CHAPTER 8

GRASSLAND MANAGEMENT WITH EMPHASIS ON GRAZING BEHAVIOUR

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Abstract. Investigations into the behavioural responses by ruminants to differences in their grazing environment have led to improved understanding of the grazing process. This has proved useful in developing management strategies which are not only sympathetic to the animals' natural behaviour, but can improve the level and efficiency of resource use. The components of grazing behaviour considered are as follows: constraints and responses at the level of the sward/animal interface, such as bite rate, bite mass, short-term intake rate and grazing time; temporal patterns in behaviour regarding the aforementioned parameters, meal duration and distribution over the day; dietary preference and selection for grass and clover. For each of these broad areas, evidence is presented of the implications for improving current management practices on farm, or novel approaches to improving the utilization of traditional pasture species.
Keywords: bite mass; herbage mass; temporal patterns

INTRODUCTION

The longstanding economic arguments for maximizing the contribution of grassland, as a relatively inexpensive food source, toward the production of milk and meat are still valid. However, more recently additional concerns and benefits have added to the argument for utilizing fresh pasture. With a reduction in the drive toward maximizing production, and over-production of some commodities, there has been increasing emphasis on product quality, aesthetic and ethical considerations and environmental impact. The important role which grazed herbage can play not only in improving meat and dairy product safety, but actually increasing the content of compounds beneficial for human health has been recognized. Consumer attitudes toward these aspects of product quality as well as animal welfare are impacting upon the food supply chain. Legislation aimed at reducing the environmental impact of intensive animal-husbandry practices will, in some areas, lead to a reduction of fertilizer inputs and reversion to more extensive grazing. However, in the Western European dairy industry, perhaps more than in any other livestock farming enterprise, maximizing the efficiency of use of the primary product, grassland, will

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remain the key to economic survival.

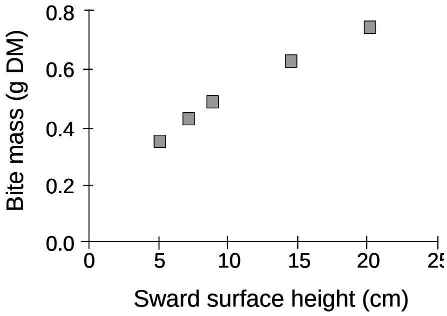
This paper presents the results of research into the different components of grazing behaviour and considers, in turn, their consequences for grassland and grazing management. These are discussed within three broad areas – mechanical constraints and responses, temporal patterns in behaviour and dietary selection – although it will be apparent that they are not isolated and each has implications for the other.

CONSTRAINTS AND RESPONSES AT THE LEVEL OF THE SWARD/ANIMAL INTERFACE

An understanding of the natural patterns of grazing behaviour by ruminants and their reactions to the constraints imposed upon them can help in improving grassland management to maximize the efficiency of utilization of this resource or individual animal intake. It is nearly 40 years since Spedding et al. (1966) expressed intake as the product of time spent eating, bite rate (BR) and bite mass (BM). Since that time, not least because of the development of automatic behaviour-recording equipment, we have slightly extended this simple model to envisage BR as the product of grazing jaw movement (GJM) rate and the number of bites GJM^{-1}, and eating time as the product of the number of meals and meal duration, as follows:

At the level of the pasture/animal interface, the weight of herbage consumed in each bite (BM), is constrained by the morphology of the sward. Whilst the latter is most conveniently measured and expressed as sward surface height (SSH), what is of more direct relevance is the mass of plant material within the bite horizon, which is more directly related to green leaf mass (GLM). Thus, in a study comparing grazing behaviour by sheep under continuous and rotational stocking management, it has been shown that GLM or leaf area index (LAI) rather than SSH, is a better basis for relating intake and sward state when the ratio of leaf to stem may be changing rapidly (Penning et al. 1994). However, in a subsequent study when BM and short-term intake rate (IR, DM g min^{-1}) were measured at intervals as sward masses were reduced, using dairy heifers (Orr et al. 1997b), both GLM and SSH were shown to be significantly correlated with BM (r = 0.71 and 0.78, respectively) and with IR (r = 0.81 and 0.78, respectively). The correlation between BM and total herbage mass (DM t ha^{-1}) in that same study was poor (r = 0.48). However, because SSH can be more easily determined than GLM and is a principal determinant of BM (e.g. McGilloway et al. 1999), it has frequently proved to be a useful descriptor of sward state for research purposes (e.g. Hutchings et al. 1992) and in formulating grazing management guidelines (e.g. Mayne 1991). SSH will, therefore, be used as the sward descriptor to demonstrate the interaction between sward state and grazing mechanics.

Sward state has a fundamental and constraining effect on BM such that each successive reduction of 1 cm in SSH results in an increasing reduction in BM, as shown by data measured using lactating dairy cows grazing under steady sward state conditions (Figure 1).



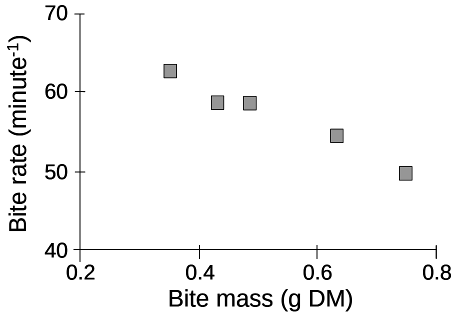
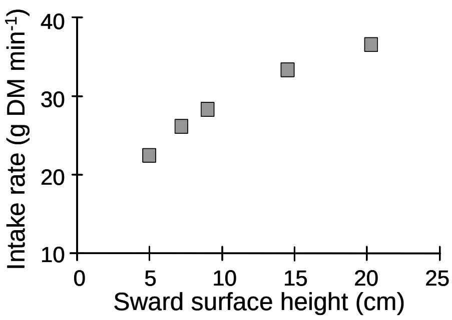


Figure 1. *Effect of sward surface height on bite mass by lactating dairy cows (Gibb et al. 1996)*

Figure 2. *Effect of bite mass on bite rate by lactating dairy cows (Gibb et al. 1996)*

However, when BM is reduced there is an increase in BR (Figure 2), which results not only from an increase in the rate of movement of the jaws, but also from an increase in the proportion of total GJM, which are represented by bites. Whilst there is an overlap in function, insofar as that some mastication of plant material takes place during biting, in cattle a minor though significant proportion of GJMs are not involved in biting, but are manipulative or masticative in function (non-biting GJMs). It is easy to understand how, as SSH and consequently BM increase, the need for manipulative and masticative GJM, respectively, increase, both in the gathering of herbage into the mouth and in forming the herbage into a bolus preparatory to swallowing.

The increase in BR in response to reduced BM, however, does not fully compensate for the effect of shorter SSH and, as a result, IR is reduced on shorter swards (Figure 3). The response by the animal to the reduction in short-term intake rate is to increase the time spent grazing over 24 hours (Figure 4).



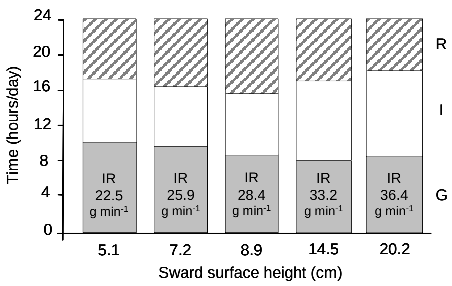


Figure 3. *Effect of sward surface height on short-term intake rate by lactating dairy cows (Gibb et al. 1996)*

Figure 4. *Effect of sward surface height and constraint on short-term intake rate on time spent grazing (G), idling (I) and ruminating (R) by lactating dairy cows (Gibb et al. 1996)*

Nevertheless, due to the competing demands of ruminating and idling activity, this is usually insufficient to fully compensate for the reduced short-term intake rate, and as a result daily intakes are less on shorter swards, as was demonstrated by Gibb et al. (1996). Possibly, future breeding and use of more rapidly comminuted cultivars to reduce the time necessary for ruminating and idling might prove beneficial in allowing grazing time to increase.

In addition to ruminating activity, required to comminute the ingested material, what is frequently referred to as idling time (i.e. time when the animal's jaws are not occupied in grazing or ruminating activity) is also an essential element within the animal's time budget. Not only is idling necessary to the animal for rest and other activities such as social interaction, but it is an essential element of the digestive process during which food particles, made buoyant by the production of gas as a result of microbial digestion, rise to form the fibrous mat from which material is regurgitated for ruminative mastication.

Whilst sward state imposes a primary constraint to bite mass, which in turn affects BR and short-term intake rate and ultimately daily intake, the precise relationships are variable and have been shown in dairy cows to be affected by factors such as the physiological state of the animal, e.g. lactating vs. non-lactating (Gibb et al. 1999) and genetic potential for milk production (Christie et al. 2000). Whilst it appears that increased nutritional demand can cause dairy cows to increase BM and IR consistently, if not significantly, the major response by these animals is to increase the time spent grazing in 24 h (Figure 5).

The practical implications of the fundamental constraint of sward state on BM and its consequences for daily intake, clearly demonstrate a focus for improving intake per animal. However, just providing taller swards is not the simple answer.

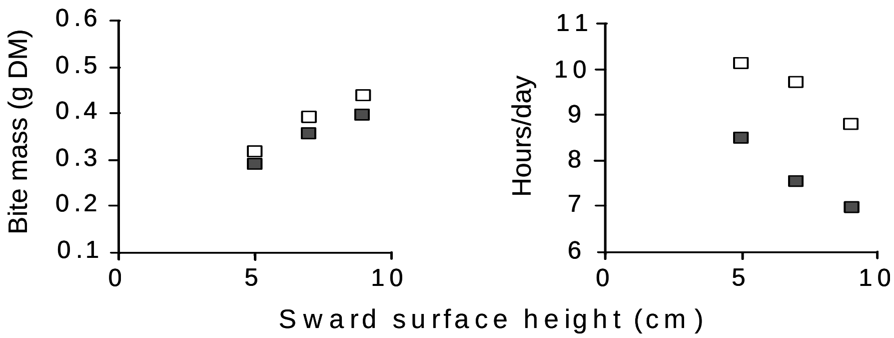


Figure 5. *Effect of physiological state (lactating □, non-lactating ■) on the response to sward surface height in bite mass and total grazing time day^{-1} by dairy cows (Gibb et al. 1999)*

It has been quoted earlier that the mass of herbage within the grazed horizon is likely to have a more profound effect on BM, than is the surface height per se (Penning et al. 1994). It is therefore important to maximize the GLM by providing dense, leafy swards to enable the grazing animal to achieve large BMs. It has been shown that at the same SSH, improving sward density can profoundly increase BM (Figure 6) particularly in the medium height range of 8 to 16 cm SSH (Mayne et al. 2000). On taller swards the effect of sward density on BM may be less important, and as many grassland managers know, it is difficult to maintain the number of tillers per unit area and the bulk density of lamina material within the grazing horizon as SSH increases. Thus, an appropriate choice of cultivar as well as correct management can improve intake in this respect.

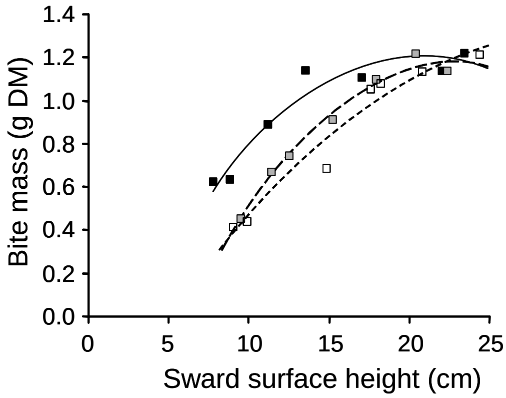


Figure 6. *Effect of sward surface height on bite mass in swards of high ■, medium ■ and low □ density (Mayne et al. 2000)*

The objective of continuous variable stocking management must be to provide dense, leafy swards giving high photosynthetic activity. Maintaining a balance between the production of new material and consumption by the grazing animals will ensure a high efficiency of utilization of the primary product, with little of the herbage becoming senescent. Whilst BM will be limited and daily intake of DM will be less than that achievable at high daily herbage allowance on tall regrowth swards, the herbage consumed will be young, highly digestible material.

Under intermittent defoliation management, leaf material is allowed to accumulate between stocking of the pasture, thereby allowing the build-up of larger masses of photosynthetic tissue and greater photosynthetic capacity per unit area of land than under continuous variable stocking management. The result should be a large GLM (DM kg ha^{-1}) presented as a tall, ideally dense, sward and avoiding the accumulation of senescent or low-digestibility herbage. In contrast with continuous variable stocking management, the accumulated herbage is grazed over a relatively short period of hours or days during which the morphology of the sward is greatly modified. The effect of this rapidly changing morphology is a relatively rapid change in grazing behaviour, notably BM, BR and IR (Barrett et al. 2001). Successive defoliations of the same area will, due to the modified morphology, result in a reduction in BM and IR as well as a change in the structure and quality of the material removed. To overcome these cyclic changes as animals graze successive paddocks, in most intensively managed enterprises nowadays, paddocks are stocked for a single day or half a day. The added advantage of such a daily paddock stocking system is that it provides flexibility of management. By assessment of the herbage mass (DM kg ha^{-1}) available to the animals, a ration to meet the requirements of the animals can be calculated and provided by adjustment of the area available to the animals on a daily or twice-daily basis. Such flexibility allows the manager to either maximize intake per animal or maximize the off-take of herbage per unit area of land or, as is frequently the case, adopt a compromise between these two extremes.

DAILY HERBAGE ALLOWANCE AND HERBAGE INTAKE

A curvilinear relationship between daily herbage allowance and daily herbage intake has been demonstrated in many experiments. Amongst those reported for dairy cows (Greenhalgh et al. 1966; 1967; Combellas and Hodgson 1979; Le Du et al. 1979; Peyraud et al. 1996), daily herbage OM allowance has ranged between about 25 and 90 g kg^{-1} LW (Figure 7). With smaller classes of livestock such as calves, lambs and ewes the reduced requirement for land area has permitted an even wider range of daily OM allowances to be implemented (Jamieson and Hodgson 1979; Gibb and Treacher 1976), from 30 to 150 g kg^{-1} LW (Figure 8).

From such relationships it is evident that to achieve unrestricted daily intakes, daily allowances equivalent to between 3 and 4 times maximum daily intake must be provided.

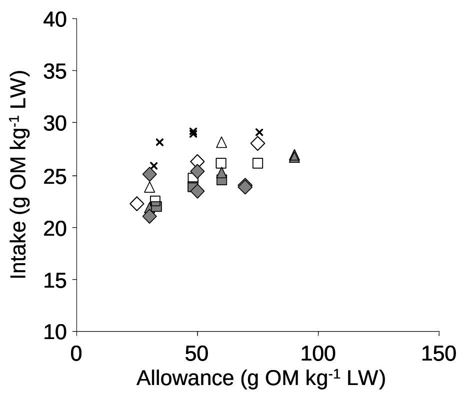


Figure 7. *Effect of daily herbage OM allowance on daily herbage OM intake by dairy cows grazing perennial ryegrass swards (Greenhalgh et al. 1966 □ and 1967 ■; Le Du et al. 1979, expts 1 ◇ and 2 ◆; Combellas and Hodgson 1979, high △ and low ▲ herbage mass; Peyraud et al. 1996 ✕)*

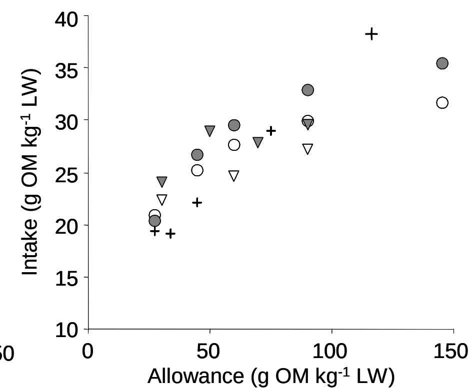


Figure 8. *Effect of daily herbage OM allowance on daily herbage OM intake by calves (Jamieson and Hodgson 1979, experiments 1 ▽ and 2 ▼); lambs (Gibb and Treacher 1976, ; and ewes (Gibb and Treacher 1978, ; grazing perennial ryegrass and lambs by lambs grazing red clover (Gibb and Treacher, 1976 ●)*

Expressing these same data as utilization (daily intake/daily allowance) upon daily allowance, demonstrates the problem of poor sward utilization when high daily allowances are offered in order to maximize daily intake per animal (Figure 9). Conversely, if high utilization of the pasture is required, then restrictive daily allowances must be provided, which will result in reduced intake per animal.

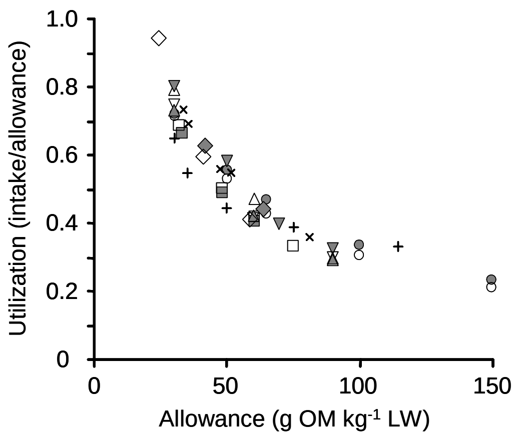


Figure 9. *Effect of daily herbage OM allowance on utilization (OM intake/OM allowance). Source data as in Figures 7 and 8*

A further factor which should not be ignored is what may be termed the relative competitive ability of the animals. This is well demonstrated by the results of an experiment in which mixed groups of primiparous and multiparous dairy cows were provided with a range of daily herbage allowances (Peyraud et al. 1996). The overall mean daily herbage intakes achieved by each group showed a curvilinear response to increasing herbage allowance (Figure 10a). However, when the values are plotted for the two classes of animals separately (Figure 10b), although both classes achieved the same level of intake relative to their live-weight, when daily herbage OM allowance was in excess of 80 g kg^{-1} LW, the primiparous cows were unable to achieve as high intakes as those of the multiparous cows at lower daily herbage allowances.

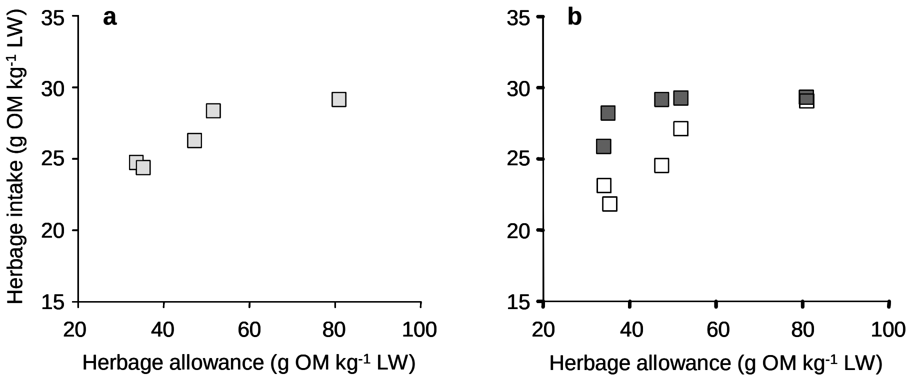


Figure 10. *Effect of daily herbage OM allowance on (a) overall mean herbage OM intake within groups of cows and heifers ■ and (b) mean herbage intake by cows ■ and heifers □ calculated separately*

TEMPORAL PATTERNS IN GRAZING BEHAVIOUR

The previous data (Figures 1 to 6) represent the mean daily values determined under continuous variable stocking management in which sward morphology changes very little over the course of 24 hours. However, it should not be assumed that the relationship between SSH and BM, BR or IR remains constant over the day. Studies of sheep grazing perennial-ryegrass or white-clover swards maintained at 6 cm SSH showed that BR increased over the day and that, although BR declined, IR also increased over the course of the day (Orr et al. 1997a).

A subsequent study with lactating dairy cows showed significant changes over the course of the day in BM, BR and IR by lactating dairy cows grazing under continuous variable stocking management (Figure 11, Gibb et al. 1998).

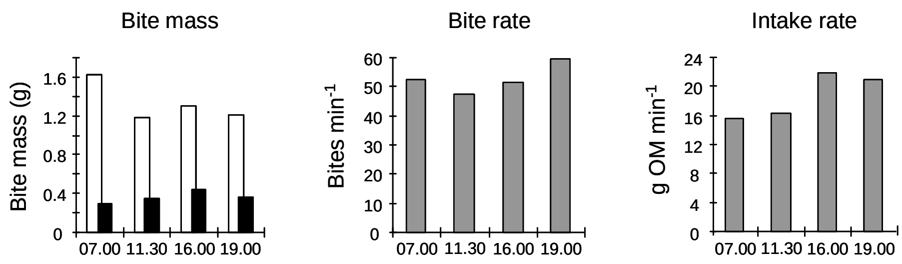


Figure 11. *Effect of time of day on bite mass (fresh matter □ and dry matter ■), bite rate and short-term intake rate by dairy cows (Gibb et al. 1998)*

Whilst fresh matter BM was highest in the early morning due to the high water content of the grass and presence of dew on the leaves, BM measured as dry matter was lowest at this time of day, possibly due to slippage of the leaf laminae between the incisors and dental pad. BR was lowest during the late morning, reflecting what can often be observed as the least intensive meal of the day by dairy cows. The highest BRs were recorded during the late evening and were achieved by a decrease in the proportion of GJMs represented by manipulative and masticative movements. The net result of these variations in BM and BR was greater IRs being achieved during the latter part of the day.

In experiments in which dairy cows grazed tall grass swards, typical of those presented under rotational stocking management (Barrett et al. 2001), it was reported that time of day did not significantly affect short-term measurements of grazing behaviour when sward conditions were maintained constant. However, when sward structure was modified as a result of grazing activity over the day, as might be expected, time of day did significantly affect BM and IR.

In practice, under such intensive daily paddock-stocking management, sward state does become modified during the period that the animals are present. The grazing animal will seldom take a single bite from an individual tiller or plant, but will return to the site and perform further bites. Thus, successive bites from the same tiller or group of tillers will be influenced by the extent to which the morphology has been modified by previous bites. Although with each successive defoliation of an area the bulk density within the grazed horizon increases, the reduction in SSH constrains the depth to which the animal can graze, thereby reducing BM and IR (Wade et al. 1989).

Examination of spectral analysis of grazing activity from continuous recordings of sheep behaviour over several days have shown that in addition to a peak of activity occurring at a cycle length of 24 hours, and additional peak occurs with a periodicity of 8 hours (Figure 12).

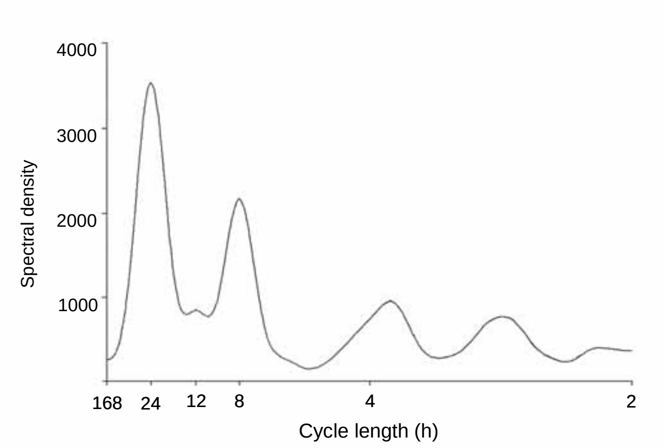


Figure 12. *Smoothed spectral analysis of grazing behaviour by grazing sheep (Champion et al. 2004)*

It has been suggested that this 8-hour periodicity reflects attempts by the grazing animal to maintain optimum conditions within the rumen for fibre digestion (Phillips 1992). Similar cycles of grazing activity have been demonstrated in dairy cows, although the intensity of the 8-hourly peaks are not equal and, not surprisingly, are influenced by management factors, such as milking times, and natural phenomena, such as the weather and phases of the moon. Figure 13a shows a theoretical grazing activity curve with peaks occurring at intervals of 8 hours. Figure 13b shows the number of minutes spent grazing by dairy cows within each hour, which, although of varying magnitude, have a similar 8-hourly periodicity when there is a full moon. However, during nights when there is a new moon (i.e. dark phase) there is almost complete suppression of night-grazing activity (Figure 13c).

As previously explained, continuous variable stocking management can provide conditions in which sward state varies little over the course of a day so that, with the exception of removal for milking, we can expect to find a minimally perturbed temporal pattern of grazing, ruminating and idling activity. Figure 14 shows such a pattern by a cow during a dark-phase period of the moon. During the hours of darkness the cow performs alternating periods of idling and ruminating. However, on return to pasture at 06:30 h following morning milking the animal undertakes a relatively short grazing meal of approximately 90 minutes duration, followed by alternating periods of idling and ruminating. In the late morning (ca 11.00 h) the cow undertakes a second grazing meal, of slightly longer duration (approximately 150 minutes) followed during the early part of the afternoon by further periods of idling and ruminating. On returning to the paddock at 16:00 h following afternoon milking, the vast majority of the remaining time until dusk is occupied in grazing.

In our experience, similar underlying temporal patterns of grazing activity have been found repeatedly under continuous variable stocking management (Gibb et al. 1997; 2000; 2002) albeit with occasional occurrences of night grazing when there has been moonlight or disruption due to supplementation at pasture. However, not only was the late afternoon and evening the time when the longest periods of almost uninterrupted grazing activity occurred, it was also the time of highest BM, BR and IR. Under such a regime it appeared likely that in excess of 60 % of daily herbage intake was occurring during the period between afternoon milking and dusk. This led to examination of the hypothesis that under daily paddock-stocking management provision of the fresh herbage allowance following afternoon milking rather than following morning milking would allow greater intake of herbage before it had been fouled and trampled (Orr et al. 2001). Figure 15 shows an example of the temporal pattern of grazing, ruminating and idling behaviour by cows moved to a fresh area of pasture following morning or afternoon milking. In the former case, despite the provision of fresh pasture during the morning, meals during the earlier part of the day are short and fragmented, whereas in the latter case the major grazing meal of the day occurs when the animals are provided with their fresh allowance and the water-soluble carbohydrate content of the herbage is highest. The benefit accrued from offering the same area of pasture, but following afternoon rather than morning milking, was an increase in milk yield of about 5% and an increase in fat and protein content of the milk of 4.7 and 0.4 g kg^{-1}.

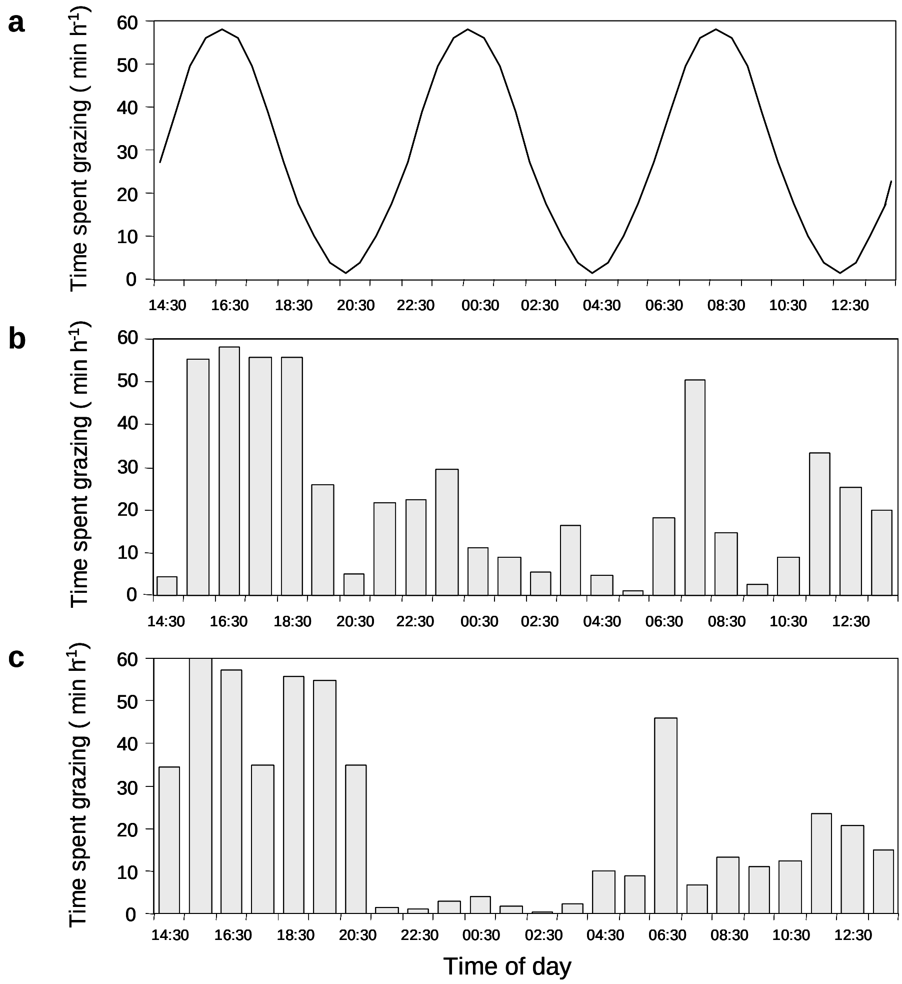


Figure 13. *(a) Schematic representation of 8-hourly cycle of peak grazing activity and actual time spent grazing during each hour of the day by dairy cows grazing (b) during a period of a full moon phase and (c) new moon phase. Cows were removed for milking at 14.30 and 05:30 h. (Gibb et al. in press)*

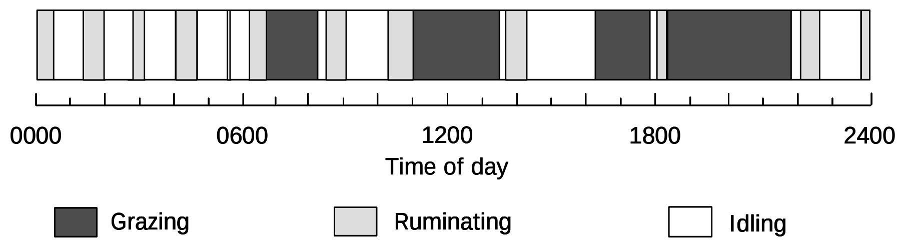


Figure 14. *Typical temporal pattern of grazing, ruminating and idling activity by a dairy cow under continuous variable stocking management (Gibb et al. 1997)*

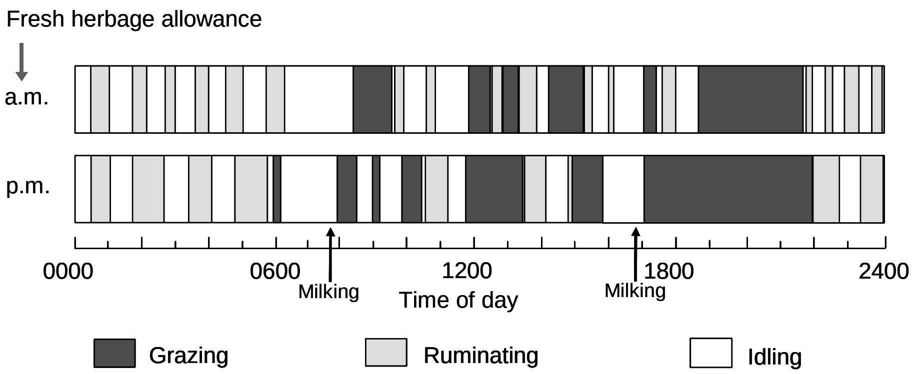


Figure 15. *Typical temporal patterns of grazing, ruminating and idling activity by dairy cows under daily paddock-stocking management provided with the same daily herbage allowance either following morning milking or following afternoon milking (Orr et al. 2001)*

DIETARY PREFERENCE AND SELECTION FOR GRASS AND CLOVER

Over recent years there has been a resurgence in the use of clover in pastures for intensively managed dairy and meat enterprises, not only as an essential component of the organic systems, but also as an alternative to increasingly expensive inorganic nitrogen fertilizers and what is seen by some as a more ethically and aesthetically acceptable approach. In addition, the provision of clover in the diet can facilitate greater intakes and animal performance per unit of intake.

Studies of the grazing behaviour of ruminant livestock have provided useful insights into their interactions with these different dietary components, which in turn have led to novel approaches to their utilization. The majority of research in this area has focused on the use of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) as the most agriculturally relevant grass and legume species used in intensive livestock production systems in Western Europe. Usually, these two species are grown together in mixed swards so that the grass component can most readily benefit from the nitrogen fixation by the legume and the grazing animal has the opportunity to select a preferred diet if it chooses to do so.

Research has shown that sheep, cattle and goats do not graze at random, but show a partial preference for about 70 % white clover in the diet in the case of sheep (Parsons et al. 1994) and cattle (Rutter et al. 2004), and 50 % white clover in goats (Penning et al. 1995). Moreover, results have demonstrated a diurnal pattern of preference in sheep (Parsons et al. 1994) and cattle (Rutter et al. 2004), with animals spending more time grazing clover during the morning and more time grazing grass during the late afternoon and evening. However, if sheep and cattle prefer to select a mixed diet rather than graze at random, providing the different dietary components in an intimate mixture may increase the animals' searching activity during grazing. The time taken and the daily intake achieved by ewes grazing pure swards of perennial ryegrass or white clover, adjacent monocultures or intimate mixtures of the two species are shown in Figure 16 (Champion et al. 2004). The figure shows that slightly greater daily intakes can be achieved on clover compared with ryegrass swards in less grazing time. It also shows that greater daily intakes can be achieved in less time when the ewes have access to adjacent monocultures of both species compared with a mixed sward.

The time required for the searching element of grazing activity appears to penalize daily intake. Whilst this work was conducted with grass and clover, it should be recognized that similar time costs may well face cattle grazing in a mixed grass or structurally heterogeneous sward.

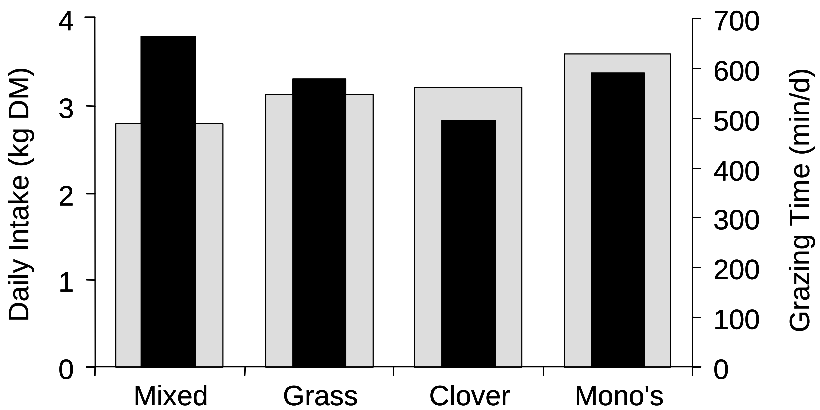


Figure 16. *Daily intake ■ and time spent grazing ■ by ewes offered either a mixed perennial ryegrass/white clover sward (Mixed), a monoculture of perennial ryegrass (Grass), a monoculture of white clover (Clover), or adjacent monocultures of perennial ryegrass and white clover (Champion et al. 2004)*

However, utilizing the valuable contribution to be made by legumes is not without its problems concerning management and environmental impact. In addition to the possibly devastating consequences of bloat, grassland managers often see the late start to clover growth in the spring, the unpredictable and possibly reduced performance of mixed swards, their heterogeneous appearance and the difficulty of weed control as reasons for not incorporating white clover with grass in their swards.

The use of separate perennial ryegrass and white clover swards for dairy cows, rather than mixed swards, offers several benefits. From the point of view of grassland management and food supply, growing the two species separately offers the opportunity of earlier and strategic use of nitrogen on the grass and easier weed control in both swards. Furthermore, the results presented in Figure 15 would suggest that higher daily intakes might be achievable when cows are provided with access to adjacent monocultures of grass and clover. An experiment was therefore conducted under continuous variable stocking management, to compare the performance of dairy cows with free access to adjacent monocultures of perennial ryegrass and white clover with that of cows grazing a mixed sward of the two species (Nuthall et al. 2000). The results demonstrated that providing access to adjacent monocultures made diet selection easier, improved intake and increased milk yield (Figure 17) compared with cows grazing the mixed sward.

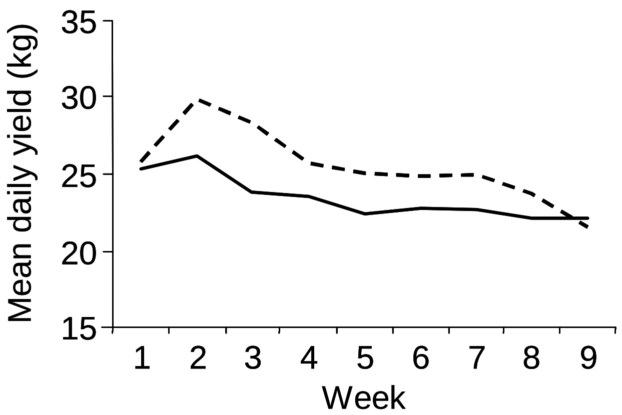


Figure 17. *Milk yield by dairy cows grazing either a mixed perennial ryegrass/white clover sward (——) or adjacent monocultures of perennial ryegrass and white clover (-----) (Nuthall et al. 2000)*

However, providing access to adjacent monocultures of grass and clover may often be logistically difficult due to farm layout. It was therefore decided that use might be made of the diurnal pattern of dietary selection demonstrated in earlier experiments. An experiment was conducted, again under continuous variable stocking management, in which cows had access either to adjacent monocultures of grass and clover throughout the day, or access to a clover monoculture following morning milking and a grass monoculture following afternoon milking (Rutter et al. 2001). The results show that allowing the animals temporally-restricted access to the two pasture species, did not penalize milk production compared with access to the two monocultures throughout 24 hours. A third experiment was conducted to examine whether, compared with grazing mixed swards, separate temporal allocation of grass and clover could improve milk production by dairy cows under a twice-daily paddock-stocking management (Rutter et al. 2003). The swards were managed to provide approximately 5 tonnes DM ha^{-1}, measured to ground level, when the cows entered them. The half-day paddock area for each group of four cows was 190 m^2, sufficient to provide about 24 kg DM cow^{-1}. Milk yields were measured for 2 weeks prior to the experiment, and then for 9 weeks during the imposition of the two treatments. The results demonstrate that providing white clover and ryegrass at different times of the day under twice-daily paddock management significantly increased daily herbage intake and milk production.

These experiments, based upon the findings of earlier behaviour studies, demonstrate that novel approaches to the management of perennial ryegrass and white clover can be used to boost milk yield and reduce the use of inorganic fertilizers whilst allowing a margin of safety against delayed legume growth. Studies will continue in order to examine scale of patch size of grass and clover necessary for grazing cattle to benefit from the reduced cost of selecting a mixed diet from areas of pure grass and clover and for optimum transference of nitrogen from the legume swards to the benefit of the grass swards.

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