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Grazing intensity and stocking methods on animal production and methane emission by grazing sheep: Implications for integrated crop–livestock system

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ABSTRACT

Among the various sources with a potential negative impact on the environment, methane (CH_4) emissions from livestock origin have been highlighted as important for the agricultural sector. Research to mitigate CH_4 emissions and understand how integrated crop and livestock production systems may contribute to the reduction of greenhouse gases, is essential for the development of public policies for environmental preservation. We hypothesized that combinations of stocking methods and grazing intensities provokes differences in the quantity and quality of herbage ingested, thus altering animal production and CH_4 emissions by the grazing animal. Experiments were carried out in 2011 (Experiment 1) and 2012 (Experiment 2), when the production of pasture and CH_4 emissions from sheep were studied in a system that integrates soybean (*Glycine max.* (L.) Merr.) and maize (*Zea mays* L.) in the summer/autumn, in rotation with Italian ryegrass (*Lolium multiflorum* Lam.) in winter/spring. Two stocking methods (continuous or rotational) and two grazing intensities (herbage allowance: moderate and low, 2.5 and 5 times the potential daily dry matter intake, respectively) in a randomized complete block design with three replicates were studied. Lambs were used in the first experiment, while lactating ewes (all with a single lamb) were used in the second experiment. Average daily gain (ADG) of lambs was greater ($P < 0.05$) in continuous than in rotational stocking, regardless of grazing intensity (150 vs. 89 g day^{-1} and 241 vs. 209 g day^{-1} in Experiments 1 and 2, respectively). Ewe ADG did not differ ($P > 0.05$) between treatments. Live weight gain per hectare (LWGHA) showed the same response in both experiments, with greater LWGHA in moderate grazing intensity ($P < 0.05$). In Experiment 1, the dry matter intake (DMI) was on average 21% greater ($P < 0.05$) for continuous stocking than rotational stocking (1345 g day^{-1} vs. 1075 g day^{-1}, respectively), while in Experiment 2, no differences ($P > 0.05$) between stocking methods and grazing intensities were observed (1673 ± 83 g day^{-1}). The CH_4 emissions per animal did not differ ($P > 0.05$) among treatments in both experiments (22.7 ± 1.0 and 39.9 ± 1.3 g day^{-1}, Experiments 1 and 2, respectively), but when expressed in g CH_4 kg ADG^{-1} emissions were on average 35 and 15% greater (Experiments 1 and 2, respectively) ($P < 0.05$) under rotational than continuous stocking, independent of grazing intensity (171 vs. 263 g CH_4 kg ADG^{-1}

Abbreviations: ADF, acid detergent fiber; ADG, average daily gain; C, carbon; CP, crude protein; DHA, daily herbage accumulation; DM, dry matter; DMI, dry matter intake; EU, experimental unit; FID, flame ionization detector; GC, gas chromatography; GE, gross energy; GEI, gross energy intake; GHG, greenhouse gases; HA, herbage allowance; HM, herbage mass; ICLS, integrated crop–livestock systems; LLS, leaf life span; LW, live weight; LWGHA, live weight gain per hectare; N, nitrogen; NDF, neutral detergent fiber; OM, organic matter; SH, sward height; SR, stocking rate; THP, total herbage production.

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and 171 vs. 202 g CH_4 kg ADG^{-1} in Experiments 1 and 2, respectively). Stocking method was more important than grazing intensity in determining methane production by grazing sheep. Continuous stocking was the most efficient grazing management in reducing methane emissions per unit animal production.

1. Introduction

Agriculture contributes 13.5% of global emissions of greenhouse gases (GHG) (IPCC, 2007). About 50% of CH_4 and 60% N_2O are from anthropogenic sources (Smith et al., 2007), while livestock contributes 18% to global GHG emissions (FAO, 2006). In Brazil, according to data from the Second National Communication to the convention – the United Nations Framework on Climate Change (2010), the agricultural sector is most responsible for emissions of CH_4 (70% in 2005), mainly due to ruminant livestock (63% of total CH_4 emitted in Brazil).

Among the various technologies that are being developed and improved to mitigate GHG emissions, FAO (2010) highlights integrated crop–livestock systems (ICLS) due to a lower input use, adequate protection of soil and water resources, and contribution to increased sequestration of atmospheric C, whilst increasing biodiversity and resilience. In Brazil, farmers have resisted this technology due to uncertainties regarding the impact of animals on soil physical properties and crop yield. However, research results have shown that ICLS can actually improve the physical, chemical and biological properties of the soil (Carvalho et al., 2010) and increase C stocks depending on grazing intensity (Franzluebbers, 2010).

Despite the benefits of ICLS, its actual potential of GHG mitigation and C balance remains unclear. In general, the crop component under no-till is considered a C sequestration phase due to no-till environmental friendly recognized features (Holland, 2004). Concerning the pasture phase, however, there is concern because C balance is highly dependent on grazing management (Carvalho et al., 2010). Depending on the grazing intensity and its spatio-temporal distribution, pasture production (sequestration) and animal production (emissions) can be highly variable. For example, Hammond et al. (2013) reported emission on a daily basis ranging from 12 to 32 g CH_4 $sheep^{-1}$ depending on herbage allowance. According to Phetteplace et al. (2001), intensive grazing can reduce CH_4 emission per unit production by approximately 10%.

Regarding pasture condition, Wims et al. (2010) quantified the effect of herbage mass (1000 kg DM ha^{-1} vs. 2200 kg DM ha^{-1}) at the entry of the animals onto the pasture on the production of CH_4 and found that greater herbage mass increased daily CH_4 emissions per cow (+42 g), per kg of milk produced (+3.5 g) and per kg of herbage intake (+3.1 g). These results suggest that lower herbage mass has greater forage quality with consequent reduction in emission of CH_4, illustrating how grazing management can influence CH_4 emissions.

Consequently, grazing management seems pivotal in determining the final C balance of ICLS. However, there is no reference about how stocking methods could influence CH_4 emissions, and how potential interactions between grazing intensities and stocking method could influence emissions in ICLS.

In this context, this study focused on CH_4 emissions of the pasture cycle in ICLS where Italian ryegrass was rotated with soybean or maize. We hypothesized that combinations of stocking method and grazing intensity provokes a difference in the quantity and quality of herbage ingested, thus altering animal production and CH_4 emissions by the grazing animal. Results would support grazing management aiming to minimize CH_4 emissions in the pasture cycle and maximize the possibility to reach favorable C balance in ICLS.

2. Materials and methods

2.1. Experimental conditions

The experiment was conducted at the Federal University of Rio Grande do Sul (UFRGS), in Eldorado do Sul, Rio Grande do Sul State, Brazil (latitude 30°05′S and longitude 51°39′W and altitude of 46 m), in an area of Italian ryegrass (*Lolium multiflorum* Lam.) pasture. The climate is subtropical humid “Cfa” according to the Köppen classification. The soil at the experimental site was classified as a Typic Paleudult (USDA, 1999) with 15% clay.

The experimental area consisted of an ICLS established in 2003. During the summer/autumn there were two no-till cropping systems: soybean (*Glycine max.* (L.) Merr.) or maize (*Zea mays* L.). After harvesting crops in autumn and during winter, Italian ryegrass established by self-seeding supported by the seed bank of previous rotation years, and animals began the stocking cycle that lasted until the next cropping phase.

The experimental data collected in this study refers to an Italian ryegrass pasture phase of two years: 2011 (Experiment 1) and 2012 (Experiment 2). In both experiments, Italian ryegrass pasture was fertilized with 75 kg N ha^{-1} as urea just after summer crop harvest (Experiment 1: May 25th, 2011 and Experiment 2: June 1st, 2012) and another 75 kg of N ha^{-1} later in the stocking cycle (Experiment 1: September, 2nd, 2011 and Experiment 2: August, 30th, 2012).

The experimental design was a randomized complete block with three replicates (paddocks). The experiment was arranged in a two-level factorial design, with two stocking methods (continuous and rotational) and two grazing intensities for sheep: herbage allowance of 2.5 and 5 times (namely moderate and low, respectively) the potential daily dry matter intake (DMI) according to the NRC (1985).

The experimental area of 3.2 hectares (ha) was divided into 12 paddocks, ranging from 0.23 to 0.31 ha. Each paddock as experimental unit (EU) received three tester-animals (permanent animals that remained throughout the experimental period) and a variable number of animals periodically adjusted to maintain the desired herbage allowance (“put-and-take” method, Mott and Lucas, 1952). The experimental animals in Experiment 1 were Texel × Ile de France growing lambs, with an average age of 11 months and weighing 35 ± 4 kg. In Experiment 2, lactating Texel × Suffolk single-bearing ewes were used, all multiparous and weighting 59 ± 6 kg.

2.2. Sward management and herbage sampling

The leaf life span (LLS) is a criterion associated to pasture use efficiency (how many days – in thermal time – a leaf remains available to grazing before senescing) and was used to determine the interval of each stocking rate adjustment to maintain predefined herbage allowance. This interval corresponds to stocking cycles described below. Data from Pontes et al. (2003) in the same experimental area were used: 500 °C/leaf for the period from June to August, and 410 °C/leaf for the period from September to November. Therefore, the number of days of each stocking cycle was derived as follows: 36, 36, 28 and 22 days in Experiment 1 and 36, 28, 28 and 22 days in Experiment 2 (differences due to different periods of the year). In