ELSEVIER
Applied Animal Behaviour Science 70 (2001) 167–176
APPLIED ANIMAL BEHAVIOUR SCIENCE
www.elsevier.com/locate/applanim

Effects of milking frequency on lying down and getting up behaviour in dairy cows

S. Österman*, I. Redbo

Swedish University of Agricultural Sciences, Department of Animal Nutrition and Management, Kungsängen Research Centre, S-753 23 Uppsala, Sweden

Received 31 December 1999; received in revised form 19 May 2000; accepted 6 July 2000

Abstract

The objective of this study was to investigate if cows milked twice per day have more difficulty lying down and getting up and spend less time lying than cows milked three times per day. Seventeen cows of the Swedish Red and White Cattle Breed were studied, seven of which were milked twice daily (2M) and ten were milked three times (3M) daily. They were kept in individual cubicles, that were closed in the rear end with a rope. They had free access to a mixture of silage, hay and concentrate. The individual cows were video-recorded for 24 h every fourth week, starting four weeks after calving for four times. The 2M cows stood significantly longer, 128.11 min, than the 3M cows, 64.88 min, ($P < 0.01$) during the 4 h before morning milking. The 2M cows also had a tendency for longer duration of standing rumination ($P = 0.059$) as well as significantly more bouts of standing rumination ($P < 0.01$) during these hours than the 3M cows. The cows in the 3M group spent less time on the getting up movement ($P < 0.05$) during the 4 h before morning milking. The distribution of the lying bouts during these 4 h differed significantly between the groups, where the 3M cows had fewer lying bouts shorter than 15 min and more lying bouts longer than 90 min. The results indicate that milking three times a day contributes to increased comfort in high-producing dairy cows.

Keywords: Dairy cow; Milking frequency; Lying down behaviour

1. Introduction

Milk yield per cow has increased dramatically during past decades in Sweden, among other countries. In 1965, average milk production for Swedish Red and White Breed, a Swedish dual-purpose breed, was approximately 5000 kg energy corrected milk (ECM). Slightly more than 30 years later, in 1998, milk production had increased to about 8000 kg

* Corresponding author. Tel.: +46-18-671634; fax: +46-18-672946.
E-mail address: sara.osterman@huv.slu.se (S. Österman).

0168-1591/01/$ – see front matter
PII: S0168-1591(00)00159-3

ECM, according to the Swedish Dairy Association (1998). This means that the production for individuals of this breed could be as high as 50–60 kg per day at the lactation peak, with milk amounts of 35–40 kg at the morning milking, when cows are milked twice a day. Several studies have shown that a more frequent milking will increase the milk yield (e.g. Allen et al., 1986). Besides an possible economic benefit of a higher milking frequency, there may be other advantages to the individual high-producing cow, such as increased lying comfort. Cows with filled udders may have greater difficulty in performing certain movements, such as lying down and getting up. These movements are largely genetically pre-programmed and fixed, and determined by the skeletal and muscular structure, meaning that the cow has small, or no, possibilities to adapt these movements to the actual circumstances. Also, an overfilled udder, together with a suboptimal environment, such as poorly designed cubicles or slippery floors, may increase the risk of step wounds on the teats during getting up and lying down movements. Krohn and Munksgaard (1993) suggested that a hard surface in combination with a distorted lying down movement pattern were causal factors for the higher frequency of teat trampling that they found in their experiment. Wounds, in turn, is a well-known factor behind mastitis, which is one of the most common reason for culling in dairy cows (Swedish Dairy Association, 1998). Furthermore, it may be uncomfortable or even painful for the cow to be lying with a filled udder, since there is an external pressure on the udder when lying. Thus, high lactation yields in combination with milking only twice per day may involve decreased welfare of the dairy cow, and possibly even suffering. The objective of the present study was to investigate the effect of milking frequency on the duration of the getting up and lying down movements, as well as the duration and frequency of total standing and lying.

2. Materials and methods

2.1. Animals and housing

Twenty cows of the Swedish Red and White Breed were included in this experiment. Ten cows were milked twice a day (2M), at 6.00 and 15.00 h and ten were milked three times a day (3M), at 6.00, 14.00 and 22.00 h. Three cows in the 2M group had to be excluded before the analysis started, two were excluded due to mastitis and one had serious leg problems. In 1994, the cows were blocked according to calving date, and thereafter, allotted to the two treatments. This experiment started in the Autumn of 1996, so the cows had been on this treatment for two years. The cows were in their second to fifth lactation, equally distributed between the treatments. The cows were housed in the same barn, but in individual cubicles (1.20 m $\times$ 1.70 m). The cubicles were designed with metal side rails between the cows, and the rear end was closed with a rope that could be lifted manually when the cows were entering and exiting. The floor in the cubicles was covered with rubber mats, on which a small amount of a mixture of chopped straw and sawdust was spread once a day. All cows were walked about 35 m to a milking parlour. After milking, the cows always went back to their own cubicle and, accordingly, they had the same neighbours during the whole experiment. During the day, natural light entered the stable, and was supplemented by some artificial light. During the evening and night the barn was dimly lit.

2.2. Feeding

The cows were fed individually and had free access to water. They were fed a mixture of silage, hay and a concentrate, A (40, 10 and 50% of DM, respectively) at 07.30, 10.00, 16.00 and 20.00 h. In addition, concentrate B was fed, also four times per day. The mixture was fed ad libitum while concentrate B was fed with 6 kg per cow and day. The individual feed consumption was registered once daily.

2.3. Registration of movements and behavioural categories

Video recordings were made of each cow during four 24 h periods, starting four weeks postpartum and thereafter in lactation weeks 8, 12 and 16. The camera was placed 2 m in front of and 2.5 m above the cow. From the videotapes, behaviours were analysed according to their duration and frequency per observation time unit (see below).

Lying down and getting up movements were analysed in detail and registered in accordance with the following definitions. The lying down movement was divided into two phases.

Lying down, phase 1	Started when the nose was moved in a pendulum movement close to the ground and ended when the cow had one knee on the floor.
Lying down, phase 2	The time it took for the cow to move from one knee on the floor until the lying down movement was completed, i.e. when the cow lies down on one of its two hips.

The getting up movement is just referred to as one movement.

Getting up	The time it took for the cow from beginning to move her head forward or sideways, pull her feet under herself, until she was standing with all four feet in contact with the floor, in a balanced position.

Lying down intention was also analysed and was defined as repeated ground sniffing with sweeping movements without lying down. Abnormal ways of getting up and lying down, such as 'dog-sitting,' were also recorded.

Besides these detailed analyses of lying down and getting up movements, the total standing and lying times were recorded, as well as the total time the cow spent eating and ruminating. These behaviours were analysed in accordance with the following definitions:

Total standing	total standing time, independent of activity or passivity
Total lying	total lying time, independent of activity or passivity
Eating, while standing	feed intake or chewing while standing
Eating, while lying	feed intake or chewing while lying
Rumination while standing	standing up while chewing bolus or in the process of regurgitating bolus
Rumination while lying	lying down while chewing bolus or in the process of regurgitating bolus

The behaviours and movements were analysed over 24 h, but also for the 4 h before the morning milking. Total standing and lying time were also analysed 4 h before and after the afternoon milking, and 4 h after morning milking, to provide a comparison. Transcribing data from the video-tapes was performed by one person.

2.4. Animal measurements

The day before the video recordings were conducted, each cow was also weighted, the production level was recorded, and the udder was measured. The udder was measured in centimetres from where the udder meets the thigh, along the *lateral suspensory laminae*, just in front of the two hind teats and up to the opposite side of the udder.

2.5. Statistical analyses

All statistical analyses for the duration of the behaviours were performed by using the procedure for mixed models (Littell et al., 1996) with the SAS® System for Windows (SAS 6.12, SAS Institute). Since this experiment was not balanced, (7 versus 10 cows), the mixed models had to be used when performing the statistical analysis. The following statistical model was applied to all data:

$$Y_{ijklmn} = \mu + G_i + \mathrm{LS}_j + M_k + W_l + U_m + (\mathrm{LS}_j \times U_m + G_i \times M_k) + e_{ijklmn}$$

where μ is the overall mean, G_i the effect of the ith level of group ($i = 2, 3$), LS_j the effect of lactation stage ($j = 1{-}4$), M_k the effect of milk amount, W_l the effect of weight, U_m the effect of udder measurement; two-way interactions, e_{ijklmn} the random effects.

There were interactions between covariates in the lying down movement and in the lying intentions. In the lying down movements there was an interaction between lactation stage and udder measurement, and in the lying intentions there was an interaction between group and milk amount.

Since there were no differences between phase 1 and phase 2 of the lying down behaviour, they were treated as one movement in the final analysis. Observations on 'eating while lying' were too few to allow any statistical analysis.

The frequencies of lying, standing, eating while standing, ruminating while standing, ruminating while lying and interrupted lying downs were analysed by using the GLM procedure of SAS® System for Windows (SAS 6.12, SAS Institute). The final statistical model for the frequencies of the behaviours was:

$$Y_{ijklmn} = \mu + G_i + \mathrm{LS}_j + M_k + W_l + U_m + (G_i \times M_k + G_i \times W_l + G_i \times U_m) + e_{ijklmn}$$

There were interactions between covariates in the frequency of lying and standing, between group and milk amount as well as group and weight. Also in the frequency of ruminating while lying, there where an interaction between group and milk amount. These interactions where both during the 24 and 4 h before morning milking.

The distribution of the time spent per lying bout was tested by the X2-test in the frequency models procedure of SAS® System for Windows (SAS 6.12, SAS Institute).

Table 1
Total standing, lying, eating and ruminating time (least square mean ± standard error) in minutes per 4 h periods before morning milking and before afternoon milking for cows milked two (2M) and three (3M) times per day, respectively

Variable	2M	3M	*P*-value
Total lying duration, morning	109.32 ± 14.89	174.22 ± 12.38	$P < 0.01$
Total lying duration, afternoon	112.58 ± 10.41	113.50 ± 8.77	n.s.
Total standing duration, morning	128.11 ± 14.94	64.88 ± 12.40	$P < 0.01$
Total standing duration, afternoon	115.38 ± 10.77	122.03 ± 9.08	n.s.
Eating while standing, morning	22.58 ± 4.54	16.56 ± 4.38	n.s.
Ruminating while standing, morning	60.53 ± 9.36	35.38 ± 8.03	$P = 0.059$
Ruminating while lying, morning	62.89 ± 7.65	78.79 ± 5.40	n.s.

3. Results

3.1. Four hours before morning milking

Total lying and standing duration during the 4 h before morning milking differed significantly between the groups, where the cows milked twice a day had shorter total lying time and, consequently, longer total standing time. No such differences between the groups were found when analysing the corresponding hours for the afternoon (Table 1). There was a tendency that standing rumination was longer for the 2M cows, while the lying rumination did not differ significantly. The time spent eating while standing did not differ between the groups (Table 1).The durations of lying bouts 4 h after both morning and afternoon milking did not differ between the two groups. The mean duration up movement was significantly longer for the 2M cows, (Table 2). In this behaviour, there also was an effect of the milk amount ($P < 0.05$) and the udder extent ($P < 0.01$). The time it took to lie down did not differ significantly between the treatments. However, a significant effect of the interaction between the lactation stage and the udder extent remained ($P < 0.05$). The duration of the lying down intentions did not differ between the groups, but there was a significant interaction ($P < 0.05$) between group and amount of milk.

The frequency of eating while standing and ruminating while standing was higher in the 2M than in the 3M group, while no differences were found in the frequency of standing, lying, ruminating while lying and interrupted lying downs (Table 3).

Table 2
The lying down and getting up movement and the lying down intention (least square mean ± standard error) in seconds for cows milked two (2M) or three (3M) times per day. Values from 4 h before morning milking

Variable	2M	3M	*P*-value
Lying down movement	28.43 ± 4.70	32.40 ± 3.77	n.s.
Getting up movement	20.72 ± 2.28	12.74 ± 1.55	$P < 0.05$
Lying down intention	23.20 ± 8.05	49.53 ± 6.79	n.s.

Table 3
Frequency of total standing, lying, eating and ruminating (least squaremean ± standard error), during 4 h before morning milking and for the 24 h, for cows milked two (2M) or three (3M) times per day

Variable	2M (4 h)	3M (4 h)	*P*-value	2M (24 h)	3M (24 h)	*P*-value
Number lying	3.5 ± 0.47	3.03 ± 0.49	n.s	17.08 ± 0.83	16.74 ± 0.69	n.s
Number standing	2.91 ± 0.39	2.39 ± 0.48	n.s.	18.02 ± 0.74	19.08 ± 0.61	n.s.
Number eating while standing	2.86 ± 0.34	1.73 ± 0.33	$P < 0.05$	19.85 ± 0.94	16.25 ± 0.77	$P < 0.01$
Number ruminating while standing	2.90 ± 0.20	2.13 ± 0.18	$P < 0.01$	10.88 ± 0.58	9.36 ± 0.49	$P = 0.053$
Number ruminating while lying	2.19 ± 0.40	2.47 ± 0.37	n.s.	12.69 ± 0.76	12.25 ± 0.64	n.s.
Number of interrupted lying downs	2.54 ± 0.41	2.00 ± 0.35	n.s.	3.97 ± 1.18	7.44 ± 0.97	$P < 0.01$

The distribution of the total time spent per lying bout during the morning, showed that the 3M group had fewer lying bouts shorter than 15 min and more bouts longer than 90 min than the 2M group (Fig. 1).

3.2. Twenty-four hours

When analysing the behavioural parameters during the 24 h, there were no differences in the movements between the groups. We found no differences between the 2M and the 3M

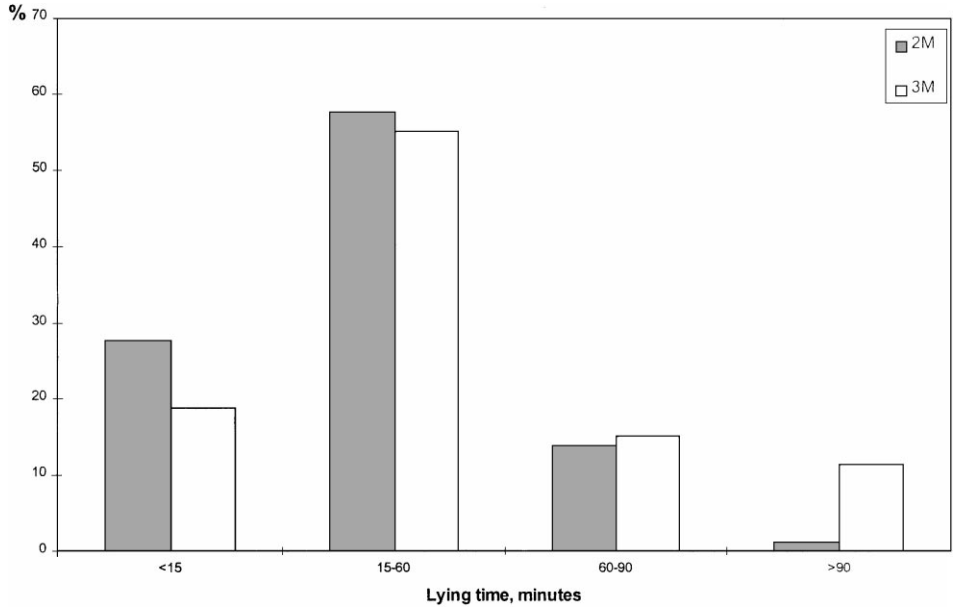

Fig. 1. Distribution of lying bouts during 4 h before morning milking according to duration. The distribution in the 2M group and the 3M group differs significantly $P < 0.01$.

groups neither in total time standing or in total lying time. Furthermore, there were no differences in eating while standing or in lying or standing rumination. Abnormal ways of getting up and lying down were not observed. Too few interrupted attempts to lie down were recorded to enable any statistical analyses.

The frequency of eating while standing, standing rumination and interrupted lying downs differed between the two groups (Table 3). During the 24 h, the distribution of total standing versus lying did not differ significantly between the groups.

Even though the cows in the 3M (592 ± 45 kg) group were heavier than the cows in the 2M group (570 ± 46 kg), there were no statistical differences in weight between the groups. Furthermore, the udder measurement of the 3M group was 94 ± 11 cm, and for the 2M group the measurement was 91 ± 6 cm. Finally, the 3M groups production level was 40 ± 5 kg ECM, compared with 38 ± 5 kg ECM for the 2M group. There were no statistical differences between the lactation stages within the groups in any of the measurements in the study.

4. Discussion

The results of the present study show that more frequent milking extends the total lying time during the hours before morning milking. The time that the cows spend lying as opposed to standing is of interest both from the cow's and the dairy farmer's point of view. Albright (1987) stated that increased standing in cattle is often taken as a sign of discomfort or discontent, and that the productivity of the dairy cow may be adversely affected by this.

When analysing the hours before morning milking, it must be considered that the cows in the 3M group had their latest milking at 22 h, while the cows in the 2M group were milked already at 15 h. Consequently, the cows in the 2M group had higher pressure in their udders, and it is reasonable to assume that it increases even more when lying down, as a result of the additional external pressure. This was probably an important causal factor behind the difference between the groups in total standing time during the hours before morning milking. Accordingly, there should be no such differences in udder extent due to milk amount, during the hours before the afternoon milking, since both groups were milked at the same time in the morning. As expected, we found no differences in total lying versus standing time during the 4 h before afternoon milking.

No differences between the groups were found in total lying time when analysing the whole 24 h period, which is in accordance with the results of Krohn and Munksgaard (1993). Their results showed no differences in total lying time between tied-up cows milked two or four times per day. The higher milking frequency in the 3M group may have disturbed the cows when they were lying, and therefore one might expect them to have somewhat shorter total lying times during the 24 h period. However, since all the cows were kept in the same barn, cows from both groups should, at least to some degree, have been influenced by this disturbance.

Metz (1985) showed that a 3 h deprivation of lying increases the need for this behaviour. The recovery was strongest immediately following the deprivation. Even though the cows in the 2M group had about 1 h shorter total lying time during the hours before morning milking, there was no increase in lying behaviour immediately after the morning milking.

However, the cows in the 2M group might have compensated for the decreased lying before morning milking during the rest of the day, since there were no significant differences between the groups in total lying time per 24 h. The reason why the cows did not compensate the lying after milking may have been due to that feeding occurred immediately after milking. Johansson et al. (1999) showed that time spent lying or standing after milking is strongly influenced by the time of feeding in relation to the milking time. They found that feeding during milking resulted in a lower percentage of lying during the 1 h after onset of milking. The authors suggest that a management routine where cows are given food directly after milking, motivates the cows to continue standing.

Wierenga and Hopster (1990) suggested that a reduction of lying during the night is compensated by an increased lying time in the evening. In their experiment, conducted in a cubicle house with 25% overcrowding, they found that a reduction in lying time during the 4 h before morning milking did not result in a significant reduction in lying time per 24 h, but that the lying time increased, although not significantly, from the afternoon milking onward for 10 h. They also showed that animals with the highest reduction in lying time during the night showed the highest increase in lying time during the evening. However, in our study there were no differences in lying time during the hours between afternoon milking and the evening feeding. At this time of the day, there were no disturbances in the stable, such as feeding or cleaning, and hence this would be the time for the cows to lie down and rest.

Munksgaard and Simonsen (1996) found that cows that were prevented from lying down from 9.00 to 16.00 and again from 22.00 to 5.00, primarily spent the increased standing time on idling and rumination. This is in accordance with our results, where the cows in the 2M group that had a significantly shorter lying duration during the 4 h before morning milking, also had a tendency to spend more time performing standing rumination than the cows in the 3M group. Several studies show that cows prefer to lie down when ruminating (e.g. Wagnon, 1963; Ruckebusch and Bueno, 1978), and the tendency for increased standing rumination found in our study further strengthens the conclusion that the cows in the 2M group experienced discomfort, at least during the late night hours. If the cows in the 2M group had found it comfortable to lie down, they probably would have preferred to ruminate while lying instead of while standing.

Wierenga and Hopster (1990) showed that with loose housed cows hardly any cow spent time eating during the hours before morning milking. In our study, the 2M group had higher frequencies of eating and rumination while standing than the 3M cows. Munksgaard and Simonsen (1996) suggested that increased frequencies of specific behaviours, such as eating or ruminating may be displacement activities caused by frustration due to the thwarting of lying behaviour.

Krohn and Munksgaard (1993) found that the duration of the total lying down movement was significantly longer for tied cows, milked twice per day, on a concrete floor covered with straw than for tied cows, milked four times per day, in stalls with rubber mats and straw. This is in accordance with Herlin (1997), who found that the preparation time required before lying down was significantly shorter on rubber mats than on a concrete floor. The cows in our experiment stood on rubber mats covered with straw, and we did not find any significant differences between the groups in the lying down movement during the 4 h before morning milking. Perhaps it is the surface of the lying area that has the greatest

influence on the lying down movement, as also reported by Andreae and Smidt (1982), while the size of the udder is of little consequence for this specific behaviour. However, in the getting up movement the groups differed significantly, the 2M group used more time for this movement during the hours before morning milking. The effect of milk amount and udder distension in this movement indicates that the cows probably had difficulties in carrying out this movement. A filled udder may lead to a more uncomfortable getting up, which might be an important reason for the hesitation in the getting up movement in the 2M cows. Difficulties in the getting up movement may be a problem, and may result in step wounds on the teats, which are a common factor leading to mastitis. There was only one lying bout in the 2M group that was longer than 90 minutes during the 4 h before morning milking, compared with the 3M group, where there were 18 bouts longer than 90 minutes. This difference is probably due to the higher udder pressure in the 2M group, that must have been even further increased when laying. The cows in the 2M group also had more bouts that were shorter than 15 minutes, leading to a higher frequency in the number of lying bouts. This suggests that the cows in the 2M group got up due to the increased udder pressure when lying, but that a continued relatively high motivation for lying probably led to new bouts of lying. This is in contrast to the 3M cows, where continued lying was more often noted. Dechamps et al. (1989) found that the mean value of a lying bout was about 1 h, which was in accordance with our results on the 3M cows, where the mean value of the lying bout was 57 min during the hours before morning milking, whereas the corresponding value in the 2M groups was 31 min.

The results found in this study indicate that a low milking frequency implicates discomfort for the dairy cow and a potentially increased risk of injuries to the teats due to trampling. Milking three times per day may contribute to increased comfort in high-producing dairy cows, partly due to reduced udder pressure, which permits higher comfort when lying down.

Acknowledgements

The authors thank the Swedish Farmers Foundation for Agricultural Research for financial support. We also gratefully acknowledge financial support from the Research Theme ‘Relationships animal production — health and welfare’ at the Faculty of Agriculture, Landscape Planning and Horticulture, SLU.

References

Allen, D.B., DePeters, E.J., Laben, R.C., 1986. Three times a day milking: effects on milk production, reproductive efficiency and udder health. J. Dairy Sci. 69, 1441–1446.

Albright, J.L., 1987. Dairy animal welfare: current and needed research. J. Dairy Sci. 70, 2711–2731.

Andreae, U., Smidt, D., 1982. Behavioural alterations in young cattle on slatted floors, in: Bessei, W. (Ed.), Disturbed Behaviour in Farm Animals, EEC-seminar, Hohenheimer Arbeiten, Heft 121, pp. 51–60.

Dechamps, P., Nicks, B., Canart, B., Gielen, M., Istasse, L., 1989. A note on resting behaviour of cows before and after calving in two different housing systems. Appl. Anim. Behav. Sci. 23, 99–105.

Herlin, A., 1997. Comparison of lying area surfaces for dairy cows by preference, hygiene and lying down behaviour. Swedish J. Agric. Res. 27, 189–196.

Johansson, B., Redbo, I., Svennersten-Sjaunja, K., 1999. Effect of feeding before, during and after milking on dairy cow behaviour and the hormone cortisol. Anim. Sci. 68, 597–604.

Krohn, C.C., Munksgaard, L., 1993. Behaviour of dairy cows kept in extensive (loose housing/pasture) or intensive (tie stall) environments: II. Lying and lying down behaviour. Appl. Anim. Behav. Sci. 37, 1–16.

Littell, R.C., Milliken, G.A., Stroup, W.W., Wolfinger, R.D., 1996. SAS® System for Mixed Models, SAS Institute, Cary, NC, 633 pp.

Metz, J.H.M., 1985. The reaction of cows to a short-time deprivation of lying. Appl. Anim. Behav. Sci. 13, 301–307.

Munksgaard, L., Simonsen, H.B., 1996. Behavioral and pituitary adrenal-axis responses of dairy cows to social isolation and deprivation of lying down. J. Anim. Sci. 74, 769–778.

Ruckebusch, Y., Bueno, L., 1978. An analysis of ingestive behaviour and activity of cattle under field conditions. Appl. Anim. Ethol. 4, 301–313.

Swedish Dairy Association, 1998. Cattle Statistics. Svensk Mjölk, Eskilstuna, Sweden.

Wagnon, K.A., 1963. Behavior of beef cows on a California range. California Agricultural Experiment Station, Bulletin No. 799.

Wierenga, H.K., Hopster, H., 1990. The significance of cubicles for the behaviour of dairy cows. Appl. Anim. Behav. Sci. 26, 309–337.