The Role of Diet Selection in Sustainable Agriculture

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Abstract

Recent research has shown that domestic ruminants have clear diet selection goals. They eat mixed diets and show consistent diurnal patterns of diet preference. Current theoretical explanations for these observed patterns of behaviour focus on evolutionary traits. Grazing ruminants will have evolved a foraging strategy that optimises their fitness (which is the ultimate currency driving natural selection). Whilst this strategy will have been modified by the process of domestication, modern domestic ruminants appear to retain many aspects of their foraging strategy from their wild forebears. These include optimising the efficiency of nutrient capture and the associated need to maintain rumen function, whilst at the same time reducing the risk of predation and the risk of poisoning from plant toxins. These diet selection characteristics need to be taken into account in the development of grazing management strategies, both those aimed at optimising their nutrient capture whilst at the same time minimising the environmental impact of the animal, as well as strategies that aim to promote biodiversity in semi-natural grazed pastures. Research in this area indicates that an understanding of the diet selection characteristics of grazing ruminants has an important role to play in the development of grazing management strategies that are both environmentally and economically sustainable.

Introduction

The intensification of grazing systems in many parts of the world over the last few decades has led to the increased use of ryegrass monocultures. These single monoculture swards restricted the dietary choice of the grazing animals to a single plant species. More recently, the incorporation of legumes into swards, principally to fix atmospheric Nitrogen, has led to an interest in the study of diet selection, as these swards contain at least two plant species allowing the animal to select a diet consisting of a mixture of the two. More recently still, the desire to maintain and promote biodiversity has seen an interest in studying diet selection from semi-natural pastures (Rook *et al.*, 2004), which offer the grazing animal a diverse range of plant species from which to select their own diets. This paper summarises research into diet preference and selection in grazing domestic sheep and cattle, considering the theoretical basis of mixed diets as well as the potential production and environmental benefits resulting from allowing the animals the opportunity to select their own diets.

Preference versus selection

It is important to differentiate between an animal's *preference* (i.e. what it 'wants' to eat) and what it actually eats (*selects*) due to some external constraint (Parsons *et al.*, 1994). The difference between the two is best illustrated by example. Grass and clover swards grazed by domestic ruminants are usually offered as an intimate mixture of the two plant species, often along with other weed plant species mixed in the sward. In this situation, the grazing animal has to search through the mixture in order to find and then prehend i.e. take a bite of the preferred plant species. The need to search through the mixture imposes a constraint on the animal and consequently is an example of selection (Hodgson, 1979). In order to study preference, the constraint of needing to search through the mixture needs to be removed. This is typically achieved in diet preference studies by offering and grazing the two plant species as separate, conterminal monoculture swards (e.g. Parsons *et al.*, 1994).

General results

In a recent review of diet preference for grass and legumes in domestic sheep and cattle, Rutter (in press) concluded that both animal species do not graze at random, but select mixed diets that generally consisted of 75% ±5% legume for lactating animals and 65% ±5% legume for non-lactating animals. This

can be generalised such that both lactating and non-lactating sheep and cattle generally select 70% ± 10% legume. Studies of the intake rates of grass and clover show that both sheep (Penning *et al.*, 1991) and lactating dairy cows (Rutter *et al.*, 2004a) eat clover more quickly than grass, but the intake rates of the two herbages were the same in non-lactating dairy heifers (Rutter *et al.*, 2002).

Where studied, diet preference studies for grass and clover show a consistent diurnal pattern of preference, with the animals showing a strong preference for clover in the morning, but with the proportion of grass in the animals' diets increasing as the day progresses and reaching a maximum at the end of daylight hours (Figure 1).

Cost of selection

Champion *et al.* (2004) demonstrated that there are selection costs associated with grazing intimately mixed grass/clover swards. Although the sheep grazing mixed ryegrass/white clover swards had the longest grazing times (compared to sheep grazing ryegrass only, white clover only or separate, adjacent ryegrass/white clover monocultures), they had the lowest intakes. This can be attributed to the time taken as the sheep searched through the mixed sward looking for their preferred herbage at that moment in time. This searching time was, ultimately, at the expense of eating time resulting in a reduction of daily intake compared with the animals on the other treatments. The highest daily intakes in the study were achieved when the sheep could select their own diets from the spatially separate but adjacent grass and clover monocultures.

Optimum spatial scale of separation

The majority of studies into diet preference using separate, adjacent monocultures have generally had a spatial scale of separation at the paddock scale i.e. each paddock typically had one contiguous area of pure clover and another of pure grass, representing the opposite extreme of spatial separation from an intimately mixed sward. The effect of the spatial scale of separation of the two herbages on diet preference and selection was studied by Rutter *et al.* (2005). They presented beef heifers with adjacent strips of

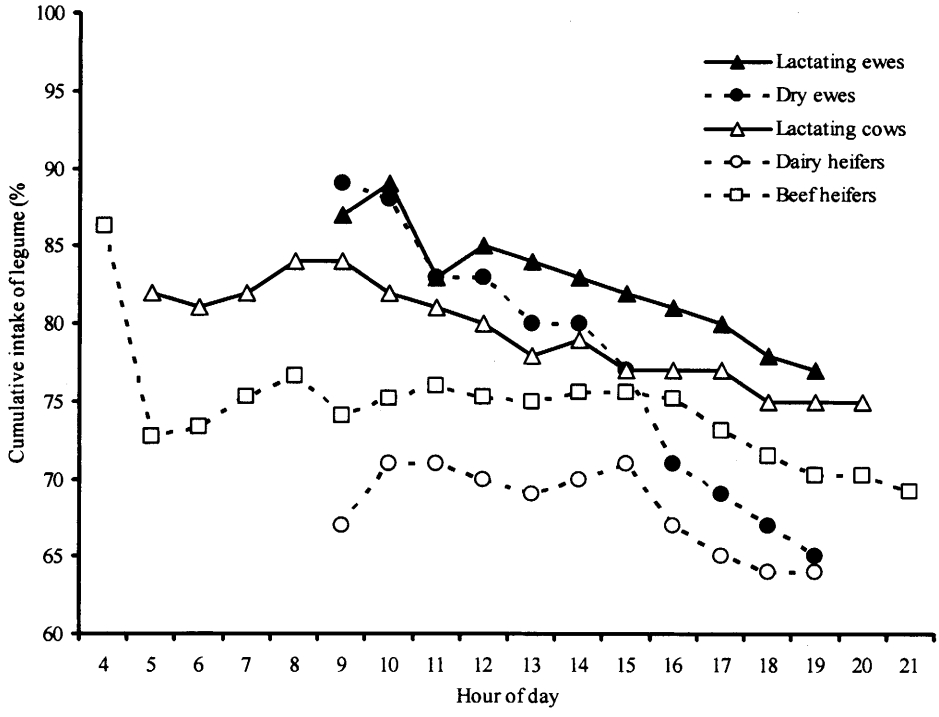

Fig.1. Diurnal patterns of preference for clover (vs perennial ryegrass) in lactating and non-lactating (dry) sheep (Parsons *et al.*, 1994), lactating dairy cows (Rutter *et al.*, 2004a), for non-lactating dairy heifers (Rutter *et al.*, 2004b) and for non-lactating beef heifers (Rutter, unpublished data). In all cases, the lines represent the mean diet selected from animals that were offered 50% clover and 50% grass (by ground area).

grass and clover at different widths: 108 cm, 36 cm and 12 cm, as well as an intimately mixed sward. The cattle selected approximately 60% from the two wider strips but only approximately 37% clover from the 12 cm width strips and the mixed sward, indicating that the animals could select their preferred diets in strips of 36 cm and wider, but not from the 12 cm strips. This suggests that the critical scale of spatial separation to allow the cattle to select their preferred diet lies between 12 and 36 cm.

Why do ruminants eat mixed diets?

Various theories have been proposed for why ruminants eat mixed diets (Rutter, in press). Whilst several theories have been discounted, those relating to the animals evolutionary traits to optimise its fitness appear to warrant further research, and these are summarised in this section.

One of the most important functions an animal undertakes is the acquisition of nutrients. Eating a single food that has an excess of a particular nutrient can be less than optimal for an animal's fitness. This is because the excretion of the excess nutrient is likely have an energetic cost associated with it, putting the animal at a competitive disadvantage compared with an animal that optimises its nutrient capture such that by balancing its nutrient intake it avoids the excess energetic costs. This is probably one reason why ruminants, when given a choice, do not eat purely clover diets, as these have a higher proportion of nitrogen (compared with carbon) than grass (Whitehead, 1995), and there is an energetic cost associate with the excretion of excess nitrogen. There is evidence to support this hypothesis from *in vitro* studies that showed that the optimum level of microbial protein synthesis in an artificial rumen is achieved with 70% clover and 30% grass (Merry *et al.*, 2002) i.e. the same proportion that grazing animals prefer when given free choice from separate, adjacent grass and clover monocultures, suggesting that this ratio of grass and clover provides the optimum balance of nutrients.

Related to the need to optimise the efficiency of nutrient capture is the need to maintain rumen function as another possible explanation of mixed diets. Although sheep and cattle can live on clover only diets, this is likely to lead to a change in their rumen micro-flora such that their ability to digest cellulose is less than that of animals that maintain cellulose-rich grass in their diet. Again, this would place these animals at a competitive disadvantage compared with those that maintain grass in their diets, and there is strong evolutionary pressure for animals to maintain the ability to cope with change.

Plants contain a variety of secondary compounds, many of which are toxic to animals. This could account for the diurnal pattern of preference seen in grazing ruminants, as the accumulation of one or more such compounds from clover could lead to the animal incorporating a greater proportion of grass in its diet in an attempt to dilute the toxins form the clover.

Another possible explanation for the diurnal pattern of preference is that the animal is filling its rumen with grass in the evening as it is a bulky feed with a slower passage rate than clover. Consequently, the animal is less likely to need to graze at night if it adopts this strategy. This has been proposed as a possible anti-predator strategy. Although modern domesticated animals are usually protected from predators, and their domestication as lead to a reduction in anti-predator responses (Mignon-Grasteau *et al.*, 2005), they still exhibit some anti-predator behaviours similar to wild animals (Biossy *et al.*, 2005).

Of the four possible explanations given above for why ruminants eat mixed diets, that latter two (toxin and predator avoidance) appear to be the most compelling as they account for both mixed diets and the diurnal pattern of preference. However, it is possible that all four explanations play a role, and that the animal has to make trade-offs between these (sometimes competing) goals as it attempts to optimise its survival and fitness. Further research is needed to explore all of these hypotheses as we attempt to understand the ultimate basis of mixed diets in ruminants.

Production benefits

Given the higher daily herbage intakes associated with grazing separate, adjacent clover and grass monocultures demonstrated in Champion *et al.*'s (2004) study (reported earlier), it would seem logical that this approach could be used to improve the production of grazing livestock. This has been demonstrated to be the case in dairy cattle. Both Nuthall *et al.* (2000) and Cosgrove *et al.* (2001) found that dairy cows grazing separate grass and clover monocultures under

continuous stocking produced at least 11% more milk than cows grazing a mixed grass/clover sward. Rutter *et al.* (2001) demonstrated that continuous free choice was not necessary, and that the intake and production benefits of grazing separate monocultures could be achieved by allowing the animals to graze clover only following morning milking and grass only following afternoon milking i.e. mimicking their natural diurnal pattern of preference (a treatment they called 'temporal allocation'). Rutter *et al.* (2003) then demonstrated that dairy cows on a temporal allocation treatment under strip grazing produced 14.6% more milk than those receiving a twice a day allocation of a mixed grass clover sward under rotational grazing. Rutter *et al.* (2003) argued that temporal allocation could provide a practical way to exploit the production benefits of grazing grass and clover as separate swards on farms.

Environmental benefits

The higher production levels from dairy cows grazing separate grass and clover monocultures reported in the previous section were originally attributed to higher daily intakes. However, some recent results from Australia (Venning, pers. comm.) show that sheep grazing separate grass and clover monocultures showed similar daily intakes but higher production levels than those grazing a mixed sward or a ryegrass only monoculture. This clearly indicates a higher feed conversion efficiency from the separate monocultures, with a more efficient capture of nutrients i.e. potentially less pollution than from animals grazing either mixed swards or ryegrass monocultures. High feed conversion efficiencies are also associated with lower methane emissions (DeRamus *et al.*, 2003), resulting in another potential environmental benefit of allowing the animals the possibility to select their own diets i.e. a reduction in a potent 'greenhouse gas' (and a contributing factor in climate change) from grazing livestock.

Summary

Domestic ruminant livestock appear to have clear diet selection goals that are related to evolutionary traits inherited from their ancestors aimed at optimising their fitness. These include the need to optimise the efficiency with which they capture nutrients, maintaining rumen function and to avoid the danger of consuming toxins and the risk of predation. Grazing domestic sheep and cattle show a partial preference of approximately 70% for clover and show a diurnal pattern of preference, with a stronger preference for clover in the early part of the day, with the proportion of grass in their diet increasing towards the evening. Such a high proportion of clover in the diet is best achieved if the two herbages are offered as separate, adjacent monocultures, with the critical spatial scale of separation between the two lying between 12 and 36cm for heifers. By allowing sheep and cattle the opportunity to easily select their own diets from spatially separate monocultures, they achieve higher daily herbage intakes and higher levels of production than animals grazing grass only, clover only or a mixed sward. The higher levels of production also appear to be associated with a higher feed conversion efficiency, with reduced levels of pollutants per unit product, including methane (a potent 'greenhouse gas') emissions, giving positive environmental benefits. The combined benefits of enhanced production with reduced pollution show that the animals diet selection characteristics should be taken into account in the design of sustainable livestock grazing systems. An understanding of the factors influencing diet selection is also a pre-requisite for the development of grazing management strategies for the maintenance and promotion of biodiversity (both floral and dependent faunal biodiversity) in semi-natural pastures grazed by domestic ruminants.

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