353

How grazing management practices affect the livestock productivity in steppe

Zhang ZH*; Rong YP*; Li PZ*; Li Z F*

* College of Grassland Science and Technology, China Agricultural University

Corresponding author: Yuping Rong, rongyuping@cau.edu.cn

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Abstract

Understanding how grazing management practices affect the livestock productivity in steppe is a key issue to the sustainable rangeland. We conducted a grazing experiment in 2022 and 2023 at the steppe of Inner Mongolia. Five grazing managements included light (LGL, 0.38 sheep units·ha^{-1}·yr^{-1}), moderate (MGL, 0.75 sheep units·ha^{-1}·yr^{-1}), and heavy (HGL, 1.06 sheep units·ha^{-1}·yr^{-1}) grazing of lambs, moderate grazing of ewes (MGE, 0.75 sheep units·ha^{-1}·yr^{-1}), and the mixed grazing of both (MIX, 0.75 sheep units·ha^{-1}·yr^{-1}) in a randomized block group design with three replicates. Of these, LGL, MGL and HGL were the grazing intensity treatments, MIX, MGL and MGE were the flock treatments, and the MIX treatment consisted of mix-grazing lambs (MML) and mix-grazing ewes (MME). The results showed that there were significant differences ($P<0.05$) among the daily grazing time (DGT) of lambs with different grazing intensities, and the DGT of lambs under MGL treatment was the shortest. There were significant differences in DGT of sheep with different flocks, where MGL treatment was the highest while MGE was the lowest. Besides, significant differences were found in daily overall dynamic body acceleration (DODBA) of sheep with different flocks, with MME treatment being the highest and MML being the lowest. There were significant differences among daily feed intake (DFI) and average daily gain (ADG) of sheep with different flocks. Among them, DFI was significantly higher in ewes (MGE, MME) than in lambs (MGL, MML), while ADG was significantly lower. The linear mixed models showed that ADG in lambs was mainly positively influenced by DFI under various grazing intensities. Differently, ADG was mainly positively affected by DGT and negatively affected by DODBA under various flocks. In conclusion, different grazing managements had significant effects on sheep productivity and their grazing activities. And the grazing intensity regulated productivity by influencing the feed intake, whereas flock had effects by influencing the activity level. These provide new ideas to guide the grazing management practices in steppe.

Introduction

Understanding how grazing management practices affect grassland livestock productivity is a key issue in achieving sustainable rangeland development. Among these practices, grazing intensity and flock structure are two key guiding parameters that are of great concern to pastoralists in practical production. These parameters regulate grazing patterns and livestock productivity within pastures (Animut et al., 2005; Grace et al., 2019). During grazing, the livestock productivity is closely related to their behavioural characteristics (Portugal et al., 2021; Yu et al., 2024). This is because animals maintain a trade-off between energy expenditure and nutrient intake, specifically balancing their activity levels and feed intake (Charnov, 1976). With the advancement and maturation of animal kinematics and related supporting technologies, overall dynamic body acceleration (ODBA), calculated by triaxial acceleration, has been proposed as a metric to characterise animal energy expenditure (Green et al., 2009; Wilson et

al., 2006). Furthermore, machine learning models built on accelerometer datasets can classify animal behaviour with accuracies exceeding 90% (Yu and Klaassen, 2021). Therefore, to determine whether there were significant differences in the productivity and grazing activity of sheep under different grazing management practices, and to explore the intrinsic relationships between these factors, we conducted the following study using triaxial accelerometers.

Methods

The study was conducted in Xilinhot City, Xilingol League, located in the Inner Mongolia Autonomous Region of China. The experimental site represents a typical steppe ecosystem, predominantly composed of *Stipa krylovii* and *Leymus chinensis*. The experiment was conducted from July to September in both 2022 and 2023, utilising crossbred *Ujimqin* and *Dorper* sheep with comparable body sizes as experimental animals. Five grazing managements included light (LGL, 0.38 sheep units·ha^{-1}·yr^{-1}), moderate (MGL, 0.75 sheep units·ha^{-1}·yr^{-1}), and heavy (HGL, 1.06 sheep units·ha^{-1}·yr^{-1}) grazing of lambs, moderate grazing of ewes (MGE, 0.75 sheep units·ha^{-1}·yr^{-1}), and the mixed grazing of both (MIX, 0.75 sheep units·ha^{-1}·yr^{-1}) in a randomized block group design with three replicates (FIG.1). Of these, LGL, MGL and HGL were the grazing intensity treatments, MIX, MGL and MGE were the flock treatments, and the MIX treatment consisted of mix-grazing lambs (MML) and mix-grazing ewes (MME). For each experimental treatment, six sheep were fitted with Druid NANO collars (Chengdu, China) to record real-time triaxial acceleration data. These data were subsequently used to calculate the daily overall dynamic body acceleration (DODBA) and daily grazing time (DGT) of the sheep. Additionally, five 1 m × 1 m grazing exclusion cages were randomly distributed across each experimental plot to estimate the daily feed intake (DFI) of the sheep using the exclusion cage method. And the sheep were weighed at each mid-month in order to determine their average daily gain (ADG). The experimental design was conducted in accordance with the established ethical guidelines for animal research. All statistical analyses in this study were conducted using R software (version 4.3.0).

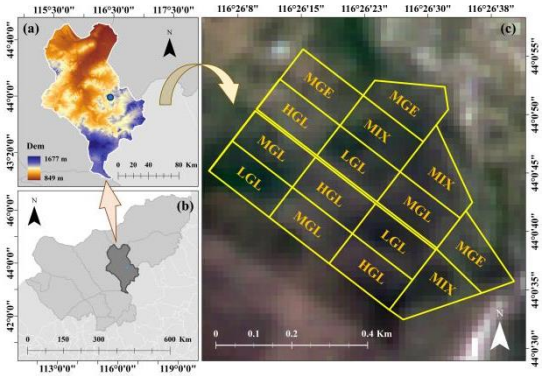

Figure 1 Study area and experimental design. Figure a showed the elevation of Xilinhot and the location of the study area, Figure b showed the location of Xilinhot in the Xilingol League, and Figure c showed the plots arrangement of the experimental design.

Results

DODBA and DGT under different grazing managements

The DODBA of lambs under different grazing intensities showed no significant differences (FIG.2-a). However, DODBA exhibited a significant decreasing trend over the months ($P<0.05$). In contrast, significant differences in DODBA were observed among sheep from different flocks (FIG.2-b; $P<0.001$), with the highest values recorded in the MME treatment and the lowest in the MML treatment. Significant differences were observed in the DGT of lambs across different grazing intensities ($P<0.05$), with the MGL treatment exhibiting the shortest DGT (FIG.2-c). And a significant decreasing trend in DGT was observed over the months ($P<0.05$). Similarly, the DGT of sheep

varied significantly among different flocks (FIG.2-d; P<0.001), with the longest DGT recorded in the MGL treatment and the shortest in the MGE treatment.

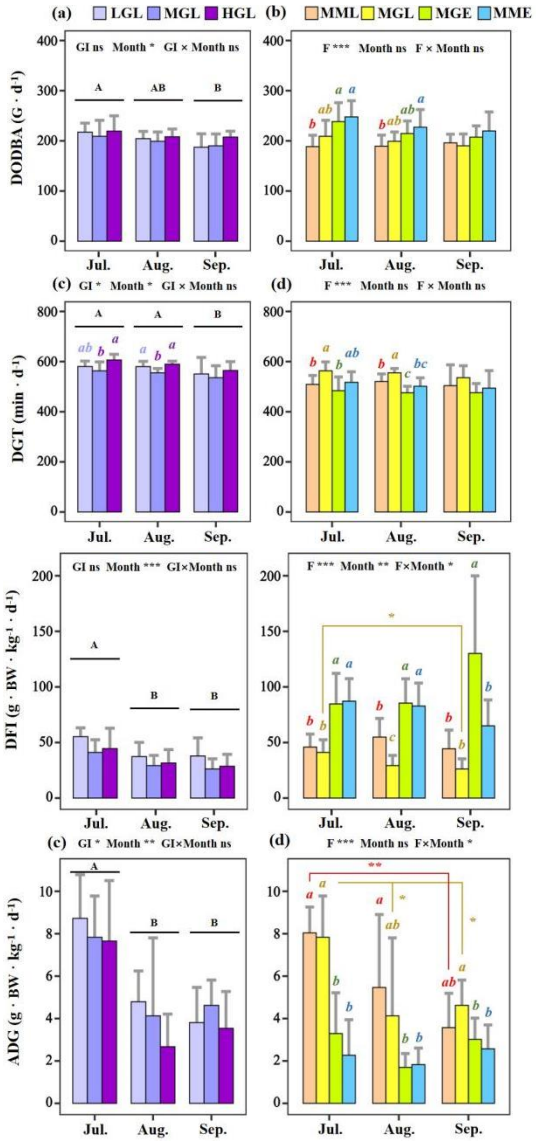

Figure 2 Differences in the sheep grazing activity among various grazing managements. Figures a,b represented the differences in daily overall dynamic body acceleration (DODBA) of sheep under different grazing intensities (GI) and different flocks (F), respectively. Figures c,d represented the differences in daily grazing time (DGT) of sheep under different grazing intensities and different flocks, respectively.

DFI and ADG under different grazing managements

There were no significant differences were detected in the DFI or ADG of lambs under different grazing intensities (FIG.3-a,c). However, both DFI and ADG exhibited a significant decreasing trend over the months (P<0.01). Conversely, significant variations in DFI and ADG were observed among sheep from different flocks (FIG.3-b; P<0.001). Specifically, ewes (MGE, MME) had significantly higher DFI compared to lambs (MGL, MML), while their ADG was significantly lower.

Figure 3 Differences in the sheep productivity among various grazing managements. Figures a,b represented the differences in daily feed intake (DFI) of sheep under different grazing intensities (GI) and different flocks (F), respectively. Figures c,d represented the differences in average daily gain (ADG) of sheep under different grazing intensities and different flocks, respectively.

Relationship between sheep productivity and grazing activity under grazing managements

The generalized linear mixed model revealed that, under varying grazing intensities, the ADG of lambs was predominantly influenced by the positive impact of DFI (Fig.a; P < 0.001). Conversely, within different flocks, ADG was predominantly influenced by the positive effect of DGT (FIG.4-b; P < 0.01) and negatively influenced by DODBA (P < 0.01).

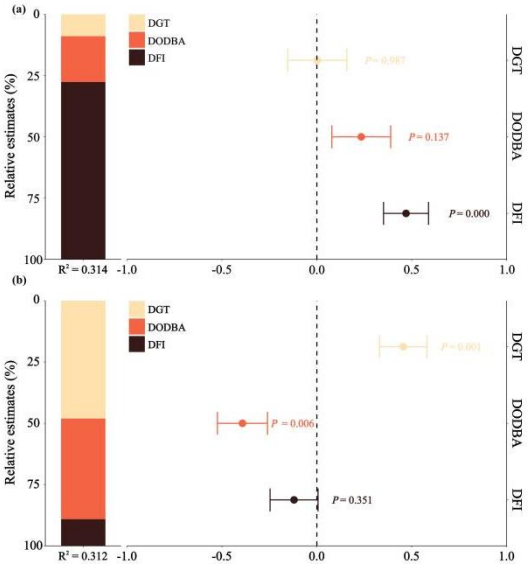

Figure 4 Effect of grazing activity of sheep on their productivity under different grazing managements (GLMM). Figure a showed the effects of grazing behaviors of sheep on their productivity under different grazing intensities, and Figure b showed the effects under different flocks.

Discussion

According to the results of the GLMM, grazing intensity influenced ADG through DFI. However, no significant differences in DFI were observed among lambs under different grazing intensities. This lack of variation could be attributed to the comparable growth stages of lambs across treatments, as factors such as body size and age−which were key determinants of feed intake and weight gain−were similar. Consequently, no significant differences in DODBA or DFI were detected among the treatments, resulting in non-significant differences in ADG (Charnov, 1976). Significant differences in ADG were observed among sheep from different flocks, with ewes displaying significantly lower ADG compared to lambs. Moreover, the DGT in the MGE treatment was significantly shorter than that in the MGL treatment, whereas the DFI of ewes was significantly higher than that of lambs. According to the GLMM, flock influenced ADG through DGT and DODBA. This could be attributed to the similar grazing intensities across treatments, which provided comparable access to pasture resources. Simultaneously, ewes, due to their greater grazing experience, exhibited higher foraging efficiency, spending less time while consuming more feed (Thórhallsdóttir et al., 1990). However, the larger body weight of ewes relative to lambs resulted in higher energy expenditure during grazing, as reflected in the higher DODBA (Mysterud and Austrheim, 2016). Additionally, the presence of ewes and lambs grazing together may have introduced lactation-related behaviors, with lambs benefiting from additional nutrition through nursing (Pullin et al., 2017). The interaction of these factors, in conjunction with the physiological stages, led to the lower ADG in ewes compared to lambs. In conclusion, grazing management significantly influenced sheep productivity and grazing behavior, with grazing intensity affecting productivity through feed intake and flock structure influencing activity levels, offering insights for optimizing steppe grazing practices.

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