The effect of pasture pregrazing herbage mass on methane emissions, ruminal fermentation, and average daily gain of grazing beef heifers

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ABSTRACT: The objective of this study was to determine the effect of pregrazing pasture herbage mass (HM) on CH₄ emissions, ruminal fermentation, and ADG of grazing beef heifers at 2 stages of the grazing season. Thirty Limousin cross heifers were allocated to 1 of 2 target pregrazing HM treatments [a low HM (LHM) or high HM (HHM) treatment] for 126 d in a randomized block design experiment. Pasture herbage and heifer rumen fluid samples were collected, and enteric CH₄ emissions were determined using an SF₆ tracer technique during two 5-d measurement periods [MP; MP 1 (25 to 29 May) and MP 2 (6 to 10 September)]. Both DMI and GE intake (GEI) were measured during MP 2, and ADG of the heifers was measured every 14 d throughout the 126-d grazing period. Mean HM for the LHM and HHM treatments were 1,300 and 2,000 kg DM/ha, respectively, during MP 1 and 2,800 and 3,200 kg DM/ha, respectively, during MP 2. The CP concentration of the offered herbage was greater (P < 0.01) for the LHM treatment during MP 1 and tended (P < 0.1) to be greater for the LHM herbage during MP 2. The NDF concentration of the herbage was found between the HM treatments during MP 1 or 2. There was no effect (P > 0.10) of HM treatment on total CH₄ emissions (g/d) for either MP [mean value across HM treatments of 121 (SED 5.4) g/d during MP 1 and 132 (8.8) g/d during MP 2], but CH₄ emissions (g) per kilogram of ADG were reduced (P < 0.05) from heifers fed the LHM treatment during MP 1 and 2 [mean values for LHM and HHM of 135 and 163 (SED 9.5) g/kg, respectively, during MP 1 and corresponding values of 150 and 194 (9.9) g/kg during MP 2]. Heifers fed the LHM treatment had greater (P < 0.001) ADG throughout the grazing period [mean value across the 126-d grazing period of 0.88 (SEM 0.032) kg/d] than those fed the HHM treatment [corresponding value of 0.73 (0.034)]. For MP 2, CH₄ emissions per kilogram of DMI (g CH₄/kg DMI) and per megajoule of GEI (MJ CH₄/MJ GEI) tended (P ≤ 0.08) to be less for heifers fed the LHM [19.3 (0.08) g/kg and 0.056 (0.0020) MJ/MJ, respectively] than for the HHM (21.1 g/kg and 0.061 MJ/MJ) treatment, and there were no differences (P > 0.10) in DMI or GEI of the heifers between the HM treatments. The results of this study suggest that offering a low pregrazing HM sward will reduce enteric CH₄ emissions relative to ADG throughout the grazing season because of increased ADG.

Key words: average daily gain, beef heifers, dry matter intake, herbage mass, methane emissions

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INTRODUCTION

Agriculture accounts for 0.305 of total green-

house gas (GHG) emissions in Ireland (Environmental Protection Agency, 2012), approximately one-half of which is methane (CH₄) produced during enteric fermentation in ruminants (Duffy et al., 2011). Approximately 0.9 of total agricultural land in Ireland is grassland, and grazed grass is the lowest-cost feed available for ruminant livestock production systems (O’Riordan and O’Kiely, 1996; Finneran et al., 2012). Thus, grass-based enteric CH₄ mitigation strategies will
form a key component in Irish agriculture meeting its GHG reduction targets. Within the predominantly grass-based animal production systems operated in Ireland and many other temperate countries, maintaining a lower pregrazing herbage mass (HM; kg DM/ha) sward may result in greater OM digestibility (OMD) of offered herbage compared with a high HM sward because of less accumulation of stem and dead material and a greater proportion of more digestible leaf in the herbage offered (Holmes et al., 1992; Wims et al., 2010). Such an increase in grass OMD can result in greater DMI by ruminants (Hart et al., 2009), which increases the rate of feed passage through the rumen. Additionally, increased OMD results in less enteric CH$_4$ production per unit of feed digested due to a greater proportion of propionic acid [which is an alternative hydrogen ($H_2$) sink to methanogenesis] in the total rumen VFA produced (Janssen, 2010). Furthermore, maintaining a low HM sward may increase forage DMI, which promotes greater animal performance, such as increased daily BW gain of grazing ruminants (Redmon et al., 1995). Thus, it is feasible that maintaining a lower pregrazing HM sward of generally high digestibility will result in decreased enteric CH$_4$ output and increased ADG of grazing heifers because of greater herbage DMI. Considering this, it is hypothesized that lower pregrazing herbage mass will reduce enteric CH$_4$ emissions from grazing beef heifers. The objective was to determine the effect of pregrazing pasture HM on CH$_4$ emissions, ruminal fermentation, and ADG of beef heifers at 2 stages of the grazing season.

**MATERIALS AND METHODS**

All animal procedures used in this study were conducted under experimental license from the Irish Department of Health and Children in accordance with the Cruelty to Animals Act 1876 and the European Communities (Amendment of Cruelty to Animals Act 1876) Regulations 2002 and 2005. The study was conducted at University College Dublin (UCD) Lyons Research Farm (Newcastle, Co. Dublin, Ireland; 53°17’56”N, 6°32’18”W). The grass pastures used were *Lolium perenne* (L.) dominant permanent grassland swards.

**Treatments and Experimental Design**

The study was conducted as a randomized block design, where the experimental heifers were subjected to 1 of 2 pregrazing HM treatments [a low HM (LHM) or high HM (HHM) treatment]. The heifers were grazed on the experimental paddocks throughout a 126-d grazing period that commenced on May 14 (2008). During this grazing period, sward herbage and rumen fluid samples from the heifers were collected, and enteric CH$_4$ measurements of the heifers were made during 2 separate 5-d measurement periods (MP), defined as MP 1 (May 25 to 29) and MP 2 (September 6 to 10). The LHM and HHM treatments examined were 1,300 and 2,000 kg DM/ha, respectively, during MP 1 and 2,800 and 3,200 kg DM/ha, respectively, during MP 2. In addition, feces samples were taken during MP 2 for the estimation of DMI and GE intake (GEI), and the BW of the heifers was measured every 14 d throughout the grazing period for the determination of ADG.

**Heifers and Grazing Management**

Before the commencement of the study, 30 Limousin cross heifers aged between 14 and 18 mo were blocked on the basis of BW [mean BW of the heifers was 346 (SD = 34) kg] and were randomly allocated to either the LHM or HHM treatment. Before the commencement of the 126-d grazing period, differences in pasture pregrazing HM were produced by altering sward regrowth intervals between grazing periods after an initial grazing of the entire experimental area (2.01 ha) on March 18. Regrowth intervals between grazing periods were subsequently altered appropriately to generate the required differences in HM during both MP and throughout the grazing period. The experimental heifers were turned out to pasture on April 30, 15 d before the beginning of the grazing period, and were allocated fresh herbage on a daily basis at the rate of 8 kg DM-heifer$^{-1}$-d$^{-1}$ using strip grazing. Temporary fencing was erected each day to prevent the heifers returning to the area grazed the previous day. No P or K was applied during the duration of the study. A total of approximately 130 kg N/ha was applied to each HM treatment throughout the experimental period. Fertilizer was applied subsequent to each grazing for both treatments.

**Pregrazing Herbage Mass Determination**

Pasture sward height above 40 mm was monitored daily using a folding pasture plate meter with a steel plate (plate diameter of 355 mm and area density of 3.2 kg/m$^2$; Jenquip, Fielding, New Zealand), and the pregrazing HM (kg DM/ha) of the experimental pastures were subsequently estimated using the linear equation of O’Riordan et al. (1997):

\[
\text{HM(kgDM/ha)} = [242 \times \text{swardheight(cm)}] - 804.
\]

**Sward Herbage Sampling**

Sward herbage samples representative of the herbage grazed by the heifers were taken daily (at 0700 h) at ran-
dom during both MP using Gardena hand shears by cutting 10 strips (0.1 × 0.3 m) of the sward to a height of 40 mm from the grazing horizon. Once collected, herbage samples were stored at -18°C and subsequently thawed at 4°C for 24 h, after which each sample was thoroughly mixed and dried at 55°C to constant weight, to determine DM content. Samples were then milled (Christy and Norris hammer mill; Christy and Norris Process Engineers Ltd., Chelmsford, UK) through a sieve with 1-mm apertures before chemical composition analysis.

**Enteric Methane Measurement**

Daily enteric CH₄ emissions from the heifers were determined using the emissions from ruminants using a calibrated tracer (ERUCT) technique, with sulfur hexafluoride (SF₆) as the tracer gas, as described by Johnson et al. (2007). The equipment was modified for grazing beef cattle as described by Hart et al. (2009). Permeation tubes containing SF₆ were blocked by SF₆ emission rate [mean rate 7.22 (SD = 0.50) mg/d] and randomly allocated to both HM treatments and heifers within HM treatment. Gas expired and eructated by the heifers, in addition to ambient air, was drawn into an evacuated gas collection canister at a rate of 0.5 mL gas/min via passage through stainless steel capillary tubing (50 mm in length, 12.7-μm i.d.; Valco Instruments Co. Inc., Houston, TX), calibrated using a digital flowmeter (Cole-Parmer Instrument Co., Vernon Hills, IL). During each MP, canisters containing gas were removed from heifers at 0800 h daily and replaced with preevacuated canisters, after which the pressure in each removed canister was immediately measured using a Qwik-Connect pressure gauge (Swagelok, Bray, Co. Wicklow, Ireland). Where negative pressure did not occur in a canister, the entire collection apparatus was replaced before the attachment of a preevacuated canister. In addition, 5 pre-evacuated canisters were placed at various locations (around the grazing areas) throughout the MP to determine background concentrations of CH₄ and SF₆. After daily canister change, canisters were positively pressurized with nitrogen (N₂) gas to approximately 1,250 hPa, after which concentrations of CH₄ and SF₆ in the gaseous contents of each canister were determined by gas chromatography using a Varian 3800 gas chromatograph (Varian BC, Middelburg, the Netherlands) as described by Lovett et al. (2003).

**Rumen Fluid Sampling.** On the final day of each MP, rumen fluid samples were taken from each heifer using a FLORA rumen scoop (Guelph, Ontario, Canada). Each sample was then strained through 2 layers of cheesecloth to remove feed particles, after which 10 mL were transferred into vials containing 0.5 mL of a 4 mM HgCl₂ solution and vials containing 0.25 mL of a 0.5 M H₂SO₄ solution for subsequent VFA and ammonia-N (NH₃-N) analysis, respectively. These samples were then frozen at -20°C before analysis.
Herbage Chemical Composition Analyses

The CP concentration of the herbage samples was determined using a Leco FP 528 N analyzer (Leco Instruments UK Ltd., Cheshire, UK) according to the method of Dumas (AOAC, 1990). The NDF [assayed without a heat-stable α-amylase (Ankom Technology, Fairport, NY) or sodium sulfite; expressed inclusive of residual ash] and ADF (expressed inclusive of residual ash) concentrations were determined using the filter bag technique (Ankom, 2006a,b). The ADF analysis was performed sequentially on the residue from the NDF assay. The ADL concentrations were determined on the residue from the ADF assay using the sulfuric acid method (Robertson and Van Soest, 1981). Ash concentration was determined by complete combustion in a muffle furnace at 550°C for 4 h. The GE concentration of the offered herbage was determined by bomb calorimetry (Parr 1281 Bomb Calorimeter, Parr Instrument Company, Moline, IL).

Volatile Fatty Acid and Ammonia-Nitrogen Analyses

The concentrations of individual VFA (acetic, propionic, butyric, and valeric acids) in the rumen fluid of the heifers were determined by gas chromatography (Varian 3800) using a CP-wax 58 capillary column (25 m × 0.53 mm; Varian BC), according to the method of Porter and Murray (2001). The concentrations of NH₃-N in the rumen fluid were determined using the microdiffusion technique of Conway (1957).

Statistical Analysis

Data were checked for normality and homogeneity of variance using histograms, QQ plots, and formal statistical tests as part of the UNIVARIATE procedure (SAS Inst. Inc., Cary, NC). Data that were not normally distributed were transformed by raising the variable to the power of lambda. The appropriate lambda value was obtained by conducting a Box-Cox transformation analysis in the TRANSREG procedure of SAS. The proportion of valeric acid required a transformation and was raised to the power of 0.25. All herbage data were analyzed for each MP separately using a mixed-model ANOVA. The ADL and ash concentrations (g/kg DM) compared with the HHM treatment during both MP. No differences (P > 0.10) in NDF concentration (g/kg DM) between the HHM and the LHM treatments for either MP (Table 1). The CP concentration (g/kg DM) was greater (P < 0.01) for the LHM compared with the HHM treatment herbage during MP 1 and tended (P < 0.1) to be greater for LHM during MP 2. There were no differences (P > 0.10) in NDF concentration (g/kg DM) between the HM treatments for either MP. The ADF concentration (g/kg DM) was greater (P < 0.01) for the HHM herbage during MP 1 but did not differ (P > 0.10) between HM treatments during MP 2. The LHM treatment herbage had greater (P < 0.05) ADL and ash concentrations (g/kg DM) compared with the HHM herbage during both MP. No differences (P > 0.10) in GE concentration (MJ/kg DM) of the herbage were found during either MP.

RESULTS

Herbage Chemical Composition

There was no difference (P > 0.10) in the DM content (g/kg fresh weight) of the herbage between the HHM and the LHM treatments for either MP (Table 1). The CP concentration (g/kg DM) was greater (P < 0.01) for the LHM compared with the HHM treatment herbage during MP 1 and tended (P < 0.1) to be greater for LHM during MP 2. There were no differences (P > 0.10) in NDF concentration (g/kg DM) between the HM treatments for either MP. The ADF concentration (g/kg DM) was greater (P < 0.01) for the HHM herbage during MP 1 but did not differ (P > 0.10) between HM treatments during MP 2. The LHM treatment herbage had greater (P < 0.05) ADL and ash concentrations (g/kg DM) compared with the HHM herbage during both MP. No differences (P > 0.10) in GE concentration (MJ/kg DM) of the herbage were found during either MP.

Methane Emissions, Dry Matter Intake, and Average Daily Gain

Overall, HM treatment had no effect (P > 0.10) on total CH₄ emissions (g/d) of the heifers during either MP (Table 2). However, CH₄ emissions per kilogram of ADG (CH₄/ADG) were decreased (P < 0.05) for heifers fed the LHM treatment during both MP. For MP 2 only, CH₄ output per kilogram of DMI (CH₄/DMI) and the megajoules of CH₄ per megajoule of GEI (CH₄/GEI) tended (P < 0.1) to be less for the heifers fed the LHM vs. the HHM treatment herbage, and there were no differences (P > 0.10) in the herbage DMI or GEI (MJ/d) of the heifers between the HM treatments (Table 3). The overall ADG (kg-heifer⁻¹∙d⁻¹) of the heifers throughout the 126-d grazing period was greater (P < 0.001) for the LHM treatment than for the HHM treatment [a mean ADG of 0.88 (0.032 SEM) kg-heifer⁻¹∙d⁻¹ for heifers on the LHM treatment vs. 0.73 (0.034) kg-heifer⁻¹∙d⁻¹ for those on the HHM treatment].
**Table 1.** The effect of herbage mass (HM) treatment on the chemical composition of the herbage offered during 2 measurement periods (MP)

<table>
<thead>
<tr>
<th>Variables</th>
<th>MP 1 (^1) (n = 5)</th>
<th>MP 2 (^2) (n = 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, g/kg FW</td>
<td>LHM(^3)</td>
<td>HHM(^4)</td>
</tr>
<tr>
<td>CP, g/kg DM</td>
<td>190</td>
<td>212</td>
</tr>
<tr>
<td>NDF, g/kg DM</td>
<td>232</td>
<td>151</td>
</tr>
<tr>
<td>ADF, g/kg DM</td>
<td>480</td>
<td>491</td>
</tr>
<tr>
<td>ADL, g/kg DM</td>
<td>225</td>
<td>237</td>
</tr>
<tr>
<td>Ash, g/kg DM</td>
<td>9.42</td>
<td>7.61</td>
</tr>
<tr>
<td>GE, MJ/kg DM</td>
<td>19.3</td>
<td>19.2</td>
</tr>
</tbody>
</table>

\(^1\)May 25 to 29.
\(^2\)September 6 to 10.
\(^3\)Low HM (1,300 and 2,800 kg DM/ha for MP 1 and 2, respectively).
\(^4\)High HM (2,000 and 3,200 kg DM/ha for MP 1 and 2, respectively).

**Ruminal Fermentation**

The rumen fluid NH\(_3\)-N concentration (mg N/L) tended \((P < 0.1)\) to be greater for heifers fed the HHM vs. the LHM treatment during MP 1 but, conversely, was greater \((P < 0.001)\) for the LHM treatment during MP 2. The total rumen fluid VFA (tVFA) concentration (mM) was greater \((P < 0.01)\) for heifers fed the LHM treatment during MP 1 but greater \((P < 0.05)\) for the HHM treatment during MP 2. For the proportions of individual VFA in the tVFA concentration (mol/mol), acetic and propionic acids were greater and less than \(P < 0.001\), respectively, for heifers fed the LHM vs. the HHM treatment during MP 1. For MP 2, the proportion of acetic acid was greater \((P < 0.05)\) for the HHM treatment, whereas HM treatment had no effect \((P > 0.10)\) on propionic acid. The proportion of butyric acid tended \((P < 0.1)\) to be greater for the HHM treatment during MP 1 and was greater \((P < 0.05)\) for the LHM treatment in MP 2. Herbage mass treatment had no effect \((P > 0.10)\) on the proportion of valeric acid in the tVFA of rumen fluid of the heifers during either MP. The acetic acid to propionic acid ratio (A:P) was greater \((P < 0.001)\) for the LHM treatment in MP 1, with no effect \((P > 0.05)\) of HM treatment on A:P being found during MP 2 (Table 2).

**DISCUSSION**

Sward pregrazing HM is an important factor in efficient use of pasture and provision of grass herbage of sufficiently high nutritional quality for grazing ruminants. In a zero-grazing study, Hart et al. (2009) found that increasing the DM digestibility of perennial ryegrass swards by reducing pregrazing HM reduced daily CH\(_4\) emissions from beef cattle. In the latter study, animals

**Table 2.** The effect of herbage mass (HM) treatment on enteric methane (CH\(_4\)) emissions and ruminal fermentation variables of beef heifers \((n = 15/treatment)\) during 2 measurement periods (MP)

<table>
<thead>
<tr>
<th>Variables</th>
<th>MP 1 (^1)</th>
<th>MP 2 (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH(_4), g/d</td>
<td>LHM(^3)</td>
<td>HHM(^4)</td>
</tr>
<tr>
<td>CH(_4)/ADG, g/kg</td>
<td>120</td>
<td>122</td>
</tr>
<tr>
<td>NH(_3)-N, mg N/L</td>
<td>135</td>
<td>163</td>
</tr>
<tr>
<td>Total VFA, mmol/L</td>
<td>88</td>
<td>106</td>
</tr>
<tr>
<td>VFA proportions, mol/mol total VFA</td>
<td>105</td>
<td>90</td>
</tr>
<tr>
<td>Acetic</td>
<td>0.73</td>
<td>0.71</td>
</tr>
<tr>
<td>Propionic</td>
<td>0.14</td>
<td>0.16</td>
</tr>
<tr>
<td>Butyric</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>Valeric</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>A:P (^7)</td>
<td>5.21</td>
<td>4.42</td>
</tr>
</tbody>
</table>

\(^1\)May 25 to 29.
\(^2\)September 6 to 10.
\(^3\)Low HM (1,300 and 2,800 kg DM/ha for MP 1 and 2, respectively).
\(^4\)High HM (2,000 and 3,200 kg DM/ha for MP 1 and 2, respectively).
\(^5\)CH\(_4\) expressed relative to ADG recorded during the 2-wk period at the end of each MP.
\(^6\)Ammonia-nitrogen.
\(^7\)Acetic acid to propionic acid ratio.
were accommodated indoors and offered freshly cut pasture herbage twice daily. On typical commercial beef farms in Ireland and in many other temperate countries, however, the majority of diets of ruminant animals are perennial ryegrass–predominant herbage grazed at pasture, which is the cheapest feed available for ruminant livestock production systems (Finneran et al., 2012). Thus, considering the importance of grazed grass as a feed for beef cattle, swards differing in pregrazing HM were generated throughout the grazing season, and measurements were made at 2 stages of the grazing season, in this study to determine the effect of pregrazing pasture HM on CH$_4$ emissions, ruminal fermentation, and ADG of grazing beef heifers fed at pasture. The overall HM treatments applied across both MP in this study (range of mean HM across MP of 1,300 to 3,200 kg DM/ha) are the extremes within what would be considered good grazing management for grazing cattle in Ireland. Thus, these considerable differences in the HM treatments applied between the MP means that the effect of pregrazing HM on the aforementioned factors was examined under 2 broadly differing sets of experimental conditions.

**Herbage Chemical Composition**

Overall, the herbage offered during MP 1 was of generally greater nutritional quality than that offered during MP 2, as exemplified by its generally decreased concentrations of cell wall components (the mean NDF, ADF, and ADL concentration values across HM treatments during MP 1 were 0.86, 0.82, and 0.60, respectively, of the corresponding values for MP 2). This outcome most likely reflects a reduced proportion of leaf and a greater accumulation of stems and dead material (Hoogendoorn et al., 1992; Wims et al., 2010), which are typically more highly lignified and of greater fiber concentration than leaf, in the herbage offered during MP 2 because of the greater pregrazing HM treatments applied. Furthermore, the herbage offered during MP 2 was most likely also of a more mature growth stage at harvest than that offered during MP 1 because of the longer regrowth intervals between grazing periods in the strip-grazing system operated. Thus, the aforementioned findings for the fiber and ADL fractions of the offered herbage are also in accord with the increase in the NDF, ADF, and ADL concentrations of perennial ryegrass that occur as it progresses through successive stages of physiological maturity (Čop et al., 2009; King et al., 2012).

Within the individual MP, the finding of greater CP concentration for the LHM herbage during MP 1 and the similar trend during MP 2, which is in agreement with the findings of Wales et al. (1999), McEvoy et al. (2009), and Purcell et al. (2011), most likely reflects a greater proportion of leaf (which is of generally greater CP concentration than the stem in perennial grasses; Mowat et al., 1965) in the total LHM herbage offered. The latter finding is in agreement with the decrease in the CP concentration of perennial ryegrass that usually occurs as it advances in maturity (Čop et al., 2009; King et al., 2012).

In contrast, the lack of differences in NDF concentration between the HM treatments for both MP, which is in accord with the findings of and Owens et al. (2008), Wims et al. (2010), and Purcell et al. (2011), was not congruent with an expected increase in the NDF concentration of the herbage with advancing maturity, as explained above. However, the reduced ADF concentration for the LHM herbage during MP 1 (May) was in line with expectation.

Considering the generally similar hemicellulose (i.e., NDF minus ADF) concentrations in the LHM (255 g/kg DM) and HHM (254 g/kg DM) herbage during MP 1, this decreased ADF concentration for the LHM herbage during MP 1 appears to have been mainly due to a generally reduced cellulose (i.e., ADF minus ADL) concentration for the LHM (mean LHM cellulose concentration of 204 g/kg DM) than the HHM treatment (corresponding value of 222 g/kg DM).

The GE concentration values for the herbage in this study (range of mean values across HM treatments and MP of 18.9 to 19.3 MJ/kg DM) were generally similar to those reported by Hart et al. (2009; range of mean values of 18.2 to 18.3 MJ/kg DM) and Smit et al. (2005; 18.3 to 18.7 MJ/kg DM) for perennial ryegrass, and the finding of no difference in the GE concentrations of the offered herbage between HM treatments during both MP is in agreement with the similar finding reported for measurement 2 of Wims et al. (2010).

**Methane Emissions, ADG, DMI, and GE Intake**

The lack of a difference in total daily CH$_4$ emissions from the heifers between the HM treatments during both MP in this study agrees with the findings for measurement 1 of Wims et al. (2010). This may have been due to the lack of effects of HM treatment on NDF concentration of the offered herbage for both MP, which most likely re-

**Table 3. The effect of herbage mass (HM) treatment on DMI, gross energy intake (GEI), and methane (CH$_4$) emissions of beef heifers (n = 15/treatment) during measurement period 2 (September 6 to 10)**

<table>
<thead>
<tr>
<th>Variables</th>
<th>LHM$^1$</th>
<th>HHM$^2$</th>
<th>SED</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, kg heifer$^{-1}$ day$^{-1}$</td>
<td>6.50</td>
<td>6.44</td>
<td>0.080</td>
<td>0.60</td>
</tr>
<tr>
<td>GEI, MJ heifer$^{-1}$ day$^{-1}$</td>
<td>123</td>
<td>123</td>
<td>1.4</td>
<td>0.82</td>
</tr>
<tr>
<td>CH$_4$/DMI$^3$</td>
<td>19.3</td>
<td>21.1</td>
<td>0.68</td>
<td>0.07</td>
</tr>
<tr>
<td>CH$_4$/GEI$^4$</td>
<td>0.056</td>
<td>0.061</td>
<td>0.0020</td>
<td>0.08</td>
</tr>
</tbody>
</table>

1 Low HM (2,800 kg DM/ha).
2 High HM (3,200 kg DM/ha).
3 Grams CH$_4$ per kilogram DMI.
4 Megajoules CH$_4$ per megajoule GEI.
sulted in similar DMI between the HM treatments (as occurred during MP 2 when DMI was measured) and thus the similar daily CH\(_4\) emissions for both HM treatments. This outcome reflects the close relationship between NDF concentration and forage intake in ruminants (Van Soest, 1965; Waldo, 1986; Arelovich et al., 2008). The apparent relationship between DMI and daily CH\(_4\) emissions in this study is in general agreement with Pinares-Patiño et al. (2007), who found total daily CH\(_4\) emission of heifers to be consistently related to OM intake of pasture forage, and Hart et al. (2009), who found greater daily CH\(_4\) emissions (g/d) from heifers grazing grass swards due to greater DMI.

For MP 2, the lack of an effect of pregrazing HM treatment on the DMI of the heifers is in general agreement with Curran et al. (2010), who found no effect of pregrazing HM (1,600 vs. 2,400 kg DM/ha) on grass DMI of dairy cows from April to October, and Owens et al. (2008), who found no difference in beef steer DMI (kg/d) between perennial ryegrass herbage after 28 (2,727 kg DM/ha) vs. 38 d (3,558 kg DM/ha) of sward regrowth. This absence of an effect of HM treatment on total DMI, in addition to the lack of an effect of HM treatment on the GE concentration of the offered herbage, resulted in the similar total GEI of the heifers for both HM treatments in MP 2. Considering the absence of effects of HM treatment on DMI, GEI, and daily CH\(_4\) emissions of the heifers, the trends for decreased CH\(_4\) emissions for the LHM vs. the HHM treatment during MP 2 when expressed relative to DMI and GEI were unexpected. Despite this, the latter findings are in partial agreement with Wims et al. (2010), who found lower GEI lost as CH\(_4\) (measurements 1 and 2) and lower CH\(_4\) emissions per kilogram DMI (measurement 2) from dairy cows offered a decreased pregrazing HM (1,000 vs. 2,200 kg DM/ha) sward. This tendency toward decreased CH\(_4\)/DMI for the heifers subjected to the LHM treatment despite the similar DMI of the heifers for both HM treatments during MP 2 may reflect the greater ADL concentration of the LHM herbage offered, as the proportion of ADL in total DMI is negatively correlated with daily CH\(_4\) emissions from ruminants (Hindrichsen et al., 2004; Ellis et al., 2007).

Because the total daily CH\(_4\) emissions did not differ between HM treatments for either MP, the reduced CH\(_4\)/ADG for the LHM treatments appears to have been mainly due to the greater ADG for the LHM treatment. However, the reasons for the greater ADG for the heifers on the LHM treatment are unclear.

The greater rumen NH\(_3\)-N concentrations for the heifers on the LHM treatment during MP 2 is in accord with Owens et al. (2008) and most likely reflect the tendency toward a greater CP concentration of the offered herbage, as dietary CP concentration is positively related to rumen NH\(_3\)-N concentrations (Roffler and Satter, 1975; Pritchard and Males, 1985) because of dietary true protein and NPN being metabolized by rumen microbes to ammonia (Bach et al., 2005). Considering this, the finding that the NH\(_3\)-N concentration tended to be greater for HHM during MP 1 despite there being a decreased CP concentration in the herbage was surprising.

**Conclusion**

No difference in total daily CH\(_4\) emissions of the grazing heifers was found between the HM treatments examined in this study for MP 1 or 2 (i.e., during May or September, respectively), most likely reflecting the similar total cell wall concentrations (i.e., NDF concentration) of the offered herbage during both MP. This resulted in similar DMI for both HM treatments during MP 2. However, when expressed relative to ADG (CH\(_4\)/ADG), CH\(_4\) emissions were decreased for the LHM treatment during both MP, reflecting the greater ADG of the heifers on the LHM treatment. During MP 2, CH\(_4\) output relative to DMI (CH\(_4\)/DMI) and GEI (CH\(_4\)/GEI) tended to be less for the LHM treatment, and there was no effect of HM treatment on the DMI or GEI of the heifers. The results of this study suggest that offering a low pregrazing HM sward will reduce enteric CH\(_4\) emissions relative to ADG throughout the grazing season because of increased ADG and may also result in decreased CH\(_4\) emissions relative to DMI and GEI for grazing beef heifers.

**LITERATURE CITED**


