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Increasing intake by the development of optimal grazing management in relation to animal behaviour at pasture.

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Summary

- In each month from July to December, grazing activity for each of 12 animals was recorded over a number of days continuously using vibrarecorders. The work was done at Killarney National Park and the animals were heifers of the Kerry breed living under semi-natural conditions with abundant pasture available.

- In July (16 hour day-length) - all animals began grazing at dawn and grazed for about 2.5 hours. This first bout was followed at intervals of about 2 hours by shorter bouts each about one hour in duration. In late afternoon another bout commenced which continued for 4 to 5 hours through until after dusk. During darkness, about midnight, there was a short bout of grazing. All of the animals behaved thus and the pattern was repeated each day. Total grazing time was near 11 hours each day.

- By October day-length had decreased. There was still a bout at dawn and a bout at sunset. As in July there were three smaller bouts but all occurred during darkness. The total grazing time was close to 11 hours as before. The pattern of grazing was consistent between animals and days. In August-September-October and November there were always two major bouts of grazing related to dawn and dusk. Grazing total time was always near 11 hours. As day-length decreased the smaller daylight bouts were progressively replaced by bouts during darkness. Similar patterns were also found in studies of grazing Holstein/Friesian heifers and of housed non-lactating cows at Moorepark.

- The primary feature of the grazing pattern is the bout. The bout implies that there is a control that determines when grazing commences and ends. Rumen capacity plays a part but does not explain why minor bouts are only one hour and major bouts are more than 4 hours. The rigid association of the two major bouts with dawn and dusk implies that light also plays a part. That the total grazing time is constant suggests that yet another control is operating that is related to the state of the animal relative to a target state. And this control relates to a 24-hour period. Domestic bovines do not display any patterns of behaviour related to seasonal or lunar cycles. The patterns appear to be circadian and in that case it would not be surprising to find that the suggested light cue was present as a means of measuring the day.

Introduction

- Milk yield per cow has become more important than yield per hectare since the introduction of milk quota limitations on production from dairy farms. It is a recognised feature of the milk production system typically practised in Ireland that annual milk yield per cow is restricted by more than 10% of the animal's potential. With the introduction in recent years of cows bred for greater milk yield the restriction assumes greater importance. Milk yield is related to feed intake.

- In Ireland, grazed grass is the main source of feed during each lactation so that the identification of the factors that control intake rate when the cow is grazing is critical. One of the components of the total daily intake of grazed grass is the duration of feeding during the day. Typically lactating dairy cows graze for approximately ten hours daily. There are two major feeding bouts, around sunrise and sunset. Other bouts occur at intervals during the day. Most feeding occurs during daylight. The association of major feeding bouts with sunrise and sunset and the tendency for feeding to be restricted to daylight hours suggests that diurnal feeding follows a pattern and this implies that feeding is not random but is regulated. In this project the first objective was to determine, quantitatively, the parameters of the diurnal pattern of feeding. The second objective was to determine to what extent the pattern may be modified by management.

- The project was funded by the Walsh Fellowship Programme and was a joint venture between Teagasc, Moorepark and University College Cork. Work was done at Moorepark and at Killarney National Park. The investigation involved comparison between the Friesian-Holstein breed at Moorepark and the Kerry breed at Killarney. Throughout, attention was restricted to non-lactating heifers or cows to eliminate the possible effects of milking routines on the pattern of feeding. Similarly, the Kerry herd at Killarney was chosen for study because this herd lives in a semi-feral state and is not subject to management routines that may affect feeding patterns.

3. Analysis of feeding patterns of Kerry heifers.

3.1. Methods

Observations were carried out on a group of non-pregnant 2- and 3-year-old heifers of the Kerry breed during observational periods from July to December 1996 in Killarney National Park. The study group consisted of 12 animals with an average weight of approximately 377kg. For the duration of the study period, the group continuously grazed a lowland field of area 4.7ha.

The pasture was classed as Old Permanent Pasture and was dominated by Holcus spp. and Agrostis spp. Feed availability was never limiting and it was assumed that grazing behaviour was not influenced by feed availability. Length and periodicity of grazing was measured using Kienzle vibracecorders (Kienzle Apparate GmbH, Villingen/Schwarzwald) which were fitted to the necks of seven animals. Grazing movements were recorded on a chart inserted into the vibracorder. The chart rotated once every twenty-four hours. The trace on the chart, which indicated grazing activity, was created by a stylus attached to a freely oscillating pendulum. The vibracorder was attached to the neck of the animal at an angle such that the stylus created a trace when the animal was grazing. The total time spent grazing was determined as follows.

A grazing bout was defined as a period of at least ten minutes grazing activity separated from preceding and subsequent periods of grazing activity by at least thirty minutes non-grazing activity. Therefore an inter-meal break was taken as a break in grazing activity greater than thirty minutes and an intra-meal break was taken as a break in activity less than thirty minutes. During each observational period from July to December a minimum of five days of uninterrupted grazing patterns were recorded. Over the study period median day-length decreased from 15.58 hours (July - observation period 1) to 7.55 hours (December-observation period 6).

One-way ANOVA was carried out to test whether total grazing time per day varied significantly from July to December. Analysis of distribution of the percentage time grazing per hour was carried out at three levels using Spearman Rank Correlation Analysis in the SAS statistical package):

Level 1:

- ***The average diurnal grazing activities of the group across the six observational periods from July to December .*** This analysis determined whether or not the group displayed a similar distribution of grazing activity through the season.

Level 2:

- ***The diurnal grazing activities of individual animals within observation periods.*** Individual patterns were the average of at least five days data (Table 1). This level of analysis examined the extent of animal variation in grazing patterns and tested whether individual animals behaved as the group did over the same time periods. It served as a means of checking whether group patterns are a correct representation of the behaviour of individuals.

Level 3:

- ***The diurnal grazing activities of the average animal on individual days in each observational period.*** This analysis allowed an examination of the degree of similarity in grazing patterns across days and showed if external environmental factors were a frequent source of variation in grazing patterns at the group level.

Table 1. Number of days and number of animal replicates used in the construction of Figures 1-6 and in Spearman Rank Correlation analysis. Animals are replicates.

	Day 1 - No. animals	Day 2 - No. animals	Day 3 - No. animals	Day 4 - No. animals	Day 5 - No. animals	Day 6 - No. animals	Day 7 - No. animals	Day 8 - No. animals
Period 1	7	7	7	7	7			
Period 2	6	6	6	5	5	5		
Period 3	5	5	7	6	7	7	7	
Period 4	7	7	7	6	6			
Period 5	7	6	6	6	6	4		
Period 6	5	5	3	5	5	6	5	5

3.2. Results

Total daily grazing times remained relatively constant (range 9.5-11.9 hours) over most of the grazing season. There was a significant reduction in grazing time in December compared to October and September but otherwise the differences were not significant. The distribution of group grazing activity per observation period followed a definite pattern (Figures 1 & 2).

Throughout the study there was a total of five clear grazing periods each day. Two main grazing periods occurred, as expected, around sunrise and sunset irrespective of season but the time interval between these peaks decreased with declining day-length through the season. Three smaller grazing periods occurred daily but the temporal distribution of these periods changed as the season advanced and day-length decreased. In July there were two small grazing periods in the middle of the day and one at night. By October progressive displacement of the small grazing periods meant that all minor grazing periods occurred at night. By December almost 50% of grazing occurred at night.

Spearman Rank Correlation analysis showed that the diurnal grazing activity of the group was significantly correlated ($P<0.05$) between observation periods in July , August and September. Distribution of grazing activity was also significantly correlated between observation periods in October and December, ($P<0.05$), but these two periods displayed no significant similarity with the earlier periods. The time interval between feeding bouts was usually 2 - 3 hours and in all observation periods a peak in grazing activity occurred from 0200h - 0300h.

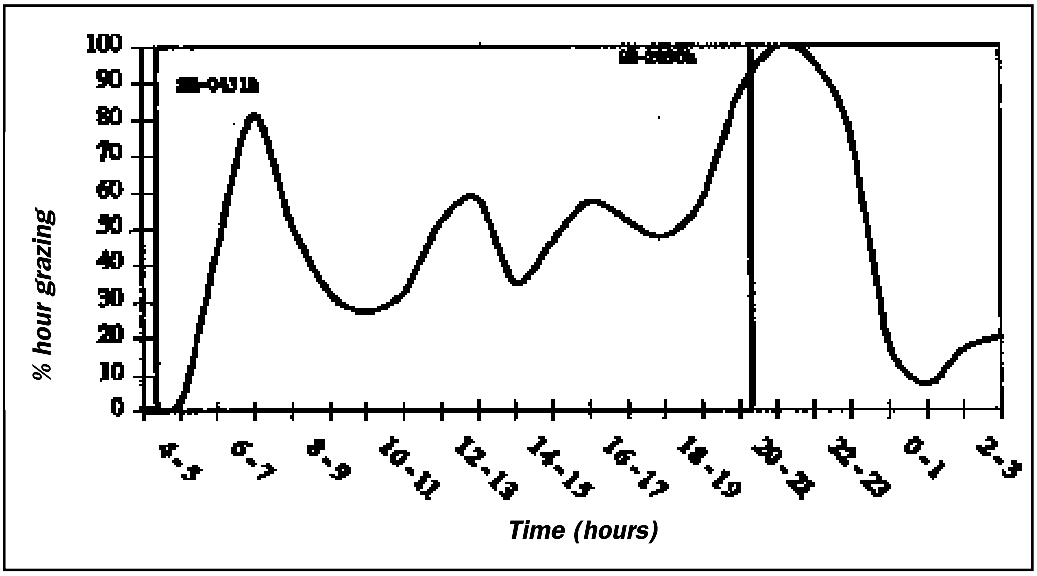

Figure 1: Group diurnal grazing patterns, July, (n=7)

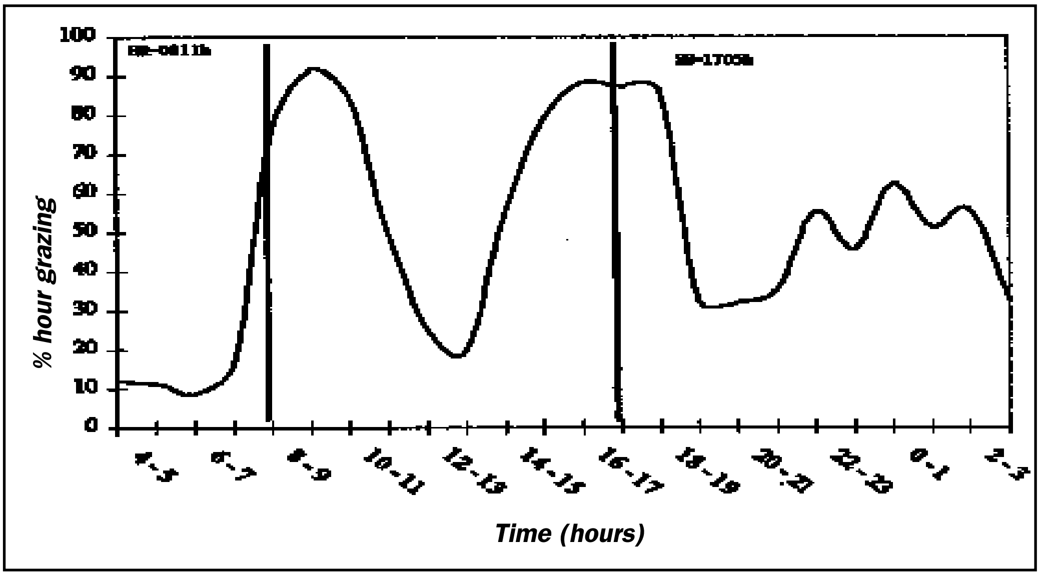

Figure 2: Group diurnal grazing patterns, October, (n=7)

Spearman analysis showed that in 92% of tests, the average diurnal grazing activity of individual animals within observation periods was significantly correlated ($P<0.05$). Correlation coefficients for each period showed a general tendency to decrease (0.81 - 0.60) from July to December.

Correlation analysis carried out within each observation period on the behaviour patterns of the group from day to day showed that these behaviour patterns were significantly correlated on 85% of comparisons. No increase or decrease was evident as the season advanced implying that occurrence of environmental variation was random. In general, correlation coefficients were higher where data for individual animals were averaged over days rather than where data for individual days were averaged across animals.

3.3. Discussion

Grazing times recorded during this study ranged from 9.5 to 11.9 hours and grazing time was only found to vary significantly between September, October and December. Phillips and Hecheimi (1989) noted the relative constancy of total daily grazing time. O' Donnell and Walton (1969) observed the behaviour of Irish cattle grazing hill pasture between June and September and also noted that despite changing environmental conditions, time spent grazing remained essentially the same for the duration of observations. This suggests that animal demand, in the form of an intake quota, may be the determinant of total daily intake and grazing times (Stricklin *et al*. 1976) and that grazing times are set to maintain an optimum energy balance rather than to attain a maximum intake level (Ketelaars and Tolkamp, 1992). Thornley *et al.* (1994) suggest that the upper limit on total daily intake is not set by any physiological or morphological constraint on the animals, or by constraints imposed by the sward, but by animals behaving in such a way that they maximise their benefits minus their costs. Ketelaars and Tolkamp, (1992) argue that if feed consumption represents measurable costs as well as benefits to the animal then it seems more logical that the animal aims at some optimum rather than maximum intake level.

Cattle are crepuscular animals and the occurrence of intense grazing periods at dawn and dusk is a well established feature of cattle behaviour. The association of the most intense grazing periods of the day with sunrise and sunset imply that the grazing pattern is sensitive to a photo-effect (Figure 1). Such an association was also noted by Sibbald (1994) in red deer stags. Schanbacher and Crouse (1981) studied the photo-periodic regulation of growth and concluded the existence of a photo-sensitive phase for the secretion of prolactin during the light-dark cycle. They suggested that this photo-sensitive phase is also connected to the neural centres which regulate feed intake and weight gain. Photo-periods are thought to entrain circadian rhythms via the retino and/or retino-hypothalamic pathways to the supra-chiasmatic nucleus. There does seem to be an indication that a light characteristic occurring at this time of the day has a stimulatory effect on appetite. In Kenya (close to the equator, where day length remains constant through-out the year), arousal of cattle from a lying to a grazing state occurs predictably between twenty minutes before, and thirty minutes after sunrise.

In terms of physical and sensory characteristics of feed having an influence on grazing behaviour, it is known that the sugar content of grasses varies diurnally, with sugar levels being highest in the evening. This may play a part in driving a grazing event like the intense period of grazing at dusk. The intense grazing period around dawn is not explained by such a palatability theory indicating that these sward/herbage factors do not act for the entire twenty-four hour period but rather assume differing degrees of dominance at different times of the day.

The higher correlation values obtained for tests of between-animal compared to between-day correlations in grazing activity patterns suggests that where variations in grazing activity did occur that daily variation was stronger than animal variation.

In this study 92% of correlation analyses to test for between-day agreement showed that average animal grazing patterns were significantly correlated on any given day. The decrease in the average between-animal correlation co-efficient from July to December indicated that animals behaved less cohesively as day-length decreased. This feature has been reported in previous studies (O' Donnell and Walton, 1969; Stricklin *et al.*, 1976; Philips and Denne, 1988; Penning *et al.*, 1993) and can be accounted for by environmental effects and social factors which vary diurnally and seasonally. The need to huddle to avoid insect annoyance decreases later in the season.

Although correlation coefficients for the day-to-day behaviour patterns of the group were not as high as between-animal correlation coefficients, there was a high level of agreement between days. Days where group behaviour patterns were not significantly correlated may have been days where contrasting weather patterns occurred. Other sources of day-to-day variation in group behaviour patterns may have included disturbance due to oestrus activity.

Based on the findings of the present study and those of previous studies, one may conceptualise as to the overall control of grazing. The diurnal cycle of feeding begins at dawn as the animal is induced to commence grazing by a light cue. From dawn, feeding continues in bouts that are controlled by changes in rumen distension, intra-cellular pH, volatile fatty acid and metabolite concentrations and by other factors including weather conditions, sward conditions, social factors, possible anthropogenic disturbances. Feeding continues until the accumulated products of intake satisfy the current nutritional demand of the animal. If light quality is involved in shaping the grazing pattern then at sunset the conditions produced at dawn may be amplified by the diurnal variation of other factors, (e.g. sward factors), and the animal is induced to graze intently. This response appears to over-ride a supposed rumen control of feeding bouts and results in an extended period of continuous feeding.

The occurrence of the extended period of feeding about sunset suggests that the full physical capacity of the rumen is not exploited during the day. This reinforces the theory that rumen fill is only one of the factors integrated by the animal in determining the level of intake. Along with other features of feeding behaviour, this casts doubt on whether feeding behaviour invariably aims at achieving maximum nutrient intake. Elevated intakes during cold stress, along with greater than normal growth rates during compensatory growth and increased growth and production rates as a consequence of hormonal treatments also all suggest that the animal normally adopts a sub-maximal rather than maximal intake and growth rate (Ketelaars and Tolkamp, 1992).

4. Grazing patterns in Holstein-Friesian heifers

Differences exist between breeds in behavioural characteristics such as ingestive, reproductive and maternal behaviours (Hohenboken 1986). In sheep various breeds have been found to have different sensitivities to timing of dawn and dusk and subsequent timing of initiation and termination of grazing (Dudzinski & Arnold, 1979). In this part of the investigation the behavioural patterns of Holstein/Friesian heifers were compared with the patterns observed in the Kerry breed. The observations on the Holstein Friesian breed were carried out at Moorepark.

4.1. Methods

Behaviour patterns of a group of 12 pregnant, 1.5-year-old, Holstein/Friesian heifers were recorded from October 11th - 18th. Median day-length for the week was 9.65 hours. Average weight of individuals approximated 500kg. The group grazed a 7.5ac perennial rye-grass paddock. The group was established prior to the recording period so that a stable social order had developed before the start of observations. The comparative data set for the Kerry breed was the data collected during October 21st - 29th when the day-length was 8.90 hours in the study described in section 3. Feed availability was not limiting in either location. Duration and periodicity of grazing was measured using the same apparatus and procedures described in section 3.1. Analytical procedures were the same also.

4.2. Results

Within groups, individuals displayed similar daily grazing times to each other (Moorepark, ANOVA, $F_{5,29}=1.54$, $P>0.05$ $P=0.21$), (Killarney, ANOVA, $F_{5,29}=0.76$, $P>0.05$, $P=0.59$). However individual Kerry heifers spent more time grazing per day than individual Friesian heifers. Average daily grazing times for the heifers at Moorepark ranged from 8.5 to 11.0 hours compared to the range of 10.8 to 12.4 hours for the Kerry heifers at Killarney. This difference in grazing times was found to be significant (ANOVA, $F_{10,64}=4.39$, $P<0.05$, $P=0.0002$).

Major peaks of grazing activity occurred at dawn and dusk at Moorepark as at Killarney. At Moorepark both peaks lasted for two hours. In Killarney the dusk peak lasted for four hours - twice as long as the dawn peak. In both data sets there was a rapid increase in grazing activity leading to sunrise and a rapid decrease in activity after sunset. Peak grazing intensities for these two grazing periods were higher in the Killarney data. Sunrise was twenty minutes later in Killarney than in Moorepark and peak grazing activity at dawn occurred one hour later than that at Moorepark. Sunset was twenty-five minutes earlier in Killarney and the dusk peak in grazing activity began one hour earlier. The minor grazing peaks varied in their temporal location between Moorepark and Killarney. At Killarney where median day-length was 8.86 hours all of the minor grazing peaks occurred at night. At Moorepark, where median day-length was greater (9.65 hours) one of these peaks occurred during the day.

Both data sets showed similar percentages of day- and night-time grazing. Spearman correlation analysis showed that the distribution of group grazing activity of the Kerry heifers was significantly similar to that of the Holstein/Friesian heifers (Spearman Rank Correlation Analysis, P=0.0004, R_s=0.67). There was a consistent tendency for Kerry heifers to graze at higher intensities than the Friesian heifers. Individual Kerry heifers frequently displayed bouts of 100% grazing per hour whereas the grazing activity peaks of individual Friesian heifers never exceeded 70% grazing per hour. Typically the evening grazing period in Moorepark did not feature as prominently in terms of duration and intensity as that in Killarney.

Spearman correlation analysis showed that in 80% of comparisons in Moorepark, animals exhibited similar diurnal grazing activity distributions. In Killarney the distribution of average behaviour patterns of all individuals over the week of 21 - 29 October were all significantly correlated. As a consequence the mean between-animal correlation coefficient for Moorepark was 0.51 whereas at Killarney it was 0.77.

Moorepark results showed that average behaviour patterns were similar on 90% of days. The mean between-day correlation co-efficient for Moorepark (0.53) was again lower than that for Killarney (0.58). This indicates that the Kerry group maintained a more constant grazing activity distribution over the week than the Friesian heifers. Within both data sets the correlation results show that the behaviour patterns of the Friesian heifers are more closely correlated from day to day (0.53), than from animal to animal (0.51). In contrast, the behaviour patterns of the Kerry heifers were more correlated from animal to animal (0.77) than from day to day (0.58). The group of Kerry heifers behaved more cohesively and displayed greater between-animal and between-day similarities in grazing distributions than the Friesian heifers did.

4.3. Discussion

Mercer (1997) states that it is unlikely that there has been sufficient evolutionary time for major adaptation to specific environments to have taken place naturally in rare breeds (e.g. the Kerry breed). Thus as in this study, because of the biological similarity of the two breeds, it was unlikely that different grazing behaviour patterns should be observed. The similar daily grazing times of the individuals within both groups is a reflection of similar animal size, age, weight and physiological status within groups. All of these factors are known to have an effect on voluntary feed intake and therefore potentially on grazing times. The Friesian heifers were in the early stages of gestation hence any effects of pregnancy on grazing behaviour or voluntary food intake were not expected.

Because rumen volume and gut capacity scale isometrically with body size and nutrient requirements scale allometrically with body size ($W^{0.75}$) (Allison, 1985; Mysterud, 1998), the longer grazing times in Killarney are surprising as the Kerry heifers were smaller than the Friesian heifers. Tolkamp & Ketelaars (1992) however in a review of the experimental data on the factors which regulate intake state that there is no exclusive role for rumen fill in intake regulation and that the animal, rather than feed composition, actively controls the removal rate of material from the rumen.

Comparisons of grazing behaviour of breeds or animals of different biological types have shown that grazing time is not the usual aspect of ingestive behaviour which varies with breed (Funston *et al.*, 1991). Different grazing or metabolic efficiencies may exist between animals with different productive performances which may account for the absences of larger differences in grazing times (Bao *et al.*, 1992). Observations on both groups were carried out within the same season and climate type and large variations in abiotic factors e.g. day-length and temperatures, did not occur from one location to the other. Therefore it is most likely that the different grazing times between Moorepark and Killarney were due to differences in sward structure and biomass rather than animal or environmental variation. There was a larger proportion of stem and dead material in the Killarney sward and a greater diversity of species compared to the Moorepark sward.

The similarities in the diurnal grazing patterns of both groups illustrates that even though breed differences (in production traits) may exist because of artificial selection by man, that the same diurnal changes occur universally in terms of light/photo-period changes in sward parameters, and changes in hormone profiles relevant to driving feeding behaviour patterns. Outside of potential breed/biological type effects, the strength of impact of the external/abiotic environment on behaviour patterns can be seen in the timing of the dawn and dusk grazing peaks in Killarney and Moorepark. From October 11th to the 29th day-length had decreased. Table 2 shows that in Killarney the dawn peak occurred one hour later and the dusk peak one hour earlier than in Moorepark. This is an illustration of the effect of the timing of sunrise and sunset or light/quality/intensity in controlling grazing patterns.

Table 2. Time, height (% hour grazing) and durations of dawn, dusk and minor grazing periods during October in Flagstaff and Knockreer. Data is taken from Figures 1 and 2. Dawn peak in activity is taken as any peak > 60% grazing per hour. Dusk peak activity is taken as any peak > 70% grazing per hour. SR: sunrise, SS: sunset.

Peak Features	*Flagstaff*	*Knockreer*
Time SR	**7.51**	**8.11**
Hour a.m. peak	**0800h-0900h**	**0900h-1000h**
Max. ht a.m. peak (%)	**70.1**	**92.0**
Approx. duration peak (hrs>60%)	**2**	**3**
Time SS	**17.30**	**17.05**
Hour p.m. peak	**1700h-1800h**	**1600h-1800h**
Max. ht. P.m. peak (%)	**79.4**	**87.1**
Approx. duration peak (hrs>70%).	**2**	**4**
Hour minor peak 1	**1300h-1400h**	**2200h-2300h**
Max. ht. Minor peak 1 (%),	**58.8**	**55.4**
Approx. duration peak (hrs)	**0.25**	**0.50**
Hour minor peak 1	**1300h-1400h**	**2200h-2300h**
Max. ht. Minor peak 1 (%),	**58.8**	**55.4**
Approx. duration peak (hrs)	**0.25**	**0.50**
Hour minor peak 2		**0000h-0100h**
Max. ht. Minor peak 2 (%)		**60.9**
Approx. duration peak (hrs)		**0.30**
Hour minor peak 3	**0000h-0100h**	**0200h-0300h**
Max. ht. Minor peak 3 (%).	**54.4**	**53.1**
Approx. duration peak (hrs)	**0.25**	**0.30**

Killarney animals displayed greater animal to animal cohesion (0.77) than Moorepark animals (0.51). The same trend is true of between day correlation co-efficients. This indicates that the Kerry group maintained a more constant grazing activity distribution over the week than the Friesian heifers and suggests that the Friesian heifers were either more sensitive to environmental variation or were exposed to more environmental variation over the week in question. The animals in Moorepark were younger than those in Kerry and even though the group was set up prior to commencement of observations this group had not been in existence as a twelve animal unit as long as the Kerry heifers had. It is possible that this may have impacted on animal grazing styles. Lesser-developed grazing styles occur in younger animals. Along with the effects of social rank and age on paddock utilisation patterns this may have contributed to the greater between-animal variation seen in the Friesian heifers.

5. Persistence of feeding patterns in housed animals.

The primary objective of this part of the investigation was to see the extent to which diurnal activity and feeding behaviour patterns observed in field conditions persist indoors. These patterns are relevant to understanding the control of intake and to the establishment of welfare standards for livestock. Of secondary interest in the study was an evaluation of the direct effect of density and housing conditions on the levels of intake of non-lactating cows in late pregnancy.

5.1. Methods

The behaviour of sixty-four Spring-calving Holstein/Friesian cows was observed. The trial was carried out in a conventional design slatted house with sixty-four cubicles. Animals were divided into four groups - two high density (HD) groups of twenty-four animals each and two low density (LD) groups of eight animals each. Groups were balanced for lactation number, calving date and weight. The groups were established two weeks prior to commencement of observations to allow a social order to stabilise.The shed was divided into four blocks to accommodate the groups, each block having enough cubicles for the animals in that block. One side of the shed (facing southwest) was more exposed to prevailing winds than the other and groups were allocated to blocks so that each density level was represented at each side of the shed. All cubicles were of Newton-Rigg design. Lime was scattered on the cubicles each morning. The passage-way between the cubicles and the area behind the feed-face were of slatted concrete. The passage-way was manually cleaned each day and the area behind the feed-face was cleaned at regular intervals by an automatic scraper. All four groups had access to equal lengths of feed-face (8.5m). The shed was illuminated during hours of darkness by overhead fluorescent lights. During the day natural light filled the shed. Animals were fed *ad libitum* and feed was administered by feed loader once daily, between 1100h - 1400h. Feed which had been tossed out of reach by the animals was forked back up to the feed-face at 2200h each evening. The ration consisted of a silage, beet pulp, straw mix. Daily group intake figures were calculated by weighing feed refusals each morning between 1000h- 1200h.

Behavioural activities of the cows were recorded over three 48-hour periods (three pairs of days). During each observation period, the activity and location of each cow was recorded at 15 minute intervals.

The feeding and queuing durations of HD and LD groups were compared using repeated measures analysis of variance. Time engaged in these activities was averaged for each group (HD n=24 and LD n=8) for each day. Twenty-four hour data was analysed along with day and night time data. Day-time was classed as 0900h-1600h and night-time as 1700h-0800h. Intake values (per 24-hour periods) were also compared. The shed was considered as the main plot with the two sides split for treatments (HD or LD). The three pairs of days were treated as a repeated measures design (SAS, 1989-1992).

5.2. Results

There were usually three peaks in feeding activity. The first peak occurred around sunrise. The other feeding peaks occurred at time of feed placement (1100h - 1400h) and at time of feed push-up (2200h). Generally the HD groups exhibited a more even temporal distribution of feeding activity than the LD groups. Following the second feeding peak, feeding activity progressively declined around sunset, until the third feeding peak when feed was being pushed up to the feed-face at 2200h. This decline was more pronounced in the

LD groups. Feeding activity peaks in the HD groups lasted longer than those of LD groups. The hourly proportions of queuing activity were slightly higher during the day than at night, particularly in the LD groups.

Queuing peaks often coincided with refusal weighing and feed placement in the late morning - early afternoon and also at the time of feed push-up at 2200h. Maximum length of time spent queuing was approximately 10 minutes irrespective of animal density. Generally very little queuing was seen between 0400h - 0700h. Usage of the passage-way was relatively low over the 24-hour period and showed no trends.

Intakes were about 12 - 13kg /head/day^{-1} except on the middle pair of days when intakes of 8kg per head^{-1} were recorded. This may be due to the inclement weather conditions on these two days. On the middle two days, a southerly wind was driving heavier rain onto the exposed (southwest facing) side of the shed. On these two days the depression of intakes in the LD groups, especially the LD group on the exposed side of the shed, was more marked. Intakes (per average animal) were consistently higher in the HD groups (12.80 kg/hd/day and 13.38 kg/hd/day) compared to the LD groups (11.97 kg/hd/day and 10.76 kg/hd/day). Average intake rates during feeding on the sheltered side of the shed for high and low density groups respectively were 2.35 kg /hd/ hr^{-1} and 1.87 kg/ hd/hr^{-1} compared to 2.24 kg/hd/hr^{-1} and 1.83 kg/hd/hr^{-1} on the exposed side.

On average about 6 hours per day^{-1} were spent feeding. There was a significant effect of treatment (Anova, $F_{1,12}$=11.21, P=0.0286) and exposure (Anova, $F_{1,12}$=12.08, P=0.0255) on hours feeding with HD groups consistently spending less time feeding than LD groups. Feeding durations were consistently and significantly higher on the sheltered side of the shed (Anova, $F_{1,12}$=12.08, P=0.0255).

There was a significant treatment effect on hours feeding during daylight (Anova, $F_{1,12}$=25.39, P=0.0073) with HD groups spending consistently less time feeding than LD groups. Night was twice as long as day and more feeding occurred during the night than during the day. Anova did not detect an overall effect of treatment on hours feeding at night but HD groups tended to spend more time feeding at night than LD groups. An overall effect of exposure on hours feeding at night was detected (Anova, $F_{1,12}$=17.88, P=0.0134) with sheltered groups consistently spending more time feeding at night than their exposed counterparts.

No overall effect of treatment on queuing was detected.

5.3. Discussion

The peak in feeding activity which occurred around sunrise is possibly linked to the crepuscular aspect of cattle behaviour. The large feeding period that occurs outdoors around sunset was not very distinct in this trial. This is probably a reflection of the intense activity in the middle of the afternoon following feed placement. This intense activity began to decrease leading to and after sunset. The decrease in feeding activity after sunset is more obvious in LD groups. In these groups queuing activity remained more stable or sometimes increased temporarily at this time. This suggests that even though animals may have been satisfied following the large feeding period associated with feed placement, they remained active during this time of the day as they do in a grazing environment.

Even though the animals were indoors, natural light filled the shed during the day and entrainment to the natural cycle of night and day seems to have persisted. Despite the fact there would have been very little feed accessible after sunrise, feeding and queuing activity began to increase around dawn. Where the LD groups are concerned, with the exception of the time when feed was pushed up to the feed-face, feeding and queuing activity peaks were generally lower at night than during the day. Thus in this experiment remnants of outdoor diurnal patterns are represented by the initiation and winding down of activities around sunrise and sunset respectively and the predominance of longer hourly durations of activity during the day. The reduction in the number of hours feeding by about 40% compared to the normal 10 hours observed under field conditions was associated with the increased rate of instantaneous intake. This tends to support the inference drawn from the field investigations that the animal controls intake relative to an optimisation target.

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