed milk via an automatic milk feeder?

- How do feeding group-housed dairy calves manually from a teat-bar with either a shared milk compartment or from separate milk compartments affect the competition for milk and the development of cross-sucking?

- How does weaning the calves by either gradual weaning or by gradually diluting the milk with water affect their behaviour and concentrate intake?

- How does the interaction between milk flow (high or low) and milk portion size (large and small) affect the use of a computer controlled milk feeder and the development of abnormal oral behaviours, such as cross sucking, in dairy calves?

- To what extent does the number of teats per calf (one teat per calf or one teat per five calves) affect the competition for access to the teat and the occurrence of competitive interactions and abnormal oral behaviours?

Materials and method

Paper I

The study was carried out at the Danish Cattle Research Centre at Foulum. Seventy-two dairy calves (29 Holstein-Friesian, 28 Danish Red and 15 Jersey) were divided into six blocks of 12 calves. Each block was divided into two groups of six calves of mixed breed and sex and the two groups were placed in each their pen in the same barn. Each pen was equipped with one milk feeder with one teat and one concentrate feeder, both of which were connected to a central computer controlled milk feeder (H&L100, Germany). The daily milk allowance was given on block level, and each block of calves was assigned to either a high milk allowance (9.2 l/day for heavy breeds and 7.2 l/day for Jersey) or a low milk allowance (4.8 l/day for heavy breeds and 3.6 l/day for Jersey). The daily milk allowance was given on a 12 hrs schedule with half the allowance available during each 12 hrs period. The calves could consume the 12 hrs milk allowance in at least two meals with a minimum of a 30 minute interval between each meal. When the youngest calf in each block was 42 days old one of the groups were assigned to gradual weaning from day 42 to 55 or while the other group were assigned to abrupt weaning at day 55. During the gradual weaning, the portion size and number of meals were gradually reduced until the last day of weaning where each calf received one portion of 0.4 litres per 12 hrs period (see Paper I for more details). All calves were weighed every second week throughout the experiment.
The computer controlled milk and concentrate feeder continuously recorded the calves' use of the feeders. The number and duration of all visits and the milk and concentrate intake for each calf were recorded (Table 1).
Behavioural observations were performed using one-zero sampling with 30 sec interval when the youngest calf in the block was 41 days old (before weaning), 48 and 55 days old (during weaning) and 56 and 59 days old (after weaning) all recording were made from 7.00 to 11.00 am and from 5.00 to 9.00 pm (Figure 4).

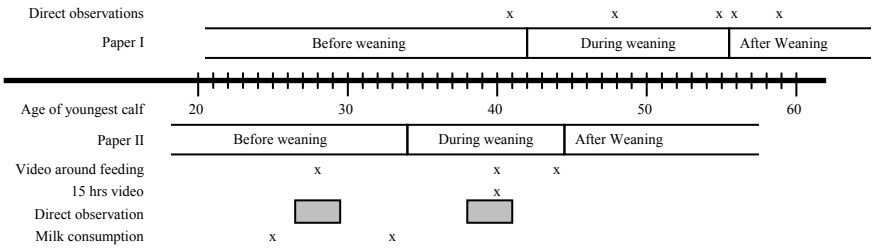

Fig 4. Time plan illustrating the time for weaning treatment, behavioural observations and milk consumption during the milk feeding period for paper I and II. The symbol 'x' mark when the observation or measure were made on the exact day whereas the gray square mark when the observations were made over several days (here two groups per day).

Paper II

This study was carried out at the University of Aarhus research farm in Foulum, Denmark. Forty-eight Holstein-Friesian calves, two blocks of 24 calves, were used. Each block was divided into six groups of four calves; three groups were fed from a teat-bar with four teats connected to a shared compartment (distance from the tip of teat to neighbour tip of teat = 13 cm; Figure 5) and three groups were fed from a teat-bar with four teats connecting each to a separate compartment (distance from the tip of teat to neighbour tip of teat = 18.5 cm; Figure 5). All calves received six litres of milk per day served in two meals. When the youngest calf in each block was five weeks old the weaning procedure were initiated. Half of the groups were weaned by gradual reducing the milk offered (weaning by volume reduction (WVR)) and the other half were weaned by gradually reducing the milk offered, while adding water to a total daily volume of six litres per calf (weaning by dilution (WD)).
Behavioural observations during 30 minutes after morning milk feeding were conducted once before weaning and once during weaning (Figure 4) using instantaneous sampling with 30 sec interval. From these observations the number of teat switches each calf performed, both when there was milk in the teat and when it was empty, were calculated.
The daily concentrate consumption per group was recorded on a group level from the day before weaning was initiated and until seven days after weaning was completed. During this period fresh concentrate was provided every morning and afternoon. Every morning the concentrate leftovers were weighed and disposed (Table 1).

a)  b) 

Fig 5. Calves drinking from a teat-bar with separate compartments (a) and from a teat-bar with a shared compartment (b). (Photo: Per Peetz Nielsen)

Twice during the milk-feeding period each calf's milk intake was estimated by weighing the calves immediately before and immediately after milk feeding (Figure 4). The difference between the two weight measures was used to estimate the volume ingested. Furthermore, the animals were weighed at the start of the experiment, three days before weaning was initiated and at the end of the experiment.

Paper III

Forty-eight calves (43 Holstein-Frisian and 5 Swedish Red) on a private farm in the South-western part of Sweden were used in this experiment. After birth the

calves were housed in individual pens until the age of approximately 14 days when they were allocated to a group pen with a computer controlled milk feeder (SM1 Alpro, Sweden). The calves were divided into three groups of ten calves each and two groups of nine calves each. The calves had free access to water from a water bowl and they were fed a mixture of silage and concentrate ad libitum from a crate. The calves received 8.0 litres of whole milk per day delivered according to the treatment plan. The calves were exposed to two different milk portion size treatments (two litres per meal or one litre per meal) and two different milk flow rates (300 ml per min or 600 ml per min) in a full cross over design and a total of four different treatments over the four week experiment. The milk flow was controlled by a vacuum controlled pump activated by the vacuum the calf produced while sucking on the teat (Figure 6).
A stand alone computer recorded the calves' use of the milk feeder in four different types of visits. Rewarded visits, unrewarded visits, rewarded visits where the calf did not drink and rewarded visits were the calf did not finish the portion. The duration of each of these visits were decoded from video recordings the last two days of each treatment. From these video recordings the occurrence and duration of cross-sucking was also recorded (Table 1).

a)  b) 

Fig 6. Vacuum switch (in dark gray) and pump (a) controlling the milk flow from the automatic milk feeder (b). (Photo: Per Peetz Nielsen)

Paper IV

Fifteen calves on a private farm in the Eastern part of Sweden were used in this experiment. The calves were divided into three groups of five calves that were moved to individual straw bedded pens immediately after birth and fed 3-4 litres of milk through teat buckets twice a day. When five calves were approximately 9-17 days old they were moved to a straw bedded experimental pen (5 x 5 m). In the experimental pen the calves had free access to water, hay and a commercial concentrate. The calves were fed acidified milk *ad libitum* from an artificial teat feeding system (Öjeby amman, Sweden). The calves were exposed to two different milk feeding treatments (competition or non-competition for access to a teat providing milk). The first 14 days of the experiment the five calves in each group had access to one teat providing milk; whereupon they had access to five

teats providing milk for 14 days when the experiment ended. The first six days of the experiment were assigned for the calves to acclimatize themselves to the treatment. Video recording were performed for 24 hrs at day 7, 13 and 14 and direct observations were performed from 8.00 to 12.00 am and from 3.00 to 7.00 pm on day 13 and 14. Instantaneous sampling with five min intervals were used to record behaviours from the video recordings and continuous sampling were used to record frequency and duration of manipulating the teat from the video recordings. One-zero sampling with 30 sec interval were used to record the behaviours through the direct observations (Table 1).

Table 1: Overview of the experimental design of the four studies.

Paper	Breed[1] and no. of calves	Milk feeding method	Milk allowance (litres/day)	Weaning method and age	Recordings
I	HF 29 DR 28 J 15	Computer controlled milk feeder (Calvex)	9.2 vs. 4.8 9.2 vs. 4.8 7.2 vs. 3.6	Gradual from 6 to 8 weeks Abrupt at 8 weeks	Behaviour, milk and concentrate intake
II	HF 48	Teat-bars Shared vs. separate milk compartments	6.0	From 35 to 45 days of age. Gradual weaning and weaning by diluting with water	Behaviour, concentrate intake and individual milk intake
III	HF 43 SR 5	Computer controlled milk feeder (SM1 Alpro)	8.0 1 or 2 L/portion 300 or 600 ml flow	Stopped before weaning	Use of milk feeder and cross-sucking
IV	SHF 15	Öjeby amman. One teat or five teats per group of five calves	*Ad libitum*	Stopped before weaning	Behaviour

[1] HF=Holstein-Friesian; DR=Danish Red; J=Jersey; SR=Swedish Red; SHF=Swedish Holstein-Friesian

Statistical analysis

When recording the behaviour of animals, the observed processes are rarely normal distributed. Instead, data is typically counts of the number of behavioural occurrences within a predefined period of time and is therefore an integer ranging from zero to principal infinity. Another common method is to register whether or not behaviours occur along an equidistant timeline where the proportion of occurrences is continuously distributed within the interval (0, 1) and a direct estimate of the probability for the behaviour to occur. Since a random process generating any positive integer may be approximated with a Poisson distribution, and since the corresponding proportion may be regarded as estimating the probability parameter of a binomial distribution, the characteristics of these distributions are utilised in the statistical analyses of animal behaviour performed below.

Paper I

The behaviours recorded from the direct observations were analysed using a log-linked generalized linear model in SAS® 9.1 (PROC GENMOD, SAS Institute Inc., Cary, NC, USA) where the data collected on different days were separately analysed. The data collected for each calf per day were counted and represented with a number from 0 to 960 (theoretically) and assumed to be approximately Poisson distributed. Within-calf correlation structures were estimated using the quasi-likelihood method, where an autoregressive correlation structure was used as the subject in the repeated statement of GENMOD. Least-square means of significant fixed effects were computed and the PDIFF procedure was used to specify the difference of the least-square means.

The data from the automatic milk and concentrate feeder (type, duration and number of visits), the daily energy intake and weight gain were analysed using a variance component analysis procedure in SAS® 9.1 (PROC MIXED) with the COVTEST option. The general Satterthwaite approximation was used to calculate the correct denominator degrees of freedom and the solution option was used to compute parameter estimates for the fixed effects. The least-square means and PDIFF procedures were used as described above.

The proportion of bull or heifer calves performing cross-sucking and the proportion of all cross-sucking performed by either bull or heifer calves before weaning was analysed as described in Paper III. This analysis was performed after the paper was accepted for publication and the results are therefore only presented in this thesis.

Paper II

The behaviours recorded during direct observations and from the video recordings were analysed using a logit linked generalized linear model in SAS® 9.1 (PROC GENMOD). The data were grouped with respect to day of recording and presented as the proportion of behavioural occurrences to the total number of trials, hence estimating the probability parameter of a binomial distribution. Least square means of significant fixed effects were computed and the CI procedure was used to generate 95% confidence intervals.

Latency, concentrate intake, weight gain and milk intake were analysed using a variance component analysis procedure in SAS® 9.1 (PROC MIXED) as described above under Paper I. Residual milk was analysed using an analysis of variance procedure in SAS® 9.1 (PROC ANOVA). The MEANS procedure was used to compute means of the response variable.

Paper III

The duration and number of visits to the milk feeder were analysed using a variance component analysis procedure in SAS® 9.1 (PROC MIXED) as described above under Paper I. The data was grouped with respect to treatment and gender, and presented as the proportion of cross-sucking occurrences to a logit-linked binomial model in SAS® 9.1 (PROC GENMOD). The number of calves receiving and performing cross-sucking within each gender were analysed using a logit-linked binomial model in SAS® 9.1 (PROC GENMOD) as described above.

Paper IV

The behaviours recorded during direct observations and video recording were analysed using a generalized mixed model in SAS® 9.1 (PROC GLIMMIX). These responses were presented as either the count or the proportion of behaviours, and were represented with log-linked Poisson and logit-linked binomial models respectively. The models account for correlation structures within the nested interaction of calf individuals within groups, where correlation strength was estimated via the variance components of a mixed model. Least square means of the fixed effects were computed and the CI procedure was used to generate 95% confidence intervals.
The duration and number of milk meals were analysed using a variance component analysis procedure in SAS® 9.1 (PROC MIXED) as described under Paper I above.

Summary of results

Milk allowance and weaning method, Paper I

Milk allowance did not have any effect on the frequency of cross-sucking before, during or after weaning. During weaning, the calves being gradually weaned had a lower frequency of cross-sucking than calves on an unchanged milk allowance. This difference, however, was not present the day before all calves were weaned. The first day after all calves had been weaned, the abruptly weaned calves had a higher frequency of cross-sucking compared to the gradually weaned calves. Four days after weaning, there was no difference in frequency of cross-sucking between the two weaning methods. The proportion of bull- or heifer calves performing cross-sucking did not differ, however, in total more cross-sucking was performed by bull calves than by heifer calves (Table 3).

Before weaning the calves on the low milk allowance had a higher duration and frequency of unrewarded visits to the milk feeder as well as a higher total occupation of the milk feeder compared to calves on the high milk allowance. However, the calves on the low milk allowance were eating twice as much concentrate as the calves on the high milk allowance, but they still only consumed around 66% of the energy that the calves on high milk allowance were consuming (Day 28: 31.1 ± 3.1 vs. 20.6 ± 1.4 MJ/day, $F_{1, 24} = 10.2$, $p < 0.01$; Day 41: 29.9 ± 1.5 vs. 21.3 ± 1.5 MJ/day, $F_{1, 42} = 18.4$, $p < 0.001$, High vs. Low milk allowance respectively). The milk allowance did not affect the number or duration of rewarded visits (Table 2). During the gradual weaning, the calves being gradually weaned had, due to the reduced milk allowance, a lower duration and number of rewarded visits than the calves not being weaned. Furthermore, they had a higher frequency of unrewarded visits and tended to have a higher total duration of unrewarded visits than calves not being weaned. The lower milk intake of the gradually weaned calves gave a higher concentrate intake during the weaning period compared to not weaned calves. After weaning, the abruptly weaned calves had a higher frequency and duration of unrewarded visits compared to the gradually weaned calves. The frequency and duration of these unrewarded visits decreased with time after weaning. All calves increased their concentrate intake after weaning. Before weaning was initiated, the calves on a high milk allowance had a higher total energy intake than calves on a low milk allowance. The first seven days after weaning the calves previously given a high milk allowance, independent of weaning method, had a lower concentrate intake than the calves previously given a low milk allowance. The abruptly weaned calves, independently of milk allowance, had a lower concentrate intake than gradually weaned calves. Before weaning was initiated, the calves on a high milk allowance had a higher daily weight gain than the calves on a low milk allowance.

Teat-bar design and weaning method, Paper II

The occurrence of cross-sucking was very low in this study, and there were no differences between the calves fed milk in a separate compared to calves fed milk in a shared compartment teat-bar. Throughout the experiment, the calves with the

separate compartment teat-bar were switching between teats more often while there was still milk in the teat-bar compared to calves fed with a shared compartment teat-bar. The duration of ingesting milk within the group was longer in groups fed with the separate compartment teat-bar but there was no difference in milk intake between the two teat-bar designs (Table 2). Calves fed via a separate compartment teat-bar started eating concentrate after milk feeding later than calves fed with a shared compartment teat-bar. During weaning, the WD (weaning by dilution) calves had a lower concentrate intake than WVR (weaning by volume reduction) calves even though they tended to spend more time on eating concentrate the first 30 min after milk feeding. The WD calves had a shorter latency to lie down after milk feeding. However, they were lying down less both during the first 30 min after milk feeding and during the light hours. During the weaning period, the WD calves fed milk from a separate compartment teat-bar tended to perform more cross-sucking than any other calves. During the first seven days after weaning the WD calves tended to have a lower concentrate intake than WVR calves. From three days before weaning was initiated and until seven days after weaning, the calves fed milk with the separate compartment teat-bar tended to have a higher daily weight gain compared to the calves fed milk with the shared compartment teat-bar. No other effects on weight gain were observed.

Table 2: Mean number of milk meals and least square means (± S.D.) of number of milk meals and duration (min) of milk meals (drinking and non-nutritive sucking), ingesting milk, non-nutritive sucking and unrewarded visits in minutes per calf per 24 hrs while the calves were on the full milk allowance

Paper	Number of meals	Duration of milk meals	Duration ingesting milk	Duration performing non-nutritive sucking	Duration of unrewarded visits
I	4.4	19.8 ± 0.6	15.0 ± 2.6	4.8 ± 0.6	15.1 ± 2.2
II	2	22.8 ± 4.6	15.9 ± 4.0	6.9 ± 4.1	-
III	2.7 (large)	24.55 ± 2.5	-	-	29.2 ± 6.2
	5.4 (small)	30.65 ± 2.9	-	-	35.2 ± 6.5
IV	7.8	One teat: 71.3 ± 7.8	-	-	-
		Five teats: 90.6 ± 7.8	-	-	-

Portion size and milk flow, Paper III

We did not see any effect of portion size or milk flow on the total number of calves performing cross-sucking. However, during the first 30 min after a visit more calves tended to perform cross-sucking when they were on the fast milk flow compared to when they were on the slow milk flow. When the calves had not been visiting the milk feeder for more than 60 min twice as many calves performed cross-sucking on the fast milk flow than on the slow milk flow, and twice as many performed cross-sucking when they received small milk portions compared to when the received large milk portions. All bull calves received cross-sucking whereas a lower proportion of heifer calves received cross-sucking. The bull calves also received a higher number of the cross-sucking performed than the heifer calves did. There was no difference in the number of bull or heifer calves

performing cross-sucking (Table 3), but the heifer calves performed a higher number of cross-sucking than the bull calves.
A large portion size resulted in a longer duration of each rewarded visits irrespectively of milk flow compared to a small portion size. When the calves received the small portion size with the slow flow they had the highest number of rewarded visits per day and when they received the large portion size with the slow flow they had the fewest rewarded visits per day. When the calves received their milk in large portions with a slow flow they spent more time in total per day and on each rewarded visits where they did not finish their whole portion or where they did not drink any milk at all. Furthermore, they had more rewarded visits where they did not drink at all. During the four weeks of the experiment the calves gradually reduced the total time occupying the milk feeder and the total time spent on rewarded visits. Whereas the daily total duration and the mean duration of rewarded visits where they did not drink varied over time.

Number of teats per calf, Paper IV

When the five calves had access to five teats (no competition) they spent more time manipulating the teats and less time waiting for access to a teat compared with when they only had access to one teat (competition). Furthermore, the calves performed more cross-sucking directed towards other body parts than under the belly and they sucked the fixture more when they had access to five teats compared with one teat. Moreover, when the calves had access to five teats they were spending less time eating concentrate and hay as compared to when they had access to one teat.
Even though the calves did not manipulate the teat more frequently when they had access to five teats they spent more time in total per day on manipulating the teat than when they had access to only one teat (duration of milk meals, Table 2). Throughout the treatment period the calves maintained the same duration of manipulating the teats when they had access to five teats whereas they reduced the total duration of manipulating the teat with time when they had access to one teat. Independent of the number of teats per calf the calves reduced the frequency of manipulating the teats over time in treatment.

Cross-sucking

Throughout these four papers cross-sucking in particular has been observed. In Table 3 I have summarized the percentage of calves that have performed cross-sucking during either direct observations (Paper I, II and IV) or video recordings (Paper III) while they were still on their full milk allowance. Throughout these papers cross-sucking has been observed as a calf either performing cross-sucking towards the udder region of another calf or towards the mouth region of another calf. The percentages of cross-sucking performed on these two regions are presented in Table 3.

Table 3: Percentage of calves in each study performing cross-sucking before weaning. Percentage of either heifer or bull calves that performed cross-sucking out of the total number of either heifer or bull calves performing cross-sucking, and the region (belly or head) of the calf where the cross-sucking was performed[1]. The total observation time from which these data are collected is also presented. For milk feeding method and milk allowance see Table 1

Paper	Percentage of calves performing cross-sucking	Percentage of either bull or heifer calves performing cross-sucking	Proportion on body part (number of observations)	Time observing per day
I	73%	♀ = 71% ♂ = 76%	Belly = 96% (3145) Head = 4% (137)	8 hrs, in 2 observations of 4 hrs
II	27%	♀ = 25% ♂ = 30%	Belly = 29% (35) Head = 71% (87)	30 min right after morning feeding
III	79%	♀ = 82% ♂ = 77%	Belly = 100% (1038) Head = 0% (3)	24 hrs
IV	73%[2]	♀ = 67% ♂ = 83%	Belly = 57% (116) Head = 43% (89)	8 hrs, in 2 observations of 4 hrs

[1] Please note that for Paper I, II and IV the proportion of cross-sucking on either body parts are presented as the proportion of observations were cross-sucking occurred. For Paper III the proportion is presented as the number of cross-sucking events that occurred.
[2] A minimum of 3 observations of cross-sucking had to occur before the calf was classified as a cross-sucking calf.

Concentrate intake during weaning

The concentrate intake was measured for the calves in Paper I and Paper II around weaning. Figure 7 shows the average concentrate intake per calf around weaning for the calves being gradually weaned and clearly shows that the concentrate intake increased during the weaning period.

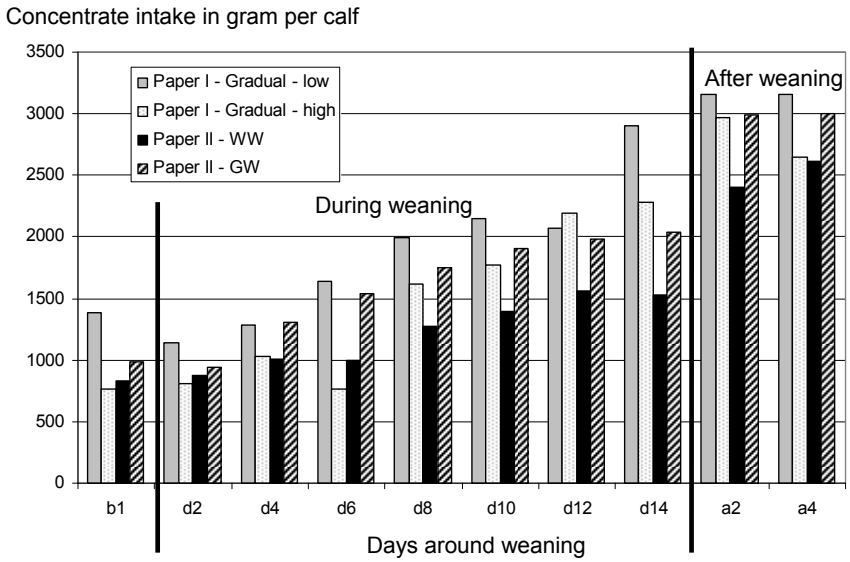

Fig 7. Concentrate intake per calf around weaning for calves in Paper I and Paper II. Please note that for Paper I intake are only shown for calves being gradually weaned and that the calves in Paper II are about one week younger than the calves in paper I and that their weaning period was 4 days shorter.

General discussion

The present study shows that in order to reduce the occurrence of cross-sucking the calves should receive their daily milk allowance in few large portions with a reduced milk flow. Cross-sucking around weaning can be reduced by weaning the calves gradually over a substantial time. Furthermore, gradual weaning over 10-14 days increases the calves daily intake of concentrate as compared to both abrupt weaning and gradually diluting the milk, and does thereby ease the calves' transition to becoming a ruminant.

Cross-sucking

Sucking time

The calves in my experiments that were fed a restricted milk allowance from an automatic milk feeder or a teat bucket were on average fed two to four times per day and spent about five minutes per meal. This correspond to no more than 20 minutes sucking milk from a teat per day, which is less than half the time a calf would normally suckle under natural conditions (Hafez & Lineweaver, 1968; Odde, Kiracofe & Schalles, 1985; Paranhos da Costa*, et al.*, 2006). Although they may be nutritional satiated the low suckling time may explain why they develop abnormal sucking behaviours such as cross-sucking (Jensen, 2003), or excessive sucking of pen fixtures, since they are not able to get a sufficient outlet for their sucking motivation during the short meals (de Passillé & Rushen, 1997). However, even among the calves fed milk *ad libitum* from a teat based system (Paper IV) there was a high proportion of calves performing cross-sucking. These calves spent on average 70 – 90 minutes suckling on the teats per day, which should be sufficient to provide an outlet for their sucking motivation. The high levels of cross-sucking in these *ad libitum* fed calves thus require an alternative explanation which will be discussed later.

Milk feeding method

When calves are raised in groups of four with a foster cow, they increase the synchronisation of the suckling bouts over time (Loberg, 2007), which may indicate that social facilitation or learning has occurred. When group housed calves are fed milk from an automatic milk feeder they do not have the opportunity to ingest milk at the same time, but even in this situation social facilitation may occur. It may be hypothesised that the calves learn, through Pavlovian conditioning, that the sound from the milk feeder, when mixing and delivering the milk, is related to ingesting milk and thereby their motivation to suck is triggered. Furthermore, it may be hypothesised that when this is not possible, due to another calf occupying the milk feeder, they redirect this motivation by cross-sucking on another calf. This may explain that a lower proportion of calves are observed performing cross-sucking in experiments where calves are fed from a teat based milk-bucket system. In this case all the calves in the group are fed milk at the same time. However, differences in timing of observations and methods used in these studies may also have affected the results,

and experiments testing the above stated hypothesis must be conducted before any clear conclusions can be drawn.

Weaning method

When the calves were fed from an automatic milk feeder the weaning method was found to have a profound effect on the occurrence of cross-sucking both during and right after weaning (Paper I). Weaning the calves gradually by reducing the portion size and the number of portions gradually over two weeks, reduced the occurrence of cross-sucking, compared to abrupt weaning (Paper I). However, Jung & Lidfors (2001) found that reducing the milk allowance in teat buckets during a shorter period than in my study increased the occurrence of cross-sucking after a meal. This difference might be due to the somewhat faster weaning by Jung & Lidfors (2001), which might not allow the calves a sufficient period of time to change from milk dependency to becoming more dependent of concentrate. Keil and Langhans (2001) found that a low energy intake increased the risk of cross-sucking, which may explain why abruptly weaned calves performed more cross-sucking immediately after weaning compared to gradually weaned calves, which have had some time to adjust their feed intake to a more solid feed based diet (Paper I). Even when the calves were weaned by gradually diluting the milk with water they tended to perform more cross-sucking compared to gradually weaned calves. The dilution with water may have satiated the calves due to the larger volume and the satiety from the diluted milk may have caused the calves to eat less concentrate (Paper II).

When do calves perform cross-sucking?

Allowing *ad libitum* fed calves to ingest milk at the same time, i.e. with no competition for access to a teat as in Paper IV, increased the risk for calves performing cross-sucking on the mouth region of another calf. However, there was no difference regarding the occurrence of cross-sucking under the belly between the two treatments. The high level of cross sucking in the calves fed *ad libitum* with one teat per calf is difficult to explain. These calves spent on average 90 minutes sucking. The milk started to pour out of the teat as soon as the teat was compressed. This means that the calf did not have to produce any vacuum. Under natural suckling the calf produces a vacuum ranging from zero to 48 kPa while suckling the udder (Rasmussen & Mayntz, 1998), and it has been suggested that the teats should have a certain resistance, requiring the calves to produce natural vacuum pulses, in order to provide an out-let for the sucking motivation (Zerbe & Fischer, 2007). The findings that a reduction in flow reduces non-nutritive sucking (Haley*, et al.*, 1998b) and reduces cross sucking (Loberg & Lidfors, 2001) supports this. Furthermore, it has been found that calves that cross sucked after a milk meal produced a higher vacuum while sucking milk via an artificial, as well as a higher sucking frequency, than calves that did not cross-suck (Zerbe & Fischer, 2007). This may suggest that calves with a forceful suckling style or a strong motivation to suck may be more prone to cross suck and that for these calves especially providing opportunity to suck with a natural vacuum and sucking frequency may be necessary to the satisfaction of the need.

In Paper I and III the calves performing cross-sucking did not suck other calves much around the mouth, but did more or less only suck under the belly of another calf. This might also be related to the feeding method since calves that suck milk from a teat have some milk left on the mouth. Other calves, that have been fed milk at the same time, may therefore be more prone to suck this area, as seen in Paper II and IV, because of the close vicinity of other calves. However, calves that are fed from an automatic milk feeder may not have this opportunity since no other calf can be ingesting milk at the same time, and they might thereby start sucking on a more natural part of the body of another calf, the udder region.

The daily milk allowance in Paper I and III did not influence the total occurrence of cross-sucking nor did the portion size. However, in paper III more calves performed cross-sucking 60 min or more after a visit to the milk feeder if they received eight portions of one litre per day compared to four portions of two litres per day. Studies have shown that cross-sucking occurs mostly within the first 10 minutes after a milk meal (Lidfors, 1993; Bokkers & Koene, 2001; Margerison*, et al.*, 2003). It may be reduced by preventing the calves from performing cross-sucking by e.g. tethering them for a short period of time after feeding (Sambraus, 1985; de Passillé*, et al.*, 1992) or by installing a gate preventing other calves from displacing the calf occupying the milk feeder (Weber & Wechsler, 2001). However, the latter procedure will probably not reduce the cross-sucking occurring when the calf has not been visiting the milk feeder for more than 60 minutes, as in Paper III, and other factors than sucking motivation stimulated by ingesting milk must be involved in regulating this behaviour pattern. One factor could be the stimuli of the sound of the milk feeder when another calf is ingesting, as discussed above. However, calves often have preferred cross-sucking victims and it was noted more than once in paper III that a calf would jump up in the middle of the night and start performing cross-sucking if the calf which usually received cross-sucking got up.

Where do calves perform cross-sucking?

In paper III I found that even though there was no difference in the proportion of bull or heifer calves performing cross-sucking, heifer calves performed a higher proportion of cross-sucking than bull calves and the vast majority of cross-sucking was directed towards the bull calves. This may be explained by the anatomy of the bull calves with scrotum and prepuce placed in what would normally be the udder region of a cow. In this experiment only one calf out of the initial 49 calves were removed from the experiment due to excessive urine drinking, which might indicate that the calves prefer to suck the scrotum compared to the prepuce. The findings especially from Paper III suggest that cross-sucking might be reduced if the calves are split into groups of either bull or heifer calves. And if successful, it might even reduce the proportion of heifer calves that starts performing inter-sucking later in life, since this is related to the occurrence of cross-sucking during the milk feeding period (Keil, Audige & Langhans, 2001). However, one have to bear in mind that single sex groups might also increase the risk of inter-sucking later in life, since the heifer calves does not have any bull calves to redirect their sucking behaviour towards but only have the undeveloped udder of other heifer

calves. However, these are only speculations and further investigations of the connection between group compositions and cross-sucking are required.

Milk feeding methods

Milk allowance and portion size

The results presented in this thesis show that when calves were fed their daily milk allowance in large portions (2 litres) they occupied the milk feeder less on a daily basis and spent almost 30% more time on a rewarded visit compared to when they were fed small portions (1 litre). Furthermore, when calves were fed a low milk allowance (Paper I) they tended to occupy the milk feeder for a longer time on a daily basis compared to when they were fed a high milk allowance. The major reason for this difference was an almost tripling in frequency and duration of unrewarded visits of the calves on low milk allowance since no effect of milk allowance was found on the frequency or duration of rewarded visits between the calves on the two milk allowances. Unrewarded visits may be a sign of hunger in calves (Jensen & Holm, 2003; Jensen, 2006; De Paula Vieira*, et al.*, 2008) and even though the calves on low milk allowance consumed twice as much concentrate as the calves on high milk allowance (Paper I) apparently this may not sufficiently cover their nutritional need. Van Amburgh and Drackley (2005) suggest that calves weighing around 50 kg requires about 20 MJ per day with a weight gain of 1 kg per day. Before weaning the weight of the calves in Paper I was on average 64 kg and would therefore need more than 20 MJ in daily energy intake, however, they had a daily energy intake of 30 MJ for the high milk allowance and 20 MJ for the low milk allowance. This suggests that in relation to standard energy intake, the calves on the low milk allowance were not able to reach a sufficient level of energy intake. This is supported by the lower daily weight gain before weaning of these calves (Paper I) and by similar results found by Jensen (2006).

When calves were fed an allowance of 8 litres in milk portions of 2 litres with a slow flow they often did not finish the portion and it was also observed that they did not ingest any milk even though they were allowed to (Paper III). In correspondence with this Jensen (2007) found that calves fed fewer and larger portions spent more time on rewarded visits where they did not ingest any milk. This may be because the calves were experiencing some sort of muscles fatigue reducing their sucking behaviour as discussed in Haley *et al.* (1998b). The calves may simply not have been able to overcome the reduced flow for the time it takes to ingest a portion and they may therefore have stopped drinking before finishing a portion, or they may not even have started ingesting milk when the milk flow was to low.

Feeding calves' milk *ad libitum* from a teat based system provides them with an increased time for ingesting milk and sucking the teat compared to restrict feeding (Paper I, III and IV). Hammell, Metz & Mekking (1988) found that calves spent around 72 minutes per day on milk meals even though they only consumed 12 litres of acidified milk per day in 17 meals on average. On the other hand

Appleby, Weary & Chua (2001) found that *ad libitum* fed calves would drink about 11 litres per day in 10 meals with a total meal time of 47 minutes. This corresponds to the result from Paper IV where the calves also increased the meal duration with a higher teat-per-calf ration, which has also been found by von Keyserlingk, Brusius & Weary (2004b). The calves in Paper IV would take around 8 milk meals per day irrespective of the teat-per-calf ratio indicating that if the calves have the opportunity they will take longer meals. The shorter time ingesting milk in competitive situations reflects that the calves increase the rate of ingestion when there is competition.

Teat-bar design

The idea behind a teat-bar with separate milk compartments is to guarantee each calf a minimum of milk (the volume each compartment can hold) compared to when a teat-bar with a shared milk compartment is used. However, the results presented in this thesis (Paper II) show that the design of the teat-bar did not affect the individual calf's milk intake. For the calves fed milk with the shared teat-bar the single factor affecting milk intake was the calf's sucking intensity since all teats are connected to the same milk compartment. For the calves fed milk with the separate compartments teat-bar several factors affect the individual milk intake. As with the shared teat-bar the calf's sucking intensity affects the milk intake. However, since the calves do not finish ingesting the milk in their individual milk compartments simultaneously, the calf's propensity to switch teats and its ability to displace another calf from a teat with milk, also affects the individual milk intake. Feed-barriers have been shown to reduce, but not eliminate, displacements from feeding troughs by group members in sows (Andersen, Bøe & Kristiansen, 1999) and cows (DeVries & von Keyserlingk, 2006; Huzzey *et al.*, 2006). The length of a feed-barrier between teats may be of importance. In pair-housed calves placing a barrier between two teats reduced switching if the barriers separated part of the body in addition to the head of the calves. These long barriers successfully prevented milk stealing (Jensen, 2008). The most efficient method to ensure that all calves drink their full milk allowance and that they are not displaced from the teat while ingesting seems to be confining the calves in individual stalls during the milk feeding period until all calves have finished their milk meal. However, further research is needed in order to determine which feeding methods that works best from a calf's perspective.

Competition for access to a teat

Increasing the competition at the milk feeding place by reducing the number of teats per calves have been found to increase competitive interactions around the feeding station (von Keyserlingk, Brusius & Weary, 2004b). However, in Paper IV no differences in competitive interactions between the calves were found with a reduced number of teats per calf. The differences may be explained by different designs in the study by von Keyserlingk, Brusius & Weary (2004b) and in Paper IV. In my study the calves were on the same treatment (teats-per-calf ration) for 14 days and observed the last two days of this period before the treatments were changed. Von Keyserlingk, Brusius & Weary (2004b) changed the teat-per-calf ratio every day, which might give a more direct reaction of the calves to the

treatment. However, in both studies a eventual carry-over effect between the treatments will have to be taken into account when interpreting the results. The calves react to a decreased teat-per-calf ratio and most likely a decrease in milk intake (von Keyserlingk, Brusius & Weary, 2004b) by increasing the time spent eating concentrate. This is probably in order to increase the total energy intake as seen in other studies with restrictively fed calves (Appleby, Weary & Chua, 2001; Jensen, 2006).

Weaning methods

In Paper I and II three different weaning methods were investigated in order to study how they affected the calves' behaviour, specifically their use of the automatic milk feeder (Paper I) and behaviours in relation to milk feeding from teat buckets (Paper II).
When calves were fed milk from an automatic milk feeder (Paper I) gradual weaning did not reduce the daily occupation of the milk feeder during weaning compared to not weaned calves, mainly because the gradually weaned calves increased the frequency and duration of unrewarded visits. This type of visit indicates that the calves are hungry (Jensen & Holm, 2003; De Paula Vieira*, et al.*, 2008) because they repeatedly checked if they are allowed another meal. However, during weaning the gradually weaned calves compensated for this decrease in energy from the milk intake by increasing their concentrate intake significantly (Jensen, 2006; Roth*, et al.*, In Press, Corrected Proof) compared to calves on full milk allowance. This gradual shift in the main energy source might have given them a nutritive advantage over the abruptly weaned calves, since they increased their chance of not experiencing a negative energy balance right after weaning. The first few days after the calves had been abruptly weaned they increased the frequency and duration of unrewarded visits, significantly more than the gradually weaned calves. Since unrewarded visits are strong indicators of hunger, as described above, the abruptly weaned calves may have experienced an energy deficiency, strengthened by the fact that they had a 5 MJ lower energy intake per day the first week after weaning.

When weaning the calves by gradually diluting the milk offered twice a day through teat-bars (Paper II) the calves started eating concentrate sooner after they had finished the milk, but in total they ate less concentrate than gradually weaned calves. This indicates that weaning by gradually increasing the dilution with water deceived the calves to act as if they were on a full milk allowance. This indicates that even the volume offered has an effect on satiety. Five days after weaning was initiated the calves weaned by water dilution slowly started to increase their concentrate intake, but over the ten days weaning period they only increased their concentrate intake from 1 kg/day to 1.5 kg/day, However, Chua *et al.* (2002) found a steeper increase when they weaned calves by diluting the milk over 5 days. The gradually weaned calves doubled their concentrate intake, an increase also observed in Paper I and by Jensen (2006). Mid weaning the calves weaned by gradually diluting the milk were lying less from 06 to 21 hrs than the gradually

weaned calves, which strengthen the indication of an increased nutritive deficit of the calves weaned by gradually diluting the milk.
After weaning the calves weaned by gradually diluting the milk also tended to have a lower concentrate intake than the gradually weaned calves (Paper I). However, there were no differences in the daily weight gain between the two treatments neither during nor after weaning. Furthermore, in Paper I the abruptly and gradually weaned calves did not differ in daily weight gain after weaning even though the gradually weaned calves had a higher concentrate intake. These results suggest that even though the abruptly weaned calves (Paper I) and the calves weaned by diluting the milk (Paper II) had a substantially lower energy intake compared to gradual weaned calves, they could still somehow compensate for this and have the same daily weight gain as gradually weaned calves during and after weaning.

Methodological considerations

The behavioural observations in Paper I were performed using the one-zero sampling technique, observing if the behaviour of interest occurred, or not, during a fixed interval of 30 sec. I chose this sampling method because of the special distribution of cross-sucking (duration ranging from a few seconds to minutes) and because it allowed me to observe more animals at the same time compared to continuous or instantaneous observations. However, one of the problems with one-zero sampling is that it does not present an estimate over the duration or frequency of the behaviour in question, but only the frequency of intervals where the behaviour were observed. Continuous recording of cross-sucking from video recordings would have provided me with the real frequency and duration of the cross-sucking events and I would have been able to analyse if the treatments had any effect on the real frequency and duration of cross-sucking throughout the day. This might, however, not have had any influence on the conclusions drawn, since the percentage of calves performing cross-sucking, as presented in Table 3, does not differ considerably between 8 hrs observations per day (Paper I) to 24 hrs observations (Paper III).

When the initial design for Paper II was made I planned to have three different weaning methods; weaning by diluting the milk with water, gradual weaning and abrupt weaning. This might have allowed me to draw further conclusions on the effect of diluting the milk gradually with water in relation to the satiety feeling this might have given the calves, since I could have compared this weaning with the calves still not weaned. But unfortunately I did not have access to the number of calves nor the time needed for an experiment with three weaning methods and after thorough consideration I decided to remove the abrupt weaning from the experiment. Running the experiment with three weaning methods would drastically have reduced the number of calves per weaning methods and would probably have reduced the value of the statistical test and thereby jeopardised the results and conclusions drawn.

When interpret ting the data from Paper III one should take into account that there might have been a carry-over effect from one treatment to another, even though I

tried to take this into account in the statistical analysis. If I would get the chance to replicate this study I would change the design so that the calves would only receive one of the four treatments, which in addition also would provide us with a good indication of how cross-sucking develops over time with different portion sizes and flows. When running experiments with the amount of technical equipment as used in this study (one computer to record the video, one computer to record the visits to the milk feeder and the milk pump with a vacuum switch) one has to rely on that everything is running smoothly otherwise too much data can be missed, as in this study were a simple power outages meant that both computers had to be restarted to maintain the data collection.

The data from Paper IV has been reduced from five groups to three groups before statistical analysis because of an unbalanced design. It would have been preferable to have a totally balanced design with an equal number of groups first being on either one-teat-per-group or five-teats-per-group in order to reduce the effect the order of treatments might have had on the results. Between the two treatments the calves differed in total time manipulating the teats and having an estimate of their milk intake would have added significant information to the discussion of how they adjust their milk intake in relation to teat availability. Furthermore the calves should have been weighed before and after each treatment for analysis of differences in weight gain caused by the treatment. In this paper we found some highly significant effects of day in treatment to several of the behaviours observed, however with only 15 calves observed the differences in behaviour between day 13 and 14 might be more related to the variation in the calves behaviour than to the effect of day in treatment and more calves would be needed in order to further investigate this effect.

Future research

This thesis has explained some important factors in the milk feeding methods of dairy calves that can reduce cross-sucking and improve milk intake. However, it has also drawn attention to new questions. Some areas that need to be further investigated are:

- Can we break/stop the occurrence of cross-sucking in calves fed milk from an automatic milk feeder by changing the feeding method to teat buckets?
- What affects the difference in cross-sucking between calves fed with teat buckets and calves fed with an automatic milk feeder?
- How does splitting the calves into pure heifer and bull calf groups affect the occurrence of cross-sucking during and after the milk feeding period?
- What triggers the occurrence of cross-sucking if the calf has not been visiting the milk feeder for a longer period of time?
- Does weaning the calves by gradually increasing the dilution of their milk over a longer period of time perceive the calves to act as if they were on full milk allowance?

Final conclusion

When feeding calves milk from computer controlled milk feeders it is of great importance to give them a high milk allowance in large portions of milk. This ensures that the calves have the opportunity to get a sufficient outlet of their sucking motivation and reduces the occurrence of unrewarded visits to the milk feeder. Reducing the milk flow mechanically can lower the occurrences of cross-sucking right after the calf has been visiting the milk feeder and when it has not been in the feeder for more than 60 minutes. When feeding calves' milk *ad libitum* from a teat based system, increasing the number of teats available per calf will increase the duration the calves are drinking milk and reduce the duration they spend waiting for access to a teat.

The design of a teat-bar does not influence the individual calf's milk intake. If the calves individual milk intake should be controlled other measures must be used than having separate compartments for each teat, e.g. separate feeding stalls.

These experiments show that choosing the right weaning method is very important in order to ensure the calves an easy change to become fully dependent on solid feed. Gradual weaning over a sufficient period of time (10 to 14 days) has been shown to increase the calves' concentrate intake, both during and after weaning compared to both abrupt weaning and weaning by diluting the milk. Furthermore gradual weaning decreases the occurrence of cross-sucking after weaning and might, therefore, reduce the risk of calves developing inter-sucking later in life.

Practical application

For the dairy farmer several considerations must be taken into account when deciding which method is most beneficial for both the people working with the calves but also which method that is most appropriate from the calves' perspective.

- Calves fed milk from automatic milk feeders should be fed their daily milk allowance in large portions of 1.5 to 2.0 litres.
- The calves should be fed a high milk allowance during the milk feeding period, at least 8 litres per day.
- Weaning should be done gradually over 10 to 14 days by every day reducing the milk offered.
- The manufactures of the automatic milk feeders should include the findings from this thesis in their development of the system.

Svensk sammanfattning

Inom konventionell mjölkproduktion tas kalven vanligtvis bort från kon under de första dagarna efter födelsen och hålls i ensambox de första veckorna i livet. Under denna tid utfodras de vanligtvis med mjölk två gånger om dagen i en vanlig hink eller en hink med spene. Spenhink används för att ge kalvarna möjlighet att kunna suga i sig mjölken på ett för dem mer naturligt sätt. När kalvarna är omkring två veckor gamla rekommenderas det att hålla dem i gruppbox. Detta görs för att ge kalvarna möjlighet att utveckla sina sociala beteenden. Under mjölkperioden kan man utfodra mjölken till kalvarna på olika sätt. Det är ganska vanligt i Sverige att fodra kalvarna från ett gemensamt tråg eller en hink men man kan också utfodra dem med spenhink, permanenta spenar med fri tillgång till mjölk eller en automatisk mjölkamma. Det är viktigt att kalvarna får möjlighet att utföra sugbeteenden i samband med mjölkutfodringen, för att undvika att de utvecklar onormala beteenden som t ex spensugning på andra kalvar. Detta beteende kan kalvarna ta med sig när de blir äldre då de kan börja suga på andra kvigors spenar och därmed öka risken för utveckling av mastit eller så kan de dricka mjölk från en annan ko och sprida sjukdomar.

Syftet med avhandlingen var att undersöka hur olika mjölkutfodrings- och avvänjnings- metoder påverkar kalvars beteende, foderintag och viktökning under och omedelbart efter mjölkutfodringsperioden.

I den första studien (Artikel I) ville jag undersöka i vilken utsträckning mjölkmängden (hög eller låg) och avvänjningsmetoden från mjölken (plötslig eller gradvis) påverkade kalvars utveckling av onormalt sugande, deras användning av mjölk- och kraftfoder-automaten och deras totala energiintag före, under och efter avvänjning.
Studien utfördes på Danskt Nöt Forsknings Center och Aarhus Universitet, Jordbruksvetenskapliga Fakulteten, Foulum, under hösten 2004 och vintern 2005. 72 kalvar av raserna Holstein-Friesian (n=29), Dansk Röd (n=28) och Jersey (n=15) delades upp i sex block på 12 kalvar, där varje block bestod av två boxar. Kalvarna i varje block fick antingen hög (9.2 liter/dag för de stora raserna och 7.2 liter/dag för Jersey) eller låg mjölktilldelning (4.8 liter/dag för de stora raserna och 3.6 liter/dag för Jersey) vid minst fyra måltider per dygn genom en automatisk mjölkamma (Calvex, Danmark). När den yngsta kalven i varje block var 42 dagar gammal började en gradvis avvänjning för den ena boxen. När den yngsta kalven var 55 dagar gammal var den gradvisa avvänjningen över och samtidigt blev den andra boxen också avvand (plötsligt).
Kalvarnas mjölk- och kraftfoderintag registrerades varje dag. Dessutom registrerades deras beteende fyra timmar på morgonen och fyra timmar sent på eftermiddagen, en dag före avvänjningen började, två dagar under och två dagar efter avvänjningen. Kalvarna vägdes varannan vecka under hela försöket.
Kalvarna som avvandes plötsligt utförde mer onormalt sugande de första dagarna efter avvänjningen än kalvarna som avvandes gradvis över 14 dagar. Denna skillnad observerades dock inte fyra dagar efter avvänjningen, vilket kanske beror på att kalvarna vid den tidpunkten hade ökat sitt intag av kraftfoder betydligt och

därför inte hade så stor energibrist. En låg mjölktilldelning resulterade i flera och totalt längre besök i mjölkautomaten där kalven inte fick någon mjölk än en hög mjölktilldelning. Detta kan ses som ett tecken på att kalvarna var hungriga. Kalvarna på låg mjölktilldelning kompenserade dock det lägre energiintaget från mjölken genom att äta mer kraftfoder. Den gradvisa avvänjningen från mjölk ökade successivt kalvarnas intag av kraftfoder, en ökning som dock var tydligast hos kalvarna med den höga mjölktilldelningen. Efter avvänjningen hade kalvarna med en hög mjölktilldelning som avvandes plötsligt ett mycket lägre energiintag än de andra kalvarna, och de plötsligt avvanda kalvarna besökte mjölkautomaten i försöket för att få mjölk oftare än de gradvis avvanda kalvarna, vilket som beskrivits tidigare kan ses som ett tecken på att kalvarna är hungriga.
Slutsatserna från detta försök är att en hög mjölktilldelning ger färre besök till mjölkautomaten där kalven inte får någon mjölk, och att en gradvis avvänjning ger en lägre förekomst av onormalt sugande omedelbart after avvänjningen.

I den andra studien (Artikel II) ville jag undersöka effekten av designen på en mjölkbar och avvänjningsmetoden på kalvarnas beteende och konsumtion av kraftfoder. Denna studie utfördes på Aarhus Universitet, Jordbruksvetenskapliga Fakulteten, Foulum, under hösten 2006. Fyrtioåtta kalvar av rasen Holstein-Friesian delades upp i två block på 24 kalvar vardera, och därefter delades varje block upp på sex boxar med fyra kalvar per box. Kalvarna utfodrades med en spenhink (Milk Bar^{TM}, Dairy Spares Ltd, Shropshire, Storbritannien) med fyra spenar som antigen var anslutna till en gemensam behållare eller till en separat behållare för varje spene. Kalvarna utfodrades med sex liter helmjölk per dag vid två utfodringstillfällen. När den yngsta kalven i varje block var 35 dagar gammal började en gradvis avvänjning på 10 dagar. Kalvarna blev antigen avvanda med en gradvis reduktion av mjölken eller med en gradvis utspädning av mjölken. Kalvarnas beteende observerades vid två tillfällen med direktobservation i 30 min direkt efter morgonutfodringen, tre gånger med video omkring morgonutfodringen och en gång med video från klockan 06.00 till 21.00. Dessutom mättes deras individuella mjölkintag två gånger innan avvänjningen började.
Det var ingen skillnad i mjölkintaget mellan den kalv som drack mest mjölk och den kalv som drack minst mellan de två mjölkbardesignerna. Men, de kalvar som fick mjölken i en mjölkbar där varje spene var ansluten till en separat behållare, knuffade bort andra kalvar från deras spene oftare än de kalvar som drack mjölk från en mjölkbar där spenarna var anslutna till en gemensam behållare. Dessutom dröjde det längre innan de började äta kraftfoder efter mjölkmåltiden. Kalvar som blev avvanda med utspädning av mjölken åt mindre kraftfoder och låg ned mindre än de kalvar som blev avvanda med en gradvis reduktion av mjölken.
Slutsatserna från detta försök är att en mjölkbar med en behållare till varje spene ökar antalet byten mellan spenarna när det finns mjölk i mjölkbaren. Avvänjning med utspädning av mjölken ger ett mindre intag av kraftfoder under avvänjningen än en gradvis reduktion av mjölkmängden gör.

I den tredje studie (Artikel III) ville jag undersöka hur måltidsstorleken och mjölkflödet påverkade kalvars användning av en mjölkautomat och på förekomsten av onormalt sugande mellan kalvarna. Fyrtioåtta kalvar av rasen Svensk Holstein (n=43) och Svensk röd och vit boskap (n=5) delades in i tre

grupper med tio kalvar och två grupper med nio kalvar. Alla kalvar fick 8 liter mjölk per dag genom en mjölkautomat (SMI Alpro, Sverige) antigen med 1- eller 2-liters måltidsstorlek i kombination med antingen 300 ml/min eller 600 ml/min mjölkflöde. Under studien genomgick kalvarna alla fyra behandlingar med en veckas längd för varje behandling som kom i olika ordning. Kalvarnas användning av mjölkautomaten, samt antal gånger och hur länge de sög på andra kalvar registrerades de sista två dagarna i varje behandlingsvecka.
När kalvarna fick mjölken i 2-liters portioner använde de nästan dubbelt så mycket tid vid varje besök till mjölkautomaten där de drack mjölk än när de fick mjölken i 1-liters portioner. Dessutom spenderade de mycket mera tid i mjölkautomaten på besök där de hade möjlighet att dricka mjölk men inte drack något eller bara drack lite när de fick mjölken i 2-liters portioner med lågt flöde (300 ml/min). Detta kan vara ett tecken på att de med stora måltider med lågt flöde antigen fick sitt sugbehov tillgodosett eller att kalvarna blev utmattade. Varken portionsstorleken eller mjölkflödet påverkade antal kalvar som sög onormalt på varandra, men om kalvarna inte hade besökt mjölkautomaten inom de senaste 60 min var det många fler kalvar som sög onormalt på varandra när de fick mjölken i 1-liters portioner än 2-liters portioner och när de fick mjölken med det höga flödet än när de fick den med det låga flödet. Det var ingen skillnad i andelen tjur- eller kvigkalvar som utförde onormalt sugande, men kvigkalvar utförde onormalt sugande fler gånger än tjur- kalvar. Dessutom blev alla tjurkalvar utsatta för onormalt sugande medan endast 77 % av kvigkalvarna blev det och huvudparten av det onormala sugandet riktades mot tjurkalvarna (95 %).
Slutsatserna från detta försök är att för att kalvarna skall kunna tillfredsställa sitt sugbehov är det en fördel om man ger kalvarna stora portioner med ett lågt flöde. Detta reducerar inte det onormala sugande som förekommer i direkt anslutning till ett besök i mjölkautomaten, men det reducerar den del som kommer oberoende av ett eventuellt besök i mjölkautomaten.

I den fjärde studien (Artikel IV) ville jag undersöka vilken effekt antal spenar per kalv hade på kalvarnas beteenden, med speciell inriktning på onormalt sugande och hur mycket de knuffar bort andra kalvar från spenen. Femton kalvar av rasen Svensk Holstein blev uppdelade i tre grupper med fem kalvar i varje grupp. Kalvarna hade fri tillgång till syrad mjölkersättning från en Öjeby amma. De första två veckorna hade de tillgång till en spene med mjölk, och därefter fick de tillgång till fem spenar med mjölk under två veckor. Kalvarna observerades manuellt fyra timmar på morgonen och fyra timmar på kvällen under de sista två dagarna av varje period. Dessutom filmades de 24 timmar under dag 7, 13 och 14 i varje period. Utifrån dessa observationer visar det sig att kalvarna använde mer tid till att dricka mjölk när de hade tillgång till en spene per kalv, men de hade samma antal måltider per dag som när de hade tillgång till en spene per fem kalvar. Detta beror troligen på att de, när de hade tillgång till en spene per kalv, hade möjlighet att dricka när de var hungriga. När de hade en spene per fem kalvar använde de mer tid till att äta kraftfoder troligen p.g.a. ett lägre mjölkintag orsakat av den ökade konkurrensen om tillgången till spenen. Jag fann ingen skillnad i konkurrensbetonade beteenden för att få tillgång till en spene mellan en resp. fem spenar per grupp, men när kalvarna hade en spene per kalv så sög de mer på varandras kroppsdelar, utom under buken.

Slutsatserna från detta försök är att om kalvar som har fri tillgång till mjölk får en ökad tillgång till spenar med mjölk, så ökas tiden kalvarna använder till att dricka. Men, denna längre tid vid spenen gör att kalvarna använder mindre tid till att äta kraftfoder och detta kan kanske leda till problem när de senare avvänjs från mjölk.

Med denna avhandling hoppas jag kunna öka kunskaperna om hur den teknik vi använder till att utfodra mjölk och olika avvänjningsprinciper påverkar kalvarna. Sammanfattningsvis pekar resultaten på att för att undvika beteendestörningar hos kalvarna måste måltidsstorleken vara så pass stor (1.5 till 2.0 liter) att kalvarna har möjlighet att tillfredsställa sitt behov av att suga under varje mjölkmåltid. Vid mjölkutfodring av kalvar från en spenhink med flera spenar, så påverkar den enskilda kalvens sugförmåga och dess beredvillighet att knuffa bort andra kalvar från den spene som de diar ifrån hur mycket den dricker. Däremot påverkas det inte av om varje spene ansluts till ett stort fack eller om varje spene ansluts till ett avskiljt fack.
Avvänjningsmetoden är mycket viktig för att säkra att kalven böjar att äta kraftfoder så snabbt som möjligt. Dessa försök visar att en gradvis avvänjning över 10-14 dagar påverkar kalvens kraftfoder intag positivt i förhållande till både abrupt avvänjning och avvänjning med en gradvis utspädning av mjölken. Dessutom minskar risken för att kalven suger på andra kalvar efter avvänjningen om de avvänjs gradvis.

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