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ASSESSING THE PUT & TAKE, FENCING AND TOPPING TECHNIQUES TO CONTROL SWARD STRUCTURE UNDER CONTINUOUS STOCKING

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Porto Alegre

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ASSESSING THE PUT & TAKE, FENCING AND TOPPING TECHNIQUES TO CONTROL SWARD STRUCTURE UNDER CONTINUOUS STOCKING

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ABSTRACT

‘Rotatinuous’ is a grazing management concept based on animal behavioral responses to sward structure, to minimize time and consequently maximize herbage intake per unit of grazing time. The application of this strategy under rotational stocking is already known and is eased by the proposal of the control of the pre- and post- grazing sward heights. On the other hand, the application of the concept under continuous stocking can be a challenge. The objective of this dissertation was to evaluate if management interventions on Italian ryegrass, to offer an ideal sward structure, affect sheep and herbage production under continuous stocking. The experiment was carried out in 2019, in a randomized complete block design with three grazing intervention strategies and three replicates, in southern Brazil. All treatments were managed targeting sward height at 15 cm and also had their stocking rate adjustments by put-and-take technique. On T1 treatment just put-and-take; T2 treatment use of fences to concentrate or exclude animals in under- and overgrazed areas, respectively; T3 treatment use of fences in overgrazed areas and the under-grazed areas were mechanically topped. Twenty-seven castrated lambs with an average live weight of 32 ± 2 kg were used. The actual average sward heights were 14.5, 14.7 and 14.9 cm (*P* = 0.286) for T1, T2 e T3, respectively. Despite the average sward heights that did not differ statistically, the sward height distribution of T1 presented greater heterogeneity (Gini coefficient = 0.273) than T2 (0.227) and T3 (0.248). There were no differences (P > 0.05) for any of the other pasture variables neither animal. In conclusion, our results demonstrated that in the attempt to offer ideal sward structures — using deferment in under-grazed areas and topping or concentration of animals in overgrazed areas — the evaluated techniques just homogeneized sward height distribution, with no detectable benefits to pasture nor animal production. Considering the limits of the experimental spatio and temporal scales, in addition of managing swards at the optimal average sward height, the stocking rate adjustment is enough to maximize animal intake and performance.

Keywords: grazing management; sward height; animal performance; stocking method; heterogeneity; sheep

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AVALIAÇÃO DAS TÉCNICAS DE *PUT & TAKE*, CERCA E ROÇADA PARA CONTROLE DA ESTRUTURA DO PASTO SOB PASTOREIO CONTÍNUO

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RESUMO

O “Rotatínuo” é um conceito de manejo do pasto baseado nas respostas comportamentais dos animais à estrutura do pasto, para minimizar o tempo e consequentemente maximizar o consumo de pastagem por unidade de tempo pastejado. A aplicação desta estratégia sob o pastoreio rotativo já é conhecida e é facilitada pela proposta de controle de alturas de pré e pós-pastejo. Por outro lado, a aplicação deste conceito sob o pastoreio contínuo pode ser um desafio. O objetivo desta dissertação foi avaliar se intervenções, para oferecer estruturas de pasto ideais, afetam a produção vegetal, o consumo e o desempenho de ovinos sob pastagem de azevém em pastoreio contínuo. O experimento foi conduzido em 2019, em um design experimental em blocos completamente casualizados com três estratégias de manipulação do pasto e três repetições, no sul do Brasil. Todos os tratamentos foram manejados com o objetivo de manter o pasto na média de 15 cm de altura e tiveram o seu ajuste de carga pela técnica do *put-and-take*. No tratamento T1 foi utilizado somente *put-and-take*; no tratamento T2 teve uso de cercas para concentrar ou excluir animais de áreas sub ou super pastejadas, respectivamente; no tratamento T3 teve uso de cercas para isolar áreas super pastejadas e de uma roçadeira costal para cortar o pasto nas áreas sub-pastejadas. Vinte e sete cordeiros castrados com peso vivo médio de 32 ± 2 kg foram utilizados. As alturas médias reais do pasto foram 14,5; 14,7 e 14,9 cm (P = 0,286) para T1, T2 e T3, respectivamente. Apesar de não haver diferença estatística significativa para as alturas de pastagem, a distribuição das alturas do T1 apresentou um maior grau de heterogeneidade (coeficiente de Gini = 0,273) do que T2 (0,227) e T3 (0,248). Não houve diferença estatística (P > 0,05) para nenhuma outra variável do pasto. Além disso, o desempenho animal e o consumo de forragem pelos ovinos não diferiram entre os tratamentos (P > 0,05). Em conclusão, nossos resultados demonstram que a tentativa de oferecer estruturas de pasto ideais — utilizando diferimento em áreas sub-pastejadas e roçada ou concentração de animais em áreas super pastejadas — as técnicas avaliadas apenas homogeneizaram as ditribuições de altura do pasto, sem benefícios encontrados para a produção vegetal nem animal. Considerando os limites das escalas espacial e temporal do experimento, juntamente com o manejo do pasto em uma média de altura ótima, o ajuste de lotação é suficiente para maximizar o consumo e a performance animal.

Palavras-chave: manejo de pastagens; altura do pasto; desempenho animal; método de lotação; heterogeneidade; ovinos

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CHAPTER I

1. INTRODUCTION

Animal production in pastoral ecosystems is quite complex since the plant and the animal share the same environment, with animals needing leaves to feed and plants needing these same structures to intercept light and perform photosynthesis. Therefore, severe grazing results in the consumption of a large part of the available forage (Benvenutti et al., 2016; Savian et al., 2021), negatively affecting the regrowth of the pasture and, in addition, the animal is also penalized when it is forced to access the bottom of the sward canopy (Schons et al., 2021)

Thus, one of the goals of grazing management is to achieve sward structural characteristics that result in optimal levels of animal performance (Hodgson, 1990), because commercial grazing systems are remunerated based on animal performance. In this way, the “Rotatinuous” concept has been proposed, where the animal is considered as the main agent to define grazing targets (Carvalho, 2013). It is also an efficient alternative to reduce environmental impacts (Savian et al., 2021) and improve animal and pasture production (Savian et al., 2019, 2018; Schons et al., 2021).

However, the "take the best and leave the rest" principle can be challenging to apply in continuous stocking because there is no direct control of the defoliation interval (Carvalho, 2013), which might lead to repeated impacts on preferred areas while others are less or not even used (Teague et al., 2004). Whereas in rotational stocking we can leave an unfavorable sward structure behind and move to the next strip (Schons et al., 2021).

Despite being used in southern Brazil (Carvalho et al., 2021; Carvalho, 2013), we still lack scientific evidence on how to offer ideal sward structures in continuous stocking under the “Rotatinuous” concept. Which makes us question if just the stocking rate adjustment is enough or if other anthropic interventions, like fencing (Anderson et al., 2014; Odintsov Vaintrub et al., 2020; Turner et al., 1997) and topping (Lambert et al., 2000; Mc Donald, 1986) are needed to facilitate the grazing process.

This dissertation shows the results of this concept applied under continuous stocking by analyzing plant production and animal performance. The results of this study are presented in the second chapter of this document in a scientific article format.

2. LITERATURE REVIEW

Forage produced on well-managed pasture is one of the most sustainable feed sources that can be produced and utilized in the grazing livestock system (Rao et al., 2015; Savian et al., 2021). Yet, grazing is a complex process that varies in time and space and involves animals that need to search, gather, and process herbage (Ungar & Noy-Meir, 1988; Bailey, 1996). Grazing management, the art of guiding the grazing process aiming to feed animals (Allen et al., 2011), emerged only after animal domestication, during the Neolithic period. Since then, men, as a shepherd, determine the choices trajectory, displacement speed, and total trajectory duration, as well as the animal's grazing opportunities.

The barbed wire arising, which was recent (created in 1876), led to distance men from the necessities of deep comprehension of the preferences and behavior dynamics of grazing animals (Carvalho et al., 2019). This distance is not an isolated phenomenon because the disconnection between agriculture and nature is a global process (Gordon et al., 2017). In commercial grazing systems, the same pattern is observed, through grazing managers' practices which promote homogenous sward, multi-paddock grazing, and the overuse of resources to control the grazing process.

So, pastoralism has evolved basically in terms of two grazing methods: rotational and continuous (di Virgilio et al., 2019). Essentially, both of them converge to a variation in the animal distribution in time (e.g., occupation time and rest) and space (e.g., the multi-paddock area in rotational stocking method controlled by the fence) (di Virgilio et al., 2019). The traditional pasture management is static and based on the balance between productivity and dynamics of plants growth and their utilization by the animals by manipulating different variables such as stocking rate, herbage allowance and frequency of defoliation (Carvalho et al., 2009; Pontes-Prates et al., 2020) leading to a management focused mainly on the plant (Schons et al, 2021).

Despite the different propositions of stocking methods, it is defined or justified by controlling the frequency and intensity of the defoliation (Carnevalli et al., 2006; Barbosa et al., 2007), a combination that directly affects the sward structure. As a rule, rotational stocking is capable of defining the space-time allocation of bites through the definition of occupation periods and rest. Yet, continuous stocking has a lower capacity of controlling where and when the defoliation will happen (Carvalho et al., 2009).

In order to try to control sward structures in paddocks continuously stocked, many interventions are used to reach an intensification of commercial grazing systems, which are usually translated into the better usage of forage resources. For example, paddocks are highly subdivided to homogenize the area, which is believed to guarantee uniform grazing (Turner et al., 1997). Also, topping (defoliation by mowing the top stratum of the sward) has been largely used in order to reduce dead matter material and early inflorescences (between the emergence and flowering) to improve pasture quality (McDonald, 1986). Nevertheless, these interventions try to sort out problems created by the management itself, disregarding animal evolutionary knowledge (Carvalho et al., 2019)

Briske et al. (2008) indicate that animal and plant productivity do not differ between continuous and rotational stocking methods in most of the published grazing experiments when under similar stocking rate, but concepts guiding matter the most since bites are a detached event and thus, in any grazing management system it is "rotational" at the plant level. (Pontes-Prates, 2020).

Some studies (e.g., Bergman et al., 2001) suggest that ruminants adopt a minimum grazing time strategy. Harvesting a higher quantity even though this strategy offers them the harvest of a diet with lower nutritional quality (Gordon & Lascano, 1993; Bergman et al., 2001). When it comes to time restriction, some studies suggest that both cattle and sheep prefer forages that can be consumed faster, or a high ingestion per unit of time (Kenny & Black, 1984; Black & Kenny, 1984; Illius & Gordon, 1990; Laca & Demment, 1991; Illius et al., 1992; Demment et al., 1993; Laca et al., 1993; Utsumi et al., 2009).

Allden and Whittaker (1970) state that when the structure is not favorable for bite mass, sheep are able to compensate for the difficulty of prehension by an increase in grazing time (from 6 to 13 hours). From the same point of view, Hodgson (1981) claims that bite rate and grazing time are often considered as the primary compensatory responses of animals to ingestive limitations. However, when the sward conditions diverge from optimal increases, compensation becomes progressively more inefficient as animals have other social activities to perform during the day and their physical conditions are also limiting.

Grazing is a complex combination of various movements and activities performed at different temporal and spatial scales. In Figure 1 it is shown why daily dry matter intake and consequently animal performance are built through bites (Laca & Ortega, 1995; Bailey, 1996). Hence, the major concern in grazing management is to offer an adequate sward structure in order to optimize bite mass, and consequently, intake rate (Carvalho, 2013).

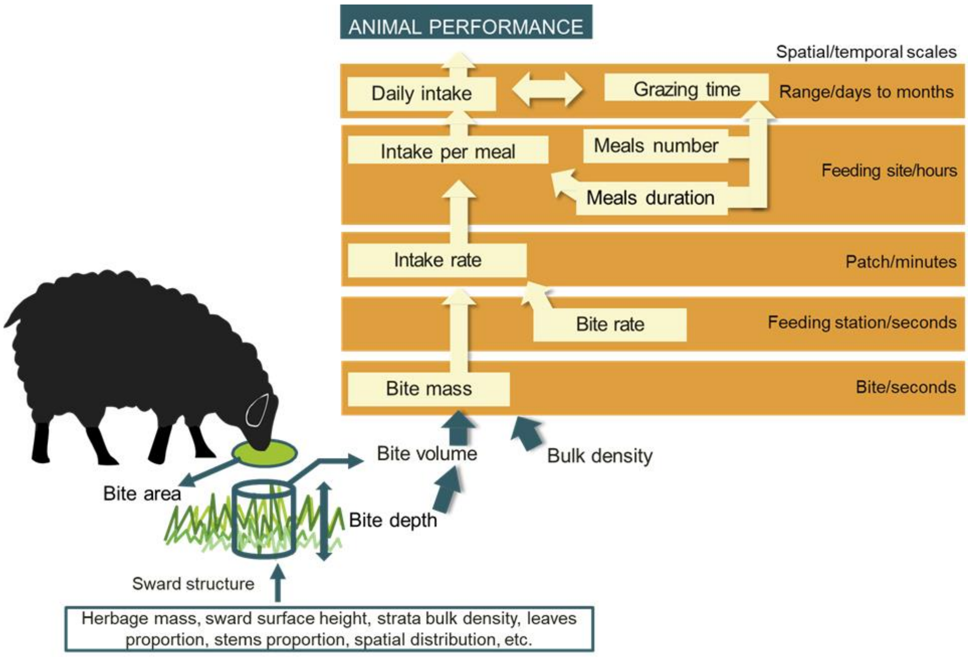

Figure 1 – Spatial and temporal scale of grazing (adapted from Bailey et al. 1996; Bailey e Provenza 2008)

Laca and Lemaire (2000) defined sward structure as the spatial arrangement of morphological components of a plant, in other words, the arrangement of the aerial part of the plants in a plant community. Two types of dry matter distribution can characterize sward structure: vertical and horizontal. In the vertical dimension, the pasture has height, leaf/stem ratio, and distribution of pasture components (blade, stem, and pseudostem) or species in different horizons of the pasture, with the horizons themselves varying in density of plant components or species. In the horizontal dimension, there is variation in tillers density, plant component, and species composition, thus varying in density and mass (Carvalho et al., 2008; Gordon & Benvenutti, 2006).

The variable of sward structure most related to bite mass is sward height (Laca, 1992). Mezzalira et al. (2014) and Gonçalves et al. (2009) observed that the short-term intake rate of cattle and sheep is optimized in sward heights that also optimize bite mass. Bite mass has a quadratic relationship with increasing sward height (Mezzalira et al 2017). It is explained because bite depth has a linear and positive relationship with sward height, but the density increases to a certain point and then decreases by the distribution of more dispersed leaves (Cangiano et al., 2002; Laca et al., 1992).

On the other hand, the lower the sward surface height and the denser the pasture, the less effective is the ability of animals to increase the amount of forage brought to the mouth. Laca et al. (1992) argue that animals obtain heavier bite mass on higher heights and scattered leaves than on dense pastures with lower heights.

Therefore, sward height affects the ingestive behavior of animals (Fonseca et al., 2013).

Carvalho (2013) proposed a pasture management strategy designed to offer to the animals an optimal sward structure to maximize forage intake per unit of grazing time based on the concepts of grazing behavior. This grazing management strategy, which was named "Rotatinuous", is characterized by low intensity and high grazing frequency, which means that animals eat predominantly the top grazing stratum of the sward, almost exclusively composed of leaves. For that, Carvalho (2013) integrated the principles of sward structure (optimal sward height) and animal behavior (short-term intake rate), to create a grazing management strategy that maximizes and maintains the highest forage intake rate.

This grazing management concept with animal-based pasture targets has been already discussed under rotational stocking method (Savian et al., 2018; Savian et al, 2019; Schons, et al., 2021). The ideal pre-grazing height that maximizes the short-term intake rate by animals was investigated for different forage species, such as native grassland (Gonçalves et al., 2009), *Sorghum bicolor* (Fonseca et al., 2012), *Pennisetum glaucun* (Mezzalira et al., 2013), *Lolium multiflorum* (Amaral et al., 2013), *Cynodon* sp. and *Avena strigosa* (Mezzalira et al., 2014) and *Festuca arundinacea* Schreb. (Szymczak et al., 2020).

The same theoretical basis of grazing behavior was used to determine post grazing sward height. In order to remain at a constant intake rate, the average post-grazing height should not be reduced by more than 40% of the pre-grazing height (Fonseca et al., 2013). When animals are forced to graze the bottom canopy strata, significant reductions in forage intake occur (Mezzalira et al., 2014; Fonseca et al., 2013), so, the decline in intake rate is associated with changes in sward structure.

The "Rotatinuous" concept is already applied at the farm level (Carvalho, 2013) under rotational stocking method. Mezzalira (2012) noticed that, at bite level, there is no difference between stocking methods in the definition of optimal structure. Sward height target in continuous stocking is the average between the optimal sward height. However, grazing trials in continuous stocking have not been done yet (Carvalho, 2013). One of its challenges is the spatial control of grazing distribution because animals naturally create patches, preferring and avoiding areas in the paddock (Anderson et al., 2014).

Animals face different spatial heterogeneity of sward height under "Rotatinuous" when compared to traditional rotational method and also to the most common continuous stocking in Brazil. Opportunities for grazing animals to select preferred parts of the plant, such as green leaves, results in greater conversion of forage consumed in kg of animal product (Savian et al, 2021; Schons et al., 2021). Also, when different patches are available, animals can select feeding stations that maximize their nutrients intake.

However, besides adjusting stocking rates, and in order to create a more favorable sward structure for animals, is it necessary to use different tools to offer them? If so, how to offer the structure that maximizes the intake rate under continuous stocking, using stocking rate adjustment, fences and topping to modify sward height distribution, is the main focus of this Dissertation.

3. HYPOTHESIS

The grazing intervention strategies with fencing or topping to offer plants that optimize intake rate do not improve pasture production, herbage intake and performance of sheep managed under continuous stocking because the optimum sward height is already maintained by stocking rate adjustement.

4. OBJECTIVES

To test if interventions to control the sward structure affect/improve pasture production, herbage intake and performance of sheep grazing Italian ryegrass under continuous stocking method oriented by the Rotatinuous concept.

CHAPTER 2

Assessing the put & take, fencing and topping techniques to control sward structure under continuous stocking

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Abstract

Livestock use 2.5 billion ha of land and consume 6 billion tonnes of feed, of which 86% is not eaten by humans. Despite the diversity of production systems, grasslands are the main source of ruminant feeding. Thus, grazing is the pivotal feeding process and grazing management should seek to provide opportunities to obtain better animal performance. These targets are met with the "Rotatinuous" concept, a grazing management strategy based on the responses of animal behavior to sward structures, which means minimizing time costs and consequently maximizing herbage intake per unit of grazing time. However, its application under continuous stocking can be a challenge due to the lower control of animals in the paddock. This work was conducted in 2019, in a randomized complete block design, analyzing the effects of sheep grazing Italian ryegrass (*Lolium multiflorum* Lam.) in continuous stocking with three different grazing interventions strategies targeting sward height at 15 cm. Which were: stocking rate adjustment (Put & Take); use of fences to concentrate animals and mechanical topping to reduce sward heights in undergrazed areas or the use of fences to exclude animals from overgrazed areas. Twenty-seven castrated lambs with an average live weight of 32 ± 2 kg were used. Results indicated that the evaluated techniques just homogeneized sward height distribution and did not improve pasture production neither increased sheep performance, when Italian ryegrass is managed in a range of 12 to 18 cm. Considering experimental limits of spatio and temporal scales, stocking rate adjustment was enough to offer ideal Italian ryegrass sward structures for sheep grazing under continuous stocking.

Keywords: grazing systems, sheep performance, stocking rate adjust, sward structure, Italian ryegrass, resource heterogeneity

Implications

Our results showed that in continuous stocking method, pasture production and sheep performance on Italian ryegrass swards do not improve with manipulations in the sward structure with fencing or mechanical topping. This techniques just homogeneize sward height distribuition on the spatial and temporal scales studied. Also, we confirmed that to achieve high sheep intake and performance, and production per area, Italian ryegrass swards under continuous stocking should be managed at 15 cm, on average.

Introduction

Grazing is a singular process composed of animal and plant, which has been developed and evolved throughout time on grassland ecosystems. Managers try to control and improve this action through the use of interventions over space and time (with fences and rest and occupation periods). Nonetheless, their main goal is to achieve a more efficient use of forage resources, which might have negative results, depending on the limits imposed.

However, our ability to control environmental effects is inefficient due to traditional paradigms and the set of factors selected to manage grazing systems (Laca, 2009). The aim of grazing management should be to provide grazing opportunities with a high rate of herbage intake and at appropriate grazing intensities, in order to obtain better individual performance of the animal.

Thus, the “Rotatinuous” grazing management concept suggests a new approach, using pre- and post-grazing sward heights aiming to allow animals to maximize and sustain their intake rate (Carvalho, 2013). Studies applying this approach have observed an improvement in animal performance and pasture production (Savian et al., 2018; Schons et al., 2021), associated with a reduction in methane emissions (Savian et al., 2019, 2021).

The application of this concept in rotational stocking is eased by the nature of control of entry and exit moment of the animals from the strips. Yet, under continuous stocking, the use of the same concept reaches a new level of challenge. Even though animal control is lesser, the concept does not change and animals may find the ideal structures on their own. Studies suggest the need of manipulating the temporal foraging pattern considering that grazing creates sward heterogeneity due to the selection or avoidance of plants (Rook and Tallowin, 2003). As managers, we may have a stocking control in order to provide patches with an optimum average of sward heights in the paddock for animals to maximize their intake rate.

Despite facilitating grazing management and animal control, just controlling paddock size does not eliminate uneven sward heights because animals seek preferred areas regardless of paddock size (Anderson et al., 2014). This leads us to our main question: Would anthropic intervention ease the grazing process in a continuously stocked paddock? If yes, would this ease provide improvements to herbage intake, animal performance and pasture production?

Thus, our objective was to analyze if the use of interventions to provide grazing opportunities improves herbage intake, animal performance and pasture production. To offer these opportunities, we controlled sward height distribution with stocking adjustment, fencing and topping using sheep grazing Italian ryegrass under continuous stocking method oriented by the "Rotatinuous" concept.

Material and methods

Experimental site

The experiment was conducted at the Experimental Station of the Faculty of Agronomy (EEA) of the Federal University of Rio Grande do Sul (UFRGS), in southern Brazil (30°05"22'S, 51°39"09'W, and 46 m a.s.l.), with a subtropical humid "Cfa" climate according to the Köppen classification. In 2019, the annual mean air temperature was 19.8°C and annual rainfall was 964.8 mm (EEA-UFRGS).

An experimental area of 2.25 ha was divided into nine square-shaped paddocks (experimental units) of 0.25 ha each. The soil of the experimental site was classified as a Typic Paleudult (USDA, 1999), with 17.5% clay, 20% silt and 62.5% sand. Yet, in the 0–20 cm layer, the soil presented a pH of 4.05, SMP index of 6.05, 23.2 mg/dm^3 of available P by Bray method, 105.5 mg/dm^3 of available K by Mehlich 1 extraction method, 22.7 g/kg of OM, 0.60 cmol$_c$/dm^3 of exchangeable Al3$^+$, cation exchange capacity of 3.77 cmolc/dm^3 and 39.5% of base saturation (Schons et al., 2021).

Italian ryegrass (*Lolium multiflorum* Lam.) seeds (36 kg/ha) were broadcasted on May 20th and June 7th, 2019, after conventional soil preparation (plowing and disking). A total of 70 kg of nitrogen in the form of urea were broadcasted equally in two moments, on June 25th and August 30th, 2019.

The experimental stocking season was 95 days, starting on July 25th and finishing on October 28th, 2019.

Experimental design and treatments

A randomized complete block design with three replicates (paddocks) was used to test three grazing intervention strategies, and the slope of the area was used as a blocking criterion. The pasture manipulation treatments were applied under continuous stocking, and the sheep grazed Italian ryegrass swards in a target sward height of 15 cm because it is the average between optimal sward heights for rotational stocking (18 and 12 cm for pre- and post-grazing) as proposed by Amaral et al. (2013) and Carvalho (2013). T1) only put-and-take (Mott and Lucas, 1952), which means that the stocking rate was adjusted weekly to maintain the sward height target of 15 cm; T2) put-and-take plus fence, which means that the stocking rate was adjusted weekly and animals were concentrated in under-grazed areas of the paddock (where the average sward height was above 18 cm) and a grazing deferment with the fence was promoted in over-grazed areas of the paddock (where the average sward height was below 12 cm), both of them for short periods until Italian ryegrass reach 15 cm, on average; and T3) put-and-take plus fence plus topping, which means that the stocking rate was adjusted weekly and pasture of under-grazed area of the paddock was mechanical topping with a string trimmer at 15 cm when it exceeded 18 cm, and over-grazed areas also were fenced for grazing deferment when sward height was below 12 cm. In T2 and T3 treatments, the paddocks were divided into eight virtual quadrants of 312 m² (Figure 1) in order to apply the pasture manipulation treatments (fence or mechanical topping).

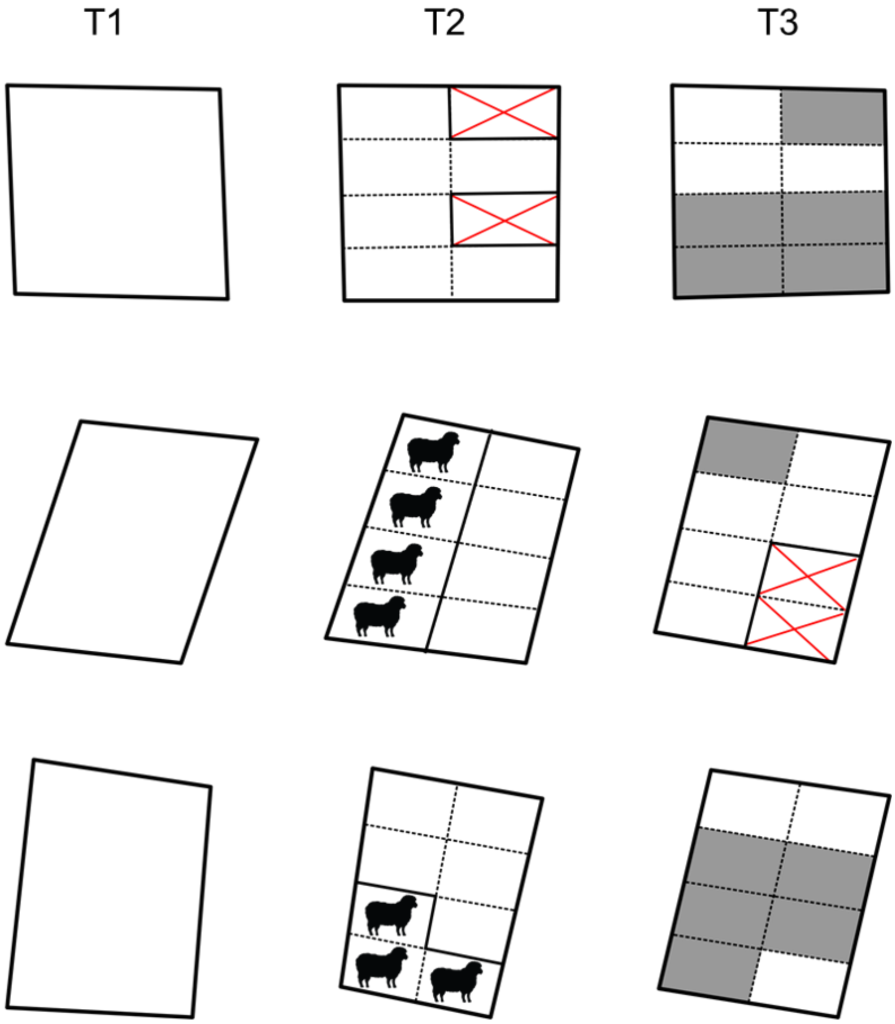

Fig. 1. Illustration of grazing intervention strategies treatments. All treatments had stocking rate adjustments. (T1) Put-and-take treatment uses just animals for regulating average sward height; (T2) Put-and-take plus fence treatment had deferment of overgrazed areas (<12cm) illustrated by the red X and concentration of animals in areas undergrazed (>18cm) illustrated by the sheep; (T3) Put-and-take plus fence plus mechanical topping treatment had areas

deferred when overgrazed (<12 cm) illustrated by the red X and undergrazed areas were topped with a string trimmer (>18 cm) identified by the grey color.

Pasture measurements

The sward height was measured through 280 points per paddock every 15 days using a sward stick (Barthram, 1985) coupled to an RTK-GPS (EMLID REACH RS GNSS RTK) to record spatial distribution of sward height, and to identify over-grazed or sub-grazed areas in the paddock in order to apply the interventions in each paddock. Between the georeferenced measurements, the sward stick without RTK-GPS was used to make 150 undisturbed readings of sward heights per paddock, which means that every week the sward heights in all paddocks were measured.

Herbage mass was determined by clipping five random quadrats (0.25 m^2 each) per paddock at ground level every 21 days. At the end of the stocking season, five random quadrats were clipped in each paddock to measure residual herbage mass.

Five grazing exclusion cages randomly distributed in each paddock were used to estimate daily herbage accumulation rate every 21 days (Klingman et al., 1943). Herbage accumulation rate was obtained by dividing the accumulated herbage by the number of days between cuts. Total herbage production (THP) was calculated as the mean daily herbage accumulation rate along the stocking period, multiplied by the number of days of the stocking season and summed to the herbage mass at the beginning of the experiment.

Italian ryegrass sub-samples were taken to morphological separation. Each sub-sample was manually separated into leaf blades, stem plus sheath, dead material and inflorescences. To know the partial dry matter (DM) of herbage, all herbage samples were dried in a forced-air oven at 55°C for 72 hours until constant weight. The herbage samples were not corrected to DM at 105°C.

Average herbage allowance was calculated according to Sollenberger et al. (2005) [herbage allowance (kg DM/kg LW) = herbage mass (kg DM/ha) / animal LW (kg/ha)]. We used the Gini coefficient as an indicator of the sward height heterogeneity, which is a mathematical measure of inequality that is applied in several fields (Gini, 1921). Gini values quantify the relative inequality height among points of sward heights in a paddock when applied to sward structures.

Sward structure manipulations

The pasture interventions were applied right after the accomplishment of sward height measurements with the RTK-GPS. During the stocking season, georeferenced sward heights were measured on 7 occasions (period).

In the first two weeks of the stocking season, the target sward height was maintained using only the put-and-take method for all treatments. After that, in addition to animal adjustment by put-and-take method, it was necessary to fence 21% and 46% of the overgrazed areas in T2 and T3 treatments, respectively. These areas were evaluated daily with 30 points of sward height to determine the duration of sward manipulations, which varied from 3 to 16 days. From September 9th until the end of the stocking season, we increased the grazing pressure in 46% of the area of T2 treatment. The duration of these manipulations varied from 2 to 7 days. In the T3 treatment, 45% of the surface was topped to 15 cm once on September 20th.

Animal management and measurements

The experimental animals were Corriedale and Texel castrated male lambs with 32 ± 2 kg of LW and an average of 10-month-old. The sheep were separated by breed and LW and allocated randomly in blocks at the beginning of the stocking season. Each paddock had three test-sheep (permanent animals over the whole stocking season). Sheep had free access to freshwater. At the beginning and end of the stocking season, to quantify LW, sheep were fasted for 12 hours.

The stocking rate (kg LW/ha) was obtained by the relationship between the number of animals and the total area of the paddock. Average daily gain (ADG; kg/animal/day) was obtained by the difference of the final and initial LW of the test-sheep divided by the number of days of the stocking season. The LW gain per hectare (LWG, kg/ha) was calculated by the number of animals per hectare multiplied by ADG of test-animals and its result was divided by stocking season duration in days to obtain the daily LW gain per hectare. Feed conversion (kg OM intake/kg LW gain) was calculated by dividing the organic matter intake per sheep per day divided by the ADG.

Estimation of sheep herbage intake

To estimate daily organic matter intake, we used the faecal crude protein technique (Penning, 2004). For that, we used an Italian ryegrass equation proposed by Azevedo et al. (2014) [OM intake (g/sheep per day) = 111.33 + 18.33 × faecal crude protein (g/sheep per day)].

Two daily OM intake measurement periods were performed during the stocking season, each period consisted of total faeces collection during five consecutive days. For that, three test-sheep per paddock were used (n = 54; 3 sheep per paddock, 9 paddocks, and 2 measurement periods). The sheep were equipped with faeces collecting bags (Penning, 2004), which were emptied every morning. The faeces were weighed and homogenized and a sub-sample of 20% of the total was taken. Then, these faecal samples were dried at 55°C for 72 h, grouped per animal, ground with a knife mill (1-mm screen), and analysed for DM, OM and crude protein (N × 6.25) (AOAC, 1975).

Statistical analysis

All response variables were checked for normality by the Shapiro test (*P*>0.05), homogeneity of variance by Bartlett's test (*P*>0.05) and visual residual analysis. When the assumptions of the analysis of variance (ANOVA) were not achieved, the data were $\log_{10}$ transformed.

Data were subjected to ANOVA at a 5% level of significance, using linear mixed-effects models with the LMER function from the *lme4* package in R Studio software version 3.6.1 (R Core Team, 2020). The grazing intervention effect was considered as a fixed effect in the statistical models, and we tested the inclusion of different random effects. Then, to define the best fit model the Akaike's Information Criterion was used. Also, sward height classes were considered fixed effects for sward height frequency as well. The model for sward height frequency, herbage mass and herbage intake that was evaluated in different periods over time includes the effect of paddock nested in each period as random effects to account for a potential lack of independence among repeated observations on the same paddocks over the periods. For average sward height, Gini coefficient, herbage allowance, morphological composition of herbage, random effects were period and block. For the herbage accumulation rate, total herbage production, stocking rate, gain per area, daily gain per area and average daily gain variables the final model included block as a random effect. For the variable forage mass residual, the final model included only paddock as a random effect.

Results

Pasture

Italian ryegrass sward heights did not differ (P = 0.286) between the grazing intervention treatments (Figure 2), with an average of 14.7 ± 0.3 cm during the stocking season, which was in line with the sward height target proposed. Despite the average sward heights that did not differ statistically, when the Gini coefficient was performed the average sward height heterogeneity was different between treatments (P < 0.001). That is, the sward heights distribution of T1 treatment presented greater heterogeneity (0.273) than T2 (0.227) and T3 (0.248) treatments (Figure 2).

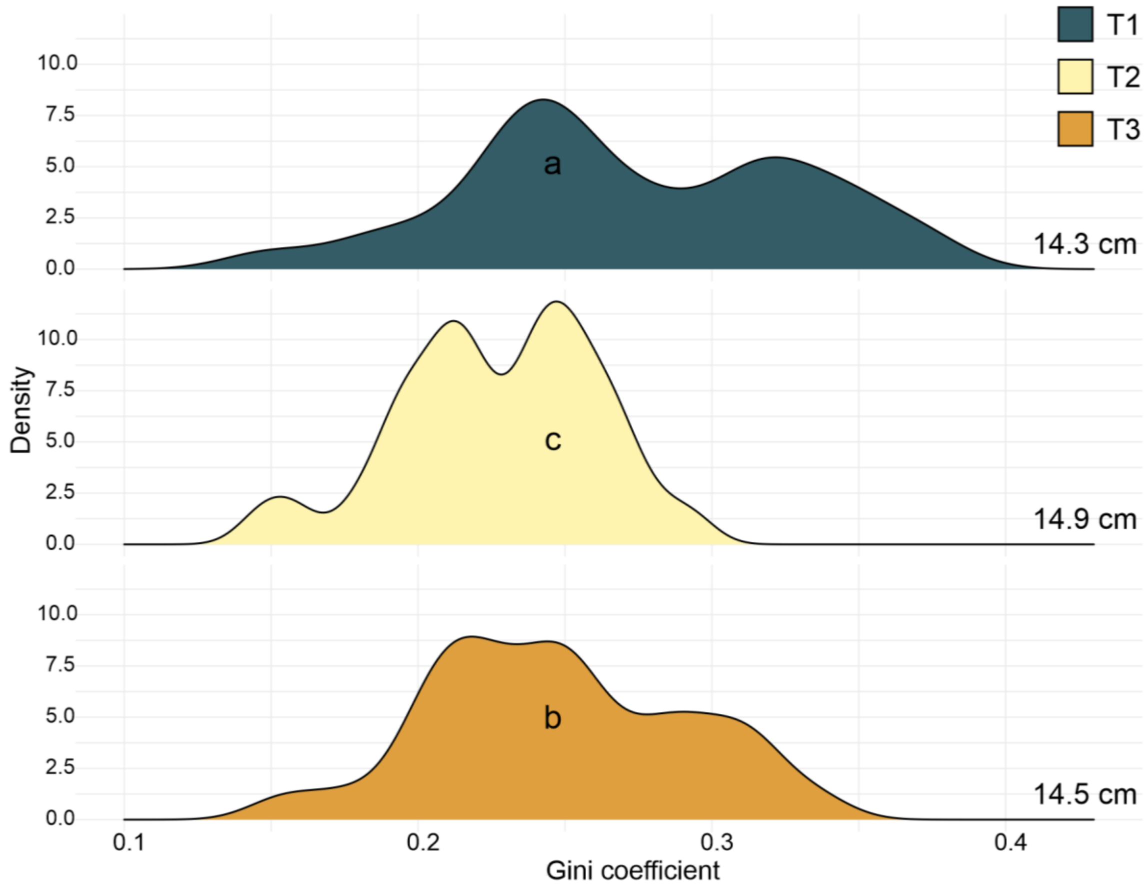

Fig. 2. Gini coefficient density of Italian ryegrass sward height distribution managed under continuous stocking and grazed by sheep under different grazing intervention strategies. (T1) put-and-take treatment uses just animals for regulating average sward height; (T2) put-and-take plus fence treatment had deferment of overgrazed areas (<12cm) and concentration of animals in areas undergrazed (>18cm); (T3) put-and-take plus fence plus mechanical topping treatment areas were also isolated when overgrazed (<12 cm) and were topped at 15 cm with a string trimmer when undergrazed (>18 cm). Mean sward height is plotted to the right of each treatment curve and do not differ (P = 0.286). Different letters differ significantly at 0.05.

The frequency of sward height classes that were below (from 0 to 12 cm), above (> 18 cm), and in the ideal animal intake height range (between 12 and 18 cm) over the entire grazing season are presented in Figure 3. We observed a difference in the sward height classes offered (P < 0.001). On T1 treatment, sward heights in the range 0 to 12 cm represented 42%, which are 9.5% and 16.5% higher than ideal (32.5%) and above (25.5%) classes, respectively. On T2 treatment, the ideal class was 39.7%, which was numerically higher than the below class (33.5%) and significantly higher than the above class (26.8%). Moreover, for T3 treatment, both below and ideal classes were significantly higher than the above class, being 37.8, 36.7 and 25.6%, respectively. However, no differences among treatments were observed for each sward height class offered (*P* > 0.05).

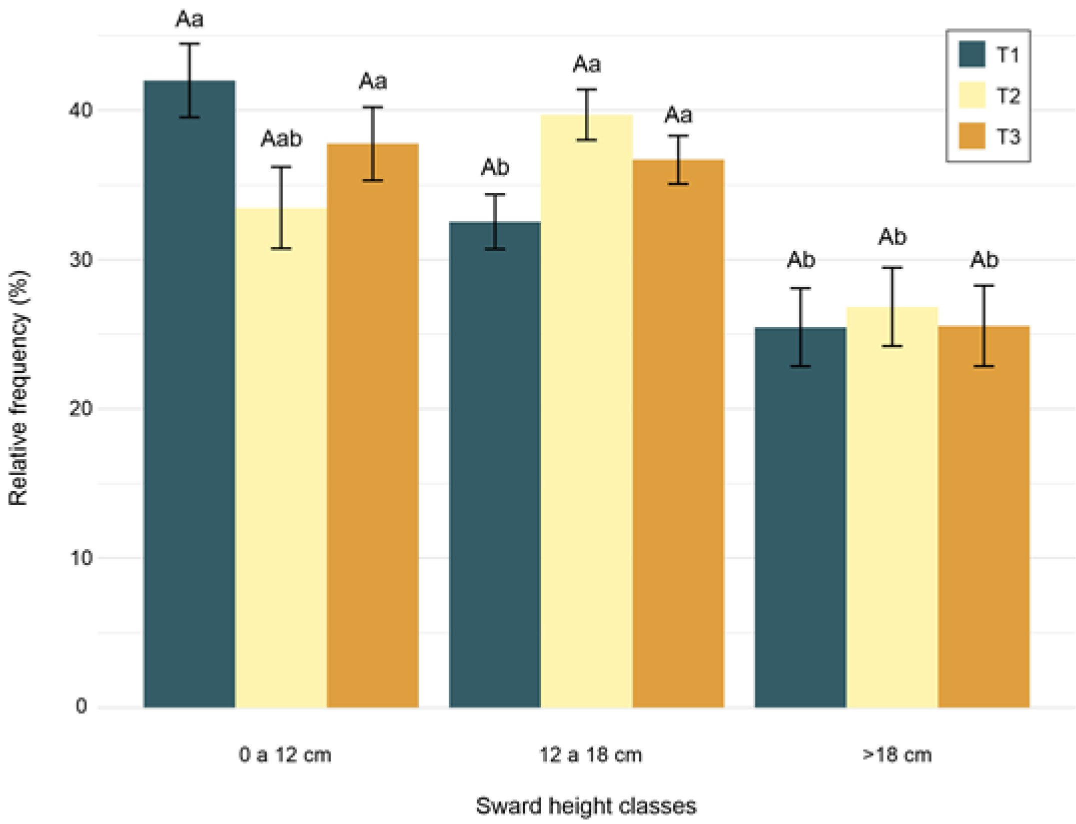

Fig. 3. Frequency of sward height classes of Italian ryegrass swards managed under continuous stocking and grazed by sheep under different grazing intervention strategies. (T1) put-and-take treatment uses just animals for regulating average sward height; (T2) put-and-take plus fence treatment had deferment of overgrazed areas (<12cm) and concentration of

animals in areas undergrazed (>18cm); (T3) put-and-take plus fence plus mechanical topping treatment areas were also isolated when overgrazed (<12 cm) and were topped at 15 cm with a string trimmer when undergrazed (>18 cm). Lowercase letters show the difference of the sward height classes offered within each treatment. Capital letters show the difference between the treatments within each sward height class offered. Different letters differ significantly at 0.05.

Table 1 shows the average value for variables of Italian ryegrass pastures for each treatment. There were no statistical differences (*P* > 0.05) for any of the following variables: herbage accumulation rate (mean 56.1 ± 6.9 kg DM/ha), total herbage production (mean 6765 ± 807 kg DM/ha), herbage allowance (mean 2.8 ± 0.22 kg DM/kg LW), herbage mass (mean 1625 ± 46 kg DM/ha), and residual herbage mass (mean 1503 ± 81 kg DM/ha).

Table 1 - Variables of Italian ryegrass pastures grazed by sheep under different grazing manipulation strategies.

Variables	T1	T2	T3	SEM	*P*-value
Herbage mass (kg DM/ha)	1716	1618	1542	46	0.221
Morphological composition					
Leaf blade (%)	61.8	63.5	63.8	2.85	0.808
Stem+sheath (%)	24.7	21.7	21.0	1.78	0.092
Dead material (%)	11.2	11.1	11.7	1.29	0.981
Inflorescence (%)	2.9	2.3	1.9	0.379	0.398
Leaf blade:Stem+sheath ratio	0.93	1.17	1.22	0.698	0.166
Herbage allowance (kg DM/kg LW)	3.28	2.63	2.55	0.22	0.235
Daily Herbage accumulation rate (kg DM/ha)	62.5	47.6	58.2	6.87	0.527
Total herbage production (kg DM/ha)	7666	6042	6587	807	0.569

Residual herbage mass (kg DM/ha)	1503	1440	1581	81	0.751

T1 = only put-and-take treatment uses just animals for regulating average sward height; T2 = put-and-take plus fence treatment had deferment of over-grazed areas (<12cm) and concentration of animals in areas under-grazed (>18cm); T3 = put-and-take plus fence plus mechanical topping treatment areas were also isolated when over-grazed (<12 cm) and were topped at 15 cm with a string trimmer when under-grazed (>18 cm).

DM = dry matter; LW = live weight; SEM = standard error of the mean.

Animal performance

Table 2 shows the effect of grazing manipulation strategies under continuous stocking on animal performance in each treatment. No differences ($P > 0.05$) between treatments were observed for all variables. The ADG was 0.117 ± kg/sheep, on average. The total LW and daily LW gain per area were, on average, 240 ± 30 kg LW/ha and 2.6 ± 0.3 kg LW/ha/day, respectively. The stocking rate was 728 ± 63 kg LW/ha, on average.

Table 2 - Animal production, intake and feed conversion by sheep grazing Italian ryegrass managed under different grazing manipulation strategies.

Variables	T1	T2	T3	SEM	*P*-value
Average daily gain (kg/sheep)	0.123	0.120	0.108	0.008	0.189
LW gain (kg LW/ha)	255	260	206	30.0	0.4956
Daily LW gain (kg LW/ha)	2.8	2.9	2.3	0.34	0.505
Stocking rate (kg LW/ha)	702	806	676	63.0	0.845
OM intake (g/sheep/day)	901	787	770	26	0.308
OM intake (% LW)	2.25	2.04	1.92	0.1	0.185
OM intake per area (kg OM/ha/day)	16.9	16.2	13.6	1.2	0.460
Feed conversion (kg OM/kg LW gain)	7.6	6.7	7.6	0.4	0.506

T1 = only put-and-take treatment uses just animals for regulating average sward height; T2 = put-and-take plus fence treatment had deferment of over-grazed areas (<12cm) and concentration of animals in areas under-grazed (>18cm); T3 = put-and-take plus fence plus mechanical topping treatment areas were also isolated when over-grazed (<12 cm) and were topped at 15 cm with a string trimmer when under-grazed (>18 cm).

LW = live weight; OM = organic matter; SEM = standard error of the mean.

No difference was observed between the treatments for herbage intake (P = 0.308; mean 819 ± 26 g OM/sheep/day), OM intake expressed as a percentage of LW (P = 0.185; mean 2.07 ± 0.1 %), OM intake per area (P = 0.459; mean 7.3 ± 0.4 kg OM/ha/day), and feed conversion (P = 0.506; mean 7.3 ± 0.4 kg OM/kg LW gain).

Discussion

Our study showed that managing under continuous stocking at moderate defoliation intensity (e.g., range of 12 and 18 cm throughout the stocking cycle) offers a high proportion of green leaf to the grazing animal, and intervention with fences or mechanical topping (in order to offer ideal sward structures) does not improve their herbage intake and performance, neither affects herbage production. Hence, in Italian ryegrass swards managed under continuous stocking, it is conceivable to maintain optimum average sward heights only with stocking rate adjustment, promoting a non-limiting sward heterogeneity for the animals to find out ideal sward heights that support a high herbage intake per unit of time and consequently per day.

The sward height frequency between 12 and 18 cm, which means 1/3 of sward heights offered among treatments (Figure 3), endorse the animals were managed under sward structures that favor high herbage intake per grazing time. Therefore, our main question “How to offer optimal sward structures for grazing lambs in continuous stocking?" has been answered. Overall, all grazing manipulation strategies were efficient in offering ideal sward heights.

Despite the expectation to observe less heterogeneity under the put-and-take plus fence plus topping strategy (T3 treatment), this study showed that, in fact, this grazing manipulation strategy had a higher Gini coefficient than the put-and-take plus fence (T2 treatment) (Figure 2). It might be explained due to the intervention duration difference between T2 and T3 treatments. While on T3 — with mechanical topping — the sward height target (15 cm) was achieved almost instantaneously, on T2 treatment — by grazing down with fence concentration — it was required 2 to 7 days to reach the same goal. It is important to remember that put-and-take intervention was applied to all treatments and that the Gini coefficient difference is a result of fencing and topping.

In addition, a higher Gini coefficient was observed when only stocking rate adjustment (T1) was used. This result makes sense because grazing is the main creator of spatial heterogeneity (Adler et al., 2001), especially when associated with the lower control on the sward height distribution of this treatment. We hypothesized that no differences would be observed on animal and plant production because all treatments aimed to maintain the offer of ideal structures throughout the stocking season. The lack of differences between sward structure variables between treatments (Table 1) confirms our hypothesis and can be explained by the moderate grazing defoliation regime.

Recent studies confirmed that set grazing management goals with moderate defoliation levels promote a canopy with more leaf area and growing points to intercept and use light for herbage accumulation (Lemaire and Chapman, 1996; Silveira et al., 2013; Martins et al. 2019). Our findings suggest that continuous stocking at moderate defoliation intensity produces a high proportion of green leaves. Consequently, a higher proportion of green leaves in the grazed horizon may explain the high performance of the animals. According to da Silva et al. (2013), grazing the higher quality leaves frequently results in a better balance among the rate of leaf growth, reduced leaf senescence, and amount of leaf removal by the animals.

In the same way, the sward variables were consistent with previous findings by other authors (Savian et al., 2018; Schons et al., 2021) that found similar herbage mass and morphological components managing sward heights of Italian ryegrass under rotational stocking under “Rotatinuous” grazing concept. Herbage allowance ranged between 3.2 and 2.5 among treatments which are in agreement with the findings of Schons et al. (2021).

Similarly, animal results (Table 2) are in agreement with those reported on the literature, studies using Italian ryegrass swards managed under continuous stocking at an average of 15 cm, which means moderate grazing intensity, offered the opportunity to improve herbage production while favoring animal ADG and LWG/ha (Farias et al., 2020; Planisich et al., 2021). Also, Schons et al. (2021) found similar ADG values (0.119 kg sheep/day) to sheep grazing Italian ryegrass under rotational stocking and under the “Rotatinuous” concept.

Although there was no difference for OM herbage intake, T1 treatment was 14,54% and 12,65% higher than T3 and T2 treatments, respectively. It might have happened due to the higher heterogeneity of sward height distributions on T1 treatment. In paddocks continuously grazed with no interventions other than stocking adjustment, animals modify sward spatial distributions and maintain patches throughout the grazing season (Cid and Brizuela, 1998). It happens as a result of animal behavior (e.g., resting areas) and because grazing is a discrete process in space and time (Laca, 2009). Also, spatial heterogeneity of sward height benefits instantaneous intake rate, allowing animals to select a better diet than the average available (Pontes-Prates et al., 2020). Anthropic interventions (fence and topping) are usually used to seek homogeneity of sward structures in a paddock (Turner et al., 1997) and to induce growth and nutritional quality (Kolver et al., 1999; Mc Donald, 1986). Those practices are very labor-intensive and probably more expensive. Then, appropriate grazing management strategies by themselves result in a more practical and probably cheaper alternative for producers.

In this study, the main objective was to provide grazing opportunities through different forms of controlling sward height distributions by the “Rotatinuous” concept guidelines. Our results reinforce the importance of keeping proper management. Once a non-limiting situation for grazing behavior is set, the selection of the stocking method becomes secondary (Briske et al., 2008). Ergo, we have different pathways to achieve the same result. From this point on we should consider management parameters (e.g., costs, familiarity, goals and farm strategies) not animal performance, herbage intake nor pasture production.

Considering the experimental spatio-temporal scales, grazing intervention strategies used in this experiment (fence and topping) homogeneized the sward height distribution but did not improve any of the pasture and animal variables analyzed. Maybe in an longer stocking season and in a larger area, these interventions could impact positively since they were managed in an optimal sward height. When it comes to grazing management, humans control only spatio-temporal aspects at paddock level and we often do it poorly because our focus is to intensify the management with supplies. This tells us that we should learn from animals, not teach them (Carvalho, 2005). This study is important to give a step forward to comprehend animal and sward heterogeneity interface and how to offer an ideal sward height in continuous stocking under the “Rotatinuous” concept.

Ethics approval

All animal handling and care attended the guidelines of the law of procedure for the scientific use of animals and were approved by the Ethics Committee for the Use of Animals of the UFRGS (protocol 3571).

Declaration of interest

None.

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CHAPTER 3

FINAL CONSIDERATIONS

Stocking adjustment, fencing and mechanical topping are common interventions used by managers aiming to have a better herbage nutritive value and homogenize sward structure distributions. These actions might ease the grazing management and can help offer good sward structure to be grazed by animals. However, depending on the limits imposed they can reduce the selective behavior of animals, reducing the productive potential of the field.

In this dissertation, we hypothesized that by offering an ideal sward structure for sheep grazing Italian ryegrass in continuous stocking under the “Rotatinuous” concept, no differences would be observed for pasture production, herbage intake and sheep performance because animals are able to graze in an ideal sward height distribution (range of 12 and 18 cm), regardless the use of intervention such as fencing and mechanical topping.

Finally, in order to achieve high sheep herbage intake and performance, and production per area, we recommend that Italian ryegrass swards under continuous stoking should be managed at 15 cm, on average.

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APPENDICES

Single appendix - Rules to elaborate and submit a manuscript for Animal Journal

animal

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Last updated 24 July 2020

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[a]*Department of Animal Nutrition, Scottish Agricultural College, West Main Road, Edinburgh EH9 3JG, UK*

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[1] Kilkenny C, Browne WJ, Cuthill IC, Emerson M and Altman DG 2010. Improving bioscience research reporting: The ARRIVE guidelines for reporting animal research. PLoS Biology 8, e1000412. doi: 10.1371/journal.pbio.1000412.
[2] Lang T and Altman D 2013. Basic statistical reporting for articles published in clinical medical journals: the SAMPL guidelines. In Science editors' handbook (ed. Smart P, Maisonneuve H and Polderman A), pp. 175-182. European Association of Science Editors, Exeter, UK. This document may be reprinted without charge but must include the original citation.

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- In general, no more than 3 references can be given for the same statement (except for reviews and meta-analyses).
- The list of references used in a meta-analysis should be presented in Supplementary materials.

Tables

> *Tables should be explicit while concise and should not include details on materials and methods in the captions or footnotes. The reporting of statistical results complies with simple basic rules.*

- Tables are recommended when exact numerical values are important or may be re-used later in meta-analysis. The same material should not be presented in tabular or graphical form.

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- The animal species and the experimental treatments (or the issue) under study are indicated in each caption.
- When data are analysed by analysis of variance *animal* requests that a residual error term such as the pooled standard error, the residual standard deviation (RSD), or the root mean square error (RMSE) is reported in tables and not SE/SD for each treatment. Indeed, anovas are based on the hypothesis of homogeneous variance among treatment groups.
- Probabilities are given as numerical values and not as "NS" when considered not significant.
- The number of decimals of *P* values for means and/or the error term should be homogenized or should follow a systematic rule.
- The number of "decimal places" is different from the number of "significant figures". This is especially important when reporting coefficients in equations. In the equation $Y=a+bX+cX^2$, the number of meaningful decimal places depends on the value of X.

Figures

> *Figures should be explicit while concise and should not include details on materials and methods in the captions or footnotes.*

- Figures are recommended to illustrate trends. The same material should not be presented in tabular or graphical form.
- The animal species and the experimental treatments (or the issue) under study are indicated in each caption.

Complying with Image Integrity and Standards

Image Integrity and Standards

> *Any image produced by an instrument (e.g. scanner, microscopy) with the objective of being used to derive quantitative results is considered as original data. Manuscripts that report images without any quantitative findings are not acceptable. Digitalisation of an image converts the image into numerical values that can be analysed like any other numerical values. The full information may prove important beyond what the author would like to show. Hence images submitted with a manuscript should be minimally processed; some image processing is acceptable (and may be unavoidable), but the final image must accurately represent the original data and exclude any misinterpretation of the information present in the original image. If original data are used just to illustrate a point, this should be accompanied by a clear statement in the manuscript telling the reader this and explaining what is being demonstrated. Please refer to the Office of Research Integrity guidelines on image processing in scientific publication.*

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linear adjustments (e.g., changes to gamma settings) must be disclosed in the figure legend.

For further information, image examples, and more detailed guidance, we advise reading What's in a picture? The temptation of image manipulation (reprinted in the *Journal of Cell Biology* (2004) 166, 11-15).

- If a cropped image is included in the main text of a paper (e.g. a few lanes of a gel), display the full original image, including the appropriate controls, the molecular size ladder and/or the scale as relevant, as a single figure in a Supplementary Material file to facilitate peer-review and for subsequent on-line publication.
- The statistical analysis applied to the quantitative data associated with images must clearly define the statistical unit considered (e.g. the animal, the sample).
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Authors can include supplementary material in any type of article. It will be peer-reviewed along with the rest of the manuscript.

- Detailed description of critical methodologies and procedures and results of validation and Quality Assurance should be reported in Supplementary materials if not included in the Material and methods section.
- The main text of the article must stand alone without the supplementary material.
- A link to this on-line supplementary material will be included by the Copy Editor at the proof stage.
- The title of the article, the list of authors, their affiliations and the journal name are included at the top of the Supplementary materials.

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A **style sheet** summarising the below indications is available on our website at https://animal-journal.eu/instructions-and-policies/. We recommend that you use it to insert your text.

General presentation

Manuscript layout

> *Manuscripts should be prepared using a standard word processing programme such as Microsoft Word, and presented in a clear, readable format with easily identified sections and headings.*

- Typed with double-line spacing with wide margins (2.5 cm)
- Lines must be continuously numbered; the pages must also be numbered
- Arial 12 should be used for the text, and Arial 11 for tables and references
- Use of small paragraphs with less than 6 to 8 lines must be avoided
- Footnotes in the main text are to be avoided

Title and headings

> *The format of title and headings is in accordance with instructions in order to clarify the structure of the text.*

- Title – use bold, with an initial capital for the first word only and for words that ordinarily take capitals
- Authors' names – use lower case with initials in capitals (e.g. J. Doe)
- Authors' addresses – use italics
- Headings are left aligned with an initial capital for the first word only, and are not numbered.
- Limit sections to three heading levels – **Heading 1**, ***Heading 2,*** *Heading 3.*
  Examples:
  Material and Methods
  Experimental design
  The experiment was designed as…
  Analytical methods
  Feed analyses
  Feeds were analysed…
  Milk fatty acid composition
  The composition of…

Abbreviations

> *Standard abbreviations (Table 2) are not defined.*

- Define non-standard abbreviations at first appearance in the abstract and in the main text
- Authors should avoid excessive use of non-standard abbreviations. A maximum of 10 is advised
- No non-standard abbreviation in the (short) titles, in (sub)headings or in keywords
- Non-standard abbreviations used in tables and figures must be defined either as footnotes or in the caption
- Do not start a sentence with an abbreviation

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Table 2 Standard abbreviations that do not require definition

Item	Definition
Standard abbreviation	
ACTH	Adrenocorticotropic hormone
ADF	Acid detergent fibre
ADL	Acid detergent lignin
ADP	Adenosine diphosphate
ANOVA	Analysis of variance
ATP	Adenosine triphosphate
BLUP	Best linear unbiased prediction
BW	Body weight
CoA	Coenzyme A
CP	Crude protein
DM	Dry matter
DNA	Deoxyribonucleic acid
ELISA	Enzyme-linked immunosorbent assay
FSH	Follicle-stimulating hormone
GLC	Gas-liquid chromatography
GLM	General Linear Model
HPLC	High performance (pressure) liquid chromatography
IGF	Insulin-like growth factor
IR	Infrared
LH	Luteinising hormone
MS	Mass spectrometry
n	Number of samples
NAD	Nicotinamide adenine dinucleotide
NADP	Nicotinamide adenine dinucleotide phosphate
$NADPH_2$	Reduced nicotinamide adenine dinucleotide phosphate
NDF	Neutral detergent fibre
NIRS	Near infrared stectrophotometry
PAGE	Polyacrylamide gel electrophoresis
PCR	Polymerase chain reaction
PMSG	Pregnant mare serum gonadotropin
RNA	Ribonucleic acid
SDS	Sodium dodecyl sulfate
UV	Ultraviolet
Standard statistical abbreviation	
CV	coefficient of variation
df	degrees of freedom
EMS	expectation of mean square
F	variance ratio
LSD	least significant difference
MS	mean square
P	probability
use ns	$P \leq 0.05$, in tables
use *	$P \leq 0.05$, in tables
use **	$P \leq 0.01$, in tables
use ***	$P \leq 0.001$, in tables
r	simple correlation coefficient
R	multiple correlation coefficient
R^2	coefficient of determination
RSD	residual standard deviation
RMSE	root mean square error
SD	standard deviation
SE	standard error
SED	standard error of difference
SEM	standard error of mean
Sy.x	standard error of estimate
χ^2	chi square

The names of the chemicals do not need to be written in full; chemical symbols are sufficient. Fatty acids are abbreviated using the rule: cis-18:1 for the sum of cis octadecenoic acids. When isomers are described, the double bond positions are identified by numbering from the carboxylic acid end: c9,t11-18:2; iso-15:0. The terms "omega 3" and "omega 6" are discouraged and replaced by "n-3" and "n-6", e.g. 18:3n-3. Trivial names can be used for most known fatty acids (myristic, palmitic, oleic, linoleic, linolenic) and abbreviations in some cases: CLA for conjugated linoleic acids, EPA for eicosapentaenoic acid, DHA for docosahexaenoic acid. Chemical names and trivial names cannot be mixed in a same table.

Presentation of statistical results

In the text and tables, presentation of statistical results follows simple rules.

- Treatment means are reported with meaningful decimals. For guidance, the last digit of a treatment mean corresponds to 1x10 of standard error (e.g., for a standard error of 1.2, the mean values should be reported as 15)
- In the text, the probability of significance is indicated either by the exact level of probability (e.g. $P = 0.07$) or by the following conventional standard abbreviations (which need not be defined): $P < 0.05$, $P < 0.01$ and $P < 0.001$ for significance at these levels.
- In tables, when data are analysed by analysis of variance, a residual error term, is given for each criteria/item/variable/trait in a separate column
- In tables, probabilities are indicated in a separate column. The numerical P values (e.g. $P = 0.07$) are reported. In figures differences can be indicated by *, ** and *** for $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively
- In tables, differences between treatments (or comparison of mean values) are indicated using superscript letters with the following conventional standard: a, b for $P < 0.05$; A, B for $P < 0.01$.

Numbers and units

The format of numbers and units should be consistent.

Numerals

- In the text, use words for numbers zero to nine and numerals for higher numbers. In a series of two or more numbers, use numerals throughout irrespective of their magnitude
- Do not begin sentences with numerals
- For values less than unity, 0 is inserted before the decimal point
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- The multiplication sign between numbers should be a cross (x)
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- Use numerals if a number is followed by a standard unit of measurement (e.g. 100 g, 6 days, 4th week).
- Use numerals for dates, page numbers, class designations, fractions, expressions of time, e.g. 1 January 2007; type 2
- Dates are given with the month written in full and the day in numerals (i.e. 12 January *not* 12th January).
- For time use 24-h clock, e.g. 0905 h, 1320 h

Units of measurement

The International System of Units (SI) should be used. A list of units is found at http://physics.nist.gov/cuu/Units/units.html. Recommendations for conversions and nomenclature appeared in *Proceedings of the Nutrition Society* (1972) 31, 239-247. Some frequently used units that are not in the SI system are accepted: e.g. l for litre, ha for hectare, eV for electron-volt, Ci for curie. Day, week, month and year are not abbreviated. The international unit for energy (energy value of feeds, etc.) is Joule (or kJ or MJ).

- A product of two units should be represented as N·m and a quotient as N/m (e.g. g/kg and not $g.kg^{-1}$).

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- When there are two quotients, represent as: g/kg per day (not g/kg/day).

Concentration or composition

Composition is expressed as mass per unit mass or mass per unit volume. The term *content* should not be used for concentration or proportion.

Style

The style should be consistent.

Capitals

- Initial capitals are used for proper nouns, for adjectives formed from proper names, for generic names and for names of classes, orders and families
- Names of diseases are not normally capitalised

Italics

Use italics for:

- Authors' addresses (see above)
- Subheadings (see above)
- Most foreign words, especially Latin words, e.g. *ad hoc, ad libitum, in situ, inter alia, inter se, in vitro, per se, post mortem, post partum, m. biceps femoris*
  but no italics for c.f., corpus luteum, e.g., etc., i.e., NB, via
- Mathematical unknowns and constants
- Letters used as symbols for genes or alleles e.g. *HbA, Tf D* (but not chromosomes or phenotypes of blood groups, transferrins or haemoglobins, e.g. HbAA, TfDD)

References

It is the author's responsibility to ensure that all references are cited and accurate.

- All sources must be cited in the text using the author-date system and must have an entry in the reference list.
- Names of organisations used as authors (e.g. Agricultural and Food Research Council) should be written in full in the list of references and on first mention in the text. Subsequent mentions may be abbreviated (e.g. AFRC).

In-text citation conventions

Cite references by name(s) of author(s) and year of publication by chronological order.

- For single authors, use Doe (2014) or (Doe, 2014)
- For two authors, use Doe and Smith (2014) or (Doe and Smith, 2014)
- For three or more authors, use Doe et al. (2014) or (Doe et al., 2014)
- When multiple references are cited, rank them preferably by chronological order using commas and semicolons: (Doe, 1999; Smith and Doe, 2001; Doe et al., 2014 and 2015; Wright et al., 2018a and 2018b)

List of references

In the reference list, references should be listed in alphabetical order by authors' names. Their formatting and style should be as detailed below.

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Authors' information and publication year

Author, A., Author, B., Author, C.D., Author, E., Year.

- Include a comma after every family name and in-between different authors' names
- Include a period after every initial
- Commas before and full stops after publication years
- Note that all authors must be listed

Publisher/Conference/University location

Publisher, City, State (2-letter abbreviation) for US places, Country

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- AOCS Press, Champaign, IL, USA
- Cambridge University Press, Cambridge, UK
- International Organization for Standardization, Geneva, Switzerland
- FAO, Rome, Italy
- Louisiana State University, Baton Rouge, LA, USA
- Cambridge University, Cambridge, UK

Journal article

Author(s), Year. Article title. Full Name of the Journal Volume, first-last page numbers.

- Journal names are given in full, not in abbreviated form.
- Issue numbers are not required.

Examples:
- Martin, C., Morgavi, D.P., Doreau, M., 2010. Methane mitigation in ruminants: from microbe to the farm scale. Animal 4, 351-365.
- Berry, D.P., Wall, E., Pryce, J.E., 2014. Genetics and genomics of reproductive performance in dairy and beef cattle. Animal 8 (suppl. 1), 115–121.
- Knowles, T.G., Kestin, S.C., Haslam, S.M., Brown, S.N., Green, L.E., Butterworth, A., Pope, S.J., Pfeiffer, D., Nicol, C.J., 2008. Leg disorders in broiler chickens: prevalence, risk factors and prevention. PLoS ONE 3, e1545.
- Pérez-Enciso, M., Rincón, J.C., Legarra, A., 2015. Sequence- vs. chip-assisted genomic selection: accurate biological information is advised. Genetics Selection Evolution 47, 43. doi:10.1186/s12711-015-0117-5.
- When the article is online but not yet printed, the right format is:
  Zamaratskaia, G., Squires, E.J., 2008. Biochemical, nutritional and genetic effects on boar taint in entire male pigs. Animal, doi:10.1017/S1751731108003674, Published online by Cambridge University Press 17 December 2008.

Book (or official report)

Author(s)/Editor(s)/Institution, Year. Book title, volume number if more than 1, edition if applicable. Publisher's name, City, State (2-letter abbreviation) for US places, Country.

- If a publisher is based in more than one place, use only the first one.
- If multiple publishers are listed, it is acceptable to use only the first one.

Examples:
- Association of Official Analytical Chemists (AOAC), 2004. Official methods of analysis, volume 2, 18th edition. AOAC, Arlington, VA, USA.
- Littell, R.C., Milliken, G.A., Stroup, W.W., Wolfinger, R.D., 1996. SAS system for mixed models. Statistical Analysis Systems Institute Inc., Cary, NC, USA.
- Martin, P., Bateson, P., 2007. Measuring behaviour. Cambridge University Press, Cambridge, UK.

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- National Research Council (NRC), 2012. Nutrient requirements of swine, 11th revised edition. National Academy Press, Washington, DC, USA.
- Statistical Analysis Systems Institute, 2002. SAS user's guide, version 9.00. SAS Institute Inc., Cary, NC, USA.

Book chapter (or part of an official report)

> *Author(s), Year. Chapter title. In Title of book (ed. A Editor and B Editor). Publisher's name, City, State (2-letter abbreviation) for US places, Country, pp. first-last page numbers.*

- If a publisher is based in more than one place, use only the first one.
- If multiple publishers are listed, it is acceptable to use only the first one.

Example:

- Nozière, P., Hoch, T., 2006. Modelling fluxes of volatile fatty acids from rumen to portal blood. In Nutrient digestion and utilization in farm animals (ed. E Kebreab, J Dijkstra, A Bannink, WJJ Gerrits and J France). CABI Publishing, Wallingford, UK, pp. 40–47.

Proceedings (or Conference papers)

> *Author(s), Year. Paper title. Proceedings of the (or Paper presented at the) XXth Conference title, date of the conference, location of the conference, pp. first-last page numbers or poster/article number.*

- Conference dates in the form Day Month Year.
- Note – If proceedings are published in a journal, the article should be formatted as for a journal article. If they have been published as chapters in a book, the article should be formatted as for a chapter in a book.

Examples:

- Bispo, E., Franco, D., Monserrat, L., González, L., Pérez, N., Moreno, T., 2007. Economic considerations of cull dairy cows fattened for a special market. In Proceedings of the 53rd International Congress of Meat Science and Technology, 5-10 August 2007, Beijing, China, pp. 581–582.
- Martuzzi, F., Summer, A., Malacarne, M., Mariani, P., 2001. Main protein fractions and fatty acids composition of mare milk: some nutritional remarks with reference to woman and cow milk. Paper presented at the 52nd Annual Meeting of the European Association for Animal Production, 26-29 August 2001, Budapest, Hungary.

Website

> *Author(s)/Institution, Year. Document/Page title. Retrieved on DD Month YYYY (i.e. accessed date) from http://www.web-page address (URL).*

Example:

- Bryant, P., 1999. Biodiversity and Conservation. Retrieved on 4 October 1999, from http://darwin.bio.uci.edu/~sustain/bio65/Titlpage.htm

Thesis

> *Author, A.B., Year. Thesis title. Type of thesis, University with English name, City, State (2-letter abbreviation) for US places, Country (i.e. location of the University).*

Example:

- Vlaeminck, B., 2006. Milk odd- and branched-chain fatty acids: indicators of rumen digestion for optimisation of dairy cattle feeding. PhD thesis, Ghent University, Ghent, Belgium.

Illustrations

Tables and Figures should be simple. The same material should not be presented in tabular and graphical form.

Tables

- Each table is on a separate page at the end of the main text (one table per page)
- Tables are numbered consecutively using Arabic numbering. They are referred to as Table 1, Table 2, etc., with capital 'T', no italics
- Each table has its own explanatory caption. The caption is sufficient to permit the table to be understood without reference to the text but remains concise. The animal species and the experimental treatments or the issue under study are indicated in each caption.
- Units are clearly stated either in the caption (only if a limited number of units are used), or for each (sub-)item. Standard abbreviations for units are used
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- Single spacing is possible for long tables
- Variables are in rows and treatments in columns
- Separate columns are included to present the basic statistical results: error terms (preferably residual error terms) and exact probabilities
- No vertical lines between columns and no horizontal lines between rows of data
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- Footnotes are referenced using superscript numbers
- Abbreviations used in a table are defined as footnotes (preferred option) or in the caption
- Treatment means are reported with meaningful decimals. For guidance, the last digit corresponds to 1/10 of standard error
- Number of decimals for the indicators of residual variability (e.g. RSD, SEM, RMSE) are either identical to that chosen for mean values or have one more decimal. The choice is consistent in all the tables
- Follow the link to Presentation of statistical results for the presentation of statistical results in tables

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- Abbreviations used in each figure have to be defined in the caption and kept to a minimum
- Figures are numbered consecutively in the text using Arabic numbering. They are referred to as Fig. 1, Fig. 2, etc., with capital 'F', no italics
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- The names and e-mail addresses of at least 3 potential reviewers. Reviewers should have no conflict of interest with the authors or the submission. Authors should nominate *an international spread of reviewers; they* should not nominate reviewers who are their regular collaborators or who work in the same institution or university. The editorial board will use its discretion when selecting reviewers and the suggested reviewers may not be used.
- The names of up to 3 opposed reviewers in case of established conflict of interest
- The confirmation that it is an original contribution approved by all authors, that all permissions to reproduce copyrighted material have been obtained and that any conflict of interest is declared in the 'Declaration of interest' section.

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VITA

Thainá Silva de Freitas, daughter of Pedro Augusto Inácio de Freitas and Débora Santos da Silva, was born on June 27th in 1996, in Porto Alegre/RS. She attended elementary school at E.M.E.F. Aurora Pedroso de Camargo and high school at E.E.E.F.M. Presidente Vargas, in Dourados/MS. In 2014, Thainá started her major in Animal Science at the Federal University of Rio Grande do Sul (UFRGS), in Porto Alegre/RS. During this period, she developed research activities in the Grazing Ecology Research Group lab advised by Prof. Dr Paulo César de Faccio Carvalho. Thainá graduated in Animal Science in April/2019, and in the same month, she started her Master's degree in Animal Science at the Postgraduate Program in Animal Science — UFRGS, also advised by Prof. Dr Paulo César de Faccio Carvalho.