The Ingestive Behaviour of Cattle in Large-scale and Its Application to Pasture Management in Heterogeneous Pastoral Environments

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Abstract: Cattle may improve their feeding efficiency by altering their ingestive behaviour in response to changes in the quality of their pastoral environments. To test this hypothesis, an experiment was conducted in a native pasture that has been managed in continuous stocking at different daily forage allowances (4%, 8%, 12%, and 16% of live weight) for twenty two years thus creating different pastoral environments. For the current experiment, the animals were allocated to their respective experimental units on April 27, 2007. Two experiments were conducted; one was performed at the end of winter (experiment 1), and the other was undertaken at the end of spring (experiment 2). Four tester animals were observed per experimental unit (3-5 ha each). The animals increased their daily grazing time when forage allowance decreased. Most of this increased time was devoted to harvesting, whereas searching was reduced to a few minutes per day. Under conditions of ideal range of forage allowance (between 12% and 14%), the grazing time was reduced, and the search activity increased. These results suggest that the monitoring of indicators of ingestive behaviour can be used to determine the attributes of forage resources.

Key words: Cattle, feeding duration, search time, harvest time, grazing time, native pasture.

1. Introduction

Grazing animals interact with their food resources through the creation and maintenance of variability in the quality, quantity, and distribution of forage in the sward structure. The reciprocity of these interactions means that the value of the food resource at any given moment results from the interaction between the pastoral environment and the animal [1].

The way that an herbivore reacts to the sward structure constitutes its ingestive behaviour. The study of these reactions is important when discussing the use of natural forage resources by livestock [2], because the animal must search for and select its food within a mosaic of patches with different structures.

The interactions between animals and this mosaic are complex because of the temporal and spatial variability (i.e., [3, 4] in the availability and nutritional value of the patches [5]).

To cope with the feeding challenges of this complex environment, the grazing animal must engage in numerous decisions throughout the day. These decisions can be made on the seconds-scale (bites and feeding station (FS)), the minutes-scale (patch), the hours-scale (grazing site and meal), the days-scale (daily grazing time), or the year-scale, and these decisions may involve social, reproductive, and migration factors [6].

Animals continually make decisions concerning (1) what, (2) where, and (3) when to eat [7]. These decisions concern the choice of better quality of forage (based on either nutritional or structural
parameters) resulting in higher searching costs when forage availability is low. In opposite, in situation of more forage abundance, animal can to decide to consume lower food quality, lowering the searching costs in detriment of quality. According to Prache et al. [8], the benefits of meeting dietary needs by searching are generally outweighed by the increased costs of searching.

Our objective was to investigate how heifers cope with various forage allowances in different seasons in terms of time spent for graze, harvest, and search its daily diet. The specific questions addressed included the followings: (1) Is there any effect of forage allowance on the daily activity patterns of the heifers? (2) Is there any effect of forage allowance on the harvest time and search time of heifers? (3) Is there any effect of the grazing season on the heifer's grazing behaviours?

2. Materials and Methods

2.1 Materials

The experiment was conducted on a native pasture at the Experimental Station of the Federal University of Rio Grande do Sul-Brazil (30°05′27″ S and 51°40′18″ W). Native pastures in Southern Brazil are characterised by a bimodal structure with a slightly grazed upper strata and a frequently grazed lower strata. Cruz et al. [9] provides greater detail regarding the diversity of species in this experimental pasture after 15 years under different grazing intensities. The experiment had a random block design with two repetitions, thereby yielding a total of eight experimental units of 3 to 5 ha each and a total area of 32 ha.

The feeding of different forage allowances (FAs) at this site began in 1986. The animals assessed in this study were introduced to the experimental site in April 2007. The herd was composed of heifers that were selected from a group of crossbred Angus × Hereford and Brahman cattle. The heifers were 15 months old with an average weight of 249 ± 6 kg. Tester animals with similar weight, body conditions, and temperament were selected from this group.

The ingestive behaviour of these animals was assessed at the ends of winter and spring, constituting experiments 1 and 2, respectively. The same animals were utilized in both experiments and in the same experimental units. During the assessment of feeding behaviour in experiment 1, the average weights of the tester animals were 228 ± 4 kg; 258 ± 7 kg; 250 ± 4 kg; and 250 ± 11 kg for the 4%, 8%, 12%, and 16% treatments, respectively. In experiment 2, the average weights of the tester animals were 228 ± 6 kg; 278 ± 8 kg; 301 ± 9 kg; and 287 ± 14 kg for the 4%, 8%, 12%, and 16% treatments, respectively.

2.2 Methods

This study’s treatments included the following daily levels of forage allowance (FA): 4, 8, 12 and 16 kg DM 100 kg live weight\(^1\) (% of LW), which were fixed throughout the entire year and adjusted, on average, every 28 days according to the variations in pasture growth and the animals’ weights. The grazing method was continuous with variable stocking rate using four testers and a variable number of regulating animals [10].

The animals’ ingestive behaviours were assessed at the end of winter (September 1, 2007) 128 days after the onset of the experimental period constituting experiment 1. At the end of spring (December 1, 2007), 219 days after the onset of the experimental period, experiment 2 was conducted. At a weather station approximately 300 m from the experimental site, the following data were recorded in two days of the ingestive behaviour observations, average daily temperature: 16-22 °C; relative humidity: 96%-80%; rainfall: 2.2 and 0 mm; and solar radiation: 167 and 673 cal cm\(^{-2}\) day\(^{-1}\) for experiments 1 and 2, respectively.

Available forage mass in each experimental unit was visually estimated by 50 samples of 0.25 m\(^2\) each, disposed systematically in transects across the paddocks. Only the lower strata were sampled (effectively grazed). Using the double sampling
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The average of the 50 estimated points was corrected using the estimated regression model, \( \hat{y} = b_0 + b_1 \), which was generated from 54 other points sampled in the all experimental area on each assessment [11]. These points were visually estimated and subsequently cut with electric shears. The forage was collected in paper bags, dried in a forced air circulation oven at 60 °C for 72 hours, and weighed on a precision balance to the nearest 0.001 g to determine the dry matter content (DM).

A sample of forage per paddock was taken, in areas representative of the condition of the pasture, trying to simulate the morphological composition of the forage consumed by animals. A single trained measurer carried out these samples by observation of the forage intake of animal testers. The forage was collected in paper bags, dried in a forced air circulation oven at 60 °C for 72 hours. Subsequently, these samples were processed in a stationary Wiley mill using 1 mm sieves. After milling, the samples were sent to the Animal Nutrition Laboratory at the Federal University of Rio Grande do Sul (UFRGS), where the crude protein (CP) and neutral detergent fibre (NDF) contents were determined. To quantify the CP and NDF, the samples were processed by the Kjeldahl method and Van Soest et al. [12], respectively.

The sward height was measured with a sward stick within the same 50 sampling squares used to estimate the forage mass. In each square, three points were measured in an oblique transect to generate an average value on a systematic approach was followed in each experimental unit. The reproductive portions of the plants and dead or non-grazed material were not considered. The tussock frequency (%) was obtained using the same procedure used for the sward height assessment. When tussocks were found, they were identified to determine their frequency. The immediate neighbour of an effectively grazed stratum was evaluated the parameters of the sward height and forage mass.

The daily DM accumulation rate (AR) was assessed every 28 days in the grazed stratum using four grazing exclusion cages per experimental unit according to the following calculation: \( AR = (W_i - O_{i-1}) n^{-1} \), where \( W_i = DM \text{ ha}^{-1} \) within the exclusion cages at date \( i \); \( O = DM \text{ ha}^{-1} \) outside exclusion cages at date \( i-1 \); and \( n \) = the number of days between \( i \) and \( i-1 \).

The ingestive behaviour was registered by observers positioned on a scaffold measuring approximately 4 meters in height. Grazing, ruminating, and other activities of the 4 tester animals per experimental unit were recorded every five minutes by visual observation [13]. This procedure was conducted continuously between sunrise and sunset (from 6:25 am to 6:40 pm and from 5:55 am to 8:30 pm in experiments 1 and 2, respectively).

Grazing was defined as the time spent either harvesting forage or searching for it. Rumination was defined as the time when the animals were not grazing and were rechewing the bolus. Other activities encompassed the periods during which the animal was not grazing or ruminating [14].

A meal was considered to be a sequence of at least two successive grazing observations or grazing for ten minutes. Following the same criteria, other activities than grazing were distinguished by their occurrence in two observations. The number of meals and the intervals between the meals were calculated according to the criteria previously mentioned, i.e., the time spent for each of these activities was used to calculate the meal duration and duration between meals.

To determine the harvest and search times, the time spent moving among the ten feeding stations (FSs) and the number of total steps between these stations were quantified. The diurnal grazing time (tG) was separated into the time spent harvesting (tH) and the time spent searching (tS) for herbage. The harvest time corresponded to the portion of the grazing time during which the animal effectively harvested forage. The search time corresponded to the time spent shifting between FSs. These variables were obtained from the following formulae:
Harvest time = \{tH^* [1 – (NSsel NSbs^{-1})]\}
Search time = tG – \{tH^* [1 – (NSsel NSbs^{-1})]\}

Where NSsel is the number of steps in the selection, and NSbs is the number of steps between FSs.

Six measurements were obtained for each tester animal throughout the day.

2.3 Data Analysis

To analyse the effects of treatments on ingestive behaviour the experimental unit was the average of the four animal testers.

Within each experiment, the variables related to the pasture and the animals were subjected to a third-order regression analysis that conformed to the model \( Y_{ij} = a + bx_{ij} + cx_{ij}^2 + dx_{ij}^3 + \varepsilon_{ij} \), where \( Y_{ij} \) is the dependent variable, \( a \) is the intercept of the regression, \( x \) is the independent variable, \( b \) is the linear regression coefficient of the \( Y \) variable in relation to the independent variable, \( c \) is the quadratic regression coefficient of the \( Y \) variable in relation to the independent variable, \( d \) is the cubic regression coefficient of the \( Y \) variable in relation to the independent variable, and \( \varepsilon_{ij} \) is the residual random error. When the regression model was significant \( (P < 0.10) \), authors reported the results for the model with a higher coefficient of determination \( (R^2) \).

The data were subjected to an analysis of variance with a significance level set at 0.1. The means of the treatments were estimated using the LSMEANS procedure and were compared using Tukey’s test.

When the regression models exhibited the same trend in both experiments, the models were compared using the parallelism and equal intercepts tests. When the models were equal \( (P > 0.10) \), a new model was determined with the data from both experiments to report a single model. The SAS [15] was used for statistical analysis.

3. Results

The relation obtained between the expected and actual forage allowance values in both experiments \( (y = -0.7738 + 1.13x; R^2 = 0.9076; P < 0.0001) \) confirmed that a gradient existed between treatments. This result supports the idea of creating forage allowance contrasts for the animals and, by this way, to create different sward structures. The sward height in both experiments had a positive linear fit as a function of FA (Fig. 1), and the average sward height varied between 3.5 and 8.6 cm for the 4% and 16% LW treatments. The animal stocking rate also fit a linear model in both experiments (Fig. 1), but decreasing as forage allowance increased from 4% to 16% of LW (from 515 to 157 kg ha\(^{-1}\) of LW). For each 1% increase in FA, there was a 0.35 cm increase in sward height. Conversely, the stocking rate decreased by 32 kg ha\(^{-1}\) of LW over the same range of FAs.

The forage mass fit to a quadratic model, but the models were not similar between the two experiments (Table 1). The patch frequency also fit to a quadratic regression model in relation to the FAs in experiment 1, but in experiment 2, the response was linear. The samples from the grazing simulation under the 4% treatment had an average CP of 13% in the two experiments. The CP showed a linear response to forage allowance, decreasing 0.26% at each 1% increase in FA. The NDF averaged 60.5% in the 4% treatment, increasing 1.01% with each 1% increase in FA.

A linear increase was observed in the meal duration without an increase in the number of meals in experiment 1. Under the condition of low FA, the animals significantly increased their meal duration, spending more than 3 hours continuously grazing. In this situation, the animals had shorter intervals between meals (approximately 30 minutes). The relationship between the meal duration and the interval duration indicates that the animals devoted only one minute to any other activity for every 5 minutes spent grazing. Similarly, in the spring, the animals increased their meal duration to 230 minutes when receiving reduced FA. The meal duration then decreased to 150 minutes as the FA increased to 14%
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Fig. 1  Relationship between forage allowance and sward height (SH) (cm) and animal stocking rate (SR) (kg ha⁻¹ of LW) (△ experiment 1; ▲ experiment 2); ■ experiment 1; □ experiment 2).

Table 1  Sward variables and heifer’s ingestive behaviours in native pasture submitted to different forage allowances.

<table>
<thead>
<tr>
<th>Forage allowance (kg of DM/100 kg of LW)</th>
<th>Experiment 1</th>
<th></th>
<th>Experiment 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Forage mass (kg ha⁻¹)</td>
<td>506</td>
<td>1,117</td>
<td>1,249</td>
<td>1,261</td>
</tr>
<tr>
<td>Tussocks frequency (%)</td>
<td>1.5</td>
<td>25.5</td>
<td>34.0</td>
<td>39.5</td>
</tr>
<tr>
<td>Crude protein (g kg⁻¹)</td>
<td>14.3</td>
<td>11.7</td>
<td>11.5</td>
<td>11.0</td>
</tr>
<tr>
<td>NDF† (g kg⁻¹)</td>
<td>60</td>
<td>65</td>
<td>65</td>
<td>79</td>
</tr>
<tr>
<td>Daily meals (n°)</td>
<td>3.8</td>
<td>4.5</td>
<td>4.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Intervals between meals (n°)</td>
<td>2.8</td>
<td>4.1</td>
<td>4.2</td>
<td>3.5</td>
</tr>
<tr>
<td>Meals duration (min)</td>
<td>180</td>
<td>125</td>
<td>109</td>
<td>135</td>
</tr>
<tr>
<td>IDBM‡ (min)</td>
<td>34</td>
<td>54</td>
<td>56</td>
<td>60</td>
</tr>
<tr>
<td>Daily rumination time (min)</td>
<td>24</td>
<td>81</td>
<td>113</td>
<td>125</td>
</tr>
<tr>
<td>Daily idling time (min)</td>
<td>94</td>
<td>132</td>
<td>133</td>
<td>105</td>
</tr>
<tr>
<td>Grazing/searching time relation</td>
<td>5.96</td>
<td>2.56</td>
<td>2.42</td>
<td>2.51</td>
</tr>
<tr>
<td>Grazing/harvest time relation</td>
<td>1.24</td>
<td>1.63</td>
<td>1.77</td>
<td>1.66</td>
</tr>
</tbody>
</table>

Ns = not significant; †FDN = neutral detergent fibre; ‡ IDBM = intervals duration between meals.
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A linear increase in the number of intervals between meals was also observed in addition to a quadratic increase in the number of meals (inflection in 13.6% of FA).

The daily grazing time under the higher FA treatments was approximately 2 hours less than that observed under the conditions of lower FA. At 4% FA animals dedicated approximately 500 minutes to harvesting forage (80% of the day), whereas under conditions of the highest FA, this activity was limited to 300 minutes (60% of the day). Conversely, the time dedicated to searching for forage was restricted to approximately 1 hour under the lowest FA (20% of the day) or reached more than 3 hours (40% of the day) under the highest FA.

The time dedicated to rumination increased linearly with the FA, increasing 9.5 minutes with each 1% increase in FA. The daily duration of other activities showed a quadratic relationship as a function of increasing FA; in the 9.5% FA condition, the animals spent most of their daily time engaged in other activities than grazing and ruminating.

The daily grazing time fit the quadratic model in the winter experiment and decreased when more forage was offered to the animals. However, the daily grazing time did not fit the response model of experiment 2 (Fig. 2a). Under 4% FA, the animals dedicated 80% of the total grazing time to harvesting, greatly reducing their searching activities. This increased grazing time implies increased energy expenditure and therefore a reduced efficiency in meeting nutritional needs under restricted allowances [16].

4. Discussion

In experiment 1, the animals showed a quadratic relationship between the meal duration and FA (Table 1). Thus, the intervals between meals (spent ruminating and engaged in other activities) showed an inverse response. Under 4% FA, the animals increased their meal duration without altering their number of meals, which was similar to the response observed by Barbosa et al. [17] in sheep grazing on ryegrass. Hejcmanová et al. [18] also observed a higher probability of observing animals grazing even without observing significant changes in their grazing pattern. This response indicates that the meal duration is the first behaviour response to increase intake when an animal copes with food restriction, probably because this strategy has fewer energetic costs. Increases in the meal duration occur before increases in the number of meals [17]. This finding is strengthened by the observation of different numbers of intervals between meals, which indicates that the animals had fewer than three intervals between meals in the 4% FA treatment and more than four intervals between meals at 11%
FA, i.e., the inflection point of the regression model. However, this increase in the number of intervals between meals was not observed as a reciprocal of an increase in meals, which indicates that in conditions of reduced FA, the animals had already started grazing before sunrise. In contrast, in the higher FA groups, the animals were observed to perform non-grazing activities at sunrise and at sunset.

The rate of decrease on the harvest time was higher than the rate of increase for the time spent searching for preferred FS (Fig. 2b). This interaction resulted in an inflection of the daily grazing time at 14% FA. These shows that this effect may be associated with increased percentage of tussocks, which exceeds 40% in the 14% FA (Table 1). That is, the animal would prioritize the harvest in relation to searching when the environment becomes hostile, to the extent that the increase in FA causes FS preferred pass to merge with an increasing frequency with non-preferred FS (tussocks). Confirming the strategy prioritizes the animal to minimize grazing time even if it causes a decrease in diet quality [19].

In the experiment 1, under 4% FA, the animals devoted, on average, one minute to searching for every six minutes spent grazing. In the other FA treatments, this ratio is little than 1:3. When harvesting, the animals in the 4% FA treatment devoted 2 minutes of harvesting per minute of total grazing time, compared with a 1:1.7 ratio in the other FA treatments. In the experiment 2 the treatment 8% was different of the other with 2.5 minutes of searching for minute spent grazing. In the other FAs, this ratio is 4.5:1. The reciprocal form the harvest ratio was 1.7:1 in the treatment 8%, whereas was 1.3:1 in the other FAs. These relationships corroborate descriptions in the literature that the strategy of the animals is to increase the harvest time and decrease the search time, which would allow to increase forage selectivity. Moreover, the animals select the highest nutritional quality for themselves when the sward structure shows no limitations [20]. With restrictions, the animals preferentially select the total intake that does not excessively increase their grazing time.

There were significant differences in the levels of CP and NDF (Table 1), which were more favourable in the 4% treatment. The behaviour parameters measured in this study emphasise the importance of compliance with the sward structural parameters. This inverse relationship between sward quality and behaviour indicates the need for specific studies that correlate behavioural and sward structural parameters to permit inferences about the quality of pastoral environments [1].

These results indicate that it is possible to qualify pastoral environments and sward structures using animal ingestive behaviours. Examining these behavioural differences as a function of the alterations to the sward structure, it is possible to make inferences about the behavioural patterns that relate to sward conditions. It is also possible to identify desirable sward structures, as well as factors that complicate the consumption, displacement, and searching for forage by the grazing animal. These behavioural indicators can inform management actions more effectively than a simple examination of the livestock. Moreover, these indicators allow us to work within the scope of grazing management goals [21], which integrate such parameters as animal welfare and the conservation of environmental resources used in production.

5. Conclusions
The sward intensities imposed by FAs create and maintain different sward structures that can be detected by observing the ingestive behaviour patterns of animals. In situations with low FA, the animals increase their harvesting activities and reduce their searching activities. These responses by the animals indicate maintenance of the FA between 12%-14% of LW.

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