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# Effect of colostrum feeding method and presence of dam on the sleep, rest and sucking behaviour of newborn calves

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**Abstract**

In rats, sucking milk reduces anxiety and promotes non-rapid eye movement (NREM) sleep, and in calves it induces resting but the effect on sleep is unknown. Here, we investigated how calves' sleep was affected by colostrum feeding methods. Forty-one calves were blocked by birth date and randomly allotted within blocks to the experimental treatments. Calves were housed for four days either with their dam (DAM) or individually with warm colostrum feeding (2 L four times a day) from either a teat bucket (TEAT) or an open bucket (BUCKET). DAM calves suckled their dam freely. Calves' sleeping and sucking behaviour was filmed continuously for 48 h at the ages of two and three days. Behavioural sleep (BS) was defined as calves resting at least 30 s with their head still and raised (non-rapid eye movement) or with their head against their body or the ground (rapid eye movement, REM). Latency from the end of colostrum feeding to the start of BS was recorded. We compared behaviour of TEAT calves with that of DAM and BUCKET calves using mixed models. Milk meal duration was significantly longer for TEAT calves than for BUCKET calves (mean ± S.E.M.; 8.3 ± 0.6 min vs. 5.2 ± 0.6 min), but equal to that of DAM calves. We found no effect of feeding method on the duration of daily BS (12 h 59 min ± 1 h 38 min) but we found a tendency for the daily amount of NREM sleep; BUCKET calves had less NREM sleep per day than TEAT calves (6 h 18 min vs. 7 h 48 min, S.E.M. = 45 min) and also longer latencies from milk ingestion to BS (21.9 ± 2.0 min vs. 16.2 ± 2.0 min). DAM calves slept longer bouts than TEAT calves (10.8 ± 1.0 min vs. 8.3 ± 1.0 min) and less often (78 ± 4 vs. 92 ± 4). Sucking colostrum from a teat bucket compared with drinking from an open

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bucket increased sleepiness and the amount of NREM sleep. Individually housed, teat-bucket-fed calves slept more fragmentarily than dam-reared calves.


*Keywords:* Calf; Sleep; Suckling; Dam-rearing; Feeding method; Colostrum; Individual housing

## 1. Introduction

Adequate sleep is important for the health and well-being of humans and animals, particularly during the growth phase (Everson, 1995; Rechtschaffen, 1998; Siegel, 2005). Any effects of housing or management on the quality and amount of sleep of farm animals are therefore of concern regarding animal welfare. Changes in the frequency or duration of sleep episodes may measure how well animals are adapted to changes in their physical or social environment or diet (Ruckebusch, 1975). Thus, the newborn vigilance states may offer a method for assessing the capabilities to cope with the environmental stressors.

Electrophysiologically, sleep is divided into two main phases, both important for sleep quality: rapid eye movement (REM) sleep, also called paradoxical sleep, or active sleep and non-rapid eye movement (NREM) sleep, also called quiet sleep or, in some species, slow-wave sleep (Tobler, 1995). Sleep states in animals may be identified through the animal's behaviour. We have recently shown in calves that sleeping behaviour is a good measure of the total daily sleeping rhythm and the time spent daily in NREM or REM sleep (Hänninen et al., 2008).

In altricial species, such as in rodents, a maternal deprivation affects newborns' wakefulness and sleep architecture (Hofer, 1976), some of these alterations can be prevented by providing feed and warmth (Hofer and Shair, 1982). However, these studies are not fully applicable to newborn calves, which are precocious animals, and in a modern dairy husbandry, commonly separated soon after birth. There are no studies on the effect of dam-rearing on newborn calves' sleep.

Calves have an inborn sucking motivation that is mostly stimulated by milk ingestion (de Passillé et al., 1992, 1997; de Passillé, 2001). Sucking has been shown to have a calming effect on human babies (Wang et al., 2005) and to induce resting in calves (Veissier et al., 2002). Sucking milk promotes secretion of several gastrointestinal hormones, such as oxytocin and cholecystocinin (CCK), in human babies and rats (Uvnäs-Moberg et al., 1987; Marchini et al., 1987), as well as in calves (de Passillé et al., 1993; Lupoli et al., 2001). CCK has been demonstrated to promote NREM sleep in laboratory rodents (Kapas et al., 1991a), and thus, we hypothesized that sleep and sucking are also related in calves.

This article examines the sleeping and sucking behaviour of newborn calves either housed individually and fed colostrum through an artificial teat or an open bucket or kept with their dam in the parturition pen and allowed to suckle their dam *ad libitum*.

## 2. Materials and methods

The study protocol was approved, by the ethics committee for the use of experimental animals at Agro-Food Research, Finland.

### 2.1. Animals, housing and feeding

Forty-one Ayrshire calves were born (mean weight 42.1 ± 0.8 kg, 16 heifers and 25 bulls) at the experimental barn of Minkiö, Agro-Food Research, Finland. The calves were blocked by birth date and

randomly allotted within blocks to the three treatment groups. The calves were either separated immediately after birth from their dam and placed in a straw-bedded individual pen and fed colostrum 2–4 h after birth from an open bucket (BUCKET) or an artificial teat (TEAT) or they were kept with their dam and allowed to suckle freely (DAM).

All calves were kept in the same part of the barn. The BUCKET and TEAT pens (0.95 m × 1.2 m) were separated by solid metal side walls 0.95 m high and an open metal bar front, through which they could have some visual and body contact with other calves. Each of the pens had a hayrack, a water nipple and a metal trough for concentrates. A heat lamp was adding for extra heat. The parturition pen (DAM) was 2.95 m × 3.6 m, turf-bedded and solid walls of 1.25 m high, and an open metal bar front. Dams' concentrate and silage were offered on a feeding table in front of the pen. A water bowl was provided for dams. Ventilation in the barn was mechanical. Lights were controlled manually and were on from 06:00 to 21:00, and a dim night-light was provided.

BUCKET and TEAT calves received 2 L of colostrum four times a day at 6:15, 10:00, 14:00 and 18:00. DAM calves were allowed to suckle *ad libitum*. All treatment pens were cleaned twice a day, between 10:00 and 11:00 and between 19:00 and 20:00. The cow in the DAM treatment was milked in the parturition pen at 9:30 and 18:00. Fresh grass silage was offered to dams at 12:00, and concentrate was given at 6:00, 10:00, 15:00 and 19:00.

### 2.2. Behaviour

Calves' behaviour was filmed continuously for 48 h at the ages of 2 and 3 days. Each of the calves was recorded with one camera, hanging from the ceiling. One multiplexer (Sanyo MPX-MD16P) connected three cameras for this experiment and two cameras for other purposes with a VCR (Panasonic VHS AG-6040). Recording was done in 24 h mode. Behaviours were scored continuously with The Observer© (Noldus; Netherlands).

Calves' resting was scored as either resting on the sternum or resting on the side when the side of the trunk of the calf was rested against the ground. Sleeping behaviour was recorded based on Hänninen et al. (2008) as follows: (1) NREM sleep when the calf was resting head up, being still for at least 30 s, (2) REM sleep when it was resting neck relaxed, with the head against floor or flank for at least 30 s, (3) behavioural sleep (BS), the sum of the previous behaviours 1 and 2.

In addition, we registered calves' milk drinking and sucking time. A calf was defined as sucking when its head was under the dam's belly (DAM) or the artificial teat was in its mouth (TEAT). A calf was recorded as drinking milk from an open bucket when the calf's head was inside the bucket (BUCKET). A new meal was recorded as beginning, when the calf had not been sucking/drinking after a break of at least 1 min.

Mean bout length, total daily duration and frequencies were determined for each of the behaviours over the two recording days. Latencies from milk feeding to behavioural sleep were measured. Latency was defined as the time interval between the end of the colostrum feeding bout and the beginning of the next BS bout. In addition, to examine the effects of diurnal sleep distribution during the two days, data were divided into day (06:00–18:00) and night (18:00–06:00) sequences, and the overall 12-h means for BS, REM and NREM were calculated for the 48-h recordings.

## 3. Statistics

An analysis for the complete block design mixed model was used to study the effects of sucking (TEAT vs. BUCKET), and dam presence (DAM vs. TEAT) on the mean total daily durations and bout frequencies of sleeping, resting and sucking behaviour during the two consecutive observations days. The model had as fixed effects colostrum feeding type (TEAT vs. BUCKET or DAM). The random part contained the block (one block consisted of three calves born within 1 week). The mean diurnal behaviour during the two consecutive observation days

was analysed with a model equivalent to the one described above. The model has as fixed effects day–night, and colostrum feeding type (TEAT vs. BUCKET or DAM), and an interaction between colostrum feeding type and the day–night factor. The random part contained the block. The mean latency from the end of a milk meal to the next BS bout was also analysed with a mixed model. The fixed effect was a colostrum feeding type and the random part contained the block. Sex and birth weight were non-significant factors in all three models and thus removed from the models. All statistical analyses were conducted with the SPSS 13.0 for Windows (SPSS Inc. 2004).

## 4. Results

### 4.1. Overall resting behaviour and sleep

We found a significant effect of colostrum feeding method on calves total daily duration spent resting ($p = 0.02$) and spent resting on side ($p = 0.04$); TEAT calves rested daily longer than DAM calves (20 h 14 min ± 38 min vs. 19 h 11 min ± 39 min, $p = 0.02$), and similar time to BUCKET calves (20 h 1 min ± 38 min). TEAT calves rested daily on side more often and for longer than BUCKET calves (10 ± 4 vs. 4 ± 4, and 47.2 ± 9 min vs. 18.3 ± 9 min, $p = 0.04$), but similar to DAM calves (8 ± 4 and 42.7 ± 9.1 min, respectively). No significant difference ($p > 0.05$) was present between TEAT and DAM or BUCKET calves in the mean daily number (29 ± 2, and 27 ± 2 or 26 ± 2, respectively) or length of resting bouts (43.4 ± 4.3, and 47.8 ± 4.3 or 48.8 ± 4.3 min, S.E.M. = 4.3 min, respectively).

Calves slept daily 12 h 41 min ± 24 min, which was 64.0 ± 2.6% of their total resting time. Of total sleeping time, REM sleep comprised 44.3 ± 8.0% and NREM sleep 55.7 ± 8.0%. We found a significant effect of colostrum feeding method on calves' mean daily amount of NREM sleep, and mean daily BS bout duration and frequency (Table 1); TEAT calves had more NREM sleep than BUCKET calves ($p = 0.04$), with the amount being similar to that of DAM calves. DAM calves had longer but fewer BS bouts than TEAT calves ($p = 0.04$ for both).

### 4.2. Sucking and sleep

We found a significant effect of colostrum feeding method on the mean daily duration ($p = 0.001$), mean meal duration ($p = 0.01$) and numbers of times the calves spent sucking or drinking colostrum ($p = 0.001$); TEAT-fed calves spent less time daily sucking colostrum than did DAM calves (28.8 ± 3.4 min vs. 64.4 ± 3.5 min, $p = 0.0001$), but did not differ significantly from the mean milk drinking time of BUCKET-fed calves (18.1 ± 3.5 min). DAM calves suckled their dam 10 ± 2 times per day, which was significantly more sucking bouts ($p = 0.0001$) than the four feeding times for TEAT and BUCKET calves. TEAT calves' mean colostrum meal length did not differ significantly from DAM calves' meal duration (8.3 ± 0.6 min vs. 7.2 ± 0.6 min), but their meal length was longer than that of BUCKET calves (5.2 ± 0.6 min, $p = 0.002$). Calves were not observed to suck any pen structures or each other.

Also, we found a significant effect of the colostrum feeding method on the latency for the calves from the end of colostrum ingestions to the first BS bout ($p = 0.03$); TEAT calves had overall shorter latencies than BUCKET calves (16.2 ± 2.0 min vs. 21.9 ± 2.0 min, $p = 0.02$), but did not differ from DAM calves (18.5 ± 2.0 min).

Table 1
Effects of colostrum feeding method on newborn calves' sleep quality and daily duration

| Sleep variable (mean ± S.E.M.) | Sleep phase | Colostrum feeding method (mean ± S.E.M.) | | | | Significance in the model |
|---|---|---|---|---|---|---|
| | | DAM | TEAT | BUCKET | S.E.M.* | |
| Frequency (no.) | NREM | 77 | 88 | 79 | 12 | ns |
| | REM | 58 | 52 | 68 | 15 | ns |
| | BS | 78x | 92ya | 99a | 4 | 0.003 |
| Bout length (min) | NREM | 4.8 | 4.3 | 3.9 | 0.3 | ns |
| | REM | 6.4 | 6.2 | 5.4 | 0.5 | ns |
| | BS | 10.8x | 8.3ya | 7.7a | 1.0 | 0.01 |
| Total daily duration (min) | NREM | 421.5x | 468.3xa | 378.1b | 62.6 | 0.06 |
| | REM | 352.6 | 291.4 | 370.7 | 29.1 | ns |
| | BS | 774.5 | 759.7 | 748.8 | 31.6 | ns |
| Percentage of BS | NREM | 55.0 | 61.4 | 50.7 | 3.5 | ns |
| | REM | 45.0 | 38.6 | 49.3 | 3.5 | ns |
| Percentage of total rest | NREM | 36.7 | 38.5 | 31.6 | 4.7 | ns |
| | REM | 30.4 | 24.2 | 30.8 | 2.3 | ns |
| | BS | 67.1 | 62.7 | 62.3 | 3.0 | ns |

BS: behavioural total sleep; NREM: non-rapid eye movement sleep (estimated from behaviour); REM: rapid eye movement sleep (estimated from behaviour); DAM: calves housed with their dam; TEAT: individually housed calve, fed colostrum through a rubber teat; BUCKET: individually housed calves, fed colostrum from open bucket.

* DAM S.E.M. = 1.01 × S.E.M., figures with different letters differ significantly ($p < 0.05$), where TEAT was compared with DAM (x–y) or BUCKET (a–b).

### 4.3. Diurnal sleep and rest patterns

Calves rested more at night than during the day (79.0 ± 2.9% vs. 73.8 ± 2.9%, $p = 0.001$). The proportion of resting on side was greater at night than day (3.7 ± 1.7% vs. 1.9 ± 1.7%, $p = 0.001$), while the proportion of resting on the sternum was smaller at night (96.3 ± 1.7% vs. 98.1 ± 1.7%, $p = 0.001$).

A greater proportion of calves' night-time rest than daytime rest was BS. Calves had more NREM and REM sleep at night than during the day. In addition, the proportion of REM sleep was greater during the night than during daytime (Table 2). We found no significant interactions between diurnal BS distribution and colostrum feeding type.

## 5. Discussion

A sucking possibility increases the daily amount of NREM sleep in calves and induces them to sleep sooner after milk meal. We found no evidence that the possibility to suck milk or being kept with the dam affected calves' total daily sleep amount. However, calves housed with their dam had longer and fewer sleeping bouts than teat-bucket-fed calves housed individually. This might indicate the better sleep quality, but we need more basic studies on calves' sleep.

### 5.1. Sucking behaviour

Dam-reared calves aged two and three days suckled their mother approximately 10 times a day, a finding consistent with earlier studies (Lidfors, 1996). Interestingly, we also found that the

Table 2
Mean (±S.E.M.) percentage of time spent in each vigilance state during the day and the night by newborn calves

| Vigilance state | Day 6:00–18:00 | Night 18:00–6:00 | S.E.M. | *P* |
|---|---|---|---|---|
| BS (%) | 62.3 | 67.4 | 4.6 | 0.0001 |
| NREM sleep (%) | 62.1 | 58.6 | 7.3 | 0.02 |
| REM sleep (%) | 37.9 | 41.4 | 7.3 | 0.02 |
| NREM sleep (min) | 203.5 | 222.7 | 31.4 | 0.02 |
| REM sleep (min) | 125.3 | 158.9 | 28.8 | 0.0001 |

BS (%): behavioural sleep, expressed as a percentage of total resting duration, REM (rapid eye movement) and NREM (non-rapid eye movement) sleep durations are expressed as a percentage of all time spent in BS and total duration of time (min) in both state.

milk meal was equally long, 7–8 min, for dam-reared and teat-bucket-fed calves. The suckling time is similar to previous reports in dam-reared calves (Lidfors, 1996). In calves, the taste of lactose in the milk stimulates sucking, the motivation vanishing after about 10 min (de Passillé et al., 1992; de Passillé and Rushen, 2006). The 7- to 8-min meal length observed here was apparently sufficient to satisfy the sucking need of newborn calves.

Bucket-fed calves consumed their meal sooner (within 5 min) than teat-bucket-fed calves. However, we did not register any sucking behaviour directed towards pen structures, even though these calves did not have the possibility of sucking their milk portions. Contrary to our findings, Krohn et al. (1999) observed more sucking of equipment in newborn calves fed colostrum from an open bucket than in dam-fed calves. However, the calves in our study received almost double the amount of colostrum, i.e. 8.0 L versus 4.6 L in their study. Thus, an explanation for the absence of redirected sucking behaviour in our study could be greater satiety of calves, a factor shown to affect calves' sucking behaviour (Rushen and de Passillé, 1995). Moreover, stronger sucking motivation may develop later, as the mean lactose content in cows' colostrum is 20–40 g/L during the first days *post partum*, gradually increasing to 50 g/L, the concentration found in the whole milk (Sjaastad et al., 2003). A higher concentration of lactose in milk results more non-nutritive sucking, at least in older calves (de Passillé and Rushen, 2006).

### 5.2. Sucking and housing in relation to sleep quality in newborn calves

Calves fell asleep sooner after sucking milk from a rubber teat or from their dam than calves fed milk through an open bucket. This is in accordance with the findings of Veissier et al. (2002), who reported that sucking induced resting in 1.5 to 2.5-month-old calves. We did not find any effect of sucking possibility on the mean daily sleeping time of newborn calves, but it did increase their amount of NREM sleep, which is similar to findings in laboratory rat pups (Kapas et al., 1991b). We need further studies on the effect of sucking and sleep on calves, as NREM sleep is relevant for the developing brain, such as synaptic development (Peirano et al., 2003). Nutritive sucking has been shown to have an effect on the brain activity of the newborn babies (Lehtonen et al., 1998). We also know that body energy is restored (Benington and Heller, 1995; Berger and Phillips, 1995; Gip et al., 2002) and a significant proportion of daily growth hormone is secreted during NREM sleep (Steiger, 2002; Obal and Krueger, 2004).

Having the possibility of sucking milk did not change total daily resting time in individually housed calves. This is in agreement with our earlier studies, where total resting time was very constant in calves kept in different environments (Hänninen et al., 2003, 2005; Hänninen, 2007). However, we found that when newborn calves could suckle colostrum either from their dam or

from an artificial teat, they rested more on their side than calves fed colostrum from an open bucket. As we proposed in our earlier studies, resting on side may be a sign of a more secure environment (Hänninen et al., 2005), thus representing CCK-induced anti-anxiety behaviour; a phenomenon also shown in rats and human babies (Wang et al., 2005).

We found that calves slept longer bouts and less often when they were kept with their dam in the parturition pens than when housed individually and teat-bucket fed. This is somewhat surprisingly similar than found earlier in the newborns of altricial species, such as in rat pups, in which a maternal deprivation increased wakefulness and number of phase transitions and reduced time and bout duration of both of the sleep phases (Hofer, 1976). We suggest, that calves housed with their dams may have better quality sleep, as the quality of sleep can be defined by measuring the sleep duration, consolidation and intensity (Tobler, 2005). However, we need more studies in the future, about the importance of maternal care on calves' sleeping rhythm and brain development.

In addition, the presence of the dam in conjunction with the suckling behaviour may have had a calming effect on calves. Dam-rearing has been shown to increase oxytocin secretion and decrease cortisol secretion in calves (Lupoli et al., 2001). Oxytocin and CCK both have calming effects (Uvnäs-Moberg, 1998). Human infants have been demonstrated to have less arousal during sleep when in direct contact with their mothers (Ludington-Hoe et al., 2006). Moreover, dam-reared calves presumably had more milk daily, and a full stomach is a sleep-promoting factor in rats (Lorenz, 1986).

Housing calves with their dams decreased calves' total daily resting time compared with housing calves individually. This is probably due to the longer sucking time of dam-reared calves. This is in agreement with other studies, where the presence of the dam has been shown to activate newborn calves (Lidfors, 1996; Krohn et al., 1999). Calves housed individually also had relatively few possibilities to explore and interact with conspecifics and the environment, thus spending a larger proportion of their wake time resting.

### 5.3. Sleep structure

Although the calves rested almost 20 h a day, they slept for only 12.5 h, representing 52% of the 24 h. This is considerably more than the 25% we recorded in 3-month-old calves (Hänninen et al., 2008) or the 17% reported in adult cows (Ruckebusch, 1965, 1974). Newborn calves seem to spend a larger proportion of their daily sleep time in REM sleep than older calves or adult cattle; i.e. 5.5 h compared with less than 3 h in older calves (Hänninen et al., 2008) or less than 1 h in adults (Ruckebusch, 1965, 1974). This is in accordance with the finding of others, as the young of many terrestrial mammalian species sleep more overall and have more REM sleep than older animals (Siegel, 2005). Sleep is essential for the development of the brain, and REM sleep is connected to the early developmental phase (Mirmiran, 1986; Morrissey et al., 2004). Young animals have a greater need than older animals for energy retention, which can be achieved through more sleep (Siegel, 2005). Calves in our study spent around 44% of their total sleeping time in REM sleep, corresponding to 23% of their day. This is similar to finding in older calves (Hänninen et al., 2008) and in accordance with the notion, that precocial young mammals, such as bovine calves, have proportionally less REM sleep of total sleep time than altricial young mammals (Siegel, 2005). REM sleep in newborn rat puppies, for instance, accounts for 68% of the day (Jouvet-Mounier et al., 1970).

REM sleep occurred in bouts of about 6 min, which is longer than in older calves (Hänninen et al., 2008) but similar to adult cows (Ruckebusch, 1965, 1972, 1974). We might have

overestimated the amount of behavioural REM sleep, as calves have rapid shifts between REM and NREM sleep, which are not always reflected in their body postures (Hänninen et al., 2008). Younger calves also rest more in a curled body positions, to save energy by reducing the body area exposed to air (Hänninen et al., 2003).

Newborn calves' sleep, as a whole, occurred in short, approximately 10 min bouts, which is longer than the average length of 5 min that we observed in older calves (Hänninen et al., 2008). Also the 80–100 daily sleeping bouts that we recorded in newborn calves in this study were greater than the 50 sleeping bouts that we recently recorded in older ones (Hänninen et al., 2008). Calves' appear to cope with their greater sleep demand both by lengthening their sleep bouts and by increasing the number of sleeping bouts. This fragmented sleep pattern may reflect an evolutionary adaptation to predators. During evolution, some prey species have adapted to the increased need to remain vigilant by reducing time spent in sleep, especially in the REM sleep, when they are extremely vulnerable (Elgar et al., 1988; Tobler, 1995; Siegel, 2005).

No evidence emerged of a diurnal rhythm in sleep; calves slept quite equally during the night as during the day. This is in contrast to cows, who sleep around the clock on pasture, but mostly sleep at night when kept indoors (Ruckebusch, 1972). The calves spent a larger proportion of their night-time sleep than their daytime sleep in REM phase. This may reflect greater disturbances during barn working hours since animals under stressful conditions have lighter sleep (Lima et al., 2005).

## 6. Conclusions

Neither colostrum feeding method nor the presence of the dam influenced calves' daily behavioural sleep. However, a sucking possibility did affect calves' sleep quality by increasing the behavioural NREM sleep. Sucking also induced more resting on side, probably reflecting reduced anxiety. Dam-reared calves have longer and fewer sleeping bouts than individually housed teat-bucket-fed calves, which might be an indication of the better sleep quality, but more studies are needed.

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