RESTING BEHAVIOUR OF DAIRY COWS: APPLICATIONS TO FARM ASSURANCE AND WELFARE

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ABSTRACT

Lying is a restful, high priority behaviour for dairy cows which can be affected by various factors associated with production but is not directly related to productivity. As such, lying behaviour has potential for use as an indicator of welfare. Information in the literature regarding the effect of stage of lactation on lying behaviour was contradictory and information on optimum lying behaviour and maximum bout lengths was scarce. The aim of this study was to improve knowledge in these areas and find a way of using lying behaviour to assess welfare.

Pregnant heifers were observed at pasture in order to describe lying behaviour in conditions that may be considered optimum. Lying behaviour at pasture was characterised as having 10.5h total lying time per 24h, few (6-7) lying bouts and a long maximum bout length (3.5h).

The effect of two very different levels of production on the lying behaviour of heifers during their first lactation and housing period was compared. Although total lying times did not change much over the lactation, early lactation was associated with disturbed lying behaviour (increased lying frequency and short bout lengths) and indicators of metabolic challenge in low input heifers. High input heifers however, showed more disturbance later in lactation associated with being moved to another feeding group.

Two pilot studies were carried out to investigate cows' preferences for cubicles with mats or mattresses and to compare lying behaviour on the two surfaces. Social factors appeared to affect preference and lying behaviour. Consequently total lying times were very low (less than 8h) and preferences were not clear. However, lying times were low even in a group of undisturbed late lactation cows and the pattern of lying (number of bouts and maximum bout length) was similar to that of heifers at grass.

In a controlled comparison at two dairy units, cows bedded on mattresses had longer total lying times than cows on mats. Again, total lying time did not change much over the course of the housing period (and lactation) but in both groups, lying frequency decreased and bout lengths increased as the housing period progressed. Lower total lying times were associated with an increase in idling and particularly idling in cubicles.

Selected cows from one dairy unit in this study were restrained in yokes so that their behaviour could be video recorded and analysed in more detail. The cows were bedded on the same bedding type that they had been allocated in the main trial. Cows on mattresses had more sleep bouts than cows on mats and tended to spend longer sleeping (defined as lying with complete relaxation of the neck muscles and the head resting on the flank). However, there were no differences in any other aspects of lying behaviour, although there were few cows and there was considerable variation. Older cows were more likely to show abnormal behaviours such as leaning and had a higher frequency of intentions to lie down.

A score for rising proposed by researchers in Denmark was assessed and found to be repeatable between and within observers, although the score should be recorded three times for each cow for maximum reliability. The score was a good predictor of lying frequency and maximum bout length but not of total lying time. Cows with higher rising scores, indicating a longer time taken to rise and awkward movements whilst rising, had a lower lying frequency and longer maximum bout length. A comparison was made of two similar scores for rising using two observers, each familiar with one score and unfamiliar with the other. This comparison revealed the importance of experience in making full use of the score and suggested that the Denmark rising score could be reduced to a binary level. However, this did not explain as much variation as the original five-point score.

This study has clarified the effect of stage of lactation on lying behaviour, added to the existing information on optimum lying behaviour and provides an extensive analysis of lying bouts under various conditions. Defined scores are a cheap and practicable way of assessing large numbers of cows and are therefore useful for farm assurance. However, the rising score which was investigated needs further validation before it can be recommended for use in an assurance scheme. Analysis of lying behaviour, using an automatic recording device, is recommended for use in farm assurance but should include information on lying bouts and not rely on total lying time alone. Lying bouts should be assessed at early lactation and mid or late lactation, including both first lactation and older cows to take into account differences due to stage of lactation and age. Further work is needed to elucidate the relative contributions of housing and calving to the disturbance of lying behaviour

DECLARATION

The studies described in this thesis were carried out from a base at the Dairy Health Unit of Scottish Agricultural College Veterinary Science Division, using animals, facilities and staff at: SAC Crichton Royal Farm, Dumfries; SAC Auchincruive Farm, Ayr; Myerscough Agricultural College, Preston; Research Centre Foulum, Denmark, between September 1996 and January 2000. The author was responsible for all results except where it is stated otherwise.

No part of this thesis has been presented to any other university but it has been reproduced in parts in the following scientific publications and abstracts:

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Chapter 1. Introduction

1.1 Introduction

Lying behaviour was chosen for the main focus of this study, although sleep, idling and other behaviours were also considered. Idling, sleep and lying behaviour have been grouped together as "rest" because they are not directly related to activity and production. Idling and sleep will be considered in detail in the chapters where they have more prominence and this introduction will focus mainly on lying behaviour and farm assurance.

Lying behaviour was considered in particular because the function of lying is rest and it has been demonstrated to be a high priority behaviour (Metz, 1985). A certain amount of lying is essential but a proportion of total the time spent lying may be a "luxury" behaviour, or alternatively may be a response to a lack of stimulation. Hence it is important to know how much lying is essential and what is indicated by longer lying times. Furthermore, although lying behaviour has no direct relationship to production it can be affected by various factors associated with production. It is possible therefore that investigation of lying behaviour could be a sensitive indicator of welfare in the dairy cow.

The aim of this introduction is to describe normal lying behaviour in the dairy cow and how it is affected by various individual cow and management factors. A study of the changes caused by these factors is directed towards determining the characteristics which describe optimum lying behaviour. The implications of depriving cows of lying will also be discussed, leading onto a consideration of farm assurance schemes and whether changes in lying could be used in welfare assessment.

1.2 Description of lying behaviour

The recumbent cow can usually be seen either with her head raised, often ruminating, or with her head turned back and resting on the rib-cage. One hind leg is usually tucked under the body whilst the other is stretched out to the side, partially flexed. The front legs are usually bent, although one or both may be stretched out forwards for short periods. Occasionally the cow may be seen lying entirely on the side of her body with all four legs stretched out, in lateral recumbency (Hauptman *et al.*, in Cermák, 1977; Fraser and Broom, 1990). Blood flow to the udder increases in recumbency and heart rate decreases (Rulquin and Caudal, 1992). Several authors have reported that cows lie more often on their left side than on their right but this preference is usually only slight (56%, Wagnon and Rollins, 1972; 53%, Yungblut *et al.*, 1974; 62-65%, Arave and Walters, 1980) and O'Connell *et al.* (1989b) found, conversely, a 54% preference for right laterality.

The cow has a species-specific lying down movement and starts the movement by searching for a lying down place by walking with the muzzle close to the ground. Due to restrictions in some housing systems, this part of the procedure can only occur in straw yards and at pasture. The cow then stands still and swings her head from side to side in a rhythmical motion with her muzzle close to the ground before bending one foreleg, lowering the shoulder and dropping down onto the knee. At this stage 78% of the cow's weight is on her forelimbs (Faessler, in Gustafson, 1994). One hind leg is lifted and the cow's rear is dropped to the ground so that she assumes the recumbent position described above. The lying down procedure can be interrupted at the stage of investigation of the floor, with one foreleg raised or even in the kneeling position. At pasture, the lying down movement from investigation to a recumbent position takes 47 seconds, on average (Krohn and Munksgaard, 1993).

When a cow rises she lunges forwards, then raises her hindquarters. The head and neck are used more actively in rising than in lying down (Snitzer, in Gustafson, 1994) and for a Holstein-Friesian cow to rise unimpeded, she requires between 0.6 and 1.2 m in front of her head for lunging (Cermák, 1990; O'Connell *et al.*, 1991; Faull *et al.*, 1996). Cermák (1990) called this extra space needed for lying down and rising, the cow's space envelope. The time taken for rising is shorter than for lying down as the different phases of rising pass rather quickly. Abnormal behaviour, such as dog-sitting (raising the front quarters before the hind quarters), is more common than interruptions (Gustafson, 1994).

Table 1.1 Lying times reported in published studies (hours per 24h)

System	Details	Av. lying time (h)	Reference
Tie-stall	straw	9.37	Hauptman *et al.* (in Cermák, 1977)
	total confinement	10.30	Hedlund *et al.* (1972)
	yoke	10.46	Dechamps *et al.* (1989)
	Unrestrained	11.54	Dechamps *et al.* (1989)
	total confinement	12.20	Hedlund and Rolls (1977)
	mats and straw	14.48	Munksgaard and Simonsen (1995)
	concrete and slats	15.63	Ladewig and Smidt (1989)
Cubicle housing	Concrete	7	Bölling (1994)
		7.50	Cermák (1990)
Cubicle housing	rubber mat	9.70	Chaplin *et al.* (2000)
		nearly 10	Bölling (1994)
		10.50	Cermák (1990)
		10.78	Hauptman *et al.* (in Cermák, 1977)
Cubicle housing	sawdust	10.93	Hauptman *et al.* (in Cermák, 1977)
Cubicle housing	straw	6.83	Singh *et al.* (1993a)
		8.40	Hauptman *et al.* (in Cermák, 1977)
	2cm straw	14.00	Cermák (1990)
		>14	Bölling (1994)
Cubicle housing	cow cushions	>14	Bölling (1994)
Straw yard	straw	9.72	Singh *et al.* (1994)
		10.08	Krohn and Munksgaard (1993)
		10.50	Hauptman *et al.* (in Cermák, 1977)
		12.35	Schmisseur *et al.* (1966)
	(straw pens)	13.04	Mogensen *et al.* (1997)
		14.79	Ladewig and Smidt (1989)
Pasture	heifers	9.58	Singh *et al.* (1993b)
	cows	10.33	Singh *et al.* (1993b)
	spring calvers	10.60	Phillips and Leaver (1985)
	autumn calvers	12.15	Phillips and Leaver (1985)

Total lying times reported in the literature vary from 7h to more than 14h per day, depending on the housing system, bedding type, management routine and many other variables (Table 1.1). Generally, lying times are shortest in cubicle systems and can be increased by the provision of softer bedding surfaces, although long lying times (> 12h per day) have been recorded in all types of system. Singh *et al.* (1994) suggested that lying times of 10h or more per day were adequate for proper rest for dairy cows.

A greater proportion of lying occurs at night, whether the cows are at pasture, housed in a straw yard or in cubicles (Hauptman, in Cermák, 1977; Singh *et al.*, 1993a & b; Singh *et al.*, 1994; Hedlund and Rolls, 1977). Lying at night is usually divided into two main periods of lying with a break corresponding with the midnight grazing period described by Phillips and Denne (1988). Phillips and Leaver (1985) also described a midnight grazing bout which replaced early morning grazing late in the season. O'Connell *et al.* (1989a) observed lactating dairy cows and reported two periods of lying at pasture, the first occurring before evening milking and the second from sunset to sunrise, but did not mention the night lying period being split into two bouts.

A cow's total lying time over 24 hours comprises between 6 and 20 bouts, each of which starts with the cow lying down and ends with her rising. Dechamps *et al.* (1989) suggested that an investigation of lying bouts is a useful way to characterise lying behaviour and some reported frequencies are given in Table 1.2. However these authors also concluded that mean bout length is not a meaningful measure as lying bouts are not normally distributed. It is clear in Table 1.2 that lying frequencies are highest for cows housed in tie-stalls. The lack of information on pasture and straw-yards prevents any comparison between these systems and cubicle-housing.

Table 1.2 Average lying frequencies reported in published studies (bouts/24h)

System	Details	Lying frequency	Reference
Stanchions/		10.0-14.0	Gustafson (1994)
Tie-stalls		10.4	Munksgaard (1986)
		10.8	Ladewig and Smidt (1989)
		12.8	Herlin (1994)
	mats and straw	13.6	Munksgaard and Simonsen (1995)
		14.1	Dechamps *et al.* (1989)
		17.0	Hedlund *et al.* (1972)
Cubicles	lame	6.0	Singh *et al.* (1993a)
	non-lame	6.0	Singh *et al.* (1993a)
	late pregnancy	6.5	Arave and Walters (1980)
	pregnant heifers	7.6	Chaplin *et al.* (2000)
	heifers, post-housing	8.9	Singh *et al.* (1993b)
	lactating heifers	9.7	Chaplin *et al.* (2000)
	cows, post-housing	9.9	Singh *et al.* (1993b)
Straw yard		10.3	Singh *et al.* (1994)
	young heifers in strawed pens	10.3	Mogensen *et al.* (1997)
	bulls	20.4	Ladewig and Smidt (1989)
Pasture	cows	6.1	Singh *et al.* (1993b)
	heifers	6.2	Singh *et al.* (1993b)

The longest lying bouts usually occur at night and last for between 1.5h and 4.8h (average of maximum bout lengths, Table 1.3). O'Connell *et al.* (1992) reported a range of maximum bout lengths from 0.25 to 9.00h in the group of cows they studied and both ends of this range are extreme compared with other average values given in Table 1.3. It is possible that lame cows may have influenced the results as this was a lameness investigation, although Singh *et al.* (1993a) found no difference in maximum bout length between normal and lame cows. In general, it appears that maximum bout lengths may be longer when cows are at pasture but there is not much difference between straw yards, cubicles and tie-stalls.

Table 1.3 Average of maximum lying bout lengths reported in published studies (hours)

System	Details	Max. bout length	Reference
Tie-stalls	very experimental conditions; 3 cows	3.0	Ruckebusch and Bell (1970)
Cubicles	post-housing	1.7	Singh *et al.* (1993b)
	lactating heifers	2.10	Chaplin *et al.* (2000)
		2.45	Singh *et al.* (1993a)
	pregnant heifers	3.03	Chaplin *et al.* (2000)
Straw yard	housed in cubicles by day, straw yard at night	3.95	Singh *et al.* (1993a)
		2.65	Singh *et al.* (1994)
Pasture	cows	4.8	Singh *et al.* (1993b)
	heifers	4.1	Singh *et al.* (1993b)
	lameness study	1.5 (range: 0.25-9.00)	O'Connell *et al.* (1992)

1.3 Factors affecting lying behaviour

1.3.1 Individual cow factors

Factors which affect lying behaviour can be related to individual cows or management. Cow factors include parturition, stage of gestation and stage of lactation, size or weight, age, oestrus and health, although of course management can influence health. Seasonal effects, both season of year and season of calving, are considered alongside cow factors because they cannot be altered by changes in management. In fact, Phillips and Leaver (1985) reported that total lying time at pasture showed little variation over the grazing season. However, autumn calvers had longer lying times than spring calvers, suggesting an effect of stage of lactation at pasture which appeared to be partly due to longer grazing times for the spring calvers.

Bao and Giller (1991) reported that cows with twins tended to lie on their left side pre-calving but they found no such effect of laterality in cows expecting singletons. Conversely, Arave and Walters (1980) found an increase in right laterality with approaching calving for cows but not heifers. These authors suggested that the developing foetus occupies a relatively smaller proportion of the abdominal space in large, older cows and therefore the discomfort of lying on the left side, the same side as the rumen, was greater in these animals. This suggests that a change in lying behaviour in late gestation related to the increasing size of the foetus might be expected but the reported results on laterality are far from conclusive.

In a comparison of behaviour before and after calving, Dechamps *et al.* (1989) found there was no difference in total lying time between cows in late gestation compared with cows in early lactation. However, these authors also found that cows in late gestation had a lower proportion of very short lying bouts compared with cows in early lactation. This was only a comparison between two extreme states for the cows: late lactation when the cow has a much greater body size and less room for gut fill; and early lactation when she cannot eat sufficient to meet her metabolic requirements. Stage of lactation is often confounded with the length of time that cows have been housed (considered below), particularly for autumn-calvers, and is always confounded by diet. However, comparing lying and lying down at early, mid and late lactation for continuously housed dairy cows under various conditions, Krohn and Munksgaard (1993) found no effect of stage of lactation.

Double muscled yearling heifers had a higher number of lying bouts over 24h than normal heifers of the same age (Wagnon and Rollins, 1972) and were described as having finer bones and more difficult articulation of their limbs. Gwynn *et al.* (1993) found that heavier cows lay for longer than lighter cows. However, they gave no descriptions of the cows' ages and it is likely that the heavier cows were older.

Age has important consequences for lying behaviour, particularly the difference between cows in their first lactation (hereafter called "heifers") and cows in subsequent lactations. Although heifers in their first lactation are often assumed to have reached maturity, they are still immature in many ways, both behaviourally and physically. Most commonly, where cows' behaviour is affected by the housing system, the effects are more marked in heifers. For example: in the early post-housing period, heifers have shorter total lying times than older cows (Singh *et al.*, 1993b); in tie-stalls, heifers have a higher lying frequency than older cows (Pollock and Hurnik, 1979); and in cubicles heifers have the lowest frequency of lying (Pollock and Hurnik, 1979). Under a range of different conditions, Krohn and Munksgaard (1993) observed that third lactation cows take longer to lie down than heifers, apparently because the older cows spend longer examining the lying area before lying. There were no differences in total lying time or lying frequency in that study and the authors suggested that the differences in lying down were due to the third lactation cows being older, and presumably therefore more experienced, and also heavier. Herlin (1994) also found differences between older cows and heifers. When they were tethered, heifers took less time to prepare for lying down and had fewer intention movements than older cows, whereas in loose housing, these differences were reversed. Heifers showed no preference to lie on either the right or left side, but older cows lay more often on their right side (Arave and Walters, 1980).

It is commonly reported that cows in oestrus are more restless and have shorter lying times (Hurnik *et al.*, 1975; Kiddy, 1977; Pollok and Hurnik, 1979; Hurnik and King, 1987; Singh *et al.*, 1994). However, these behavioural effects appear to be less marked in tie-stalls, particularly for younger cows (Pollok and Hurnik, 1979). The oestrus period lasts on average 13h (Pollok and Hurnik, 1979), although it ranges widely. After oestrus the cow's behaviour returns to normal. When there is only a single cow in oestrus she will disturb resting non-oestrus cows (Hurnik *et al.*, 1975) and so the presence of a cow in oestrus can disturb the behaviour of the whole group (Singh *et al.*, 1994). There can be a management interaction here, however: in straw-yards the disturbance affects all cows in the group, whereas in cubicles, lying areas are more separate and cows can hide to some extent. In a small group of 42 beef cows, Hurnik and King (1987) first observed oestrus between 20 and 100 days post-calving. Consequently, there was at least one cow in oestrus every two days for two months which amounts to quite a considerable disruption. Disturbance due to cows in oestrus should not therefore be discounted as a "one-off" event.

It has been suggested that health-related problems such as stiffness or arthritis might cause the lower lying frequencies which have been observed in older cows (Pollock and Hurnik, 1979) but the main health problem which has been reported to affect lying behaviour is lameness. The consequences of lameness for behaviour have been studied most thoroughly in cubicle-housed cows by Singh *et al.* (1993a) and in cows at pasture by Hassall *et al.* (1993). Both groups found that lame cows have longer total lying times than normal cows, although Singh *et al.* (1993a) found no difference in lying frequency or maximum bout length between normal and lame cows. These authors suggested that longer time spent lying during the day might be an abnormal behaviour as lame cows lay for significantly longer during the day.

1.3.2 General management factors

Management factors related to housing can reduce total lying times, although Hedlund and Rolls (1977, p1810) compared lying times reported in the North American literature and considered that "housing conditions such as space allotment, confinement or restraint [stanchions] have little effect on total amount of time cattle spent in recumbent rest". However, other work contradicts this conclusion. For example, the introduction of a strange cow can reduce total lying (Nakanishi *et al.*, 1993) and exposure to flies caused a marked reduction in total lying and a three-fold increase in the number of lying bouts of 10mins or shorter (Hedlund *et al.*, 1972). Some management factors affect lying behaviour regardless of system, such as milking frequency, management intensity and the transition from pasture to housing. However, many management factors affecting lying behaviour are specific to the system in which the cow is housed, i.e. straw-yard, cubicles or tie-stall, so these three systems will be compared and then the particular problems of each considered in turn. In straw-yards, therefore, space allowance will be considered. For cubicles these factors will be cubicle design, bedding type and cow:cubicle ratio, and in tie-stalls, exercise and type of restraint. Although bedding type will be considered in the context of cubicle systems, it can equally have an influence in tie-stalls.

An increase in milking frequency, with a concomitant increase in handling frequency, caused cows to show increased leaning (which is sometimes interpreted as a sign of stress), a reduction in total lying and an increase in lying frequency (Munksgaard, 1986). Chaplin *et al.* (2000) also speculated that milking in the morning disturbs cows' normal lying pattern leading to a reduction in total lying. However, when cows were milked using an automated milking system and milking frequency was increased from to two to four times per day, total lying times or lying frequency were unaffected (Winter *et al.*, 1992). This suggests that handling is more disturbing to cows than milking. Although conventional twice daily milking appears to have a synchronising effect on lying, Uetake *et al.* (1997) found no difference in total lying between cows milked through a parlour and those milked through an automatic milking system. The non-specific stress seen by Munksgaard (1986), caused by increased handling and production levels, appeared to be a reversible condition as the cows seemed to adapt after 5 months.

Cows which are housed are more restless compared with cows at pasture, as shown by reduced total lying times and greater individual variation in lying times (O'Connell *et al.*, 1989a; Galindo and Broom, 1993). Ketelaar-de Lauwere *et al.* (1999) however, found no difference in total time spent lying between cows that were on zero grazing, restricted grazing and full grazing regimes. Immediately post-housing, total lying time, maximum bout length and lying at night are reduced and lying frequency is increased (Singh *et al.*, 1993b; Chaplin *et al.*, 2000). Kerr and Wood-Gush (1987) showed a similar decrease in total lying time when dairy heifers were housed at almost one year of age.

These effects of housing do not appear to be permanent. In the study of Singh *et al.* (1993b) total lying time, maximum bout length and lying at night had increased again by six weeks after housing and lying frequency had decreased. This recovery of lying behaviour was also seen by Chaplin *et al.* (2000) and Kerr and Wood-Gush (1987). The lying times of overcrowded (2:1 cow:cubicle ratio) autumn-calvers increased linearly over the whole housing period, apparently due to an increase in night lying, and lying frequency decreased (Leonard *et al.*, 1996). These results all demonstrate that although housing may cause a disruption in lying behaviour cows adapt to housing after about six weeks. Perhaps this would explain the observations of Hedlund and Rolls (1977), that four cows in total confinement continued to exhibit behavioural activities typical of less confined cattle, which led them to conclude that lying behaviour was unaffected by confinement.

1.3.3 Comparison of housing systems

It is clear from Tables 1.1, 1.2 and 1.3 that housing system influences lying behaviour. Whilst it is commonly reported that cows at pasture lie for longer than cows that are housed (O'Connell *et al.*, 1989a; Miller and Wood-Gush, 1991; Krohn and Munksgaard, 1993) only three references could be found in the reviewed literature that actually gave total lying times over a 24h period for cows at pasture (Phillips and Leaver, 1985; Hassall *et al.*, 1993; Singh *et al.*, 1993b). Hassall *et al.* (1993) reported an average total lying time of 5.35h for non-lame cows at pasture. However, it appears from the methods that lying down and lying-ruminating were recorded as separate categories even though they are not mutually exclusive. If so, then average total lying time would be increased to roughly 7.9h for this study. This anomalous result aside, it would appear from Table 1.1 that longer total lying times can be found in all three housing systems: straw-yard, cubicles and tie-stalls. In fact, total lying times in tie-stalls are frequently much longer than at pasture. The lowest reported total lying times, however, are found in cubicle systems.

Although total lying times have been reported in a large number of studies, fewer report on lying frequency and even fewer on maximum bout lengths. The lying frequencies for cows at pasture, reported by Singh *et al.* (1993b), were comparable with the lowest frequencies reported for cubicle systems (also Singh *et al.*, 1993b) but were much lower than those recorded in tethered systems. Young heifers in straw-bedded pens (Mogensen *et al.*, 1997) and fattening bulls in straw yards (Ladewig and Smidt, 1989) also had high lying frequencies. There is insufficient information in Table 1.3 to make a comparison between cubicles and tie-stalls in terms of maximum bout length, although it would appear that maximum bout lengths were longer in straw-yards than in either of these systems, and even longer again at pasture.

Evidence of cows' preference when given a free choice of cubicles or pasture comes from a study by Ketelaar-de Lauwere *et al.* (1999). Cows being milked by an automatic milking system and given free access to both cubicles and pasture spent between 80-99.6% of their total lying time at pasture, even though feed was also provided in cubicles and when they could only spend 12h outside. Faced with a choice between cubicles and pasture these cows chose to lie at pasture. Similarly, when Schmisseur *et al.* (1966) gave forty-four cows a free choice between a straw-yard and cubicles, ten were observed to use the cubicles, but only two used them more than twice and all of the ten had prior experience of cubicles. The authors concluded that cows must be "coerced or forced" to use cubicles.

It is, by definition, impossible to give cows a free choice between tie-stalls and other systems but Krohn and Munksgaard (1993) compared tie-stalls with an extensive housing system where cows were loose housed with free access to deep bedding and pasture by investigating lying behaviour in considerable detail. The cows in the extensive system had shorter total lying times (10.08h/24h) and a lower frequency of lying over 15h (8.0 bouts) than tie-stall cows. When they were at pasture, cows in the extensive system examined the lying place less than when they lay in deep bedding, had fewer interruptions of lying, lay down quicker and lay in lateral recumbency more frequently. As the pasture and the deep bedding offered greater comfort and less restriction to the cows than the tie-stalls we should clearly not expect that longer lying times always indicate greater comfort.

1.3.4 Cubicles

Where cows are housed in cubicles, the type of bedding used can influence lying behaviour (Table 1.1). In studies comparing cubicle base materials and bedding types there is enormous variation between different products and practices (Table 1.4) so comparison between them is difficult. Furthermore, there are possible interactions with other cow and management factors affecting lying behaviour. However, Irps (1983) reported on several years' work by colleagues at his institute and concluded that cattle prefer soft flooring for lying and that the base should offer security for standing cattle. Despite the variation in products investigated by other authors, they all agree (Natzke *et al.*, 1982; Nilsson, 1992), or assume (Britten, 1994) that cattle prefer softer, more compressible flooring for lying. Dregus *et al.* (1979) considered that variations in lying time due to different floor types were largely due to variation in lying during the day (08:30 - 18:30) and that lying at night stayed relatively constant.

In many studies of base material and bedding preference, total lying times over 24h are not recorded. In Table 1.1 lying times are given, derived from studies where bedding was mentioned in the methods but was not necessarily the main focus of the trial. Rubber mats do appear to be associated with long lying times although there is only one result for sawdust bedding against which to compare them and no information on the depth of sawdust used (Hauptman *et al.*, in Cermák, 1977). O'Connell *et al.* (1993) found that mats were the most effective method of encouraging dairy calves to use cubicles and were also effective in encouraging first lactation heifers which had previously refused cubicles. These authors also found, in an earlier study (O'Connell *et al.*, 1989b), that mats increased the occupancy of the less preferred cubicle design in a comparison of two types.

Table 1.4 Comparison of studies investigating cow preferences (determined by either cubicle occupation or lying times) for cubicle base and bedding materials

Choice of bedding, in order of preference	Reference
synthetic resin mat > rubber mat heated concrete > insulated concrete ≡ concrete & plywood cushion ≡ wooden frame & plywood ≡ concrete	Hacker *et al.* (1969)
packed sand-gravel covered with plastic mat ≡ sawdust plastic mat (as above) > carpet on heated concrete base carpet on heated concrete base ≡ unheated concrete base	Yungblut *et al.* (1974)
dehydrated manure solids ≡ sawdust > dewatered manure solids	Keys *et al.* (1975)
sawdust > packed soil sawdust > rubber mat 1, sawdust > rubber mat 2 packed soil > rubber mat rubber mat 1 > rubber mat 2 rubber mat 1 with sawdust > rubber mat 2 without sawdust	Dregus *et al.* (1979)
layered mat > vulcanised rubber mat > carpeting > rubber mat	Natzke *et al.* (1982)
river sand covered with canvas > maize choppings with canvas > river sand ≡ calcrete fine ≡ sand	Visser (1994)
Enkamat > concrete with little straw freshly bedded concrete with straw > Enkamat	Jensen *et al.* (1988)
soft rubber mat > conventional rubber mat > concrete	Herlin (1997)

> indicates preference of one surface over another, ≡ indicates no preference

Cubicle partitions restrict cow movement to a greater or lesser extent, depending on the design. As described earlier, cows naturally lunge forwards when rising but they can lunge to the side when forwards lunging is prevented or difficult. However, cubicle length is usually restricted to prevent cows from standing too far inside and soiling the beds so that forward lunging space is also restricted. Cubicle designs, such as Dutch Comfort and Mushroom, which offer space at the front of the cubicle division that cows can use for lunging are therefore deemed to be more comfortable than divisions which do not allow this space. If there is insufficient room for forward lunging, then cows will adopt a dog-sitting posture when rising (Cermák, 1987). Even though cubicle divisions can be designed to allow space for lunging, McFarland and Gamroth (1994), considered that cows seem more tentative and careful about their movements when lunging to the side. Furthermore, O'Connell *et al.* (1991) compared four different cubicle designs and found that lying times were always similar once a choice had been made, regardless of cubicle type.

Yungblut *et al.* (1974) suggested that the slope of the cubicle bed surface affected laterality such that with a level surface cows lay on their left side 53% of the time but when the surface was sloped, they preferred to lie with their dorsal side uphill. This finding is in agreement with Arave and Walters (1980), who found that a 2% slope across the stall had a significant effect on laterality, and McFarland and Gamroth (1994) who consider that a slope of 3% or more would encourage all cows to lie in the same direction. O'Connell *et al.* (1989b) however, proposed that laterality is a result of cows orienting themselves towards the door whereas Arave and Walters (1980) found that cows lie with their dorsal side towards occupied neighbouring cubicles.

Overcrowding in cubicles is variously expressed as the cow:cubicle ratio (Leonard *et al.*, 1996), the number of cubicles per cow (calculated by dividing the number of cubicles by the number of cows: Friend *et al.*, 1976, 1977 and 1979), or as a percentage (Wierenga, 1983; Wierenga and Hopster, 1990), referring to the percentage of cows which are not provided with a cubicle, i.e. 20 cows provided with 16 cubicles results in 25% overcrowding. Usually anything less than a 1:1 cow:cubicle ratio is considered overcrowding. However, Fraser and Broom (1990, p386) define crowding as: "the situation in which the movements of individuals in a group are restricted by the physical presence of others" and overcrowding as: "crowding such that the fitness of individuals in the group is reduced" (p389).

Total lying times are reduced at higher levels of crowding (Friend and Polan, 1975, Friend *et al.*, 1976 and 1979; Leonard *et al.*, 1996), lying frequency is also reduced (Friend *et al.*, 1976) and variation in total lying times increases (Friend and Polan, 1975; Friend *et al.*, 1976). Even at lower levels of crowding (0.80 and 0.75 cubicles per cow), Wierenga and Hopster (1990) found that lying was reduced during the last four hours before morning milking, particularly among lower ranking cows. Lying times for the evening (from afternoon milking until the start of night) increased suggesting compensatory lying.

Wierenga (1983) also found that low ranking cows were worst affected by overcrowding. Overcrowding causes increased competition for limited resources, which is lying space in this case, and this competition causes an increase in aggressive interactions (Wierenga, 1983 and 1984) and adrenocortical responsiveness (Friend *et al.*, 1979) but has no effect on milk production (Friend *et al.*, 1979). Furthermore, overcrowding has been shown to be associated with leaning (Wierenga, 1983) which has been interpreted as evidence of stress in dairy cows (Munksgaard, 1986). These effects associated with overcrowding may be due as much to the social stress as to reduced lying. However, whatever the direct cause of the changes in behaviour, overcrowding at levels of ≤ 0.5 cubicles per cow caused an increase in glucocorticoid response when challenged with ACTH (Friend *et al.*, 1979).

It is well documented that not all cubicles are used equally by cows (Hacker *et al.*, 1969; Friend and Polan, 1974; Keys *et al.*, 1975; Dregus *et al.*, 1979; Arave and Walters, 1980; O'Connell *et al.*, 1989b) and Friend and Polan (1974) suggested that an over-crowding situation may exist even when sufficient cubicles are provided for the number of cows.

1.3.5 Tie-stalls

Tether systems are still common in many countries, although as herd sizes increase they are being replaced with loose-housing in cubicles. In tether systems, cows are restrained by the neck by either a yoke or a chain and the manner of restraint itself can affect lying. Dechamps *et al.* (1989) compared American yokes with enclosed cubicles and found a negative correlation between liveweight and total lying time for the six cows they studied. They therefore suggested that the American yoke is less suitable for heavier animals. Kinetic analysis by Sato and Hasegawa (1993) suggested that a rigid yoke restricts lying and standing behaviour much more than a neck chain.

Table 1.1 shows that the longest total lying times are found in tethered cattle and Table 1.2 shows that lying frequency is higher in tie-stalls than in cubicles or at pasture. Ladewig and Smidt (1989) investigated the effects of tethering on bulls. In the first week after tethering, compared with controls in pens, tethered bulls had longer total lying times, reduced frequency of lying and more lying area investigations. By 5-6 weeks after tethering, the difference in total lying had disappeared but the frequency of lying down was still less than for controls and there was a greater frequency of lying area investigations.

Interruptions in lying down are often seen in tethered cattle but never in those on deep litter (Müller *et al.*, 1989; Ladewig and Smidt, 1989). Müller *et al.* (1989) also found that heart rate was increased in tethered 20-month old heifers and especially during the first intention to lie. These authors, like Ladewig and Smidt (1989), suggested that the slatted floor rather than tethering was responsible for the behavioural changes seen. However, other authors have also reported that tethered cows take longer to investigate the lying area and longer to lie down than cows which are loose-housed or at pasture and that more interruptions of lying down are evident in tethered cows (Krohn and Munksgaard, 1993; Herlin, 1994; Kohli, 1987, in Gustafson, 1994). The floors in these studies were not slatted.

One possible reason for the considerable differences in lying behaviour of tethered cows, at least after some time, is muscle strength. Because these cows are seldom exercised, they have weaker muscles and therefore find lying down and rising more difficult. This would explain the increased frequency of lying area investigations and longer latency to lie but not the increased lying frequency. Tethered cows which have been exercised for one hour per day have been reported to take less time to lie down than non-exercised cows and have fewer interruptions of lying down (Gustafson, 1994). In particular, exercise shortens the early stages of lying down (Krohn and Munksgaard, 1993; Gustafson, 1994). Lying frequency was not affected in one study (Gustafson, 1994) but was greater for exercised cows studied by Krohn and Munksgaard (1993). Rising is facilitated by seasonal exercise acquired during the pasture season or in loose housing (Herlin, 1994) but exercise did not affect laterality (Arave and Walters, 1980).

1.4 The consequences of reduced lying

One of the most commonly reported consequences of reduced lying is lameness and the increased incidence of solear lesions in early lactation (David, 1986; Colam-Ainsworth *et al.*, 1989; Greenough and Vermunt, 1991; Singh *et al.*, 1993a; Chaplin *et al.*, 2000). In some studies it is not clear whether behavioural changes are the cause or the result of lameness. However, Leonard *et al.* (1996) experimentally reduced lying by overcrowding and found an increase in solear lesions in autumn calving heifers. Furthermore, lame cows lie for longer than non-lame cows whether at pasture (Hassall *et al.*, 1993) or in cubicles (Singh *et al.*, 1993a). Where lying behaviour has been implicated as a cause of lameness, it is always a decrease in total lying which is cited. Therefore it seems that whilst a reduction in total lying causes lameness, lame cows lie for longer than non-lame cows.

There is a body of evidence arising from deprivation experiments which shows that cows deprived of lying will attempt to compensate as soon as possible (Metz and Wierenga, 1984; Metz, 1985; Munksgaard and Simonsen, 1996) and that deprivation of lying is aversive (Munksgaard and Simonsen, 1996). The deprivation of lying in these studies was either total, in the most severe, or partial and of varying duration. Despite, or even because of, the severity of some of these experiments, this is the strongest evidence available of cows' need to lie and the consequences of thwarting that need.

Metz (1985) deprived cows of lying for three hours following morning milking by preventing access to cubicles. Then, in order to compare the motivation to lie with the motivation to feed, he deprived the cows of feeding by preventing access to the feed-face at the same time that they were prevented from lying. Lying deprivation alone caused an increase in lying in the three hours following deprivation and when both feeding and lying were prevented, the recovery rate of lying was the same. However, feeding deprivation alone caused an increase in feeding which reduced lying in the subsequent hour. This suggests that lying had a high priority compared with feeding. However, behaviour was not sampled over 24 hours and therefore it is impossible to tell whether the cows had changed their diurnal rhythm. The results do show however that the desire to lie increases significantly after only a few hours of deprivation and that motivation to lie can compete with motivation to feed.

In a more severe experiment, Munksgaard and Simonsen (1996) deprived cows in tie stalls of lying for 14 hours out of 24 for eight weeks. These cows tried to compensate for lack of rest by spending almost all (93%) of the remaining 10h lying down but they were unable to compensate fully and the duration of lying bouts did not change. Total feeding and rumination times were unaffected but it appeared that the enforced standing time was spent in ruminating and idling. As the total durations of the major behaviours apart from lying were unaffected, it appears that compensatory lying forced a change in the cows' diurnal rhythm. The duration and frequency of leaning and grooming were also increased by lying deprivation. Leaning has previously been related to stress in dairy cows (see above, page 15; Wierenga, 1983; Munksgaard, 1986) and Munksgaard and Simonsen (1996) suggested that the increased frequencies of idling and grooming were displacement activities caused by frustration due to the thwarting of lying.

Physiologically, long term deprivation of lying causes a reduction in plasma growth hormone concentrations, which could potentially lead to a reduction in milk yield (Munksgaard and Løvendahl, 1993). There was no effect on milk yield in the cows studied by these authors but the cows were in late lactation and early lactation cows may be more susceptible. The plasma growth hormone levels of these cows did not respond to an ACTH challenge but may have been caused by a forced change in the diurnal rhythm of lying. In a later report on the same cows

(Munksgaard and Simonsen, 1996), cortisol response to ACTH challenge was unaffected, although they did show an increased cortisol response compared with control cows when tested in a novel arena. The authors considered it possible that chronic stress caused by repeated deprivation of lying caused sensitisation at the hypothalamic level.

The physiological and behavioural changes observed in all of these deprivation studies suggest that preventing lying is aversive but these observations were made under experimental conditions. Partial deprivation can occur in practice when the conditions are such that cows choose to reduce their lying times. When Singh *et al.* (1993a) compared cows in cubicles and in a straw-yard, the cows in the straw-yard were heifers which refused to lie in cubicles and which were therefore put in the straw-yard at night (19:00 to 07:00). These heifers only lay for about one hour during the day so that about 90% of their lying time took place at night. The observed increase in lying times compared with normal cows in cubicles, mediated through longer maximum bout lengths rather than an increase in the number of lying bouts, may be evidence of compensatory, or rebound, lying behaviour.

1.5 The relationship between lying behaviour and farm assurance

Lidfors (1989) recommended that lying down and rising can be used to evaluate cattle environments and this study aims to investigate the use of lying behaviour as an indicator of positive welfare in quality assurance schemes. It is proposed that welfare assurance schemes should focus on positive welfare because although we can usually determine when a cow is diseased or in pain or suffering, the absence of these does not mean that welfare is good. Even if production is good, it could be that welfare is at best only adequate. For welfare assurance schemes to guarantee good welfare, we need to find indicators of positive welfare, not just adequacy. Lying is considered as a useful indicator of welfare as this behaviour is not directly necessary for production, like feeding, for example, and it is sensitive to changes in management.

1.6 The principles and practice of quality assurance schemes

Quality assurance schemes offer customers a guarantee of quality but just as quality means different things to different people, so quality assurance schemes vary widely. Ritchie and Leat (1994) identified several different types of assurance scheme (e.g. farm assurance, welfare-based, quality assurance, eating quality, and regional branding) each emphasising different aspects of quality.

Whilst quality assurance schemes are primarily about increasing competitive advantage and raising profits they may indirectly benefit animal welfare (Swanson, 1995). Many schemes have in common a general guarantee of "best practice production methods". Although it is acknowledged (Ritchie and Leat, 1994) that supermarkets, the main instigators of many such schemes, put more emphasis on what happens outside the farm gate than on what actually happens on the farm, such schemes should offer an assurance that stockmanship and production methods reach specified standards and are monitored independently.

Ritchie and Leat (1994) found that image was not an important attribute of quality for milk and had not increased in importance as it had for meat. They suggested that this reflected a lack of brand differentiation in the milk market. However, since then the milk industry in Britain has been deregulated and the market has opened up to a number of different companies and image has increasing importance. It is now possible to choose between Jersey milk, Ayrshire milk, "organic" milk and vitamin-enriched milk. Furthermore, milk companies are beginning to use distinctive advertising campaigns. Ritchie and Leat (1994) also suggested that there was a public perception of general good quality in milk supplies. Indeed, grassland systems such as dairy farming (in the UK, at least) are not usually associated with perceived abuses of animal welfare (Potter, 1994; Spedding, 1994) and have a relatively good public image insofar as animal welfare is concerned. However, the dairy industry does have welfare problems of which the public is aware, due to the activities of animal welfare/animal rights groups. Quality assurance schemes are being used to solve these problems before public awareness can further damage an already beleaguered industry.

One problem of applying quality assurance schemes to dairy farms is that quality assured milk must be collected and mixed with milk from other farms. For the product on the supermarket shelf to be assured, many farms must conform to the standard. Consequently, although Freedom Foods, for example, have a few producer-retailers accredited, the main force of dairy cow welfare assurance is carried most easily by the milk buyers rather than the supermarkets.

Milk buyers enforce the principles outlined by EC Health and Hygiene Directive 92/46 which are enshrined in UK legislation as the Dairy Product (Hygiene) Regulations 1995. These regulations stipulate conditions for the management and housing of dairy cows which are aimed at ensuring their good health and therefore the production of quality milk. Since deregulation of the UK dairy industry in 1994, dairy farmers have been able to choose which milk company to sell their milk to. The contract between producer and buyer includes certain standards of animal production which must be maintained and the company's milk liaison technicians ensure compliance. Until recently these standards were largely concerned with milk quality and dairy cow health, with little reference to welfare *per se.*

However, milk companies now implement their own milk quality assurance schemes, based on a publication by the National Farmers Union and the Milk Development Council (National Farmers Union, 1996) which outlines a code of conduct for dairy farmers. This is a slightly more powerful tool than the Welfare Codes published by the Ministry of Agriculture, Fisheries and Food (Ministry of Agriculture, Fisheries and Food, 1989) which cannot be enforced, only used as contributory evidence in welfare cases. Milk quality assurance schemes have the force of economics behind them: non-compliance with the milk buyer's contract means no market for the producers' milk.

Schemes applicable to dairy cow welfare to date have largely been based on standards inspired by the Farm Animal Welfare Council's Five Freedoms, on existing legislation, and on current recommendations of "best practice". Some existing dairy cow welfare assurance schemes are: the National Dairy Farm Assurance Scheme Standards (National Farmers Union, 1996); Freedom Food - the RSPCA's welfare standards for dairy cattle (Royal Society for the Prevention of Cruelty to Animals, 1998); and Standards for Organic Food and Farming (Soil Association, 1996). Quality assurance schemes devised by individual milk companies in Scotland were incorporated into the Scottish Farm Assurance Scheme and have now been joined into National Dairy Farm Assured Scheme (Logue, 1999). As well as industry schemes such as these, some supermarkets, in the UK at least, have introduced their own assurance schemes, among them Tesco, Safeways and Sainsburys.

The credibility of quality assurance schemes relies upon regular monitoring and compliance with defined standards. It must be possible to identify cows which are suited to the system in which they are kept and managed. Not all systems are the same and many are not even comparable but the welfare of cows in very different systems can be equally good and likewise, the welfare of cows in very similar systems can differ widely. As Spedding (1994) noted, systems can rarely be described as 'good' for welfare, since any system can be overstocked or badly managed. It is difficult to guarantee good management so criteria are specified which must be satisfied for a system to be judged satisfactory from a welfare point of view.

One way of preventing welfare from becoming poor is to identify the conditions under which cows are able to cope. Most assurance schemes are based on this approach. For example, by specifying the size of cubicles which are appropriate for a given size of cow, we can be relatively sure that cows of that size will not have their welfare compromised when using cubicles. If every aspect of the system can be specified in this way, then we can be fairly certain that the welfare of the herd managed within that unit will be satisfactory.

However, cows within a herd are individuals and although the conditions provided for the herd may be adequate, the welfare of certain individuals within the herd may still be poor. Likewise, stockmanship is a very large part of welfare and cows on a farm which does not conform to the physical aspects of a set of standards may still have good welfare because the level of care and management is very good. A situation such as this may occur, for example, on some small family farms. Because of these problems, existing welfare assurance schemes would be improved if we were able to assess cows as individuals on each farm, rather than just the physical structure of the farm itself.

1.7 The application of lying behaviour to farm assurance

There is a common assumption that longer lying times are better than shorter and that a reduction in total lying time is to be avoided. However, a reduction in total lying can be part of a cow's normal behaviour pattern. Cows close to parturition and those which are in oestrus, for example, are usually restless but the associated reduction in lying is usually only temporary. Neither are total longer lying times always better. A longer total lying time is not always due to excellent cubicle design and comfortable bedding but can be a sign of ill-health. Moreover, total lying times in tie-stalls are far in excess of those recorded at pasture despite other evidence, such as a very high lying frequency, suggesting that lying in tie-stalls is less comfortable than lying at pasture.

An objective view of the literature shows that there are several aspects of lying behaviour on which the research consistently agrees. Most importantly, it is clear from the results of deprivation experiments that cows need to lie down. If this need is not met, and cows are in some way prevented from lying, they will engage in displacement activities, show physiological changes indicative of stress and attempt to compensate at the earliest opportunity. Other areas in which there is unanimous agreement are:

- Heifers are more affected than cows by management factors which influence lying.
- Total lying times are longer on softer bedding materials.
- Overcrowding causes a reduction in lying time.
- There are more interruptions of the lying down movement and more investigations of the lying area in tie-stalls than in other housing systems.

However, in some cases there is little consensus, for example it is not clear whether stage of lactation affects lying or not. Although we know that cows need to lie, we do not know *how much* they need to lie. A thorough review of the literature did not yield a description of optimum lying behaviour, unless we assume that behaviour at grass is normal and any deviation is abnormal. If we were to follow this supposition however, we would abandon most existing housing systems but of course there are other factors to be considered in the welfare of dairy cows. Furthermore, we do not even have a perfect knowledge of the behaviour of cows at pasture or on straw, or of the effects of level of production. Information is also lacking regarding the importance of maximum lying bout length, probably because it is recorded less often.

The aim of this study was therefore to extend knowledge in these areas and, whilst considering all aspects of rest but focussing primarily on lying behaviour, to find ways of using resting behaviour to assess welfare.

Chapter 2. Behaviour of heifers at grass

2.1 Introduction

Heifers at grass prior to and during pregnancy, with limited metabolic requirements (by comparison to lactation) and a low incidence of disease must be among the least stressed animals in any dairy herd. They therefore provide a useful baseline against which to compare the changes caused by housing and calving.

Singh *et al.* (1993b) gave a detailed description of the lying behaviour of six dairy heifers at pasture. Miller and Wood-Gush (1993) compared the behaviour of a larger number of dairy cows at pasture and when housed but observations at pasture were not made over 24h. Galindo and Broom (1993) and O'Connell *et al.* (1989a) also compared behaviour at pasture and when housed but did not quantify differences in lying behaviour. Most other studies of dairy cow behaviour at pasture focus on grazing behaviour and do not describe lying behaviour. There is therefore a dearth of information in the literature regarding the lying behaviour of dairy cows at pasture. A lack of information regarding maximum lying bout lengths was also identified in Chapter 1.

In this study, dairy heifers in early and late pregnancy and in two herds were observed at grass prior to a more in-depth study of the same heifers under housed conditions. A range of behaviours was investigated, in particular lying behaviour and idling (standing doing nothing), with the aims of quantifying the normal behaviour of these heifers under stress-free conditions and describing diurnal rhythms. Further aims were to investigate variations in lying behaviour and idling with a view to their possible use as indicators of welfare. Also, differences between heifers in the two herds and between early and late gestation were investigated.

Some of these data were presented at the Association of Veterinary Teachers and Research Workers 26th Annual Congress, 1997.

2.2 Materials and Methods

2.2.1 Study design and selection of cows

At the Acrehead unit of Crichton Royal Farm, Dumfries, there were two herds involved in a system study. Both herds had a similar high genetic merit and were managed by the same staff on two halves of the same site. Acrehead 1 (AcL) was managed on clover/grass sward as a lower input/moderate yield system whereas Acrehead II (AcH) was a medium input/high yield herd grazed on grass swards to which a moderate level of nitrogen fertiliser had been applied (225kg/ha). Each herd comprised both autumn and spring calving animals. Apart from sward differences, heifers were managed the same in both herds.

All heifers due to calve in 1996/97 were observed in this studywhich was made in late summer (September, 1996). Sunrise occurred at 6:20 and sunset at 20:08 (The Meteorological Office, 1989). In AcL, nine autumn calvers were observed with six spring calvers in a 5.44ha field, sward height 3.52cm. In AcH, eight autumn calvers were observed with five spring calvers in a 3.98ha field, sward height 5.12cm. The autumn calvers were in late pregnancy, an average 44days pre-calving, and the spring calvers were in early pregnancy, 170d pre-calving. Sward height was measured by taking the average of three random measurements recorded using a rising plate meter.

2.2.2 Behavioural observations

Behavioural observations were carried out over 24h, starting mid-afternoon as there was the greatest likelihood of finding all heifers standing at that time. AcL was observed first for 24h and then AcH for the subsequent 24h period. Individuals were identified by large numbers painted on their sides and hindquarters. During each 24h observation period, the behaviour of every heifer was recorded at 15min intervals (scan sampling). Posture (lying or standing) and activity (feeding, ruminating, doing nothing or other) were recorded. In addition, lying behaviour was recorded continuously by noting the exact times of lying down and rising for each individual to give true frequencies and durations ("all-occurrences recording", Martin and Bateson, 1986). From the continuously recorded lying data, the following parameters were used to describe the lying behaviour of each individual: number of bouts, maximum bout length and total lying time. A bout was defined as the time between lying down and rising, maximum bout length was the longest episode of continuous lying recorded, and total lying was the sum of all bout lengths. Night was defined as the period 18:00 to 06:00 for comparison with Singh *et al.* (1993b). The behaviours of interest which were taken from the scan sampling and continuous records were defined as shown in Table 2.1.

Table 2.1. Description of behaviours and behavioural categories taken from scan sampling and continuous recording

Category	Description
Instantaneous scan sampling	
Lying	the cow is resting with her body on the ground
Night lying	sampling times 18:15 to 06:00, inclusive
Day lying	sampling times 06:15 to 18:00, inclusive
Feeding	the cow has food in her mouth and/or chews
Ruminating	chewing regurgitated cud
Lying-ruminating	lying and ruminating
Proportion of lying time spent ruminating	number of lying-ruminating observations divided by number of lying observations (from scan sampling)
Idling	standing and not engaged in any activity
Continuous recording	
Total lying time	the sum of all lying bouts, where a lying bout is the time between the cow lying down and rising again
Maximum lying bout length	the longest lying bout recorded over 24h
Number of lying bouts	number of lying bouts recorded over 24h

Idling was defined in this study as standing and doing nothing else. In other studies, however, idling has been commonly defined as occurring when an animal is not grazing or ruminating, a definition which includes lying-doing-nothing as well as standing-doing-nothing (Penning *et al.*, 1984; Fraser and Broom, 1990; Rook and Huckle, 1995 and 1996). Idling, by that definition, is not a single behaviour but a collection of behaviours. As lying-doing-nothing includes sleeping it is very different to standing-doing-nothing which has no apparent function. Therefore a definition which combines these two behaviours has little functional significance.

It was impossible for one observer to do a whole 24h observation period, therefore a team of observers was employed for all observations periods described in this thesis. These were drawn from friends and colleagues (Chapters 2, 3, 4, 5), and from scientific staff at Crichton Royal Farm (Chapter 3), Auchincruive (Chapter 5) and Research Centre Foulum (Chapter 7). All observers were briefed before their watch started and were not left unaccompanied until they were competent. However, the recording sheets were designed to self-explanatory and a description of the behaviours was left with the observers (see Appendix). After each watch, record sheets were checked and the data entered and summarised electronically using Microsoft Excel Version 4.

2.2.3 Analysis

The data were collected from only two grazing groups of heifers. Rook and Huckle (1995) have made it clear that the behaviour of cows at grass is more synchronised than expectations of randomness would suggest and consequently there has been recent debate concerning the validity of using individual cows as replicates (Phillips, 1998; Rook, 1998; Weary and Fraser, 1998).

Weary and Fraser (1998) considered that cows within a herd may be used as replicates if they can be individually assigned to treatments but that the validity of using individuals as replicates depends on the type of treatment being applied (presumably whether or not it is susceptible to synchrony effects) and the population to which the experimenter wishes to generalise.

The set-up of a systems study, such as the two Acrehead herds, is interesting in this respect. In some ways, AcL and AcH can be considered as groups rather than herds as the cows derive from the same genetic stock, are housed identically and are managed by the same staff. Many farm factors which might otherwise prevent generalisation to a wider population are therefore carefully controlled. However, the cows cannot be individually assigned to one group or the other and so management cannot be considered as a treatment and ANOVA is not appropriate.

Consequently, no tests for difference and statistical significance have been used and analysis has been restricted to descriptive statistics. Means and ranges of each behaviour were calculated for autumn and spring calvers in AcL and AcH. Overall means and coefficients of variation were also calculated for all of these behaviours. Where means have been represented graphically, error bars representing the standard error of the mean have been included to give an indication of variation about the mean. The proportion of cows in each herd (AcL, n=15; AcH, n=14) which were observed lying and idling at each time point was represented graphically to illustrate diurnal rhythms apparent in these behaviours. Coefficient of variation (CoV) is a summary statistic describing variation in a set of data which has been used as a measure of behavioural synchrony. It is calculated as: (standard deviation/mean)×100, and because it represents the variation in the data it can be used to give an indication of individual differences in behaviour.

Lying at night and lying during the day were correlated with total lying to determine whether a shorter observation period could be representative of total lying over 24h. Linear regression analysis was used to test the value of night and day lying as predictors of total lying.

2.3 Results

The average lying time over 24h for all the heifers observed was 10.91h, with an average maximum bout length of 3.69h and 7.2 lying bouts (Table 2.2). In both groups, there were times when all cows were lying at the same time. For AcL all cows were recorded as lying for 23 out of 96 observations (proportionally, 0.24) and for AcH this proportion was very similar: 19 out of 96 observations (0.20). The CoV for total lying and feeding of all cows in both groups were 8.3 and 11.0, respectively. However, the corresponding CoV for idling was much higher (37.3).

Table 2.2. Behaviour of autumn and spring calvers in AcL and AcH (means and ranges (min.-max.) in parentheses)

	AcL				AcH					Coefficient
	Autumn		Spring		Autumn		Spring		All	of variation
No. heifers	9		6		8		5		27	
Lying (h)	11.42	(10.25-12.75)	10.90	(10.25-11.50)	10.47	(8.75-11.50)	10.65	(10.00-11.50)	10.91	8.3
Night lying (h)	7.73	(7.00-8.50)	7.85	(7.50-8.00)	6.31	(5.25-7.25)	7.15	(6.75-7.50)	7.21	11.8
Day lying (h)	3.55	(2.75-4.25)	2.95	(2.50-3.25)	4.17	(3.50-4.75)	3.50	(3.25-4.00)	3.63	16.7
Max. lying bout length (h)	4.07	(1.68-5.80)	4.05	(2.90-6.82)	3.28	(1.27-4.50)	3.33	(0.92-4.43)	3.69	36.3
No. lying bouts	6.6	(4-11)	7.2	(4-10)	7.6	(4-10)	8.0	(5-11)	7.2	29.9
Lying-ruminating (h)	4.65	(3.50-6.50)	4.60	(3.25-5.75)	3.81	(2.25-5.25)	4.40	(2.75-6.00)	4.34	24.0
Proportion of lying time spent ruminating	0.41	(0.27-0.52)	0.42	(0.32-0.52)	0.36	(0.24-0.50)	0.41	(0.28-0.52)	0.40	20.7
Ruminating (h)	5.00	(3.25-6.50)	4.55	(3.25-5.75)	7.33	(6.50-8.75)	6.30	(5.50-7.00)	5.87	23.7
Feeding (h)	8.88	(7.25-10.00)	9.60	(9.25-10.25)	9.83	(9.00-11.00)	10.80	(9.50-12.25)	9.63	11.0
Idling (h)	2.15	(1.25-3.50)	1.45	(1.00-2.00)	2.25	(2.00-3.25)	1.35	(0.75-2.75)	1.92	37.3

Figure 2.1 shows the diurnal rhythm of lying in AcL and AcH with two main periods of lying, one at night and one in the morning. The night lying period started at around 21:00, about one hour after sunset, and was split into two: a short period in late evening, ending quite abruptly with all cows rising within 15min, and lying down again for the second part of the night-time period. This break occurred in both groups but at different times. The night lying period had ended by 7:30 for both groups, approximately one hour after sunrise, although rising started at 5:00, one hour before sunrise. The third lying period occurred in late morning, starting at around 9:00 and ending abruptly between 12:00 and 13:00. Some individuals also lay intermittently between 13:00 and 17:00.

In contrast, Figure 2.2 shows that one or two cows were observed idling intermittently throughout the day but that there was very little sustained synchrony. However, for both herds there were times when a large proportion of the group was standing-doing-nothing. In particular, between 06:15 and 07:15 a large number of cows were seen idling in both herds.

Total lying was correlated more strongly with night lying than with day lying ($r=0.77$ and 0.32, respectively). In the regression analysis, night lying was a significant explanatory variable for total lying, explaining 58.1% of the variance ($p<0.001$), whereas day lying only explained 7.1% ($p>0.05$).

Figure 2.1. Diurnal pattern of lying behaviour in two groups of heifers at grass

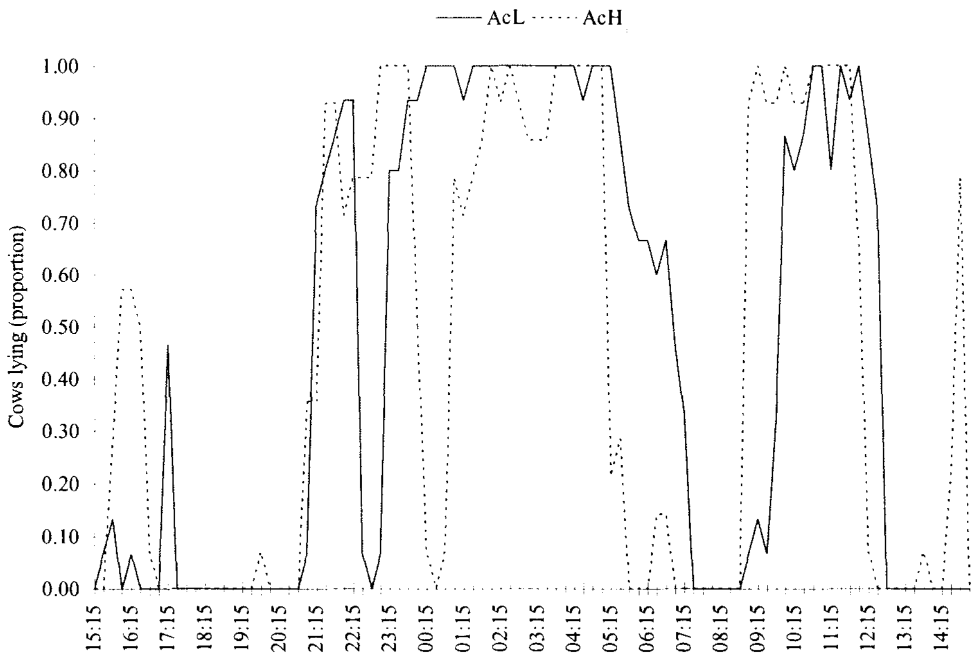
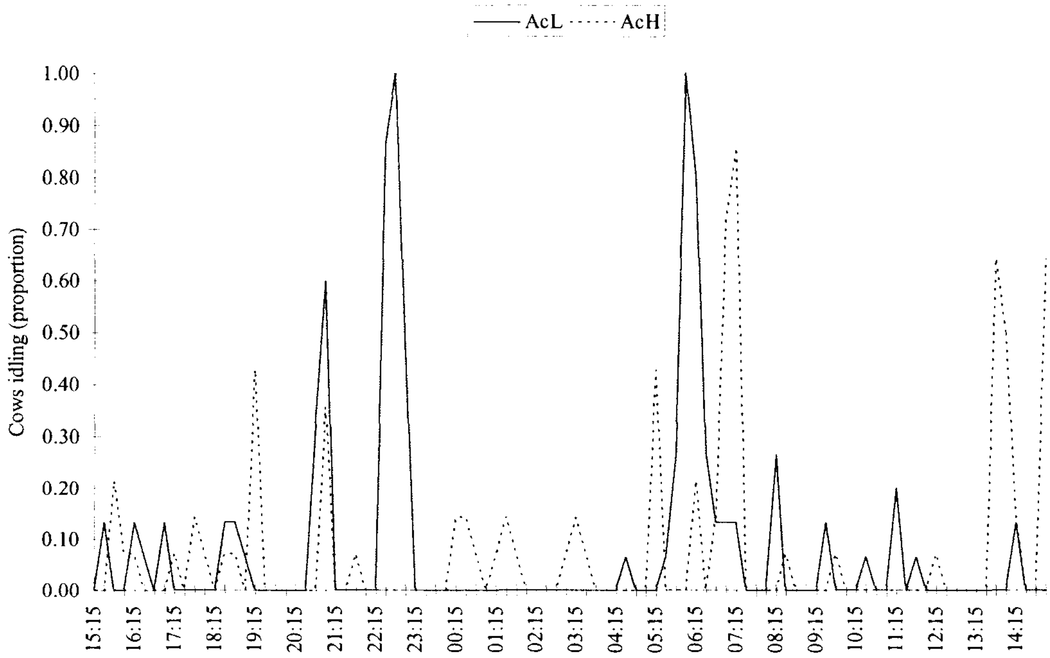


Figure 2.2. Diurnal pattern of idling behaviour in two groups of heifers at grass



Although no statistical tests for difference were carried out, some differences were evident between the herds and between late gestation autumn calvers and early gestation spring calvers. There was no apparent difference in idling between the two herds but heifers in AcH tended to feed and ruminate for longer than those in AcL (Figure 2.3). Despite the similarity in total lying, heifers in AcL tended to have a longer period of night lying and longer maximum bout lengths than heifers in AcH (Figure 2.4). Number of lying bouts and proportion of lying time spent ruminating did not seem to differ between the herds. Autumn calvers appeared to feed less and ruminate and idle more than spring calvers (Figure 2.5). There did not appear to be any difference in lying behaviour (total lying, maximum lying bout length, night lying, number of lying bouts or proportion of lying time spent ruminating) between heifers in early and late pregnancy.

Figure 2.3 Mean (± SEM) time spent lying, feeding, ruminating and idling for AcL and AcH (h/24h)

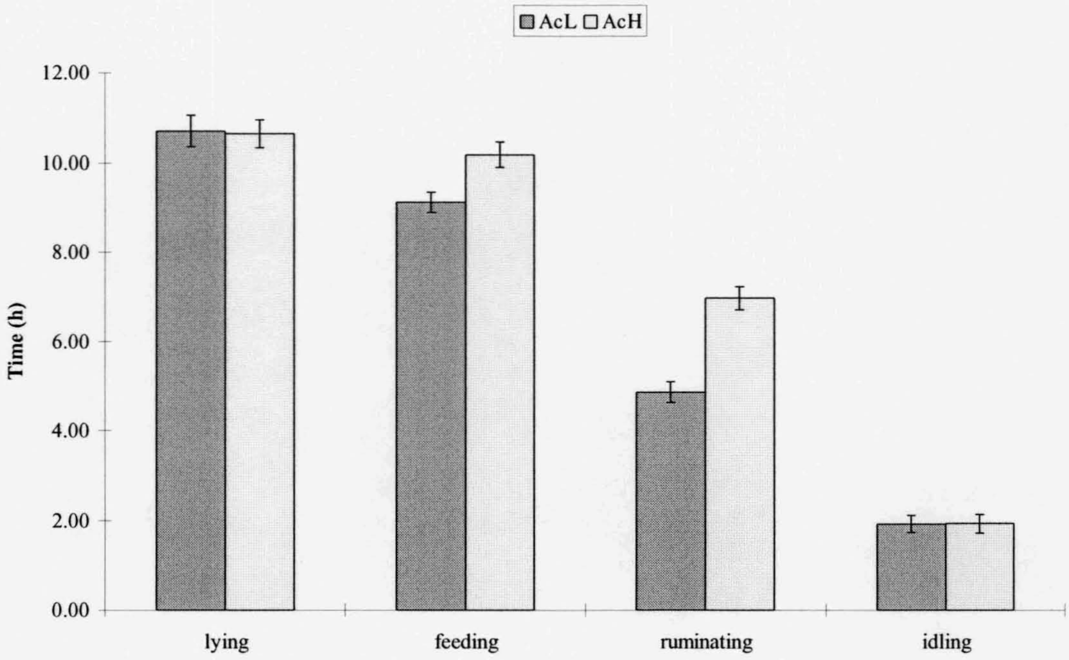


Figure 2.4 Mean (± SEM) total lying time, night lying time and maximum bout length for AcL and AcH (h/24h)

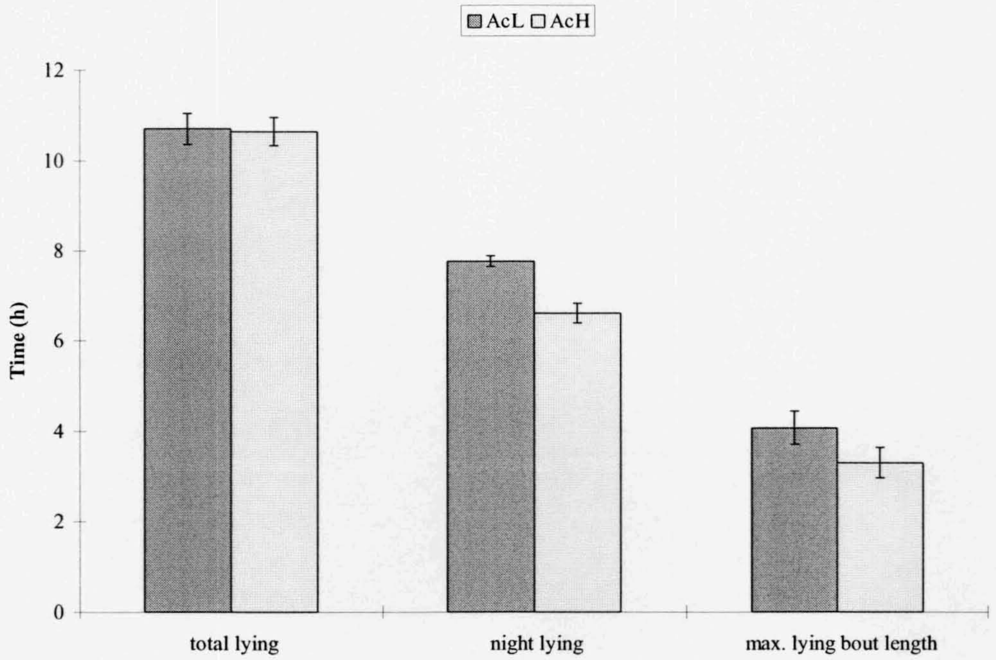
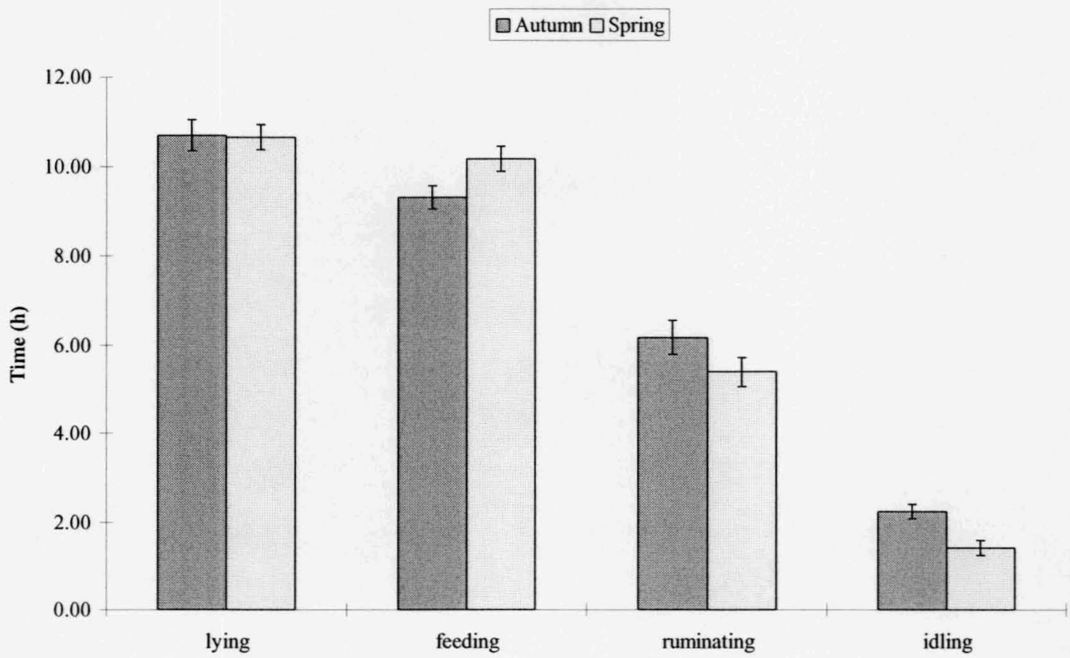


Figure 2.5 Mean time (± SEM) spent lying, feeding, ruminating and idling for late gestation autumn calvers and early gestation spring calvers (h/24h)



2.4 Discussion

A comparison of these results with the detailed description of lying behaviour given by Singh *et al.* (1993b) shows good agreement. On average, in their study, total lying was 9.58h, maximum bout length: 4.05h, number of lying bouts: 6.2, night lying: 6.00h and lying-ruminating: 5.45h. Corresponding values in the present study were: 10.67h, 3.69h, 7.2 bouts, 7.21h and 4.33h.

In what was primarily a study of social behaviour, Miller and Wood-Gush (1991) reported that, between 09:00 and 18:30, cows spent an average of 5.61h lying. This was greater than the 3.63h of day lying reported here and the 3.58h reported by Singh *et al.* (1993b). In both this study and that of Singh *et al.* (1993b), a lesser proportion of lying occurred during the day: 37% and 38% of total lying, respectively. If we assume that the 5.61h of day lying reported by Miller and Wood-Gush (1991) was 37.5% of the total, we can tentatively extrapolate and calculate that total lying must have been 14.96h and night lying, 9.42h. These times are considerably higher than in this study but apply to a mixed group of older cows and heifers and although not explicitly stated, it appears that the cows observed at pasture were in late gestation and not being milked.

Overall, very little time was spent idling at grass, less than 2.5h on average. There were peaks in the number of cows idling for both herds, occurring between 06:15 and 07:15, which may have been due to environmental cues. The heifers were probably distracted from grazing or other activities at these times by older cows returning to adjacent fields after milking. Lying down also seemed to be prompted in part by environmental cues as the night lying period began an hour after sunset and ended an hour after sunrise. This relationship between the time of sunset, cessation of grazing and commencement of lying down has been noted previously (Castle and Halley, 1953; O'Connell *et al.*, 1989a).

Differences in time budgets between the herds could be ascribed to foraging factors such as sward height and or/field size. Although AcH grazed a smaller field with a taller sward than AcL, AcH heifers fed and ruminated for longer. Grazing time can increase when grass is long and of low quality, and rumination time increases as the quality of the grass decreases (Holmes, 1989), suggesting that the grass supplied with nitrogen fertiliser (AcH) was of poorer quality at this time of year (September). These differences in grazing behaviour did not cause any difference in total lying but AcH heifers lay less at night and had shorter maximum bout lengths. Figure 2.1 shows a break in the night lying period for both herds. However, comparing Figures 2.1 and 2.2, we can see that the break in night lying corresponds with a peak of idling for AcL but not for AcH. This suggests that something disturbed the lying of AcL but that the AcH heifers were grazing. A "midnight snack" has been previously described by Phillips and Denne (1988). This evidence of a midnight grazing period for AcH but not for AcL further supports the suggestion that forage quality was poorer for the former. This must remain a tentative conclusion as forage analysis was not carried out but does suggest that differences in lying behaviour were due to foraging factors and not pre-existing differences between the herds.

The late gestation autumn calvers tended to feed less and ruminate and idle more than the spring calvers which were at an earlier stage of gestation. It is possible that the capacity of the rumen was affected by the developing foetus and furthermore, their nutritional requirements would have been greater. However, the advanced stage of pregnancy of the autumn calvers did not appear to affect any aspects of lying behaviour.

A common observation in studies of grazing dairy cows is the high degree of behavioural synchrony, gauged either by CoV (Galindo and Broom, 1993; Singh *et al.*, 1993b) or by the number of cows engaged in any one activity at the same time (O'Connell *et al.*, 1989a; Miller and Wood-Gush, 1991). The CoV for lying in this study (8.3) compares well with that reported by Singh et al. (9.2, 1993b) but both of these figures are much less than the 12.5 reported by Galindo and Broom (1993) for a much larger group of cows. Also, the degree of synchrony as illustrated by the number of cows lying at one time (Figure 2.1) compares favourably with figures presented in O'Connell *et al.* (1989a) and Miller and Wood-Gush (1991).

The CoV for lying (8.3) and feeding (11.0) were very similar but the CoV for idling was much higher, 37.3 (compare also Figures 2.1 and 2.2). This suggests that there is more individual variation in idling than in either feeding or lying.

Rook and Huckle (1995) found that idling was significantly more synchronised than expectations of randomness would suggest but this conclusion was based on a very different definition of idling to that used here. Their definition included both standing and lying components and so the high synchrony of lying makes it more likely that idling will appear to be synchronous under this definition.

It would be useful if observations over a shorter period could be used to give an indication of cows' lying behaviour and therefore forego the need for 24h observations. The correlation and regression results of the present study confirm that day lying alone is unsuitable as a predictor of total lying but that night lying is a very good predictor. Unfortunately, night is also the most impractical time to make direct observations of cows, although the proportion of cows lying an hour before sunrise might be a possibility.

2.5 Conclusions

The lying behaviour described here compares well with values reported in the literature for a comparable group of heifers (Singh *et al.*, 1993b). These average values for unstressed heifers can be used as a baseline against which to compare further observations under different conditions.

If lying and possibly idling are to be considered as indicators of welfare they need to be consistent when welfare is good but sensitive to poor welfare and expressive of individual differences. Apart from slight differences in maximum bout length and night lying, which appeared to be due to foraging factors, lying behaviour was consistent in both herds. It was also unaffected by stage of pregnancy. The high degree of synchrony, at grass at least, could be a problem if individual differences are suppressed. However, in this study no stressors were applied to the heifers and there was no apparent cause for variation in lying. Furthermore, it is often noted that lying is much less synchronised when cows are housed compared with at pasture.

Idling occupied a much lower proportion of the 24h time budget and showed much greater variation than lying. Idling was markedly less synchronised than lying. Although there were no differences between herds, idling appeared to be affected by stage of pregnancy and also appeared to be strongly influenced by environmental disturbance.

Lying and idling cannot be ruled out as potential indicators of welfare but further information is needed regarding the response to housing and stage of lactation. Night lying could be used as a good predictor of total lying time over 24h but day lying cannot be used to indicate total lying times.

Chapter 3. A comparison of extensive and intensive systems of milk production and their effects on the lying behaviour of housed, first-lactation heifers

3.1 Introduction

It is a common assumption that welfare is compromised in more intensive dairy farming systems and that the incidence and prevalence of disease are worse in such systems. Intensification is associated with higher inputs and higher outputs whereas more extensive systems have lower inputs. However, as a consequence of genetic selection for high levels of milk production, the modern dairy cow will continue to produce milk, even on low inputs. Thus a medium yield from a low input system may be as detrimental to welfare as a high yield from a high input system.

The aims of this study were firstly to investigate the consequences, in terms of production, performance, health and particularly behaviour, of two extreme systems of management, one intensive and one extensive. Secondly, using all the collected data, to determine whether there were any differences in the welfare of cows in the extensive and intensive systems and between the calving groups within each herd. The study was carried out on heifers which are less likely to be influenced by a history of disease such as lameness (Offer *et al.*, 1998). Furthermore, it is clear from Chapter 1 that where cow behaviour is affected by the housing system, the effects are most marked in heifers (Pollock and Hurnik, 1979; Singh *et al.*, 1993b).

3.2 Materials and methods

The two herds run at the Acrehead unit were managed according to very different strategies. In AcL, the use of concentrates was minimised to study the effects of managing cows of high genetic merit on forage-based diets, i.e. low input - medium output. The annual target yield was 5,500 l/cow from 2×/day milking, with the aim of producing most of this milk from forage. AcH was managed to

Some of these data was presented at the 10th International Symposium on Diseases of the Ruminant Digit in Lucerne, Switzerland, 7-10th September 1998.

investigate the possibilities for higher output systems based on the extensive management of grassland without clover, i.e. medium input - high output. Cows in this herd were milked 3×/day for a target yield of 7,500 l/cow. A comparison of the two herds in 1996/97 is given in Table 3.1.

Table 3.1 Comparison of the two herds involved in the Acrehead systems study in 1996/97

	AcL	AcH
Land area (ha)	46	46
Number of animals in herd	69	67
Stocking rate (livestock units/ha)	2.0	2.0
N fertiliser use (kg/ha)	0	225
Milk quota (l)	385,000	not limited
Concentrate use (t/cow)	0.09	0.21
Daily milking	2×	3×
Milk sales (l/cow)	5,752	8,145
Fat (%)	4.22	4.08
Protein (%)	3.31	3.36
Conc. input (kg conc./l)	0.11	0.25

The heifers described in Chapter 2 were studied throughout their first lactation. All heifers calving in 1996/97 were included in the present investigation and joined the milking herd after calving; spring calvers were grouped with dry cows until they calved. Two heifers (one autumn and one spring calver) were lost from AcH at or before calving and data from these cows have not been included. Consequently, 15 heifers were studied in AcL (nine autumn calvers and six spring) and 11 in AcH (seven autumn calvers and four spring). Spring calvers were defined as those calving between 1st January and 20th April. Autumn calvers calved between 1st September and 20th December.

The milking herds were both housed in sawdust bedded, Newton Rigg cubicles (2.1m × 1.2m) with slatted passageways between the cubicles and a solid feedface passageway. AcL and AcH were housed on two separate halves of the same site but milked through the same parlour at the centre of the site. A ratio of at least one cubicle and one feeding space per cow was maintained. There was no fixed winter diet for the two herds but they were fed a total mixed ration of varying composition, outlined in Table 3.2.

Table 3.2 Dry weight (kg DM) fed of all winter rations fed to AcL and AcH with total dry matter and estimated total metabolisable energy content of the diet for each herd (after Leach, 1997)

AcL	Nov. – Jan.	Feb.	Mar.
Grass silage (kg DM)	6.8-9.0	6.2	2.8
Wholecrop[1]	2.2	3.1	5.1
Fodder beet	2.1-3.5	3.5	3.2
Supergrains	0	2.0	2.9
Straw	-	-	0.5
"Regumaize[2]"	2.4	2.1	1.4
22% protein dairy concentrate	2.1	0.8	1.9
Total DM fed (kg)	13.5-17.1	16.9	15.9
Estimated ME content (MJ ME)	158-201	194	177

AcH	Nov. – Dec.	Jan. – Mar.
Grass silage	6.8	6.4
Wholecrop[1]	3.1	2.3
Fodder beet	3.5	3.5
Grainbeet[3]	2.1	2.3
28% protein blended concentrate	4.7	4.7
22% protein dairy concentrate	3.8	2.6
Total DM fed (kg)	24.0	21.8
Estimated ME content (MJ ME)	283	259

[1] ensiled cereal; wheat for AcH and barley for AcL

[2] a urea-molasses mix, added to the forage to balance the low protein content of the diet.

[3] 2:1 mix of malt distillers grains and molasses sugar beet pulp on a DM basis

The performance of the heifers in terms of production, behaviour and health was monitored throughout the housing period.

3.2.1 Production and performance

Monthly data on milk yield, composition and quality were available from the Scottish Milk Records Association (SMRA) as the farm was milk recorded. From the 305d lactation data the following were extracted for each heifer: milk yield (l/cow); average butterfat and protein percentages; average somatic cell counts ($\times 10^3$ cells/ml) and maximum somatic cell counts ($\times 10^3$ cells/ml).

Weights and body condition scores (BCS) were recorded fortnightly. Cows were always weighed at the same time of day and, as far as possible, body condition scoring was always carried out by the same person. From these data the first recorded weight/BCS post-calving and minimum weight/BCS were determined. Weight and BCS loss were calculated by subtracting the minimum weight/BCS from the first recorded weight/BCS after calving.

3.2.2 Behaviour

Behavioural observations were undertaken at approximately monthly intervals after housing, following the same basic protocol as described in Chapter 2. The position of the cow (cubicle/passageway/feedface) was added as an extra record in the scan sampling. This extra record meant that cubicle use was studied as well as the basic time budget and lying behaviour and so a more extensive range of behaviours was investigated than in Chapter 2:

Time budget: total time spent lying, feeding, ruminating, idling and standing in cubicles.

Lying behaviour: maximum lying bout length; minimum lying bout length; number of lying bouts; proportion of lying time spent ruminating

3.2.3 Health and fertility

As these heifers were also part of a lameness investigation, detailed information on their foot health was available. Locomotion scores were recorded fortnightly according to the method described by Manson and Leaver (1988a). The feet of all heifers were examined at -4, 0, 2, 4 and 6 months relative to calving. All four feet of each heifer were lifted in turn, cleaned and thinly pared but not trimmed. The site and severity of any lesions were recorded on a foot map based on recommendations of the 6th Symposium on Diseases of the Ruminant Digit (see Greenough and Vermunt, 1991). A photographic record was made of each foot so the size and site of lesions could be determined by image analysis as described by Leach *et al.* (1998). Measurements of growth and wear, hardness (using a Shore A meter), and the angle and length of outer and inner claws were made on the right, hind foot of each cow (Manson and Leaver, 1988b).

Blood samples were taken by venipuncture from the tail at each hoof examination and also at 30 days post-calving. These were analysed at SAC Veterinary Science Division (Ayr) for standard metabolic profiles to give each heifer's biochemical status. The parameters analysed fell into four categories:

Energy status: β-hydroxybutyrate and non-esterified fatty acids.

Protein status: total protein, urea, albumin, albumin/globulin ratio,

Mineral status: magnesium, calcium, phosphorus

Tissue damage: aspartate aminotransferase, γ-glutamyl transferase, creatinine kinase

Dates of calving and service were recorded and used to calculate conception to calving interval and days to first service as measures of fertility.

3.2.4. Statistical analysis

See Chapter 2 for discussion on using ANOVA for systems studies. The high degree of synchronisation and lack of independence between individuals was the main reason for not performing a statistical analysis in Chapter 2. However, when they are housed, cows show considerably less synchronisation and therefore, it was considered appropriate to undertake statistical analysis. There was no selection of cows to treatment but all cows in their first lactation were chosen for this study. Therefore the cows were not individually assigned to one group or the other, precluding analysis by ANOVA with management and season of calving as treatments.

Differences between the herds, season of calving and interactions between these factors were therefore investigated using REML (Residual Maximum Likelihood, Patterson and Thompson, 1971) for measurements summarised over a whole lactation. The maximal model used was: herd+season+herd*season and non-significant terms were dropped from the model. For repeated measures data, the maximal model was: herd+month+
herd*month+month*season+herd*month*season. Variations on this method are discussed below for each variate in turn.

Approximate metabolisable energy (ME) requirements over the lactation were calculated for heifers in the two herds and for each season of calving using the following formula, taken from Wilson and Brigstocke (1981, p195) and the 305d milk yields from the lactation summary supplied by SMRA:
Average ME requirements (MJ ME/day) = yield (kg) × 1.694 × 3.01.

Body condition score data were analysed for the effect of herd and season of calving, separately, using Kruskal-Wallis.

Behavioural data collected by scan sampling were represented as proportion of 24h but lying behaviour was continuously recorded and therefore exact times were analysed. Although behavioural observations were made at monthly intervals, the spread of calving dates and the small number of cows meant that not all these data could be analysed. Behavioural data for all cows from the first observation post-calving were analysed by REML using the model herd+season+herd*season+adjusted days post-calving (dpc). Then, using only data from autumn calvers, behaviour was compared at three stages of lactation: early (0-100dpc), mid lactation (100-150dpc) and late-mid lactation (150-200dpc). The model used was: herd+stage+herd*stage+adjusted dpc. For both analyses, dpc was included as a covariate but had to be adjusted to prevent Genstat from centring all treatment means to zero dpc. The adjustment was made by subtracting the mean dpc from each value of dpc. Adjusting the covariate in this way meant that Genstat centred treatment means to zero deviation from the average dpc, as it would for ANOVA (Horgan and Hunter, 1993).

Lesion scores were not normally distributed and were therefore transformed logarithmically ($\log_{10}$(score+1)) prior to analysis. Area and linear lesion scores recorded at each hoof examination (-4, 0, 2, 4 and 6 months relative to calving) were analysed by REML using the maximal model: herd+season+month+herd*month+season*month and including initial lesion score (area or linear score at -4 months) as a covariate. Growth and wear of hoof horn were also analysed using this model but only data from 0, 2, 4 and 6 months post-calving were used.

Any cow with a locomotion score of 3 or greater was considered lame. The number of cows scored as lame at least once in the housing period was compared using Fisher's Exact Test as numbers in the frequency table were too small to use Chi-square analysis.

The incidence of digital dermatitis, interdigital dermatitis, interdigital growths and heel erosion was recorded at hoof examinations and each cow was scored for whether or not she developed these conditions during the course of the housing period. Heel erosion severity was scored on a scale of 0 to 5. The incidence of digital dermatitis and interdigital dermatitis in each herd was compared using a Chi-squared test but the incidences of interdigital growth and heel erosion had to be analysed by Fisher's Exact due to zero values in the frequency table. Heel erosion was further analysed by comparing the average heel erosion scores of each cow at each examination over the whole housing period using REML.

All statistical tests were carried out using Genstat Version 5, Release 4.1 (© Lawes Agricultural Trust, IACR, Rothamsted) except non-parametric tests which were carried out using Minitab for Windows, Version 10 (© Microsoft).

3.3 Results

3.3.1 Production and performance

Over the whole lactation, average 305d milk yields for the heifers in both herds were 5,588 l/cow for AcL and 7,813 l/cow for AcH ($p<0.001$) but there was no difference in milk composition or quality (Table 3.3). Autumn calvers had a greater fat percentage in their milk over the whole lactation compared with spring calvers but there was no difference in yield between spring and autumn calvers (Table 3.4). There was however, an interaction between herd and season in milk yield (Table 3.5) which suggested that AcH autumn calvers yielded more than AcH spring calvers, whereas there was no difference between the calving groups in AcL. Metabolisable energy requirements corresponded with the milk yield results: ME requirements were much greater for the high output herd (Table 3.3) and there was no difference between the calving groups (Table 3.4). The interaction between season and herd was significant and again, there was no apparent difference between autumn and spring calvers in AcL but AcH autumn calvers had higher requirements than AcH spring calvers (Table 3.5).

There was no significant difference between AcL and AcH in somatic cell count and average SCC values were very low for both herds. However, AcL autumn calvers averaged a maximum SCC of over 400×10^3 cells/ml.

Table 3.3 Mean and SEM (in parentheses) of production (milk yield, composition and quality, and ME requirements) and performance (weight and body condition loss) of all first lactation heifers in a low input and a high input herd (AcL and AcH)

	AcL		AcH		p-value
305d milk yield (l/cow/305d)	5,588	(146)	7,813	(231)	<0.001
305d fat percentage	4.0	(0.10)	3.8	(0.20)	NS
305d protein percentage	3.2	(0.03)	3.3	(0.06)	NS
Average SCC ($\times 10^3$ cells/ml)	98.6	(18.4)	66.9	(11.4)	NS
Maximum SCC ($\times 10^3$ cells/ml)	441.2	(125.8)	227.9	(71.2)	NS
ME requirements (MJ ME) [1]	28,495	(747)	39,836	(1234)	<0.001
First BCS[2]	2.5		2.5		NS
Lowest BCS[2]	1.6		2.0		0.035
Loss of BCS[2]	0.9		0.5		NS
First weight recorded (kg)	510	(8)	511	(16)	NS
Lowest weight recorded (kg)	463	(10)	492	(18)	0.011
Weight loss (kg)	46.4	(8.0)	19.2	(5.4)	0.009
Days to minimum weight	111	(19)	109	(29)	NS

NS p>0.05

[1] ME requirements based on 305d lactation yields.

[2] median values are presented for body condition score

There was no difference between the herds in the first weight recorded after calving but cows in AcL lost more weight after calving and consequently had a lower minimum weight than AcH (Table 3.3). Spring calvers were lighter than autumn calvers at the first weight recorded after calving and tended to lose more weight post-calving, reaching a lower minimum weight (Table 3.4). AcL had a lower minimum BCS than AcH, although there was no difference between the herds in body condition score (BCS) at calving and the difference in BCS loss was not significant (Table 3.3).

Table 3.4 Mean and SEM (in parentheses) of production (milk yield, composition and quality, and ME requirements) and performance (weight and body condition loss) of autumn and spring calving heifers in a low input herd (AcL) and a high input herd (AcH) when data for both herds were pooled

	Autumn		Spring		p-value
305d milk yield (l/cow/305d)	6,879	(386)	7,813	(314)	NS
305d fat %	4.2	(0.10)	3.6	(0.10)	0.004
305d protein %	3.3	(0.04)	3.2	(0.05)	NS
Average SCC ($\times 10^3$ cells/ml)	82.8	(17)	88.0	(17)	NS
Maximum SCC ($\times 10^3$ cells/ml)	334.5	(122)	267.3	(79)	NS
ME requirements (MJ ME)[1]	35,074	(1,969)	39,836	(1,599)	NS
First BCS[2]	2.5		2.6		NS
Lowest BCS[2]	1.9		1.8		NS
Loss of BCS[2]	0.8		0.8		NS
First weight recorded (kg)	534	(10)	486	(8)	0.002
Lowest weight recorded (kg)	510	(11)	445	(10)	<0.001
Weight loss (kg)	24.0	(5.9)	41.6	(10.4)	0.061
Days to minimum weight	141	(23)	79	(17)	0.069

[1] ME requirements based on 305d lactation yields.

[2] median values are presented for body condition score

Table 3.5 The interaction between herd and season of calving for milk yield and metabolisable energy requirements (mean ± SEM)

		AcL		AcH		p-value of interaction
305d milk yield	Au	5,496	(199)	8,261	(227)	0.043
(l/cow)	Sp	5,681	(260)	7,364	(353)	
ME requirements	Au	28,025	(1,016)	42,123	(1,155)	0.043
(MJ ME/lact.)	Sp	28,965	(1,324)	37,550	(1,799)	

3.3.2 Behaviour

3.3.2.1 Time budgets

At the first observation post-calving there were no differences between the herds in proportion of time spent feeding, ruminating, idling or standing in cubicles, or in the total time spent lying (Table 3.6). Spring calvers spent a greater proportion of their time ruminating in early lactation than did autumn calvers (autumn, 0.45±0.02; spring, 0.33±0.05, $p<0.001$) but otherwise there were no differences between autumn and spring calvers in the behaviours described by the basic time budget.

Over the whole period that they were housed and lactating, AcL autumn calvers spent a greater proportion of their time feeding than AcH autumn calvers (0.26±0.01 vs. 0.21±0.01, $p=0.034$) but there were no differences between stages of lactation. In both herds, the proportion of time spent ruminating decreased from early to mid lactation (early, 0.44±0.01; mid, 0.37±0.01; late-mid, 0.38±0.01, $p<0.001$) but there were no differences between the herds. There were no differences in total lying time or in idling, either between herds or between stages of lactation. The proportion of time spent standing in cubicles decreased between early lactation and mid lactation (early, 0.13±0.02; mid, 0.06±0.02; late-mid, 0.07±0.01, $p=0.009$). There was no difference between the herds in early lactation, but the decrease in time spent standing in cubicles was significantly more marked for autumn calvers in AcL than in AcH. Consequently, the interaction between herd and stage of lactation was significant for this behaviour (AcL early, 0.13±0.03; mid, 0.05±0.03; late-mid, 0.04±0.01 vs. AcH early, 0.13±0.02; mid, 0.07±0.04; late-mid, 0.10±0.01, $p=0.039$).

3.3.2.2 Lying behaviour

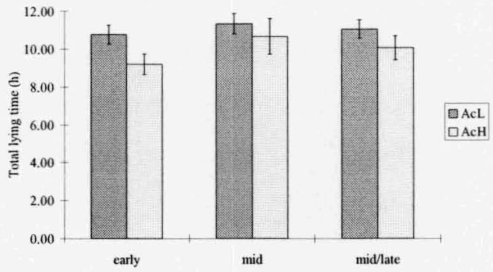
At the first observation post-calving there were no differences either between herds or between seasons of calving in any aspects of lying behaviour (lying frequency, maximum bout length, minimum bout length or proportion of lying time spent ruminating) (Table 3.6). The covariate, dpc, was not significant.

Table 3.6 Predicted means (SEM in parentheses) from REML analysis for some aspects of lying behaviour for all heifers in AcL and AcH at the first observation post-calving

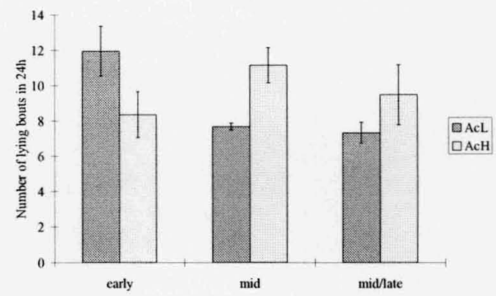
	AcL		AcH		p-value
Total lying time (h)	9.60	(0.42)	9.80	(0.45)	NS
Lying frequency	10.0	(0.9)	10.7	(1.2)	NS
Max bout length (h)	2.40	(0.12)	2.44	(0.22)	NS
Min bout length (h)	0.14	(0.03)	0.15	(0.03)	NS
Proportion of lying time spent ruminating	0.58	(0.03)	0.58	(0.04)	NS

Changes in lying behaviour for autumn calvers in the two herds at three stages of lactation are shown in Figure 3.1. As lactation progressed, lying frequency declined for AcL autumn calvers, and maximum bout length increased. However, in AcH the trend was reversed, with lying frequency increasing and maximum bout length decreasing. Minimum bout lengths increased between early and mid lactation for both herds (early, 0.09±0.04 h; mid, 0.32±0.06 h; late-mid, 0.37±0.11 h, p=0.004) but this increase was much more marked for AcL compared with AcH and the interaction between herd and stage of lactation was highly significant (p=0.001). Overall, minimum bout lengths were much longer for AcL compared with AcH (0.40±0.07 h vs. 0.13±0.03 h, p=0.009). The proportion of lying time spent ruminating differed only between the herds (AcL, 0.66±0.02; AcH, 0.56±0.02, p=0.005). The covariate, dpc, was not significant for any of the lying behaviour parameters.

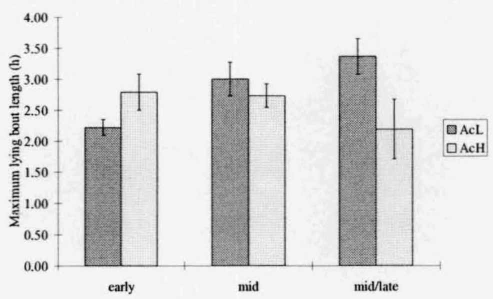
Figure 3.1 Lying behaviour (mean ± SEM of total lying time, number of lying bouts, maximum lying bout length and minimum lying bout length[1]) at three stages of lactation for autumn calving heifers in AcL and AcH



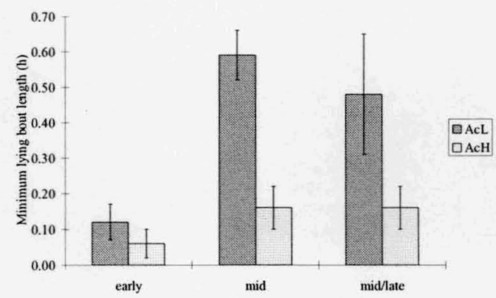
a) Total lying time



b) Number of lying bouts in 24h



c) Maximum lying bout length



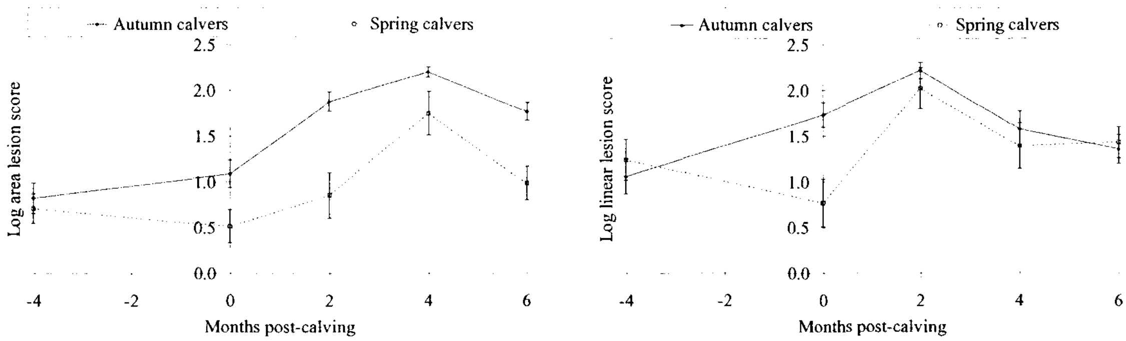
d) Minimum lying bout length[1]

[1] log10 transformed values

3.3.3 Health and fertility

Four cows were scored lame in each herd over the housing period. Heifers in AcL had higher (worse) area lesion scores than those in AcH (1.35±0.08 vs. 1.17±0.11 log lesion score, p=0.005) although there was no difference between the herds in linear lesion score. Autumn calvers had higher area and linear lesion scores than spring calvers (log area lesion score 1.55±0.08 vs. 0.96±0.11, p<0.001; log linear lesion score 1.59±0.08 vs. 1.37±0.12, p=0.032). Both area and linear lesion scores peaked after calving (p<0.001) but area lesions peaked at 4 months post-calving whereas linear lesions peaked earlier at around 2 months post-calving (Figure 3.2). The herd*months post-calving interaction term was not significant for either area or linear lesions but there was an interaction between season of calving and months post-calving for both types of lesions (Figure 3.2). The differences between the calving groups appear to develop around calving, with autumn calvers having higher lesion scores at this time.

Figure 3.2 Changes in lesion score (mean ± SEM of log area lesion score and log linear lesion score) with months post-calving for autumn and spring calving heifers



a) log area lesion score b) log linear lesion score

There were no differences in either growth, wear, or net wear of claw horn for the two herds but autumn calvers had less growth over all observations than spring calvers (4.82±0.45 vs. 5.58±0.22 mm/month, p=0.038). Consequently, there was net wear of hoof horn in the autumn calvers compared with net growth in the spring calvers (-0.51±0.44 vs. 0.38±0.24 mm net growth, p=0.024). When the data for all cows were pooled, growth did not vary significantly over the first six months of lactation but wear was greater in the second month post-calving (4.69±0.49; 6.39±0.38; 4.65±0.29; 5.33±0.41 mm/month wear at 0, 2, 4 and 6 months post-calving, p<0.001).

The number of cows showing various foot conditions (digital dermatitis, interdigital dermatitis and interdigital growth) at least once during the housing period was the same in both herds (Table 3.7). Approximately two-thirds of cows in each herd developed interdigital dermatitis and half developed digital dermatitis. Only one cow of all those examined had an interdigital growth but all cows showed varying degrees of heel erosion. There was no difference between the herds in the extent of heel erosion (Table 3.7).

Table 3.7 The number of heifers developing digital dermatitis, interdigital dermatitis and interdigital growth at least once during the housing period and the mean (SEM in parentheses) heel erosion score of cows in AcL and AcH

	AcL (n=16)	AcH (n=12)	p
interdigital dermatitis[1]	10	8	NS
interdigital growth[2]	1	0	NS
digital dermatitis[1]	6	6	NS
heel erosion[2]	16	12	NS
Average heel erosion score[3]	4.33 (0.57)	3.89 (0.82)	NS

Analysed by: [1] Chi-square; [2] Fishers Exact Test; [3] REML

Metabolic profiles of blood samples taken at 30dpc showed that there were no differences between the herds in energy status, as judged by levels of β-hydroxy butyrate (βHB) and non-esterified fatty acids (NEFA). There were, however differences in NEFA between autumn and spring calvers (autumn, 0.25±0.02 vs., spring 0.56±0.13 mmol/l, $p<0.001$) and a significant interaction between herd and season of calving. Spring calvers in the low input herd had higher levels of NEFA than any other group (AcL autumn calvers, 0.23±0.03; AcL spring calvers, 0.78±0.19; AcH autumn calvers, 0.27±0.04; AcH spring calvers, 0.34±0.04 mmol/l, $p=0.006$).

Some indicators of protein status differed between the herds: total protein and urea were higher for AcH than AcL but there were no differences in albumin and albumin/globulin ratio (Table 3.8).

Table 3.8 Protein status of heifers in AcL and AcH at 30dpc (mean ± SEM)

	AcL	AcH	p-value
total protein (g/l)	69.02 (1.05)	72.77 (1.73)	0.028
urea (mmol/l)	3.33 (0.29)	4.86 (0.44)	0.008
albumin (g/l)	36.0 (0.71)	37.04 (0.73)	NS
albumin/globulin ratio	1.11 (0.06)	1.06 (0.05)	NS

Magnesium, calcium and phosphorus levels were the similar for both herds and for both seasons of calving. Although AcL autumn calvers had higher levels of phosphorus than spring calvers in that herd and in AcH the trend was reversed: spring calvers had the higher levels (p=0.011), all values were well within the normal range of 0.9-2.6 mmol/l (AcL autumn calvers, 2.30±0.09; AcL spring calvers, 2.01±0.07; AcH autumn calvers, 2.09±0.11; AcH spring calvers, 2.33±0.12 mmol/l, p=0.006).

Levels of aspartate aminotransferase (AST), γ-glutamyl transferase (γGT) and creatinine kinase (CK), all indicators of tissue damage, were similar for both herds. All heifers were well within the normal ranges for AST (20-60 iu/l) and γGT (27-31 iu/l) but a few spring calvers and one autumn calver had elevated levels of CK. Only one of these was outside the normal range (44-150 iu/l) but these few outliers resulted in a tendency for spring calvers to have higher CK than autumn calvers (autumn, 66±7; spring, 91±18 iu/l, p=0.078). On average, AcL autumn calvers had the highest levels of CK (AcL autumn calvers, 55±6; AcL spring calvers, 112±13; AcH autum calvers, 76±28; AcH spring calvers, 70±16 iu/l, p=0.061).

The calving to conception interval in both herds was slightly over 100 days (AcL, 102±6; AcH, 105±8 days, p>0.05) and although days to first service appeared to be slightly less in AcH than in AcL, this difference was not significant (AcL, 102±6; AcH, 85±9 days, p>0.05). Overall, five heifers failed to conceive: three in AcL and two in AcH (p>0.05). Spring calvers had poorer fertility than autumn calvers: the calving to conception interval was significantly longer (autumn, 95±6; spring, 112±9 days, p=0.048) and days to first service was also longer, but not significantly so (autumn, 84±8; spring, 102±7 days, p>0.05).

3.4 Discussion

The two herds of cows studied here were of the same genetic merit and yet were managed according to two very different strategies. The success of the strategies is evident in the 305d yields of heifers in the two herds. The average yield of Scottish cows in 1997 was 5583 l/cow but some herds produce more than 10,000 l/cow. Therefore, the low input herd in this study can be seen as conforming to the Scottish average whereas the high input herd is well above average.

In early lactation when intake does not match yield, cows repartition their energy supplies and mobilise body reserves to sustain lactation. In a systems study such as this, the use of metabolism crates and exact measurement of intake are not possible. The degree of metabolic stress endured by the heifers can be gauged indirectly by comparing the shortfall in metabolisable energy, loss of weight and body condition, and metabolic indicators of energy status. The consequences of the two strategies were assessed by analyses of behaviour, health, fertility and blood parameters of protein status and tissue damage.

The low input herd (AcL) had a much lower milk yield than the high input herd (AcH), accompanied by greater weight loss and lower levels of total protein and urea in the blood. However, the consequences of this difference in production and the accompanying weight loss were few. There was no difference in terms of fertility or disease incidence: although area lesions were worse in the low input herd, the incidence of lameness did not differ.

Despite having a lower milk yield and much lower ME requirements, heifers in the low input herd lost more weight post-calving and reached a lower minimum weight and minimum body condition score. However, levels of βHB and NEFA suggest that neither herd underwent excessive fat mobilisation and that both were fed diets with an adequate energy supply for their output.

Broom (1986) defined the welfare of an animal as its state as regards its attempts to cope with its environment. Failure to cope is seen in animals which have mobilised their body reserves or changed their behaviour and which are still subject to detrimental consequences. Although there were no signs that, overall, heifers in either herd were failing to cope, spring calvers seemed to have more difficulty than autumn calvers and in particular, spring calvers in the low input herd appeared to be struggling. Overall, spring calvers had greater weight loss post-calving than autumn calvers and higher NEFA. Spring calvers in AcL had the highest levels of NEFA. The optimum range for milking cows is less than 0.7 mmol/l (Whitaker, 1997) and these heifers had an average NEFA concentration slightly higher than this suggesting greater mobilisation of fat reserves and indicating that their energy intake was inadequate. CK was also elevated in this group, a sign that muscle damage had occurred. Notwithstanding these indicators of metabolic stress, spring calvers had lower (less severe) lesion scores, suggesting that metabolic challenge does not necessarily lead to claw horn lesions.

The mineral status of all heifers was good and reflects the good level of nutritional control at this farm. This probably also explains why there was little evidence of metabolic stress in the two herds. Further evidence of good management can be seen in the low somatic cell counts. Heifers usually have the lowest somatic cell counts of any animals in the herd and an average of less than 100×10^3 cells/ml is well within the premium payment band of Nestlé, this farm's milk buyer.

There were no differences between the herds in the basic time budget behaviours (lying, ruminating, idling and standing in cubicles) in early lactation, although AcH consistently spent more time feeding than AcL when behaviour at three stages of lactation was compared. However, in both herds, early lactation appeared to be associated with unsettled behaviour. Between early and mid lactation there was a decrease in ruminating and standing in cubicles, whilst minimum bout length increased. There was little difference between mid and late-mid lactation. Only data from the autumn calvers were analysed for stage of lactation effects and early lactation was also early in the housing period for these heifers. Disturbed behaviour at this time could also be attributed to the transition from pasture to housing. Unfortunately there were not enough data for the spring calvers to analyse stage of lactation effects for these heifers and thus separate the effects of housing from those of early lactation.

Although total lying time remained consistent at between 10-11h, analysis of lying bouts showed an interesting interaction between stage of lactation and herd. AcL autumn calvers appeared to become more settled as lactation, and the housing period, progressed, with maximum bout length increasing and lying frequency decreasing. These trends were reversed in the AcH-Au: maximum bout length decreased and lying frequency increased. Furthermore, minimum bout length was longer and proportion of lying time spent ruminating was greater in AcL. This increase in lying frequency suggests restlessness. Heifers in AcL were moved to a lower yielding feeding group when their milk yield began to decrease and the upheaval caused by changing social groups could be responsible for the unsettled behaviour in this herd. Nakanishi *et al.* (1993) showed that the introduction of a strange cow to a group can reduce total lying time.

Long idling times may indicate that cows are having problems with settling into the system/herd/housing. Back transformation of the predicted means derived from REML analysis shows that overall, the heifers idled for around 3.5h/24h compared with between 2.5h/24h reported for the same heifers at grass in Chapter 2.

Although popular wisdom says that the incidence of disease is greater in more intensive systems, lameness and the incidences of other foot conditions did not vary between the herds for the heifers studied suggesting that these are a consequence of housing and stockmanship, factors which were equal for the two herds. However, Logue *et al.,* 1999) found that the incidence of lameness did differ between the two herds when all cows were considered and in this study AcL heifers had higher area lesion scores than AcH heifers. Therefore it seems that in the longer term, level of production does have an effect on the incidence of foot conditions.

3.5 Conclusions

The medium input/high output herd was managed with the aim of producing a high milk yield and, in terms of production and performance, coped better with the demands of early lactation than the low input/medium output herd.

Management procedures associated with high/intensive production caused disturbance in lying behaviour. Although the period of early lactation and transition from pasture to housing seemed to be a time of disturbance in both herds, the low input herd appeared to become more settled as lactation progressed unlike the high input herd. These behavioural differences could be attributed to moving the input heifers to another feeding group.

Heifers in the low input/medium output herd, AcL, had a greater weight loss post-calving than the high input/high output herd. These animals also had higher area lesion scores and lying behaviour appeared to be more disturbed at the first observation post-calving. Hence it may be concluded that the animals in this herd were more nutritionally challenged but because there were no differences in NEFA and βHB at 30d post-calving we cannot conclude that they were under greater metabolic stress. Furthermore, the low input heifers, managed less intensively than those in the high input herd, showed evidence of worse claw horn disruption or "sub-clinical laminitis" suggesting that we should be wary of popular misconceptions regarding animal welfare. Good, *appropriate* management may be more important than the level of intensification.

Chapter 4. A pilot study comparing the behaviour of cows bedded on mats and mattresses

4.1 Introduction

In Chapter 3, first-lactation heifers were managed under two very different systems but the differences in behaviour were slight. The aim of this and the following chapter is to look at the provision of extra comfort as a simple way of improving welfare within the same management system.

It is known that lying times are longer on softer bedding (Natzke *et al.*, 1982; Nilsson, 1992) and mats have been used to improve cubicle occupation (O'Connell *et al.*, 1993). Softness can be measured by pressing a standard steel ball into the surface and recording the forces of deformation (Nilsson, 1992). However, comfort is not an objective measure like softness. Just as some people find hard beds more comfortable, and others prefer soft beds, so preferences may vary between individual cows. Therefore, the only way we can know that cows are comfortable is if we see them choose mattresses over mats or increase the amount of time spent lying in cubicles.

Auchincruive farm is used as a demonstration unit for different types of cow mattress and this pilot study was set up to determine whether cows in cubicles show a clear preference for mats or mattresses when given a choice, and what consequences such a preference may have for lying and idling behaviour. Two trials were run, one in which the cows were given a free choice of the two bedding types, and the other in which they had no choice but were allocated to one or the other.

4.2 Materials and methods

An stable group of 60 Holstein/Friesian and Ayrshire cows in late lactation, housed in demonstration cubicles bedded with a variety of bedding surfaces, was observed using this whole cubicle area at intervals through one night. Thirty cows that were observed to use habitually the 30 cubicles at one end of the cubicle area were selected. It is well documented that, although cows do not prefer individual cubicles, they show preference for certain cubicle areas (Friend and Polan, 1974; Jensen *et al.*, 1988).

4.2.1 Trial 1

Thirty Dutch Comfort cubicles were gated off from the rest of the shed. Half of these cubicles were bedded with mattresses (British Hi-Comfort Loose-fill Rubber Mattresses, approximately 75mm thick) and half with mats (Animal Comfort Mats, 22mm thick). The mattresses had been installed in the cubicles prior to the start of the trial and could not be moved. Therefore, it was not possible to lay mats and mattresses alternately, which would have been preferable. The 30 cows which had been observed to use this area were then separated from the rest of the herd and contained within the experimental area.

4.2.2 Trial 2

Fifteen cows were given access only to 15 mattress-bedded cubicles and another 15 cows were selected from a larger group of 30 cows in a cubicle area at the other end of the shed. This larger group had access to 44 cubicles bedded with mats.

In both trials, the cows were allowed to settle for approximately four hours after grouping and were then watched continuously for 24h. Behaviour was scan sampled at 15min intervals, as described in Chapter 2, and lying behaviour was recorded continuously, noting the exact times of lying down and rising for each cow, with choice of cubicle, as in Chapter 3.

4.2.3 Statistical analysis

In trial 1, two methods were used to define cubicle surface preference: 1) $\geq$ 60% of lying bouts spent on mats or mattresses and 2) $\geq$ 60% of lying time spent on mat or mattress. Cows were grouped according to their preference under each definition and a ratio of concordance was calculated (the number of cows for which the two methods agreed on preference, divided by the total number of cows, Martin and Bateson, 1986). The number of cows preferring mattresses over mats was then compared using chi-square analysis and lying behaviour was compared using general linear model (GLM) ANOVA. Cubicle utilisation (the total time that each cubicle was occupied by a cow lying down, and the number of lying bouts per cubicle) and turnover (the number of different cows using each cubicle) were compared for cubicles laid with mattresses and mats using GLM ANOVA.

In trial 2 the lying behaviour of cows on mats and mattresses was compared using Student's t-test.

Coefficients of variation were calculated for the lying behaviour of all cows in trial 1 and separately for cows on mattresses and mats in trial 2.

All statistical tests were carried out using Genstat Version 5, Release 4.1 (© Lawes Agricultural Trust, IACR, Rothamsted).

4.3 Results

4.3.1 Trial 1

The ratio of concordance for the two methods of calculating preference was 0.87, which is considered to be very good, although the number of cows preferring mattresses was different for the two methods (Table 4.1). Using ≥ 60% of lying bouts to define preference (method 1) gave a preference for mattresses and a clearer separation between the cows preferring mattresses and mats in terms of the time spent lying, idling and lying-ruminating.

The total lying times of the cows that preferred mattresses tended to be longer than those of cows which chose mats (Table 4.1), whichever method was used to define preference but there were no differences in maximum bout length. Under the second definition (≥ 60% of lying time spent on mat or mattress), there were slightly more lying bouts for cows preferring mattresses ($p=0.034$, Table 4.1.) The coefficient of variation for the lying behaviour of all cows in trial 1 was 39.39.

Table 4.1. Lying behaviour, idling and cubicle occupation results (mean ± SEM) for cows which showed a preference for mattresses and mats in trial 1, using two methods for determining cubicle preference

	Method 1: ≥ 60% of lying bouts			Method 2: ≥ 60% of total lying		
	Mattress	Mat	p-value	Mattress	Mat	p-value
No. cows preferring[1]	11	18	0.013	14	15	NS
Total lying times (h)	7.92 (0.86)	6.16 (0.55)	0.082	7.78 (0.73)	5.94 (0.36)	0.060
Max. bout length (h)	2.10 (0.02)	1.99 (0.06)	NS	2.22 (0.13)	1.87 (0.04)	NS
No. lying bouts	7.6 (0.74)	7.0 (0.70)	NS	8.4 (0.8)	6.2 (0.6)	0.034
Cubicle occupation (h)	16.13 (0.64)	13.72 (1.15)	NS	15.74 (0.58)	13.61 (1.36)	NS
Idling (h)	1.69 (0.21)	3.23 (0.54)	0.043	2.10 (0.29)	3.16 (0.64)	NS
Lying-ruminating (h)	6.17 (0.81)	4.39 (0.50)	0.058	5.77 (0.71)	4.41 (0.56)	NS
Proportion of lying time spent ruminating	0.68 (0.04)	0.66 (0.03)	NS	0.67 (0.03)	0.67 (0.04)	NS

[1] One cow showed equal preference for mats and mattresses and was not included in the analysis

Cows that preferred mats appeared to idle more than cows that preferred mattresses but this difference was only significant for method 1. They also appeared to spend less time in cubicles, however, this difference was not significant. (Table 4.1.)

There was no significant difference in the total time that mattress cubicles were occupied by a lying cow compared with mat cubicles (13.38±0.97 vs. 12.79±0.90h, $p>0.05$), or in the number of lying bouts recorded for cubicles bedded with mattresses compared with mats (8.6±0.8 vs. 7.6±0.5 bouts per cubicle, $p>0.05$). Neither was the number of different cows using a cubicle affected by lying surface (mattress, 7.1±0.6; mat, 6.5±0.2, $p>0.05$).

4.3.2 Trial 2

There were no apparent differences in the lying behaviour of cows bedded on mattresses and those on mats. However, cows on mattresses idled for longer than cows on mats (Table 4.2) and the coefficient of variation in total lying time was 46.02 for cows on mattresses, and 27.51 for cows on mats.

Table 4.2 Lying behaviour, idling and cubicle occupation results (mean ± SEM) for cows which were bedded on mattresses and mats in trial 2

	Mattress		Mat		p-value
Total lying (h)	7.31	(0.87)	8.27	(0.59)	NS
Max. bout length (h)	2.30	(0.20)	2.26	(0.07)	NS
No. lying bouts	7.9	(0.93)	8.5	(0.67)	NS
Cubicle occupation (h)	13.78	(0.48)	14.15	(0.56)	NS
Idling (h)	2.71	(0.35)	1.72	(0.23)	0.026
Lying-ruminating (h)	4.48	(0.38)	5.73	(0.53)	NS
Proportion of lying time spent ruminating	0.59	(0.04)	0.67	(0.04)	NS

However, cubicle utilisation differed: mattress cubicles were occupied by a lying cow for 7.31±0.83h compared with 2.73±0.37h for mat cubicles ($p<0.001$), and there were more lying bouts in mattress cubicles (7.9±0.9 vs. 2.7±0.4 bouts per cubicle, $p<0.001$). Mattress cubicles were used by more different cows than mat cubicles (3.7±0.3 vs. 1.4±0.2 cows, $p<0.001$).

4.4 Discussion

Natzke *et al.* (1982) concluded that cows confined to a specific surface spend slightly more time in stalls which are covered with the surfaces they prefer, and that there is a considerable increase in the usage of stalls covered with a preferable material when they are given the opportunity to choose between surfaces. These authors reported that the increase in total cubicle occupancy when cows are offered a selection is due to an increase in lying time. The results of the pilot study reported here do not agree with the findings of these authors.

Despite very low lying times for almost all cows in this trial and a lack of clear preference for either mats or mattresses, individual cows which preferred mattresses in the free choice situation (trial 1) tended to have longer lying times. The differences in some behaviours varied according to which definition of preference was used but under one definition (method 1), cows which preferred mats idled for longer and lay ruminating for less time. Under the other definition (method 2), cows which preferred mats had fewer lying bouts over 24h. In trial 2, cows confined to mattresses idled for longer than those confined to mats but there were no other differences in behaviour. Cubicle usage and turnover were the same whether cubicles were bedded with mats or mattresses in trial 1 but differed markedly in trial 2.

The preference for mattresses was not clear and depended on which definition of preference was used. Other authors, however, have found clear differences between bedding different surfaces (Chapter 1, Table 1.4). For example, Herlin (1997) compared soft rubber mats, conventional rubber mats and concrete lying surfaces for dairy cows and used percentage of observation time that a cubicle was occupied by a lying cow to define preference. He found very strong preferences for softer surfaces over harder surfaces. A comparison of total lying time on mats and mattresses in trial 1 of this study showed no preference at all.

As this trial was only a pilot study, mats and mattresses were not randomised within the cubicle area but formed two distinct sections. It is possible that preferences were confounded by cubicle area. The mats had been fitted adjacent to the gate which confined the cows. It may be that cows which apparently preferred mats actually preferred that area of cubicles and if mattresses had been placed there, different conclusions might have been reached. Furthermore, the mattresses were fitted around the crossover by which cows were able to gain access to the feedface and this may have introduced dominance effects. It has been speculated previously (Friend and Polan, 1974) that dominant cows prefer to use the cubicle area which is closest to important resources such as the feedface or access to an outside area and that social factors may interfere with bedding preferences (Jensen *et al.*, 1988).

In both trials, total lying times were short compared with 10.67h for heifers at grass in Chapter 2 and compared with data from other trials shown in Chapter 1, Table 1.1. Some cows were in oestrus and may have disturbed others with their restlessness (Hurnik *et al.*, 1975; Singh *et al.*, 1994). Also, it was assumed that because the cows were selected from an established group familiar with making choices between a selection of bedding types, they would not need a long adaptation time and so they were given only 4h to become accustomed to the new, smaller social group and cubicle area. However, in the first trial there were at least two cows which appeared to want to be on the other side of the dividing gate. In trial 1, the cows which appeared to prefer mats idled more but the cubicles with mats were nearest to the dividing gate and furthermore, in trial 2, it was the cows in the mattress group which idled more. In this trial the cows in the mattress group were separated from the rest of the late lactation cows but the cows on mats were maintained in a larger existing group. These idling results further support the theory that bedding surface was confounded with cubicle area and suggest that in the first trial and in the mattress group of the second trial, low lying times could be ascribed to insufficient adaptation time (only 4h). However, even the late lactation cows on mats in trial 2 had relatively low lying times compared with those reported in the literature.

The tendency towards longer total lying times on mattresses in Trial 1 could indicate simply that mattresses were more comfortable than mats. It is also possible that the mattresses were occupied by more dominant cows which lay for longer than submissive cows "waiting" to use the mattresses. The farm manager stated prior to the trial that he had seen cows "queuing up to use the mattresses", supporting this possibility. By making some cubicles more desirable than others, a competitive situation may have been created, similar to over-crowding: Friend and Polan (1974) suggested that an over-crowding situation may exist even when sufficient cubicles are provided for the number of cows. Wierenga and Hopster (1990) found that in an overcrowding situation it was submissive cows which were first affected and the behaviour of dominant cows remained unchanged at lower levels of overcrowding. Without analysis of dominance hierarchies, it would be impossible to say for sure whether this was the case. However, the pattern of lying seen in trial 1 fits the pattern of lying reported when cows are overcrowded: reduced total lying (Friend and Polan, 1975, Friend *et al.*, 1976 and 1979; Leonard *et al.*, 1996), reduced lying frequency (Friend *et al.*, 1976) and increased variation in lying times (Friend and Polan, 1975; Friend *et al.*, 1976).

The very different patterns of cubicle usage (total occupation of each cubicle, number of lying bouts in each cubicle and number of different cows using each cubicle) seen in Trial 2 are probably due to the different space allowance. Cows on mats were allocated 44 cubicles for a group of 30, a cubicle:cow ratio of nearly 1.5:1, whereas the cows on mattresses had a 1:1 cubicle: cow ratio. The total time spent in cubicles by these cows was similar to that in the first trial but the number of cows using each cubicle was considerably less. A comparison of cubicle usage is probably not appropriate where the behaviour of all cows in the group has not been investigated.

4.5 Conclusions

The lack of overt preference and the list of possible reasons for this show that the effect of soft lying surfaces on lying behaviour is not as straightforward as it seems from the literature. There was a tendency for cows which preferred mattresses to have longer lying times but overall lying times were low and differences were not marked. Idling provided useful clues to other factors which may have affected lying behaviour. Above all, this trial showed that there are a lot of factors affecting lying behaviour other than comfort, even when management is constant and the cows are in late lactation. It also shows the need to control for some of these factors if we are to investigate the effects of improving comfort.

Chapter 5. An evaluation of mattresses and mats in two dairy units

5.1 Introduction

Lying surfaces for dairy cows must provide thermal comfort and softness, yet be durable and have sufficient friction to allow rising and lying down without slipping. Finally they should help to keep cows clean and healthy whilst minimising daily labour requirements (Nilsson, 1992; Natzke *et al.*, 1982; Rodenburg *et al.*, 1994). Cermák (1990) and Bölling (1994) both found that as the softness of bedding in cubicles increased from bare concrete, to concrete with rubber mats, to straw bedding, lying times increased. Bölling (1994) also showed that lying times on mattresses were equivalent to those on straw bedding. These results suggest that cow comfort can be assessed by lying behaviour.

Where straw is not an economical or practical option for cow bedding (due to weather and/or slurry handling systems), mats and mattresses are often used to cushion a concrete cubicle base. There are many products available to dairy farmers, all claiming such advantages as: improved cow comfort, longer lying times, reduced stress, increased milk yield, better cow cleanliness and cubicle hygiene and less cow injury. Previous studies comparing mats and mattresses have either focused on cow cleanliness (Rodenburg *et al.*, 1994; Visser, 1994) or short term cow preferences (Natzke *et al.*, 1982). None have evaluated the longer term performance of these products. This is particularly important for mattresses which flatten with time. Rubber mats offer little cushioning and require additional bedding for cow comfort (Britten, 1994). If mattresses flatten with time and are allowed to become too hard they offer little benefit over mats and hock lesions may result (Britten, 1994).

This study was designed to compare and contrast the relative merits of mats and mattresses in terms of cow comfort, production and performance over a whole housing period.

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5.2 Materials and Methods

At each of two similar dairy units (SAC Auchincruive and Myerscough), 29 cows were housed on either mats (Cow Comfort "Maxi-bed") or mattresses (Pasture B.V. "Pasture Mat"). The mats were made of ethylene vinyl acetate (EVA), approximately 50mm thick, whereas the mattresses were 75mm thick, made of small rubber crumb enclosed in a bag with 12 cells to prevent movement and compaction, and covered with polypropylene. Both products were market leaders of their type and all mats and mattresses were newly installed at the start of the trial.

All cows calving in the 30 days prior to housing at the end of September were selected as "core" cows (15 in each group) and 14 summer-calved "fillers" were added to each group to maintain the stocking density until a further 28 cows had calved at each site. At eight weeks post-housing, the summer-calved "fillers" were replaced by these early lactation, autumn calving "fillers". The groups then remained constant for the remainder of the housing period which was approximately 28 weeks in total. At both sites, the mat and mattress groups were matched for lactation number, days post-calving, previous lameness history and previous milk yield. The groups were also balanced for breed at Auchincruive, where a mixture of Holstein-Friesians and Ayrshires were milked.

At Auchincruive all cows were housed abruptly from grass but at Myerscough the cows were allowed a transition period of about one week before housing during which the cows were housed at night and given access to all cubicles. The average days post-calving at the start of the trial were: Auchincruive mattress group, 20d; Auchincruive mat group, 21d; Myerscough mattress group, 48d; Myerscough mat group, 30d.

Cubicles at Auchincruive were all of the Dutch Comfort design (length, 2.10-2.20m × width, 1.15-1.18m). At Myerscough, Mushroom cubicles were installed (length, 2.30m × width, 1.20-1.21m). Both of these cubicle types are designed to allow space-sharing and provide forward lunging space for rising. At both dairy units, cubicle areas bedded with mattresses and mats were adjacent and as similar as possible but were separated by a gate. Each cubicle area comprised 29 cubicles connected to the feeding area by one crossover at the end of the cubicle area. There were 29 feed spaces and one drinking trough in each cubicle area. Floors were solid concrete at both sites and automatic scrapers were used.

Cows at both sites were fed 40kg fresh weight/cow of first cut silage in total mixed ration (TMR) either once or twice daily *ad libitum.* The dry matter content of the TMR at Auchincruive was approximately 27% with a 16.8% crude protein (CP) and at Myerscough, dry matter content was 30% and CP was 16.7%. Concentrates were fed in parlour according to a stepped flat rate at Auchincruive (3kg/cow up to 100 days post-calving and 0.5kg/cow thereafter) and according to yield at Myerscough (0.1-0.3kg/l). All cows were milked twice daily.

Milk yield was recorded daily and each herd was milk recorded (Auchincruive by the Scottish Milk Records Association and Myerscough by National Milk Records) so monthly milk composition and somatic cell count data were also available for analysis. Weekly feed intake per group was determined from daily records of feed offered and weekly weighing of feed refusals. Every two weeks all cows were weighed and scored for body condition, locomotion, dirtiness and hock and knee injury. Scoring was always carried out by the same person at each site (SC at Auchincruive and CS at Myerscough). Locomotion was scored on a five point scale with half points, as described by Manson and Leaver (1988). For dirtiness, four areas of the cow (body, legs, rear and udder) were scored: 1) perfectly clean, 2) quite dirty, or 3) very dirty, with half points, based on the scoring system described by Bergsten and Pettersson (1992). The sum of the four scores given was the total dirtiness score. Each hock and knee was scored for lesions, based on the scores described by Gustafson (1993): 0) no lesions observed, 1) bare, pale areas, 2) bare, red areas, 3) occurrence of serum and/or sore scabs, 4) open, infected wounds, 5) swelling and/or adventitious bursae (fluid filled sac on knee or hock).

The behaviour of the core cows was observed by scan sampling every 15 minutes for 24 hours at weeks 0, 2, 4, 6, 8, 16 and 24, with the first observation being made on the day of housing. A record was made of each cow's posture (standing or lying), location (feed-face, passageway or cubicle) and activity (feeding, drinking, ruminating, doing nothing or other). Lying behaviour was recorded continuously as described in Chapter 3. The behaviours of interest taken from these records were: feeding, lying, ruminating, lying-ruminating, proportion of lying time spent ruminating, idling (standing, doing nothing), idling in cubicles, proportion of idling time spent in cubicles, maximum lying bout length, number of lying bouts in 24h. At Auchincruive, the time between evening feeding and the subsequent lying bout was recorded and an average was calculated for each cow.

5.2.1 Statistical analysis

Idling, idling in cubicles and the proportion of idling time spent in cubicles were not normally distributed and so were logarithmically transformed before analysis by the formula ($\log_{10}+1$). The data were then analysed by spit-plot ANOVA, with herd (Auchincruive or Myerscough) as blocks, cow as the whole plot and time (week of trial) as the sub-plot using the treatment model: Group+Time+Group*Time. The main plot treatment was therefore group (mat or mattress), and the sub plot was week.

The number of cows having adventitious bursae on the hock or knee (the occurrence at least once of an adventitious bursa or swelling); having serious lesions on the hock or knee (score 3 or 4 at least once); and having no severe recorded lesions (no hock or knee injury score of greater than 2) was analysed by chi-square. Lameness prevalence was calculated as the number of lame cow weeks divided by the number of cow weeks observed, where lameness was defined as a locomotion score of ≥ 3, and chi-square was used to determine significance.

Weight loss was calculated as initial weight (the first weight recorded after housing) minus minimum weight. Weight loss data were heavily skewed, even after log transformation, so a Mann-Whitney test was used on the original data for comparison of the two groups.

All other data were summarised by taking a mean for each cow over the housing period and then analysing the means using a general linear model ANOVA and the model: Herd+Group+Herd*Group, herd being Auchincruive or Myerscough and group being mat or mattress.

As the total dirtiness score was a composite score of four areas, the lowest possible total dirtiness score for a perfectly clean cow is 4 and the highest possible score is 12. Average total dirtiness and average udder dirtiness scores were log transformed by the formula: $\log_{10}(\text{score}+1)$, before analysis.

All statistical tests were carried out using Genstat Version 5, Release 4.1 (© Lawes Agricultural Trust, IACR, Rothamsted).

5.3 Results

There was no difference in milk yield, composition or quality between cows bedded on mats and those bedded on mattresses (Table 5.1) but Myerscough cows had a higher mean daily yield than Auchincruive cows (29.5 vs. 25.1 l/cow/day, $p<0.001$), a higher mean protein % (3.27 vs. 3.19, $p=0.020$) and a lower somatic cell count (59 vs. 83×10^3 cells/ml, $p=0.010$). There was no difference in milk fat % between the two herds ($p>0.05$).

Table 5.1 Milk yield, composition and quality for cows on mats or mattresses at Auchincruive and Myerscough

	Auchincruive		Myerscough		p-value[1]
	Mat	Mattress	Mat	Mattress	
Average daily milk yield (l/cow)	24.8	25.3	30.4	28.7	NS
Protein %	3.20	3.19	3.22	3.33	NS
Butterfat %	4.14	4.13	4.03	4.22	NS
SCC ($\times10^3$ cells/ml)	73	95	67	52	NS

[1] p-value of herd*group interaction

Cows on mattresses had the highest feed intake in both herds. At Auchincruive the daily dry matter intake (DMI) of TMR of the mattress group was 12.95kg/cow compared with 12.70kg/cow for the mat group, a difference of 0.25kg DM/cow/day. At Myerscough, the daily DMI was 17.01kg/cow for the mattress group and 16.55kg/cow for the mat group, a difference of 0.47kg DM/cow/day. Average feed intake was higher at Myerscough than Auchincruive (28.15 vs. 23.67kg freshweight/cow/day). It was impossible to do statistical analysis on these figures as only group averages were available.

There was no difference in weight, body condition score or weight loss between cows on mattresses and cows on mats. Myerscough cows were heavier than those at Auchincruive (mean weight: 581 vs. 521kg, $p<0.001$) and had slightly better body condition scores (2.6 vs. 2.3, $p<0.001$).

There was a tendency for cows on mattresses to be slightly dirtier than those on mats although this was not statistically significant (total dirtiness: 7.06 vs. 6.95, $p=0.074$). However, when udder dirtiness alone was considered, the difference between the groups was significant (mattress: 1.38 vs. mat: 1.32, $p<0.05$). Total dirtiness scores were higher at Auchincruive than at Myerscough (total dirtiness: 7.50 vs. 6.52, $p<0.001$).

Table 5.2 shows the distribution of maximum hock and knee injury scores. There was no difference between the groups in the number of cows which only ever showed hair loss or reddened skin on their hocks and knees (score ≤ 2 for hock and knee injury), in the incidence of swellings and/or adventitious bursae on hocks or knees (score 5 for hock or knee injury), or in the number of cows showing evidence of lesions (sore scabs, score 3, or open lesions, score 4). However, a high proportion of cows in both groups (mattress, 46%; mat, 49%) had a maximum hock lesion score of greater than 3.

The prevalence of lameness (the number of lame cow weeks divided by the number of cow weeks observed, where a cow was considered lame if she had a locomotion score of 3 or more) tended to be lower for cows on mattresses compared with cows on mats (0.06 vs. 0.08, p=0.069).

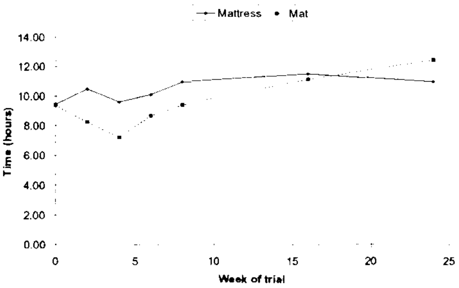
Table 5.2 The number of cows on mats and mattresses[1] which scored maximum hock and knee injury scores of "5", "3 or 4", and "1 or 2" over the course of the housing period, in both the Auchincruive and Myerscough herds

Maximum score (no. cows)	Mattress n=89	Mat n=89	p-value
Hocks			
5 (adventitious bursa)	12	14	NS
3 or 4 (sore scabs or open lesions)	29	34	NS
1 or 2 (hair loss or reddened skin)	48	41	NS
Knees			
5 (adventitious bursa)	25	19	NS
3 or 4 (sore scabs or open lesions)	7	5	NS
1 or 2 (hair loss or reddened skin)	57	65	NS

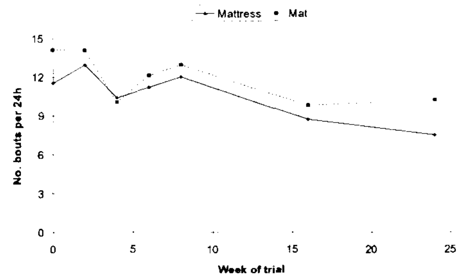
[1] all cows in each group, including summer-calved "fillers".

All of the behaviours investigated varied significantly with time (p<0.001). Total lying times increased after housing for the cows on mats in the later part of the housing period whereas cows on mattresses reached a plateau and this group*time interaction was significant (p<0.001). Maximum lying bouts were longer for cows on mattresses by about 15-20 minutes and these cows also had more lying bouts per 24 hours (Table 5.3). Figure 5.1 shows how lying behaviour changed over the course of the housing period.

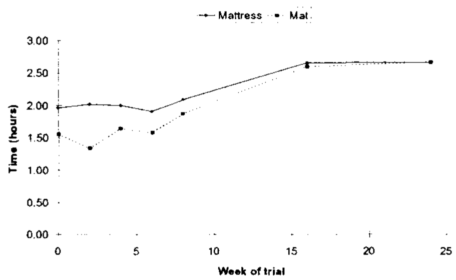
Figure 5.1 Changes in lying behaviour (total lying time, number of lying bouts, maximum lying bout length and minimum lying bout length) over the course of the housing period (and lactation) for cows on mattresses and on mats, in both the Auchincruive and Myerscough herds pooled



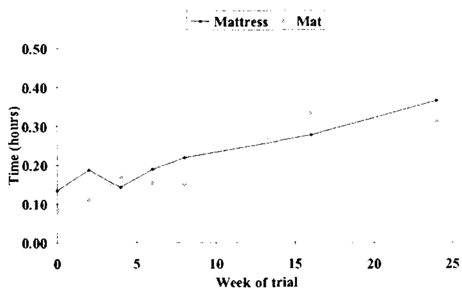
a) total lying time



b) number of lying bouts in 24h



c) maximum bout length



d) minimum lying bout length

Differences in behaviour between the mat and mattress groups are shown in Table 5.3. The group*time interaction was significant for all of these behaviours ($p<0.05$). There was a tendency for cows on mattresses to spend longer feeding. They also spent more time ruminating and lying and a greater proportion of the lying time was spent ruminating. Cows in the mat area idled for longer and spent longer idling in cubicles, although when idling in cubicles was expressed as a proportion of total idling, there was no difference between the groups.

Table 5.3 Differences in behaviour between cows on mattresses and cows on mats, in both the Auchincruive and Myerscough herds pooled (mean ± SE)

	Mattress		Mat		p-value
Feeding (h)	5.25	(0.10)	4.95	(0.11)	NS
Ruminating (h)	9.00	(0.13)	8.78	(0.15)	NS
Total lying time (h)	10.44	(0.16)	9.50	(0.22)	0.004
Lying-ruminating (h)	6.13	(0.15)	4.83	(0.17)	<0.001
Proportion of total lying spent ruminating	0.58	(0.01)	0.50	(0.01)	<0.001
Maximum bout length (h)	2.18	(0.05)	1.89	(0.06)	0.005
Number of lying bouts (bouts/24h)	11	(0.3)	13	(0.4)	0.017
Idling (h) [1]	0.47	(0.01)	0.56	(0.01)	<0.001
Idling in cubicles (h) [1]	0.29	(0.01)	0.38	(0.01)	0.003
Proportion of idling spent in cubicles)	0.17	(0.059)	0.19	(0.004)	NS

[1] $\log_{10}$+1 transformed values

5.4 Discussion

The provision of mattresses did not give any advantages in terms of production or performance: there were no differences between the groups in milk yield, weight, body condition score or weight loss in early lactation. The differences in milk yield between the herds show that Myerscough was a higher producing herd and so the herd differences in milk quality and composition and in feed intake are not surprising. The average liveweight was lower at Auchincruive, probably due to the smaller Ayrshire cows which made up a proportion of that herd.

The cost of installing mattresses is greater than for mats and mattresses are therefore a considerable investment. It is possible that many of the improvements that farmers report after fitting mattresses may be due to concurrent improvements in management. In this study, cows on mats were slightly cleaner than those on mattresses, and the farmstaff believed that this was because mats held the bedding better and were drier. However, although the difference in udder dirtiness was significant, it was not large. A small study on faecal contamination run in conjunction with the main trial showed that there was no difference in the coliform count of sawdust collected from mats and mattresses (Kelly *et al.*, 1999).

Nevertheless, udder cleanliness is important in reducing the risk of mastitis and reducing the need to wash cows' udders in the parlour. Indeed cow cleanliness is required by law: the Dairy Products (Hygiene) (Scotland) Regulations 1995 state that before milking, the teats, udders, flanks, hindquarters and adjacent parts of the abdomen should be clean. In a survey of 18 herds, Rodenburg *et al.* (1994) found that cows on mattresses were cleaner than cows on mats although their results were confounded by differences in stall management practices.

Despite reports that mattresses reduce the extent of hock injury in cubicle-housed dairy cows (Rodenburg *et al.*, 1994), there were no differences in hock and knee injury found in this trial although the proportion of cows with hock lesions scoring 3 or greater was very high in both groups.

Due to the distance between the two sites, it was impossible for one observer to score the cows in both herds and so, whilst real differences in dirtiness, locomotion and body condition may well exist between the herds no comparisons can be made on the strength of these data. However, within each herd, cows were consistently scored by the same observer (SC at Auchincruive and CS at Myerscough) so comparisons between the groups are valid.

The behavioural variation over time is worth noting: the continued improvement in resting behaviour shown by cows on mats when the cows on mattresses had settled into a plateau suggests that although the early housing period is a time of adjustment which is eased by the provision of mattresses, by the end of the housing period the cows on mats had also managed to adapt. The early housing period coincided with early lactation for the cows in this trial and cows in early lactation are known to have more unsettled lying behaviour compared with cows in later lactation, that is they have a shorter total lying time, higher frequency of lying and lower maximum bout length (Chaplin and Munksgaard, 1999). Whether the effect is due to housing or calving, or a combination of the two, the results reported here still reflect the consequences of management for a considerable proportion of cows in the UK which are winter-housed autumn-calvers.

A greater proportion of the time cows spend lying occurs at night (Singh *et al.*, 1993 and 1994; see also Chapter 2). At night, lying is usually divided into two bouts (Ruckebusch and Bell, 1970), bout lengths are longer than during the day (Hedlund and Rolls, 1977) and the time between the first intention movement and lying down is shorter (Müller *et al.*, 1989). At Auchincruive, where cows were fed morning and evening, it seemed that after the evening feeding, cows on mattresses would enter cubicles and quickly lie down whereas cows on mats would stand in the cubicles for some time before lying down. The difference in idling times between the groups was largely due to increased idling in cubicles, supporting this observation.

5.5 Conclusions

Cows on mattresses had more restful behaviour compared with those on mats, suggesting that mattresses do improve cow comfort although cows on mattresses were slightly dirtier than those on mats. However, installing mattresses offered no advantage in terms of production, performance or health to offset the higher cost.

Chapter 6. An investigation of lying and sleep in ten cows bedded on either mattresses or mats

6.1 Introduction

Total lying time can be divided into lying-ruminating and lying-doing-nothing. However, lying-ruminating is a distinct behavioural category, whereas lying-doing-nothing can include time when cows are sleeping and when they are neither sleeping nor ruminating. Therefore, in the previous chapters, proportion of lying time spent ruminating has been investigated but lying-doing-nothing has been ignored. In this chapter, one component of lying-doing-nothing, sleep, will be considered along with other aspects of lying behaviour in tethered cows bedded on either mats or mattresses.

Although it was once thought that ruminants were incapable of sleep (Balch, 1955, Merrick and Scharp, 1971), it has since been established that they do indeed sleep, although not for as long as other species (Allison and Cicchetti, 1976). Deprivation experiments have shown that there is a need for sleep (Jouvet, 1967; Ruckebusch and Buéno, 1972; Ruckebusch *et al.*, 1974) and that prolonged deprivation leads to a state of exhaustion. Sleep is therefore an important component of lying.

Sleep occurs in two forms: typical sleep, also known as light, slow-wave or non-rapid eye movement (NREM) sleep; and paradoxical, rapid eye movement (REM) or deep sleep. There are many other names for these two states (see Jouvet, 1967). Typical sleep is characterised by synchronised, high voltage, slow activity electroencephalogram (EEG) output, reduced muscle tone and reduced fore-stomach motility. Rumination only rarely accompanies typical sleep and in typical sleep cows are usually, but not necessarily, lying, with closed eyes and totally unresponsive to the environment. Ruckebusch and Bell (1970) and Ruckebusch and Buéno (1972) found that typical sleep barely exceeded 3h 20min of which more than 2h were at night.

During paradoxical sleep EEG output is characterised by low voltage, fast activity and desynchronisation. There is complete loss of muscle tone, in contrast with typical sleep during which muscle tone is only reduced. Hence, whilst cows can engage in typical sleep while standing, they must be lying down for paradoxical sleep. The characteristic position associated with paradoxical sleep can be seen in a cow with her eyelids closed and her head completely rested. Ruminal motility either stops or is strongly reduced (Ruckebusch and Buéno, 1972) and rumination never accompanies paradoxical sleep. Slow movement and rotation of the ears is common and the twitching of facial muscles and rapid eye movements occur. The end of paradoxical sleep is always sudden, signalled by the cow suddenly lifting her head, opening her eyes and taking up a more upright position.

The proportion of sleep that is paradoxical, declines from almost 100% at birth to 25% at maturity (Ellingston, 1972) and mature cows engage in paradoxical sleep for less than 70mins per 24h (Ruckebusch and Buéno, 1972). Allison and Cicchetti (196) found that only small amounts of paradoxical sleep were found in species which were heavily preyed upon, suggesting that this sleep form is disadvantageous in these species. Ruckebusch *et al.* (1974) considered that paradoxical sleep only occurs when a cow is well accustomed to her surroundings. Confinement in stanchions caused a reduction in paradoxical sleep (Ruckebusch *et al.*, 1974) and in the 24h prior to parturition, both typical and paradoxical sleep were reduced (Ruckebusch, 1975). It can take up to six days to re-establish a normal sleep sequence after it has been disturbed (Ruckebusch, 1975).

Most of the previous work investigating sleep in cows has required the implantation of electrodes to record ECG, rumen motility, eyelid movements, heart rate and respiration rate. However, Ruckebusch *et al.* (1974) found that the implantation of electrodes and the experimental set-up caused a reduction in paradoxical sleep. Ruckebusch (1974) also found however, that there was a good correlation between the usual indications of paradoxical sleep (loss of muscular tone and desynchronised, low-voltage fast activity EEG) and two selected criteria: slowed rumen contractions and full resting of the head, either on the floor or turned back along the flank. Hence, paradoxical sleep, unlike typical sleep, can be accurately recorded using behavioural correlates, i.e. complete loss of muscle tone in the neck, head resting on the flank, flickering and twitching of the ears and face, followed by an abrupt end (Jouvet, 1967; Ruckebusch, 1974).

Because bouts of paradoxical sleep last only for a short time and are less obvious than lying down and rising, paradoxical sleep is difficult to record by scan sampling or continuous recording in direct observation. However, sleep can be identified using video records of behaviour. There are a number of problems (identification, distance, focus, field of view) in trying to video record the behaviour of individual cows in cubicle housing and therefore, in this small study, cows were restrained in stanchions.

To investigate whether providing a softer lying surface affected lying behaviour, sleep, lying down and rising, twelve cows which had previously been used in the cubicle comfort trial at Auchincruive (Chapter 5) were housed in stalls bedded with either mats or mattresses (both products were the same as those used in Chapter 5) and were video recorded for 24h each.

6.2 Materials and methods

Twelve cows were brought inside from pasture and housed in cubicles bedded with mats for one week before being moved to the Metabolic Unit facility at Auchincruive where they were restrained by yokes for two weeks. The twelve stalls in the Metabolic Unit were bedded alternately with mattresses (Pasture B.V. "Pasture Mat") and mats (Cow Comfort "Maxi-bed"), so that six stalls were bedded with each product. Previous experience with this facility indicated that cows appear to adapt within one week of being introduced to the yokes. Therefore, one week of adjustment was allowed for the cows to familiarise with the restraint. In the following week, video recordings were started. After all cows had been video recorded they were put back out to pasture.

Of the 12 cows selected from the Auchincruive herd, six derived from the group housed on mats in Chapter 5 and six from the group housed on mattresses. The cows were selected to represent average behaviour. Hence, all cows whose behaviour had been recorded in Chapter 5 were assigned a rank based on their total lying time for each observation period during that trial. These ranks were then averaged and the six middle-ranking cows in each group were selected for the present study. When the lying times of these cows were checked, cow 357 had some very low lying times so she was replaced by a first lactation cow, 587. This exchange also balanced the number of heifers in the two groups.

The cows were allocated to stalls in the Metabolic Unit according to their group in the previous chapter: cows which had been housed on mattresses were again bedded on mattresses and likewise, cows which had been on mats in the main trial were again on mats in this study. All cows were in late lactation and are described in Table 6.1.

Table 6.1 The cows selected to the Metabolic Unit, described by average ranking for lying behaviour and lactation number

	Mattress			Mat	
Cow	Average rank	Lact.	Cow	Average rank	Lact.
409	7	4	387	7	4
425	8	4	432	8	4
555	6	2	539	8	2
587	6	1	592	8	1
594	6	1	595	7	1
613	8	1	604	7	1

The cows were offered silage with a concentrate mix twice daily. They were removed for milking twice daily at around 6:00 and 15:00. Milking lasted about 1.75h and while the cows were absent, the beds were scraped and bedded with sawdust and fresh food was presented.

Cows were video recorded in pairs, each video having a cow on a mattress and a cow on a mat. Video recording started after the afternoon milking and ended when cows were taken out for the afternoon milking the next day, effectively recording lying behaviour over 24h. Although 12 cows were recorded, technical problems meant that one video was unusable (cows 409 and 539) and so video records for only 10 cows were available for analysis.

Lying and rising events were each marked by four, easily identified postures, as shown in Table 6.2, and the exact time that each posture was first achieved was recorded. Using these times, various parameters of lying down, rising and lying behaviour could be calculated. The time taken for the whole lying down movement was calculated as L4 minus L1 (and likewise the time taken for the rising movement was R4 minus R1). The time between L2 and L1 was recorded as the preparatory phase of lying and the time between R4 and R3 was recorded as the final phase of rising. If a cow was seen to assume postures characteristic of lying down (usually L1 or L2) but did not compete the lying down movement, this was considered to be an intention to lie down.

Table 6.2 Characteristics of the four postures at which times were recorded during lying down and rising movements

Posture	Characteristics of the postures
Lying	
L1	The start of rhythmical swinging of the head
L2	One knee is lowered and the first shoulder begins to be is dropped
L3	Weight is taken onto both knees
L4	Sternally recumbent with the legs arranged and body still
Rising	
R1	Sternum beginning to be raised from ground
R2	Stretching forwards with the head and neck, whilst the flanks are still on the ground
R3	Weight is taken on both knees and the back legs straightened
R4	Standing with four feet on the ground. Balanced.

Paradoxical sleep as described by Ruckebusch and Bell (1970), was easily distinguished from the video recordings. The characteristic posture of the milk fever position, where the head is curled around and rested on the flanks, was referred to as "sleep" and was event sampled from the videos. A sleeping bout was defined as beginning when the cow turned her head to rest it on her flanks and relaxed her neck. The end of a sleeping bout was clearly marked by an abrupt movement of the head. Therefore, identification of a sleep bout was in many cases retrospective, i.e. having noted the end of a sleep bout, the video would have to be rewound to identify the exact moment at which that bout began. Also, in some cases, a cow would turn her head and rest it briefly but not fully, returning her head to an upright posture without the abrupt movement that was characteristic of waking from REM sleep. This action was therefore interpreted as an intention to sleep. Intentions to sleep were therefore arbitrarily defined as turning and resting the head for less than 1.5 minutes.

The time spent ruminating while lying was recorded and the incidences of leaning (leaning on stall fixtures or fittings), tongue rolling (the tongue extruded from the mouth and moved by curling and uncurling outside or inside the mouth with no solid material present: Fraser and Broom, p314) and intentions to lie and sleep were noted.

6.2.1 Statistical analysis

Student's t-test (Microsoft Excel Version 5.0) was used to investigate differences between cows on mattresses and those on mats. Paired t-test was used to test for differences between night and day in lying-ruminating and sleep.

6.3 Results

6.3.1 Lying behaviour

There were no differences in lying behaviour between cows on mattresses and those on mats (Table 6.3). Total lying times and maximum lying bout lengths were more variable for cows on mattresses than for those on mats. This difference in variance appeared to be due to cow 594 which had a much lower total lying time and maximum lying bout length than the other cows on mattresses. Minimum lying bout length and number of lying bouts, however, were more variable in the mat group.

There was no difference between the groups in the number of intentions to lie down, although there was greater variation in the mat group: cows 592 and 432 had a high incidence of intentions to lie down whereas the rest of the group had low incidences.

Table 6.3 Effect on various behavioural parameters (group means ± SE) of bedding tethered cows with mattresses or mats

Parameter		Mattress		Mat		p-value
Lying	Total (h)	12.30	(0.93)	11.42	(0.52)	NS
	Max. bout length (h)	2.09	(0.28)	2.07	(0.17)	NS
	Min. bout length (h)	0.37	(0.06)	0.43	(0.18)	NS
	No. bouts per 24h	11.8	(1.1)	11.4	(2.3)	NS
No. intentions to lie down per cow		10.2	(2.1)	11.4	(4.1)	NS
Lying down	preparatory phase (secs)	22.4	(4.9)	19.0	(3.1)	NS
	whole movement (secs)	28.0	(124.3)	26.0	(3.2)	NS
Rising	final phase (secs)	4.0	(5.0)	3.4	(0.2)	NS
	whole movement (secs)	8.6	(1.0)	7.2	(0.8)	NS
Total lying-ruminating (h)		7.37	(0.59)	6.57	(0.48)	NS
% lying spent ruminating		0.60	(0.02)	0.58	(0.04)	NS
Sleep:	Total (mins)	82.62	(7.46)	62.09	(9.02)	NS
	Max. bout length (min)	14.78	(3.03)	13.82	(3.82)	NS
	Average bout length (min)	6.95	(1.26)	6.58	(1.29)	NS
	No. bouts per 24h	13.0	(1.9)	8.2	(2.2)	NS
No. cows seen	leaning	2-		1	-	-
	tongue rolling	0-		2	-	-
No. intentions to sleep per cow		6.4	(1.7)	9.6	(5.0)	NS

6.3.2 Lying down and rising

There were no differences between the groups. Lying down was markedly more variable for cows on mattresses than for those on mats, particularly the preparatory phase. Closer examination showed that, in the mattress group, two cows (425 and 594) had long preparatory phases of lying down which then affected the total time taken to lie down, and the remaining three had fairly short preparatory phases. There was an even distribution of lying down times in the mat group.

There were no differences in rising behaviour between the groups and no marked differences in variance.

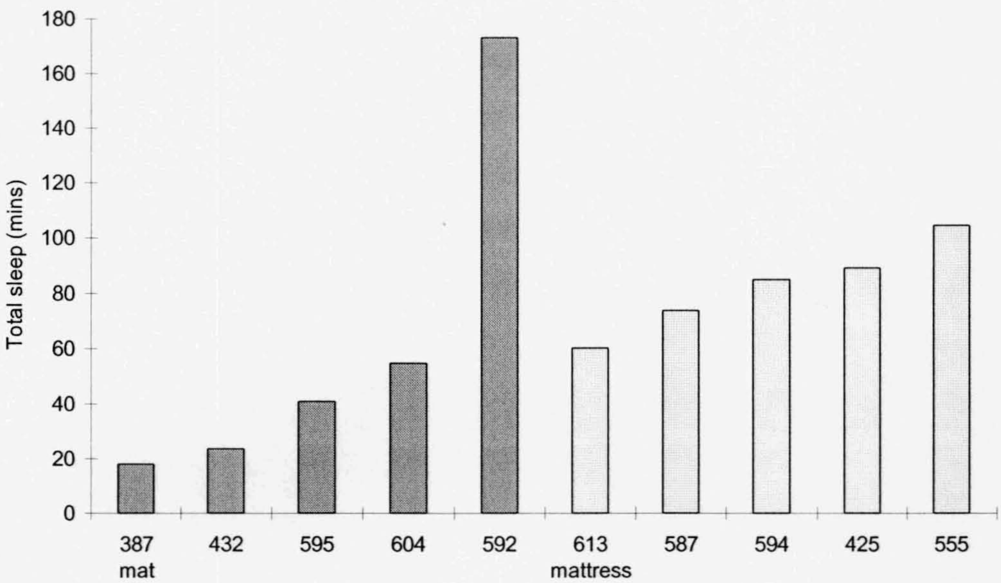
6.3.3 Lying-ruminating

Lying-ruminating and proportion of total lying time spent ruminating were the same for both groups. Considerably more lying-ruminating occurred at night than during the day (4.87 vs. 2.10h, $p<0.001$).

6.3.4 Sleep

Total sleep was more variable for cows on mats, apparently due to the very high sleep time of cow 592. Figure 5.1, showing the total sleep times for all cows, suggests that total sleep time might be greater in the mattress group, although this difference was not significant (Table 6.3).

Figure 6.1 Total sleep times for ten cows bedded on mattresses or mats



The incidence of intentions to sleep appeared to be slightly higher amongst cows on mats compared with those on mattresses. However, the variance was greater in the mat group due to two cows (432 and 592) which had exceptionally high incidences of intention to sleep.

On average 85% of sleep occurred at night (Table 6.4), considerably more than during the day (62.72 vs. 9.63 mins, $p<0.001$), and most sleeping bouts started between 23:00-24:00, 1:00-3:00 and 4:00-5:00 (Figure 6.2). On average, over 24h, each cow had more than an hour of paradoxical sleep split into 10 bouts, each lasting 6mins (Table 6.4). However, there was considerable variation in all parameters.

Figure 6.2 Number of sleep bouts starting in each hour over 24h of observation for ten cows bedded on mattresses or mats

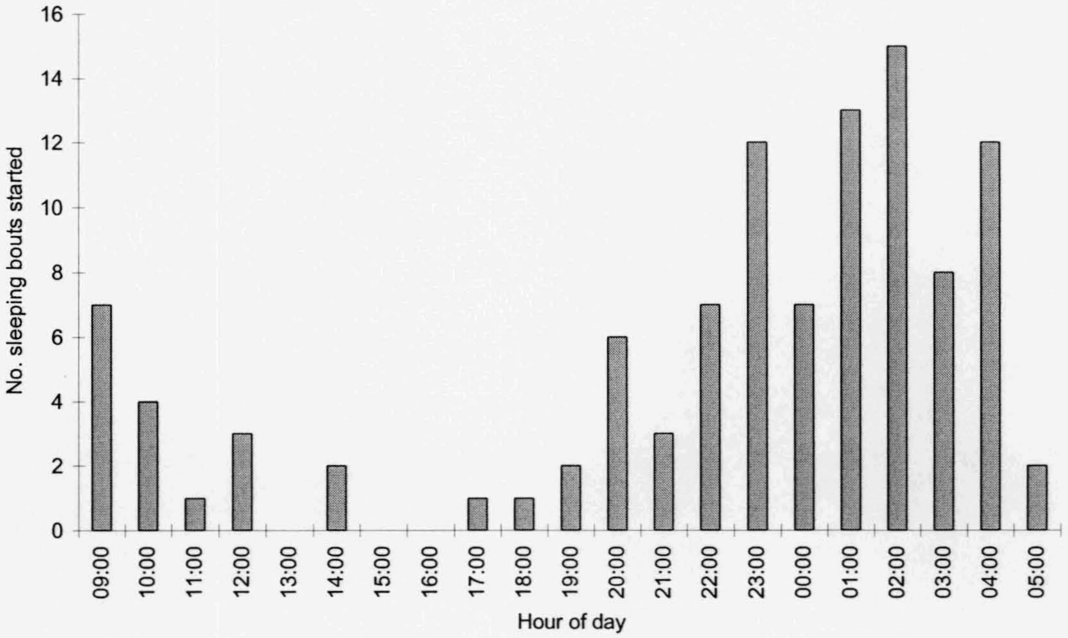


Table 6.4 Means and ranges for various parameters describing sleep in all ten cows and correlation with total lying

Parameter	Mean	Min	Max	Coefficient of variation	Correlation with total lying
Total sleeping (mins)	72.36	18.05	173.22	62.57	0.281
Day sleeping (mins)[1]	9.63	0.00	40.73	122.79	-0.145
Night sleeping (mins)[2]	62.72	10.95	132.48	60.27	0.381
Proportion of sleep occurring at night	0.86	0.46	1.00	18.89	0.508
No. sleep bouts	10.6	4.0	18.0	47.73	0.056
Max. bout length (mins)	14.30	6.30	28.25	50.97	0.303
Av. bout length (mins)	6.77	3.94	11.63	39.80	0.429

[1] Day = 6:00 to 18:00 [2] Night = 18:00 to 6:00.

6.3.5 Leaning and tongue rolling

Leaning and tongue rolling were not common enough in this small group of cows to analyse statistically but it is interesting to note the characteristics of the cows observed to engage in these behaviours (Table 6.5). Apart from 594, the only other cows to show leaning (425 and 387) were both in their fourth lactations and the oldest cows observed. These two cows showed a very high frequency of leaning (14 and 21 events per 24h, respectively) compared with 594 (only 2 events in 24h) and were also the only two cows to exhibit tongue rolling.

Table 6.5 Number of events of leaning and/or tongue rolling for the four cows seen to engage in these behaviours

Cow	Group	Lact. No.	Leaning	Tongue rolling
387	mat	4	21	13
432	mat	4	0	6
425	mattress	4	14	0
594	mattress	1	2	0

6.4 Discussion

Most sleep occurred at night but there was a lot of variation between cows for most of the parameters describing sleep. Cows on mattresses appeared to have more sleep bouts and more total sleep than cows on mats, although this difference was not significant. There were no differences between cows bedded on mattresses and those bedded on mats for any of the parameters describing lying behaviour and sleep.

Herlin (1997) found that the preparation time for lying down on soft mats was significantly shorter than on hard mats or concrete and that interruptions of the lying down movement occurred on the harder surfaces. Furthermore, interruptions are often seen in tethered cattle but never in those on deep litter (Kohli, 1987, in Gustafson, 1994; Ladewig and Smidt, 1989; Müller *et al.*, 1989; Krohn and Munksgaard, 1993; Herlin, 1994). In this study, no differences were found in lying down or rising. However, cows on mattress tended to sleep more than cows on mats. Krohn and Munksgaard (1993) observed that cows at pasture spent longer with their heads turned back and rested than did tethered cows. Therefore it seems that cows in a less restrained and more comfortable environment may spend longer sleeping.

The yokes prevented the cows from exercising free choice in terms of cubicle selection but this meant that video recordings could be made of each cow's behaviour over 24h without social interference. However, the yokes also restricted the cows' lying down and sleeping behaviour. Okamoto and Suzuki (1997) found that stanchions similar to the yokes used here restrict head movements more than neck chains do and that cows in stanchions moved their heads almost only during meals. Some cows in this study were observed to have difficulty turning their heads to rest in the characteristic sleeping position whereas others managed this with ease. This is reflected in the high variance for all parameters of sleep and for sleep intentions. These individual variations may be due to body size: at least one large cow was observed to sleep much more easily than her small neighbour, although the yokes were adjusted for each cow at the start of the study. It is more likely that individual differences in coping with this difficult situation were greater than any differences rising from the bedding surface.

Cows which were ranked in the middle of their respective groups for total lying times were chosen as only a small number of cows could be housed in the Metabolic Unit. It was thought that by choosing average cows, individual variation would be reduced and the cows would be more representative of their groups than cows from the extremes. However no differences were evident between cows on mattresses and those on mats for any of the behaviours recorded and variation was still high. Some differences might have become significant if more cows had been studied but this was not possible.

In investigating the causes of differences in variation between the groups it became apparent that several cows differed from the rest of their group on more than one occasion. There were three cows in the mat group (387, 432 and 592) and two in the mattress group (594 and 425) that fell into this category and they tended to be older cows. Perhaps being older, they had had longer to develop strategies for adapting to difficult situations and therefore whilst their lying behaviour was average, their coping strategies were singular. Krohn and Munksgaard (1993) found that third lactation cows took longer to lie down than first lactation cows, apparently because they spend longer examining the floor before lying. By selecting middle ranking cows, it is possible that cows were chosen which are adaptable.

When the data for all cows were pooled, sleep was found to occur, on average, for a total of 72mins over 24h, in 10 bouts. Ruckebusch and Buéno (1972) reported a total of up to 30mins sleep in 6 to 10 sleep bouts during the night alone and therefore the results reported here are slightly higher but comparable.

Ruckebusch (1974) found that all paradoxical sleep occurred at night-time. In this study, although some sleep occurred during the daytime, more sleep bouts were started during the night than during the day. Fewer sleeping bouts were started between 12:00 and 1:00 compared with other hours during the night, possibly reflecting the "midnight snack" reported for grazing cows (Phillips and Denne, 1988) and also seen in Chapter 2 (compare Figures 2.1 and 5.2).

Sleep bouts were timed from the moment the cow turned her head to rest it on her flank. Although the ear flickering and eyelid twitching which mark paradoxical sleep could be seen on the video, it would have been difficult to record the time in a standard fashion and so the characteristic lying posture, with the head resting on the flank was used instead. Ruckebusch *et al.* (1974) found that using the head position alone was likely to overestimate the amount of paradoxical sleep in about half the sleep episodes recorded and suggested that this excess might be due to cows appearing to rapidly explore their surroundings with the head rested on the ground just prior to sleeping. However in Ruckebusch's study, pressure detectors in the sub-mandibular space were used to detect when the neck was rested. In this study, complete relaxation of the neck was recorded by observation and so over-estimation due to automated recording should not have occurred.

In a comparison of the sleep patterns of two cows before and after pregnancy, Ruckebusch (1975) found that the milk fever position was very closely related to paradoxical sleep for one cow but exceeded paradoxical sleep for the other, a difference which disappeared in test situations involving stress. Similarly, it is possible that cow 592, which had an extremely high sleep time compared with other cows on her group, adopted this position at times when she was not sleeping.

6.5 Conclusions

Video analysis allows more precise measurement of lying behaviour than is possible by direct observation. There was a tendency for cows to sleep for longer when provided with a softer lying surface, although there were no differences in lying behaviour, lying down or rising. Older cows were more likely to exhibit abnormal behaviours, perhaps because they have more experience of coping with difficult situations.

Chapter 7. A rising score for assessing the welfare of dairy cows

7.1 Introduction

Problems with lying down and rising in cattle can result in lesions to hocks, knees and teats (Mortensen, 1978), and may be associated with increased heart rate (Müller *et al.*, 1989) and changes in cortisol secretion (Ladewig and Smidt, 1989) thus affecting animal welfare.

A number of factors in the environment can affect lying down and rising. Tethered cows examined the lying place more prior to lying, had more interruptions of lying down, took longer to lie down and had a reduced frequency of lying compared to cows which were loose housed on straw bedding (Krohn and Munksgaard, 1993).

In cubicles, the dimensions of the lying place and the type of partition can restrict lying down and rising movements, for instance due to lack of forward lunging space (Cermák, 1987; McFarland and Gamroth, 1994). Furthermore, in any system, the type of floor surfaces can have serious effects on the lying behaviour. Young animals kept on a slatted floor had a decreased frequency of lying and showed an increase in abnormal lying behaviour (Andreae and Smidt, 1982; Ladewig and Smidt, 1989; Lidfors, 1992). Dairy cows kept in tie-stalls with concrete flooring had a decreased frequency of lying bouts compared to cows kept in pens with soft rubber mats (Haley *et al.*, 1998), and the lying down movement can be facilitated in older cows by providing a softer lying area (Herlin, 1997).

Indeed, total lying times are longer and lying behaviour appears to be less restless when cow comfort is improved by providing, for example, more spacious cubicles or softer bedding materials (as shown in Chapter 5). In practice, comfort is assessed by quantifying many factors such as cubicle dimensions and

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This work has been submitted for publication as Chaplin and Munksgaard and contributions by Lene Munksgaard and Anton Steen (AS) have been acknowledged where appropriate.

construction, bedding use, space allowance and chain length (in tie stalls). However, although information is available about how production system, environment and housing design affect lying behaviour, management factors as well as different combinations of the design of the resting area may lead to unpredictable effects on the cows lying behaviour (Sandøe *et al.*, 1997). Therefore, on-farm assessment of lying behaviour could be improved by observations of responses of the animals in question, as recommended by Lidfors (1989). A scoring system for assessing cow comfort on farms should ideally be practical and simple to use. Prolonged observations to record lying times over 24h are clearly not a practical option. Even recording lying over shorter periods, at critical times, may be too time-consuming and not even be representative of 24h lying behaviour. Scoring the behaviour of the cow as she lies down (Faull *et al.*, 1996) is impractical as cows cannot be easily induced to lie down and the assessor would have to wait some time even for a few results. However, scoring of rising may be done within a limited amount of time.

A five-point system of scoring the rising behaviour of cows has been used (Sandøe *et al.*, 1997) whereby cows were encouraged to rise from lying by an assessor. The system was included in an "ethical account" assessment of 15 different farms (including units with both cubicles and tie-stalls) and showed differences between farms. However, it is not known conclusively whether scoring rising is a reliable way of describing cows' lying behaviour. Likewise, it is possible that inducing the cow to rise may influence her rising behaviour in some way. Nevertheless, rising is one component of lying behaviour which could be assessed in the restricted time of a farm visit.

If scoring cows' rising behaviour is to be used as an on-farm test for cow comfort, the repeatability and predictive value of the scoring system must be determined. Repeatability describes the variation in test within and between observers. Good within observer repeatability indicates that the same observer scores the same behaviour the same way in repeated tests under the same conditions each time. The predictive power of the test describes the ability of the scoring system to predict different aspects of lying behaviour reliably. In a practical situation, it is likely that the test will be performed on cows in different stages of lactation and of different parities and it is important to know how these variables affect both lying behaviour and the rising score.

Therefore the validity of a simple scoring system for rising, the effect of lactation number and stage of lactation on lying behaviour and/or the rising score, and how well the rising score related to other aspects of lying behaviour were studied.

7.2 Materials and methods

7.2.1 Animals and housing

Sixty-one Danish Friesian cows were used; stage of lactation and lactation number are given in Table 7.1. The cows were kept in two identical tie-stall barns at Research Centre Foulum, in Denmark (stall dimensions: 120cm × 175cm). Stalls were laid with rubber mats and were bedded twice daily with chopped straw. There were dry and milking cows in each barn. Milking cows were milked in their stalls at 04:00-05:00 and 16:00-17:00h.

Table 7.1 The number of cows of each lactation number[1] and each stage of lactation that were studied for rising and lying behaviour

Stage of lactation	Lactation 1	Lactation 2	Lactation 3
Early lactation (<100d post-calving)	12	5	2
Late lactation (>200d post-calving)	8	4	6
Dry (not milking)	10	7	7

[1] The number of lactations started, i.e. a dry cow in lactation 1 would have completed her first lactation but not yet started her second.

7.2.2 Scoring of rising

Rising was scored at 11:30 (morning), 15:00 (afternoon) and 17:30 (evening) on five successive days. At 11:30, rising was scored by two observers (SC & AS) but at 15:00 and 17:30 only one observer (SC) scored the cows. The observers walked around the barn together, persuaded any cows that were lying to rise and allocated a rising score to each of these cows without conferring. A second tour was made in the same way within half an hour. Any cow not lying at these times was not scored. Cows were encouraged to rise by the observer standing at the cow's tail and slightly behind her, i.e. in view but not in the way of her legs. Increasing levels of encouragement were used with the aim of getting the cow to rise with the minimum possible force: the voice alone was used initially (level 1), then one slap on the cow's back (2), followed by as many slaps were required to persuade the cow to rise (3). All cows that were lying had to rise so they would learn that they could not avoid rising. At each rising, a score was given, as described in Table 7.2, and the level of encouragement needed was recorded.

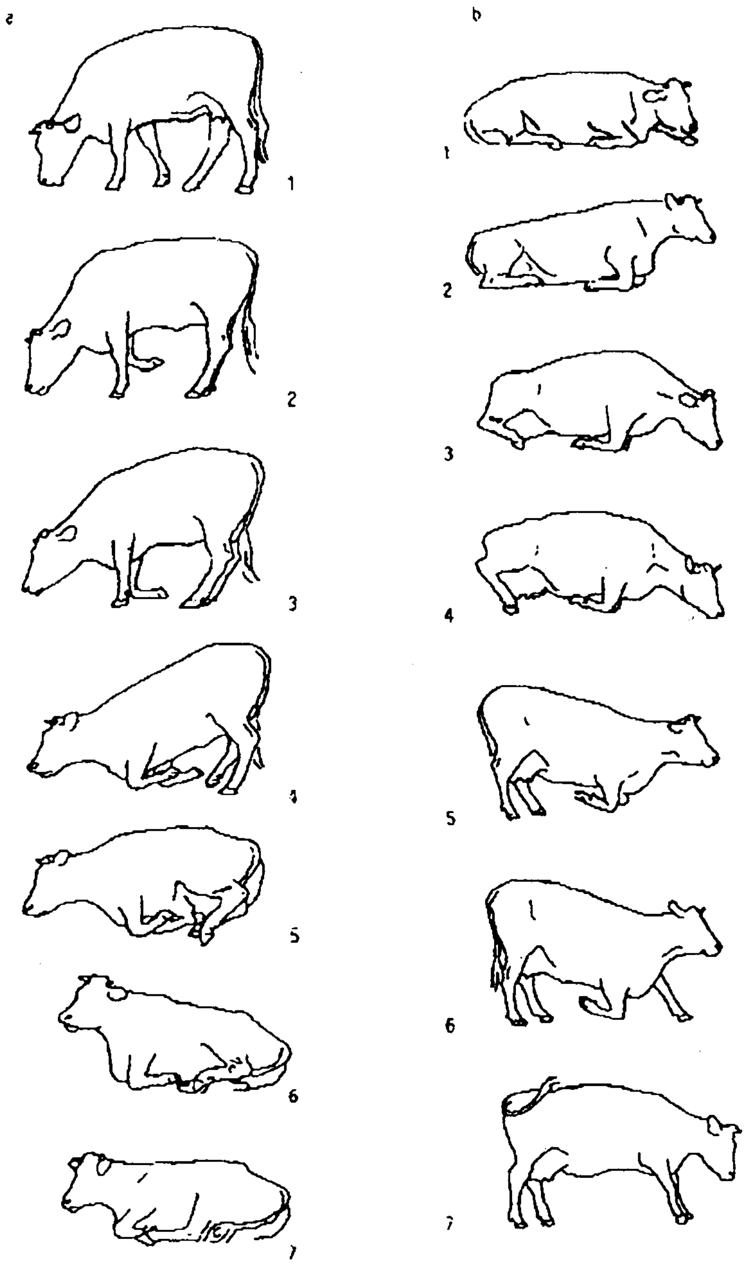
Table 7.2 Scoring of rising behaviour

Score	Description
1	Smooth fluid movement, normal sequence of events (Figure 7.1)
2	Short pause on knees, normal sequence.
3	Long pause on knees, normal sequence.
4	Long pause on knees and/or some difficulty in rising, e.g. awkward twisting of head and neck, but otherwise normal sequence.
5	Abnormal rising, deviating from the normal sequence of events, e.g. rising onto haunches first.

Figure 7.1 Normal sequence of events for a cow a) lying down and b) rising from lying (taken from Snitzer, in Gustafson, 1994)

a) lying down

b) rising from lying



7.2.3 Video analysis of lying

The behaviour of 58 cows was continuously recorded on video for 21.5 hours, starting between 12:00 and 14:30. The remaining 2.5 h each day were used for moving video equipment as only ten cows could be recorded at one time. Ten cows were video recorded for three successive days but due to technical difficulties, only data from eight of these cows were available for analysis. Cows that were being video recorded were persuaded to rise and scored at 11:30, during filming, but not at 15:00 and 17:30.

Lying down and rising movements were each split into four characteristic postures as described in Chapter 6 (see Table 6.2) and the exact time at which each posture was first achieved was recorded. From these data, the time taken for rising and for lying could be calculated as well as the time taken in the preparatory phase of lying and in the final phase of rising. These data were also used to determine the total lying time, maximum lying bout length and lying frequency for each animal. Each rising event recorded on video was scored from the video records in the same way as by direct observation (Table 7.2). As in Chapter 6, if a cow was seen to assume postures characteristic of lying down but did not compete the lying down movement, this was considered to be an intention to lie down. The incidence of leaning the forehead or muzzle on stall fixtures was also recorded.

7.2.4 Statistical analysis

An index of concordance between the two observers' scores given at 11:30 was calculated for each day in turn, giving the proportion of times that the observers agreed (Martin and Bateson, 1986). An index of 1 would indicate perfect agreement on all occasions whereas an index of 0 would indicate that the observers never agreed.

For both rising score and the level of encouragement needed to persuade the cow to rise, the effect of day of scoring was analysed using Friedman's test (Siegel and Castellan, 1988) in Minitab for Windows Version 10.0 using the first three scores given by SC for each cow, testing each time of day in turn. Due to missing data, when cows were already standing and could not be scored, there were too few cows scored on four or five days to use any more scores in the analysis. The average score for each time of day was then calculated and the effect of time of day tested by one-way ANOVA.

The effect of level of encouragement on rising score was tested by correlating average level of encouragement with average rising score.

Scores given by SC during direct observation were compared with matched scores of the same rising events given by SC during video analysis using a paired t-test. “Forced” risings were recorded on video for 35 cows. The scores for these rising events were compared with the average scores of all other risings recorded on video using a paired t-test.

In order to estimate the effects of adding another observation the following average scores were calculated: mean1=score(1+2)/2, mean2=score(3+4)/2, mean3=score(1+2+3)/3 and mean4=score(4+5+6)/3. Then Spearman rank correlations between the first five scores and between mean1-mean4 were calculated.

Effects of stage of lactation and parity on rising score, level of encouragement and aspects of lying down, lying behaviour and rising recorded from the videos as well as differences between mean1-mean2 and mean3-mean4 were tested used a mixed model procedure in SAS (Littell *et al.*, 1996). The model included stage of lactation, parity and interactions between these as fixed effects. Individual cow number was considered a random effect in all analyses.

The ability of the scoring system to predict different aspects of lying behaviour was also tested using a mixed models procedure in SAS (Littell *et al.*, 1996). This model included stage of lactation and parity, and interactions between these, as fixed effects, with individual cow number considered as a random effect. Each cow’s average rising score was subtracted from the mean average rising score of all cows of that stage of lactation and this adjusted rising score was used as a covariate in the model. The model was used to analyse total lying time, number of lying bouts, maximum lying bout length, preparatory phase of lying, total time for lying down, final phase of rising, total time for rising (log transformed).

Data from the eight cows that had been video recorded for three consecutive days were analysed by MANOVA to test for differences between days.

Unless otherwise stated, all data were analysed using Genstat Version 5, Release 4.1 (© Lawes Agricultural Trust, IACR, Rothamsted)

7.3 Results

On average 62% of the cows were scored at 11:30 (both tours), compared with 39% at 15:00 and 49% at 17:30.

Day of scoring had no effect on rising score at either 11:30, 15:00 or 17:30 ($p>0.05$). Nor was there was any difference between average scores recorded at different times of day (11:30=2.34 ± 0.09, 15:00=2.38 ± 0.08, 17:30=2.40 ± 0.07, $p>0.05$). Over the five days, 141 scores were compared (Table 7.3) and of these, there were 46 non-agreements. Investigation of the non-agreements, showed that 41 were due to a difference of only one score and of these, 26 were due to one observer scoring 2 and the other scoring 3. Indices of concordance for the two observers are shown in Table 7.3.

Table 7.3 Indices of concordance for two observers on five consecutive days of scoring

Day of scoring	Mon.	Tue.	Wed.	Thu.	Fri.
No. cows scored	30	34	29	27	21
No. agreements between observers	16	24	22	16	17
No. non-agreements	14	10	7	11	4
Index of concordance	0.53	0.71	0.76	0.59	0.81

Cows in their third lactation had higher average rising scores than cows in their first or second lactations (lactation 1, 2.30±0.08; 2, 2.34±0.12; 3, 2.76±0.14, $p=0.008$) and there was a tendency for cows in early lactation to have higher average rising scores than cows in late lactation. Dry cows had rising scores intermediate between early and late lactation cows (early, 2.63±0.12; late, 2.23±0.09; dry, 2.44±0.11, $p=0.065$).

The level of encouragement needed to persuade cows to rise was not affected by day of scoring at 11:30, 15:00 or 17:30 ($p>0.05$). However, average scores for encouragement were lower in the morning than in the afternoon or evening (morning, 1.22±0.08; afternoon, 1.50±0.08; evening, 1.45±0.09, $p=0.034$).

Lactation number did not affect level of encouragement ($p>0.05$) but cows in late lactation needed less encouragement than those which were dry or in early lactation (late, 0.13±0.09; dry, 0.40±0.09; early, 0.36±0.12, $p=0.022$). There was only a low, non-significant correlation between encouragement and rising score ($r=0.16$, $p>0.05$).

There was no difference between the scores given for forced risings and the average score of all other risings ($p>0.05$) nor did scores given for video records differ from those given in direct observation of the same rising events by either SC ($p>0.05$) or AS ($p>0.05$).

Correlations between the first five scores obtained were moderate (Table 7.4), as were correlations between mean1 and mean2 ($r=0.58$, $p<0.001$) and between mean3 and mean4 ($r=0.58$, $p<0.001$). When only two observations were included there was a significant difference between average scores obtained (mean1, 2.56; mean2, 2.36, $p=0.02$) and repeatability within cow was $r=0.49$. When three observations were included there were no differences between the average scores obtained (mean3, 2.45; mean4, 2.39, $p>0.05$) and repeatability within cow increased to $r=0.60$.

Table 7.4 Spearman correlation coefficients between the first five scores obtained (r, p-value)

n=50	Score 1	Score 2	Score 3	Score 4	Score 5
Score 1	1.00 (-)	0.36 (0.01)	0.47 (0.001)	0.35 (0.01)	0.34 (0.02)
Score 2		1.00(-)	0.39 (0.006)	0.39 (0.05)	0.55 (<0.001)
Score 3			1.00 (-)	0,49 (<0.001)	0.57 (<0.001)
Score 4				1.00 (-)	0.57 (<0.001)
Score 5					1.00 (-)

There were no interactions between stage of lactation and lactation number for the lying behaviour observed from the video recordings, therefore results are presented separately for stage of lactation (Table 7.5) and lactation number (Table 7.6).

Cows in early lactation spent less time lying in total compared to cows in late lactation and dry cows, and maximum bout length decreased from early lactation to late lactation and dry cows. Dry cows had fewer lying bouts compared to the other two groups of cows. Rising tended to take longer for cows in late lactation compared with dry cows and the time taken for cows in early lactation to rise was intermediate between these two (Table 7.5). There were no differences in lying, lying down or rising behaviour between cows in their first, second or third lactation (Table 7.6). However, contrasts between cows in first lactation and older cows (both second and third lactation together) showed that first lactation cows took less time to lie down (L1-L4) compared with older cows (26±1.3 vs. 32±1.6sec, p=0.02), and had a shorter preparatory phase (18±1.2 vs. 21±1.4sec, p=0.06).

Table 7.5 Effects of stage of lactation on lying behaviour recorded over 21.5h, least squares means (SEM in parentheses)

	Early		Late		Dry		p-value
Lying time (h)	9.58^a	(0.63)	13.68^b	(0.50)	12.68^b	(0.43)	<0.001
No. lying bouts	14.4^a	(1.2)	12.0^a	(0.9)	9.0^b	(0.8)	0.001
Maximum bout length (h)	1.70^a	(0.20)	2.33^b	(0.15)	3.05^c	(0.05)	<0.001
Preparatory phase of lying down (secs)	21	(2.3)	20	(1.8)	22	(1.5)	NS
Total time lying down (secs)	31	(2.6)	28	(2.0)	30	(1.7)	NS
Final phase of rising (secs)	6^a	(0.4)	4.9^b	(0.3)	6^a	(0.3)	0.017
Total time for rising (secs)[1]	2^{ab}	(0.09)	2^b	(0.07)	2^a	(0.06)	0.070

[1] ln transformed

[a], [b], [c] means with different superscripts are significantly different

Table 7.6 Effects of lactation number on lying behaviour recorded over 21.5h, least squares means (SEM in parentheses)

	Lact. 1		Lact. 2		Lact. 3		p-value
Lying time (h)	11.78	(0.38)	12.77	(0.58)	11.38	(0.62)	NS
No. lying bouts	12.2	(0.7)	12.0	(1.0)	11.1	(1.1)	NS
Maximum bout length (h)	2.47	(0.12)	2.43	(0.18)	2.17	(0.18)	NS
Preparatory phase of lying down (secs)	19	(1.4)	23	(2.1)	22	(2.2)	NS
Total time lying down (secs)	26^a	(1.5)	31^b	(2.3)	31^b	(2.3)	NS
Final phase of rising (secs)	5	(0.3)	5	(0.4)	6	(0.4)	NS
Total time for rising (secs)[1]	2	(0.06)	2	(0.09)	2	(0.09)	NS

[1] ln transformed

[a], [b], [c] means with different superscripts are significantly different

When the ability of the rising score to predict different aspects of lying behaviour was tested, stage of lactation and parity were included in the model as this information is likely to be available in a practical situation and these factors have already been shown to affect lying behaviour. Parameter estimates of the covariance, which is a measure of the relationship between the variables, show that cows with higher rising scores would be expected to have fewer lying bouts and longer maximum bout lengths (Table 7.7). Unsurprisingly, rising score was also directly related to rising behaviour: cows with higher rising scores took longer to rise and in particular, the final phase of rising took longer. Rising score did not explain any variation in total lying or lying down (Table 7.7).

Table 7.7 Covariance estimates for adjusted rising score, for all behaviours recorded

Behaviour (21.5 hour)	Covariance estimate	p-value
Total lying (h)	-59.68	NS
No. lying bouts	-2.33	0.045
Maximum bout length (h)	25.28	0.035
Preparatory phase of lying down (secs)	3.02	NS
Total time for lying down (secs)	2.99	NS
Final phase of rising (secs)	1.17	0.005
Total time for rising (secs)	0.25	0.008

There was no difference in lying behaviour (total lying time, maximum bout length, minimum bout length, mean bout length or number of lying bouts), lying down (L1-L2 and L1-L4) or rising (R3-R4 and R1-R4) between days for the eight cows that were videoed for three consecutive days (Table 7.8).

Table 7.8 Variation in lying behaviour, lying down and rising over three consecutive days, least squares means (SEM in parentheses)

Behaviour (21.5 hour)	Day1		Day2		Day3		p-value
Total lying (h)	12.70	(1.28)	13.32	(1.12)	13.55	(1.15)	NS
No. lying bouts	9.4	(1.0)	9.4	(1.0)	10.5	(1.2)	NS
Maximum bout length (h)	2.73	(0.25)	3.00	(0.20)	2.97	(0.23)	NS
Preparatory phase of lying down (secs)	16	(1.2)	17	(2.5)	17	(1.4)	NS
Total time for lying down (secs)	33	(9.6)	24	(2.4)	24	(1.3)	NS
Final phase of rising (secs)	6	(1.2)	7	(0.7)	6	(0.6)	NS
Total time for rising (secs)	9	(1.1)	11	(0.9)	9	(0.7)	NS

7.4 Discussion

Scoring of the rising behaviour of tethered cows was repeatable and not affected by the presence of a observer or by encouragement to rise. Stage of lactation affected total lying time, number of lying bouts, maximum bout length and rising behaviour, while lactation number only had a minor effect on lying behaviour.

Indices of concordance between observers were moderate and higher values would be desirable. However, the index of concordance is strictly defined as complete agreement between the observers and approximately half of the instances of divergence between the observers were due to disagreement between scores 2 and 3. It was thought that defining these scores loosely as "short" or "long" pause on the knees would add to the strength of the scoring system, allowing the observers to express their subjective impression of the rising event, and that a more rigid definition would be restrictive. It appears that more definition should have been given.

The results suggest that at least three observations should be included in order to obtain reliable estimates of individual cows' rising behaviour. The rising score was unaffected by the different scoring conditions tested. There was no difference in rising scores between days or between different times within day.

The cows' rising score was not affected by the presence of the observer, there was no difference between scores analysed from video recordings and by direct observation, and forced risings did not differ from the average rising score for voluntary risings. Furthermore, the level of encouragement needed to persuade the cows to rise did not affect the rising score. Thus the results suggest that the simple scoring of rising behaviour of tethered cows is repeatable.

The level of encouragement needed to persuade cows to rise was not affected by day of scoring, although only three days were considered. It is possible that if there had been enough cows with scores on four or five successive days, there might have been effects due to cows learning the procedure. Less encouragement was needed in the morning than at other times of day and this is probably because most management procedures are carried out in the morning and these cows were used to disturbance at this time. However, level of encouragement did not affect the rising scores: there was no correlation between encouragement and rising score and forced rising did not differ from voluntary risings.

As less encouragement was needed when scoring in the morning than at other times of day and as more cows were found lying at this time than at any other, this appeared to be the best time to score. Nearly half of the cows were lying at 17:30, although they were more reluctant to rise at this time than in the morning. However, as level of encouragement was not an important factor affecting rising score the evening may also be considered as a good time to score.

When considering the best time of day to score cows, it is probably not the absolute time of scoring that is important so much as the time in relation to other management events. In this herd, 11:30 is a time when the routine tasks of the morning such as sweeping the passages and bedding down have all been completed and there is still at least one hour before feeding time. As milking commenced between 16:00 and 17:00h, scoring at 17:30 did not give cows enough time to settle. Perhaps if scoring had been carried out an hour later, a greater percentage of cows would have been found lying. However, one important criterion in choosing scoring times was that they should be practical and close to normal working hours. Hence a later time was not used.

The cows' rising scores did not appear to be overtly affected by the presence of the scorer(s), given that forced risings were no different from the average rising score for voluntary risings. As there was no difference between scores given in video analysis and by direct observation for the same rising events, scoring could be carried out by making video records of cows rising and scoring them at a later date, if the score was applied to farm assurance, for example. This would be just as effective as scoring by direct observation and have the added advantage of leaving a "hard copy" which could be referred to in the case of disagreement.

The results from the eight cows that were video recorded for three consecutive days show that lying behaviour, lying down and rising are consistent across days, in the short-term at least. Although lying behaviour was only recorded over 21.5h for cows in this study, the remaining 2.5h, between 12:00 and 14:30, was a time when cows were usually either waiting to be fed or feeding (they were fed at 13:00). They were unlikely to be lying down and so results in these can be compared with 24h lying times reported elsewhere.

There were marked differences in lying behaviour due to stage of lactation. Cows in early lactation spent less time lying and had a shorter maximum bout length than cows in late lactation and dry cows. Dry cows had a lower lying frequency. Time for rising, as well as rising score, suggested that cows in late lactation had the least problems when rising. The lying behaviour of cows in early lactation may be affected by udder discomfort, while rising behaviour of dry cows may be thwarted by the extra weight of the calf. In agreement, rising score was lowest for cows in late lactation.

In agreement with our results, Phillips and Leaver (1985) found that cows in early lactation had shorter lying time than cows in late lactation when at pasture. In contrast, Dechamps *et al.* (1989) and Krohn and Munksgaard (1993) found no effects of stage of lactation, although Dechamps *et al.* (1989) used a relatively small number of cows and did find differences in the distribution of lying bouts. In the latter study lying behaviour was only observed from 6:00 to 21:00 h and daytime lying is not a good predictor of total lying (see Chapter 2).

Cows in their first lactation lay down more quickly than older cows, probably due to the shorter preparatory phase. This is consistent with the findings of Herlin (1994) and Krohn and Munksgaard (1993) who found that third lactation cows took longer to lie down than younger cows, and suggested that this was because older cows are heavier. Although rising time did not differ with lactation number, rising score was increased for cows in third lactation compared to first and second lactation. Herlin (1994) also found it difficult to detect a difference in rising time and suggested that the time taken to rise might not correlate directly with the actual effort of getting up. In an unfavourable environment, cows change the pattern of their rising movement by twisting or other awkward movements but still take the same time to rise. Because the rising score is a subjective assessment of the whole rising movement, it is better able to describe the effort of rising. Older cows are more likely to have developed distinctive strategies to cope with such environments and hence have higher rising scores than younger cows which may be fitter and stronger.

The rising score was a good predictor of the time taken to rise from knees to standing: cows with a higher score took longer to rise. This result was to be expected as the important markers in the scoring system were related to this phase of rising and in particular, the time spent kneeling. Rising score was also significantly related to the number of lying bouts and maximum bout length, suggesting that thwarting of rising behaviour reduces the frequency of lying bouts. Scores for rising did not explain any of the variation in total lying time and lying down behaviour.

7.5 Conclusions

In conclusion, the proposed score for rising reliably reflected whether the cows in tie-stalls had difficulty rising when at least three observations were included. A proportion of cows in different stages of lactation should be included in any assessment of rising behaviour, since stage of lactation significantly affected rising behaviour. A satisfactory time of day for scoring cows' rising is about one hour after milking, either in the morning or the evening.

Chapter 8. Comparisons of two methods of scoring rising and of cows with easy and difficult rising

Part 1. Comparing two methods of scoring rising

8.1 Introduction

The rising score described in Chapter 7 had subjective components. These were intended to take into account the observer's impression of cows' rising behaviour but may have been responsible for some of the non-agreements between observers. It is possible to make scoring systems less subjective by clearly defining the markers for each level. For example, the hock injury score described in Chapter 5 is more objective than the dirtiness score in the same chapter because the appearance of lesions at each level is clearly described whereas the dirtiness score relies on the observer's interpretation of "quite dirty", etc.. Therefore, in an attempt to make the rising score more objective, an alternative method of scoring rising was devised by AN, based on the time taken for cows to rise. Whereas the Denmark method relied on subjective assessment of the time a cow spent on her knees whilst rising, the alternative Ayr method required the time a cow spent on her knees to be estimated by counting seconds as she rose.

The two methods were compared using cubicle-housed, late lactation cows.

In Chapter 7 both observers were equally familiar with the rising score. Here, two observers were compared, each familiar with one score and unfamiliar with the other, to test whether observer experience affects how the score is applied.

8.2 Methods

All late lactation cows in the Auchincruive herd found lying were scored by two observers (AN and SC) at 11:30 on two consecutive days. On day 1, 48 cows were scored by both observers, each observer using the method of scoring with

The Ayr method of scoring rising was devised by Adam Noel, a final year Honours student at Auchincruive in 1998/9. Some of the work presented in this chapter was also presented by AN in his Honours thesis.

which he/she had previously become familiar, i.e. SC used the Denmark method (described in Chapter 7, Table 7.2) and AN used the Ayr method (described in Table 8.1). Rising was timed on day 1 using a stopwatch. On day 2 the observers each used the method with which they were less familiar and 38 cows were scored. Fifteen cows were scored by both observers on both days.

Table 8.1 Scoring of rising by the Ayr method

Score	Description
1	Normal rising sequence (see Figure 7.1). Two seconds or less on knees.
2	Normal rising sequence. Three seconds on knees.
3	Normal rising sequence. Four or more seconds on knees.
4	Normal rising sequence. Awkward head movement. Four or more seconds on knees.
5	Front legs straightened before back legs.

8.2.1 Statistical analysis

An index of concordance was calculated for both days to test for complete agreement between the observers using different scoring methods (Martin and Bateson, 1986). Cows were categorised according to whether they had low (1 or 2) or high (3 or 4) rising scores and an index of concordance was calculated again for both days. The time taken to rise for different rising scores was compared by GLM ANOVA, using data collected using both scoring methods on day 1. Wilcoxon matched pairs was used to test for differences in the way the two observers used the Ayr and Denmark scoring methods.

8.3 Results

Cows scored 1 or 2 by both observers took significantly less time to rise than cows scored 3 or 4 (Table 8.2).

Agreement between the observers using the two different methods on the same rising event was reasonable and consistent: on day 1, the index of concordance was 0.54, and on day 2, 0.57. When cows were categorised according to whether they scored low (score 1 or 2) or high (score 3 or 4), the agreement between the observers increased to 0.87 on day 1 and 0.78 on day 2.

Table 8.2 Time taken to rise for cows with different rising scores when scored by the two methods on day 1 (mean ± SEM)

Rising score	Ayr method (AN)	n	Denmark method (SC)	n
1	3.01^{a} (0.11)	12	3.19^{a} (0.12)	14
2	4.20^{a} (0.35)	21	3.76^{a} (0.15)	16
3	6.44^{b} (0.85)	11	6.34^{b} (0.75)	11
4	7.41^{b} (0.68)	4	7.23^{b} (1.08)	7
5		0		0
p-value	<0.001		<0.001	

[a, b] Means in the same column with different superscripts differ significantly

There was no difference between the observers in the way that they used the Ayr scoring method but SC gave higher scores than AN when using the Denmark method. Both were more likely to give high scores when using the method with which they were familiar. (Table 8.3)

Table 8.3 Median and range (min.-max.) of scores given by the two observers using the different methods of scoring on the same rising events

Method	No. events	Observer AN	Observer SC	p-value
Ayr	15	2.0 (1.0-4.0)	2.0 (1.0-3.0)	NS
Denmark	16	2.0 (1.0-3.0)	3.0 (1.0-4.0)	0.030

8.4 Discussion

Rising times for scores 1 and 2 were significantly lower than the rising times for score 3 and 4. Hence, it seems that the score could be simplified to a binary system: 0=free, fluid movement or short pause on knees; 1=long pause on knees, awkward movement of head and neck or abnormal rising sequence. A binary system would be easier to learn and use. As there was a very clear difference in the rising times of cows scored 1 or 2 and those scored 3 or 4, a short pause could be defined as less than or equal to 5 seconds and a long pause could be defined as greater than 5 seconds. In this study there were no cows with abnormal rising but the number of cows showing abnormal rising should be identified in any herd assessment of rising behaviour.

Both observers were less likely to use the full range of scores when using the system with which they were not familiar. When two observers were compared using the Denmark score in Chapter 7, they were both equally familiar and there was no difference between them. The results here and in the previous chapter suggest that training and experience can influence scoring and that when observers are familiar with the scoring system they are more likely to use the full range of scores.

Part 2. Comparison of cows with easy and difficult rising

8.5 Introduction

The results in Part 1 of this chapter indicate that there is a clear divide between cows with low and high rising scores and suggest that the five-point rising score could be reduced to a binary system. The data described in Chapter 7 were re-analysed to test whether a binary method could explain differences in lying behaviour.

8.6 Methods

Data were collected as described in Chapter 7.

8.6.1 Statistical analysis

The first score given to each cow by SC was used to categorise cows as having either easy (score 1 or 2) or difficult (score 3, 4 or 5) rising. GLM ANOVA was then used to test whether cows categorised as easy or difficult differed in aspects of their lying behaviour, lying down or rising. Data for rising (final phase of rising and total time for rising) were skewed and so were transformed using a $\log_{10}$ transformation. The incidences of intentions to lie down and leaning events were summarised for analysis. Cows either had few (less than 12) or many (>12) intentions to lie and either showed leaning, or did not. Chi-square analysis was then used to determine whether cows with easy rising were more likely to have few intentions to lie and lean less.

8.7 Results

Cows with easy rising were no different from cows with difficult rising in terms of lying behaviour, rising or intentions to lie. However, cows with easy rising tended to have a shorter preparatory phase to lying down and took less time to lie down. Fewer cows with easy rising showed leaning. (Table 8.4.)

Table 8.4 Behavioural characteristics of cows with easy or difficult rising (mean ± SEM)

Behaviour	Easy rising		Difficult rising		p-value
No. cows	31		27		
Total lying time (mins)	12.28	(0.51)	11.87	(0.50)	NS
No. lying bouts per 21.5h	11.7	(0.8)	11.2	(0.7)	NS
Max. lying bout length (mins)	2.53	(0.14)	2.45	(0.16)	NS
Preparatory phase of lying down (secs)	18.9	(1.25)	22.6	(1.42)	0.060
Time to lie down (secs)	26.8	(1.34)	31.2	(2.62)	0.040
Final phase of rising (secs)	0.74	(0.04)	0.80	(0.03)	NS
Time to rise (secs)	0.97	(0.03)	1.02	(0.02)	NS
No. cows with > 12 intentions to lie	7		9		NS
No. cows showing leaning	7		14		0.045

8.8 Discussion

Data in part 1 showed a clear difference in the time taken to rise (recorded using a stop-watch) by cows with low (1 and 2) and high rising (3 and 4) scores. In Chapter 7, the rising score was related to differences in lying frequency, maximum bout length, final phase of rising and total time for rising (recorded from video) but did not explain any variation in total lying time or lying down. However, when a binary method was used to describe rising, in this chapter, the description of cows as having either easy or difficult rising did not explain any variation in lying behaviour or rising. However, cows with easy rising lay down more quickly than cows with difficult rising and were less likely to show leaning.

8.9 Conclusions

Experienced observers are more likely to use the full range of scores, whatever scoring system is used. Agreement between the two systems was reasonable but improved when cows were categorised as having a low or high rising score. Using a binary method of scoring rising, however, did not explain any variation in lying behaviour or rising. Cows with easy rising lay down more quickly and were less likely to show leaning. Therefore, although the binary score is not useful for describing lying behaviour, it can be used to indicate how cows react to their environment.

Chapter 9. General discussion

The work presented in this thesis forms a study of the resting behaviour of dairy cows under various conditions and investigates the possible use of a score which could aid farm assurance. A review of the literature showed that in some areas information on lying was scarce or contradictory and these deficits have been rectified.

Studying the behaviour of pregnant heifers at grass confirmed the few results in the literature and set a standard against which lying and idling behaviour under other circumstances could be compared. Resting behaviour at grass over 24h was characterised by around 10.5h lying, few bouts (6-7), a long maximum bout length of around 3.5h and a relatively small proportion of the day spent in idling (2.5h). This study also showed that lying during the daytime is not a good predictor of total lying time. Therefore, unfortunately, observations of lying during the day cannot be used as a less time-consuming way of predicting total lying time.

In Chapter 3, level of production had no effect on the total time spent lying or the proportion of time spent idling over the whole housing period. Later results suggest that early lactation is the time when disturbed lying behaviour is most likely to occur. However, there were no differences between the herds at the first observation post-calving in any aspects of lying behaviour or time budget. The total lying time of autumn-calvers in early lactation (and therefore also early in the housing period) was comparable to that recorded when they were at pasture. Heifers in the low input herd however had a much higher lying frequency and the maximum bout length was shorter. As lactation progressed, the lower input herd became more restful showing longer and fewer lying bouts, and total lying time remained unchanged. The behaviour of these heifers reflected the challenge they were facing. Metabolic profiles at 30 days post-calving and weight and body condition score loss suggested that these heifers were more metabolically challenged than those in the higher output herd, although they were not experiencing actual "metabolic stress". Despite the disturbance to lying behaviour in early lactation they were able to recover by mid-lactation.

In contrast, the high output herd started off well in early lactation with lying behaviour very similar to that recorded when they were at grass. In mid lactation however, lying frequency increased and maximum bout length decreased, although total lying time remained constant. These behavioural changes were associated with management procedures necessary for the management of a high producing herd, i.e. movement into different feeding groups.

In the pilot study investigating cows' preference for mats and mattresses total lying times were extremely low despite the soft bedding offered and the cows' late stage of lactation. Lying frequency was similar to that at pasture but maximum bout length was reduced. The time spent idling by some cows was much longer than at pasture. This serious reduction in total lying time was attributed to insufficient acclimatisation time after penning the cows, even though cows were chosen from a stable social group, and for the presence of some cows in oestrus. This study showed that many diverse factors affect lying behaviour.

In the main trial comparing the effects of softer bedding (Chapter 5), the lying behaviour was much more predictable. Again, total lying time did not change much over the course of the housing period (and lactation). Cows on mattresses had longer lying times overall, compared with cows on mats but the pattern of change in lying behaviour over the lactation was similar in both groups: lying frequency decreased and maximum and minimum bout lengths increased. Again, lower lying times were associated with an increase in idling and an increase in idling in cubicles in particular.

When late lactation cows were bedded on mats and mattresses and restrained by a yoke to allow video recording of their behaviour, no difference was found in any aspect of their lying behaviour. Even though there were no differences in their lying behaviour and variation in this small number of cows was quite large, there were significantly more sleep bouts in the cows bedded on mattresses and a suggestion in the data that these cows spent more time sleeping. Older cows appeared to have a higher incidence of intentions to lie and were more likely to show abnormal behaviours such as leaning. Older cows may be more stiff and may have more difficulty getting up and lying down than younger animals. In chapter 7, cows in their third lactation had higher average rising scores than younger cows and took longer to lie down, particularly in the preparatory phase. Therefore it seems that leaning may be a response to thwarting of lying down and rising.

In all the previous studies, stage of lactation was confounded with time post-housing but in Chapter 7, there were very clear differences between cows at different stages of lactation when time post-housing was constant. Cows in early lactation had shorter total lying times than cows in late lactation or dry cows, although total lying times in early lactation were comparable with those of heifers at grass in Chapter 2. Early lactation cows also had shorter maximum bout lengths and more lying bouts. These cows were restrained in tie-stalls and so further work would be necessary to determine whether time post-housing or time post-calving was more important for cows housed in cubicles.

9.1 Total lying times compared with other aspects of lying behaviour

Throughout the lying behaviour results there were instances where lying behaviour was disturbed and cows showed signs of restlessness by increased lying frequency and shorter lying bouts but where total lying time was comparable to the behaviour of heifers at grass. Low total lying times were rare (late lactation cows in Chapter 4 were the notable exception) and lying frequency was more likely to indicate disturbance.

Low total lying times are a clear sign that comfort is poor. The consequences of reduced lying and the importance of lying were made clear in Chapter 1. Because cows are so strongly motivated to lie, a reduction in total lying time can only occur if lying is prevented. Cows may be prevented, or deterred, from lying if the act of lying down is aversive. For example, if the lying area is very hard, or slippery; if, like untrained heifers, the cow is inexperienced in using her environment; or if the motivation to lie is reduced, as in oestrus.

An increase in lying frequency indicating restlessness is more likely to occur when lying bouts are curtailed and lying down is not aversive. Cows bedded on mats and mattresses were restless in the early lactation/early post-housing period but the cows bedded on mattresses were less affected than those on mats. This suggests that cows on mattresses were able to satisfy their motivation to lie after fewer, longer lying bouts than for cows on mats. The latter group may have been uncomfortable lying for longer periods and so satisfied their motivation to lie by an increase in lying frequency. Another cause of restlessness, for all cows in early lactation, may be a competing motivation to feed, due to the demands of early lactation. Longer lying bouts may be curtailed, as the motivation to feed increases and in order to satisfy the motivation to rest the frequency of lying is increased.

This suggests that total lying time is not the most sensitive measure of disruption to lying behaviour and a full assessment of lying behaviour should not rely on total lying time alone. Analysis of lying bouts can reveal disruptions in lying behaviour which are indicative of difficulty coping.

There have been several developments of devices for automatically recording lying behaviour, some more expensive and complicated than others. Simple devices such as a tilt switch and data logger encased in an equine brushing boot (Middlemass and Roberts, 1999) can easily be attached to individual cows and a compete record of the cow's lying bouts can be downloaded after 24h or longer. However, even with the cheapest and simplest devices there is still a limit to the number of cows which can practically be recorded and decisions will have to be made as to which cows to record and when.

Older cows and heifers should be included in any assessment. Abnormalities in the behaviour of older cows indicate the extent to which they have had to develop strategies in order to cope with their environment. Younger cows however, may be more obviously affected by their environment. If lying behaviour is seriously disrupted on the introduction to housing, training of in-calf heifers should be considered.

Because lying behaviour in early lactation can be so different to lying behaviour at other times, cows should be assessed twice, once in early and once in late lactation. This will give an indication of lying behaviour when challenges are at their greatest and at their least. If assessment could only be carried at one time point, it should be in early lactation when lying behaviour is most likely to be affected.

Housing and calving were confounded in the main trial comparing mats and mattresses, and in the two Acrehead herds where there were autumn and spring calving heifers, there were too few heifers to provide conclusive results. However, results presented by Singh *et al.* (1993b) and O'Connell *et al.* (1989a) suggest that housing has as strong an effect on lying behaviour as early lactation. Therefore further work is needed to establish the relative contributions of housing and calving to disrupted lying behaviour in cubicle housed cows. In this research, the cows in tie-stalls showed clear stage of lactation effects and were all at the same time post-housing. However, feeding effects could have interacted with stage of lactation effects and these need to be investigated also. Early lactation cows may be more highly motivated to feed and this competing motivation may disrupt lying behaviour. Conversely, the very long lying times of late lactation and dry cows in tie-stalls may have been due to their having more "spare time".

9.2 Subjective scores

A number of scores were used in this study, such as scores for locomotion, condition, hock and knee injury, dirtiness and rising. If a way could be found of scoring lying behaviour, this would be a cheap alternative to automatic devices for recording lying behaviour and personnel already involved in farm assurance could easily be trained to use scores. The experiment comparing two similar systems for scoring rising (Chapter 8) showed the importance of training and experience in using any score. If scores are to be used in farm assurance they should be consistent, reliable and valid. To improve consistency and reliability, categories need to be clearly defined and discrete. There should not be too many categories as we must assume that a cow can only be scored once in any one farm visit and if there are too many categories, it can be difficult to make quick decisions.

The "Denmark" rising score proved to be reliable when two observers were equally experienced. This score was repeatable under various conditions but three scores would be required for each cow. The score was a good predictor of lying frequency and maximum bout length but not of total lying time. These results further, highlight the importance of analysing lying bouts. However, the score was only tested on cows in tie-stalls and it would need to be tested for validity when applied to cows housed in cubicles before it could be included in farm assurance in the UK. Furthermore, cows with higher rising scores had a lower lying frequency and longer maximum bout length and this anomaly would need to be clarified before the score could be used independently of lying behaviour records. Results in Chapter 8 showed that over-simplification can make a score less effective as reducing the rising score to a binary level (in Chapter 8) explained less variation in lying behaviour than the original five point score.

Other scores were also used in the course of this work and some were more subjective than others. Scores for rising and dirtiness were more subjective, and relied more upon the assessor's experience than the scores for hock injury and locomotion. The objectivity of scores can be increased by defining the categories more precisely. For example, if pictures of "quite dirty", "very dirty", etc. had been included on the score sheet for the dirtiness score, the objectivity of this score would have increased.

The farm assurance scheme currently in use for Scottish farms (National Dairy Farm Assured Scheme) allows for the subjective assessment of contamination from the cow and her environment but only on a scale of 1 to 10, from poor to excellent. Although assessors are trained to use the assessment document, there is no definition of categories. Some assessment of the cow's response to her environment would be a valuable addition to such a scheme to ensure that the specified environment and management procedures were actually achieving the desired aims, i.e. satisfying the Five Freedoms.

9.3 Summary: application of lying behaviour analysis and rising scores to farm assurance

If an assessment of lying behaviour were included in farm assurance, results from this study and from the literature suggest that farmers could ensure optimum lying behaviour by:

- not over-crowding stock;
- training heifers to use cubicles;
- providing well-designed cubicles
- providing softer lying areas by either fitting mattresses or deformable rubber mats, or by bedding deeply;
- avoiding mixing social groups;
- avoiding disturbing cows when they are lying.

Although the rising score is quicker and more convenient to use than an analysis of lying bouts and it has been proven to be reliable, there are some drawbacks to its use. Firstly, at least three observations are needed to obtain reliable estimates of cows' rising behaviour whereas, with the use of automatic recording devices, empirical data on cows' lying behaviour can be obtained in just two visits (one to attach the device, another to remove it). Furthermore, there are some inconsistencies in the relationship between rising score and lying behaviour: cows with higher rising scores have lower lying frequencies and longer maximum bout lengths, both desirable characteristics. In addition, the rising score cannot be recommended for cows housed in cubicle systems as it has not been validated for under these conditions.

On balance therefore, it seems more practicable and reliable to concentrate efforts on developing methods of automatic recording of lying behaviour. Night lying time is a reliable predictor of total lying time (Chapter 2), therefore, it may be possible to attach automatic recording devices after evening milking and remove them after morning milking. This would allow two batches of cows to be recorded within 36h, instead of the 72h that would be required if full 24h records were obtained. However, the consequences of recording in this way on lying bout analysis would have to be clarified as cows are capable of shifting their diurnal rhythm, particularly in over-crowded conditions.

In any analysis of lying behaviour it would be essential to include information on lying bouts. Although it is clear that total lying times of less than 10h are sub-optimal, an optimum or long total lying time with very high lying frequency is also indicative of disturbed behaviour. Furthermore, the causes of reduced lying might be determined by investigating lying bouts. Where there are very few bouts, then it seems that the cow is unwilling to lie down (or rise), but if where there is a relatively high lying frequency, this might indicate restlessness (perhaps due to competing motivations or an uncomfortable lying surface) or disturbance (by other cows or humans). It is essential that cows the assessment of lying bouts should include cows at two stages of lactation, and in both first and later lactation as these cow factors very clearly influence lying behaviour when all else is equal.

Further investigation of the rising score is needed before it can be recommended for use in farm assurance. Although the relative contributions of housing and calving to the disturbance of lying behaviour needed to be elucidated, analysis of lying behaviour can be recommended for use in farm assurance.

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Appendix. Example recording sheets for behavioural observations

Cubicle Comfort Trial - Event recording sheet **Date: ____________** **Group: MATTRESS**

Time			22:00			22:15			22:30			22:45	
Behaviour		L/S/S½	C/P/F	F/R/D/O	L/S/S½	C/P/F	F/R/D/O	L/S/S½	C/P/F	F/R/D/O	L/S/S½	C/P/F	F/R/D/O
No	Cow												
1	167												
2	282												
3	357												
4	359												
5	425												
6	409												
7	498												
8	502												
9	538												
10	555												
A	574												
C	587												
E	594												
W	599												
X	613												

L/S/S½, **L**ying, **S**tanding or **S**tanding half-in cubicle C/P/F, **C**ubicle/**P**assageway/**F**eedface F/R/D/O, **F**eeding/**R**uminating/**D**rinking/Doing N**o**thing

Cubicle Comfort Trial - Event recording sheet

Date: ____________ **Group:** MATTRESS

Cow	**Cubicle**	Time of **lying**	Time of **rising**	Comments