Defoliation dynamics, pasture intake and milk production of dairy cows grazing Lucerne pastures in a PMR system


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Short title: Intake and milk response to grazing pressure in PMR systems.

Abstract

The effect of lucerne pasture allocation on defoliation dynamics, pasture intake and animal production was investigated in a sub-tropical Partial Mixed Ration dairy system (PMR). The study took place at the Gatton Research Dairy, South-East Queensland, with a 28-day adaptation period followed by an eight-day treatment period during November and December 2016. Twenty four multiparous Holstein-Friesian dairy cows were offered 11 kg DM/cow.day as PMR, and four levels of pasture allocation daily (averaging 30.6, 20.5, 15.1 and 10.9 kg DM/cow.day).

Cows with lower allocations were forced to graze further down the vertical plane and pasture intake and milk yield significantly declined (P < 0.001). Cows grazed the top grazing stratum (TGS), consuming an average of 1000 kgDM/ha of pasture, across 80% of the pasture area before regrazing an area of the paddock, regardless of allocation level. Pasture intake (kgDM/ha) of the TGS was at least 2.9 times higher than lower strata, regardless of allocation level. Therefore, the decline in pasture intake is explained by the transition from grazing the TGS to grazing subsequent strata. When the horizontal utilisation of the TGS approached 100%, the proportion of un-grazed, un-contaminated pasture (PUP) approached 0% of the area and intake and milk production declined. Grazing management strategies for lucerne should allocate pasture to lactating dairy cows to achieve horizontal utilisations approaching 0% PUP to maximise intake and production. Secondary grazing herds or mechanical methods should be used to remove residual pasture to the ideal height for pasture regrowth.

Introduction

The northern Australian dairy industry has a moderate reliance on Lucerne (*Medicago sativa*) as a home-grown source of protein and energy for a cow’s diet (McDonald et al. 2003). There is potential to expand the use of Lucerne within feed base systems; however there is a need to understand the impact on productivity and economic outcomes for the whole production system. Current industry practices within high intensity dairy grazing systems aim to achieve vertical pasture utilisation levels of at least 75%, with minimal residual DM (high grazing pressure) to ensure optimum pasture productivity (NSW DPI 2005). However, various studies on multiple pasture species have found that lower pasture allocations increased grazing pressure and decreased pasture intake and animal productivity in ruminants (Gibb & Treacher 1978; Peyraud et al. 1996; Chilibroste et al. 2012). Beef cattle have been found to achieve high levels of pasture intake only when grazing the top leafy stratum (TLS) of the pastures (Benvenutti et al. 2016). Reducing pasture allocation forces cows to graze down into the bottom stemmy stratum of the swards, and consequently decreases diet quality and pasture intake.
Within high intensity grazing systems where the height of the bottom stemmy stratum varies within a pasture sward (Benvenutti et al. 2016), allocating pasture based off a fixed post-grazing pasture height (vertical utilisation) cannot be recommended to consistently achieve high levels of pasture intake. Grazing management based on the horizontal utilisation of the TLS consistently maximizes pasture intake of beef cattle, irrespective of the height of the bottom stemmy stratum (Benvenutti et al. 2016). These findings led to the development of a new grazing management target to maximize pasture intake in all pasture conditions. The target is to achieve 100% horizontal utilisation of the uncontaminated pasture area. Cattle refuse to graze around areas within the pasture sward that have been contaminated with faeces. Consequently, pasture intake declines when the uncontaminated areas of the TLS are heavily depleted across the entire area (horizontal utilisation) of the pasture, and animals are forced to graze the bottom stemmy stratum.

The aim of this study was to investigate if targeting 100% horizontal pasture utilisation is also applicable to dairy systems and to quantify the defoliation dynamics, pasture intake and milk response at increasing levels of grazing pressure. Increasing grazing pressure was achieved by reducing pasture allocation, which forced cows to fully deplete the TLS across the horizontal plane, and graze further down into the bottom stemmy stratum of the sward.

Materials and Methods

The study was undertaken at the University of Queensland, Gatton Research Dairy, Queensland, in November and December 2016. This study was conducted in agreement with the guidelines of the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes (National Health and Medical Research Council 2004) and was approved by the Department of Agriculture and Fisheries Animal Ethics Committee (reference number SA 2016/10/578). Twenty-four multiparous Holstein-Friesian (Bos taurus) lactating dairy cows were randomly allocated to four pasture allocation treatments based on days in milk (166 ± 50), milk yield (27.9 L/cow.day ± 3.6), milk fat concentration (3.68% ± 0.30), milk protein concentration (3.10% ± 0.18), somatic cell count (80000 ± 35000 cells/mL), live weight (610 kg ± 49), body condition score (4.7 ± 0.3; 1-8 scale) and parity (2.5 ± 0.9). The experiment was conducted over a 36-day period, with a 28-day adaptation period and an 8-day measurement period where grazing dynamics, dry matter intake and milk production were recorded. Six cows were randomly allocated to each of the four pasture allocation treatments, with two replicates of three cows per treatment group. The four pasture allocation treatments were 30.6, 20.5, 15.1 and 10.9 kg DM/cow.day respectively. All cows grazed from 0500 to 1230 hours and were then moved to a feedpad with shade as one group until milking time at 1500 hours. All cows returned to the feedpad after milking at 1600 hours, were separated into their treatment groups and offered 11 kg DM/cow.day of a PMR until the next milking at 0400 hours. All cows were offered the same PMR, formulated using the Nittany Cow ration formulation program (USA). Diets were balanced to meet the metabolic requirements of cows producing an average of 25 L/cow.day when combined with the expected nutrient intake from the Lucerne pasture. Daily PMR refusals were removed and weighed to calculate individual daily PMR intake as an average for each group of three cows.

Defoliation dynamics

Defoliation dynamics were defined by calculating the vertical and horizontal utilization of the pasture, using height measurements taken at fixed assessment points (2 x 2m grid pattern) within each paddock. Grazing strata were defined as the vertical section of pasture removed during the biting process of the pasture. The TLS was the vertical section of the pasture that was grazed for the first time. A new
grazing stratum was formed every time the animals re-grazed the same area of pasture, leading to multiple superimposed grazing strata. Therefore, each grazing stratum had a vertical dimension, which was its depth, but also a horizontal dimension, which was its progressive utilization across the area of the paddock. Grazing strata should not be confounded with the four vertical section cuts used to establish the vertical distribution of the pasture mass (see next section). The depth of each grazing stratum was calculated as the difference in pasture height before and after the stratum was grazed. The horizontal dimensions of each grazing stratum were calculated as a proportion of the total number of assessment points within the paddock. Trampled and contaminated points were recorded within each paddock and recorded as ‘ungrazable’ areas. These values were subtracted from the total area allocated to determine the maximum grazable area within each paddock. Time-lapse cameras (GoPro Hero4 Silver®) recorded cattle grazing pastures throughout the entire grazing period at 10 second intervals, and each image was analysed to determine the number of cattle grazing at that instant. Daily average grazing time (min/cow.day) was calculated by dividing the total grazing time from each paddock by the number of cows grazing.

**Pasture structure, intake and quality**

The physical structure, chemical composition and intake of the lucerne pasture were determined using a random, stratified double-sampling method from Benvenutti et al. (2016). Twenty-two pasture samples (ranging in height from 25-75cm) were cut 5 cm above ground level and cut into four equal vertical strata. Within each stratum, dry matter (g) was determined by drying samples in ovens at 60°C, and grazing resistance (kg/cm²) was calculated as the breakpoint force for each tiller multiplied by a given area (Jacobs et al 2013). Sub-samples from within each stratum were analysed using the Cornell Net Carbohydrate and Protein System (CNCPS; 315 Model Profile) to estimate ME (MJ/kgDM), crude protein (% DM) and neutral detergent fibre (% DM) at Dairy One Forage Lab (Ithaca, New York State, United States). Pasture intake rate (kg DMI/hr) was determined as the daily pasture intake (kgDM/cow.day) divided by the daily grazing time.

**Statistical analysis**

Multiple linear regressions were used to develop equations for pasture mass and quality parameters. The backward (step-down) selection method was used, and explanatory variables were removed if $P>0.05$. Statistics were analysed using the GenStat® (18th Edition, VSN International Ltd) software package. Residual pasture height, quality and structure were analysed using one-way analysis of variance (ANOVA) with treatments as fixed effects. Linear and non-linear regressions were used to assess the relationships between the explanatory (X) variable, residual pasture height and the following response (Y) variables: consumed pasture mass, pasture intake, milk yield and area grazed (Y).

**RESULTS AND DISCUSSION**

**Pasture quality and structure**

The lucerne pasture had a typical pasture structure with a TLS and a bottom stemmy stratum. Table 1 outlines that as grazing pressure increased due to lower pasture allocations, animals were forced to graze further down into the sward. As grazing depth increased, the consumed pasture declined in quality and the grazing resistance increased.
Table 1. Residual pasture height, consumed pasture quality and grazing resistance for different pasture allocation treatments

<table>
<thead>
<tr>
<th>Treatment allocations (kgDM/cow.day)</th>
<th>Residual Pasture Height (%)</th>
<th>NDF (% DM)</th>
<th>CP (% DM)</th>
<th>ME (MJ/kgDM)</th>
<th>Grazing Resistance (kg/100cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.6a</td>
<td>69.7a</td>
<td>26.3</td>
<td>30.7</td>
<td>11.1</td>
<td>43.9a</td>
</tr>
<tr>
<td>20.5b</td>
<td>61.1ab</td>
<td>29.8</td>
<td>29.6</td>
<td>10.8</td>
<td>53.8bc</td>
</tr>
<tr>
<td>15.1c</td>
<td>58.2abc</td>
<td>31.0</td>
<td>29.2</td>
<td>10.7</td>
<td>59.4abc</td>
</tr>
<tr>
<td>10.9d</td>
<td>50.7d</td>
<td>34.1</td>
<td>28.2</td>
<td>10.5</td>
<td>72.8d</td>
</tr>
</tbody>
</table>

Means with common superscripts within columns are not significantly different at P<0.05

This is consistent with the results found by Terry and Tilley (1964) and Martiniello et al. (1997) where stem density and grazing resistance increased with depth in lucerne pastures.

Defoliation dynamics

Cows grazed up to four grazing strata (Fig 1b, P<0.05). Lower pasture allocations forced cows to increase grazing pressure, and therefore the number of defined grazing strata increased from three to four. With increasing grazing pressure, the area of pasture grazed for the first time, the top grazing stratum (TGS), increased and approached a high proportion (>80%) of the uncontaminated area before animals regazed an area of the paddock (Fig 1b). This pattern of initiating a new grazing stratum once the horizontal utilisation of the subsequent upper stratum approached a high proportion of the uncontaminated pasture area was consistent for all treatment groups, and similar between all grazing strata. These defoliation patterns are consistent with previous studies by Benvenutti et al. (2016). On average the mass removed in the TGS was 3.1 times greater than all subsequent strata (stratum 2, 3 & 4). Previous studies on vegetative pastures, found that bite depth was approximately 50% of sward height (Laca et al. 1992; Cangiano et al. 2002). However, this fraction was measured to be as deep as 65 to 86% of the pasture height (Benvenutti et al. 2009; Benvenutti et al. 2016). These large differences in TGS depth between studies could be explained by the vertical structure of the plant. Pastures with deep top leafy strata such as ?? resulted in deeper bites (Benvenutti et al. 2009) or a deep TGS (Benvenutti et al. 2016). The presence of tough stems at the bottom of swards have been shown to act as a vertical barrier to defoliation and resulted in shallower bites (Benvenutti et al. 2006). Stems may have acted as a vertical barrier to defoliation for this study with Lucerne, as the grazing resistance of the stems greatly increased from top to bottom of the swards (Table 1).

Grazing time did not differ significantly between treatments (P<0.05), however average daily grazing time declined numerically from 216 to 170 min/cow.day for cows allocated 30.6 to 10.9kgDM/cow.day respectively.
Pasture intake

All treatment groups were allocated at least 10 kg DM pasture/cow.day, however only cows offered at least 28.5 kg DM/ha.day achieved a pasture intake of 10 kg DM/cow.day. Pasture intake declined when grazing pressure increased and the residual pasture height was less than 70% of the initial pasture height (Fig. 1a). This decline in pasture intake is explained by the transition from grazing the TGS, to grazing subsequent strata. Consistently, Benvenutti et al. (2016) found that pasture intake significantly declined at high levels of horizontal utilisation of the TGS. Like Hendricksen and Minson (1980), increasing
stem proportions and grazing resistance may have been the driving force that reduced grazing depth and pasture intake when cows were forced to graze beyond the TGS as shown in Fig. 1. Pasture intake rate also declined significantly (P=0.047) by 0.5 kgDM/cow.hr for every 10 kgDM/cow.day decline in pasture allocation. The changes in the vertical structure of lucerne can increase the difficulties of prehending the tougher lower sections of the pasture, reducing bite mass and intake rate. The more resistant portions of pasture decrease the amount of plant material that can be consumed per hour of grazing time (Stobbs 1973; Pérez-Ramírez et al. 2009) and impose an ingestive constraint to intake rate (Boval et al. 2007). Therefore, pasture intake declined at lower pasture allocations due to both lower intake rates and declining grazing time.

Milk yield

Milk yield had a significant positive linear relationship with residual pasture height (Fig. 1a). PMR intake was not statistically different between treatments (averaging 10.9 kgDM/cow.day), however total dry matter (kgDM) and nutrient intake declined due to the declining pasture intake. Where pasture intake declined below 10 kgDM/cow.day, total dietary energy and nutrients available for digestion, and consequently milk yield declined (Schingoethe 1996; Moran 2005; Fariña et al. 2011).

Conclusion

The amount of pasture removed from the TGS was over 3 times more than all subsequent strata. Pasture intake and milk production began to decline rapidly as the horizontal utilisation of the TGS approached 100% of the uncontaminated area of the paddock. The decline in intake occurred as cows transitioned from grazing the top leafy stratum, to grazing subsequent stemmy strata where pasture removal declined significantly. This point of transition can be visually observed as the PUP approached zero. Increasing the horizontal area of the paddock (higher allocation) increased the volume of the TGS on offer and consequently increased pasture intake. Allocating pastures to achieve 0% PUP could be used as a target to maximise pasture intake and milk yield in high producing dairy herds. Secondary grazing herds or mechanical methods should be used to remove residual pasture to the ideal height for pasture regrowth.

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