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COMPORTAMENTO INGESTIVO DE CORDEIROS RECÉM DESMAMADOS EM DIFERENTES ESTRUTURAS DO DOSSEL DE CAPIM ARUANA (*Panicum maximum* Jacq.)

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DEDICATÓRIA

DEDICO

A minha família. Aos meus pais,
José Roberto e Rosana, ao meu
irmão André, e ao meu namorado
Anselmo por serem a base de tudo.
Como forma de gratidão e
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COMPORTAMENTO INGESTIVO DE CORDEIROS RECÉM DESMAMADOS EM DIFERENTES ESTRUTURAS DO DOSSEL DE CAPIM ARUANA (*Panicum maximum* Jacq.)

Autor: Joseane Anjos da Silva

Orientador: Cesar Henrique Espírito Candal Poli

RESUMO - A terminação de cordeiros em pastagens tropicais apresenta-se como uma excelente alternativa aos sistemas de produção e sua eficiência está diretamente relacionada ao comportamento ingestivo dos animais, e este às características nutricionais, fisiológicas e estruturais das pastagens. O presente estudo teve como objetivo avaliar o comportamento ingestivo de cordeiros recém desmamados em Capim Aruana (*Panicum maximum* cv. IZ-5) mantido em diferentes alturas do dossel. O trabalho foi realizado em dois anos consecutivos na Estação Experimental Agronômica da Universidade Federal do Rio Grande do Sul (UFRGS). Em cada ano foram utilizados 30 cordeiros "testers" (4-5 meses), distribuídos em 3 tratamentos correspondentes às diferentes médias de altura: Baixo – 25 cm; Médio – 50 cm; Alto – 75 cm. Os animais tinham média de peso inicial de 21 kg, igual em todos os tratamentos ($P = 0.9401$), e devio padrão de 8,4 kg. Foram realizadas 2 avaliações de comportamento ingestivo em cada ano, a cada 28 dias, que consistiu na avaliação das principais atividades dos animais (pastejo, ócio, ruminação e taxa de bocado) a cada 10 min, do nascer ao pôr do sol. Foram estimadas, também, as características produtivas e qualitativas da pastagem. O delineamento utilizado foi em blocos ao acaso, sendo cada ano correspondente a um bloco. A avaliação do comportamento ingestivo demonstrou dois picos de pastejo principais ao longo do dia, no início da manhã e no entardecer. O tempo de pastejo (TP) foi semelhante entre os tratamentos (P = 0,4266). O tratamento Baixo apresentou menor tempo de ruminação (P = 0,0181) e maior taxa de bocado (P = < 0.0001). O peso inicial dos animais e altura da forragem explicaram 62% (R^2 = 0,621) da variação no TP e o peso inicial foi a variável que explicou a maior parte desta variação (48%). Conclui-se que as diferentes alturas do Capim Aruana alteram o comportamento ingestivo de cordeiros recém-desmamados, principalmente para as variáveis de ruminação e taxa de bocado e que o peso dos cordeiros tem importante influência no tempo de pastejo em uma gramínea tropical ereta.

Palavras-chave: Capim Aruana, Decision Tree, peso inicial, taxa de bocado, tempo de pastejo.

INGESTIVE BEHAVIOR OF RECENTLY WEANED LAMBS IN DIFFERENT CANOPY STRUCTURES OF ARUANA GRASS (*Panicum maximum Jacq.*)

Author: Joseane Anjos da Silva

Advisor: Cesar Henrique Espírito Candal Poli

Abstract - The termination of lambs in tropical pastures is an excellent alternative to production systems and its efficiency is directly related to the animals' ingestive behavior, and this to the nutritional, physiological and structural characteristics of the pastures. The present study aimed to evaluate the ingestive behavior of lambs recently weaned at different canopy structure of of Aruana grass (*Panicum maximum* cv. Iz-5). The work was carried out for two consecutive years at the UFRGS Agricultural Experimental Station. Each year, 30 tester lambs (4–5 months old) were used, equally divided into 3 treatments corresponding to different height averages: Short - 25cm; Medium - 50cm; Tall - 75cm. The animals had a mean initial weight of 21 kg, equal in all treatments (P = 0.9401), and a standard deviation of 8.4 kg. Two assessments of ingestive behavior were carried out each year, every 28 days, and consisted of observing and recording the main activities of the animals (grazing, idling and rumination and bit rate) every 10 min, from birth to sunset of the sun. The productive and qualitative characteristics of the pasture were also estimated. The design used was in randomized blocks, each year corresponding to a block. The assessment of ingestive behavior showed two main grazing peaks throughout the day, in the early morning and in the evening Grazing time was similar between treatments (P = 0.4266). The Short treatment had a shorter rumination time (P = 0.0181) and also had a higher bit rate (P = <0.0001). The initial weight of the animals and the height of the forage explained 62% (R^2 = 0.621) of the variation in TP and the initial weight was the variable that explained most of this variation (48%). It is concluded that the different heights of Aruana grass alter the ingestive behavior of recently weaned lambs, mainly for the variables of rumination and bit rate and that the weight of the lambs has an important influence on the grazing time in an upright tropical grass

Keywords: Aruana grass, bite rate, Decision Tree, grazing time, initial body weight.

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LISTA DE ABREVIATURAS E SÍMBOLOS

% - Porcentagem

UFRGS – UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

cm – centimeter / centímetro

DM – dry matter / MS – matéria seca

MM - mineral matter / matéria mineral

CP – crude protein / PB – proteína bruta

EE – ether extract / EE – extrato etéreo

NDF – neutral detergent fiber / FDN – fibra em detergente neutro

ADF – acid detergent fiber / FDA – fibra em detergente ácido

NIAD – insoluble nitrogen in acid detergent / NIDA – nitrogênio insolúvel em detergente ácido

NIND – insoluble nitrogen in neutral detergent / NIDN – nitrogenio insulúvel em detergente neutro

ADL – acid detergent lignin

Kg – kilograms / kilogramas

g – grams / gramas

h – hour / hora

min – minutes / minutos

ha – hectare

GT– grazing time / TP – tempo de pastejo

IT – idling time / TO – tempo de ócio

RT – rumination time / TR – tempo de ruminação

BT– biting rate / TXB – taxa de bocado

SAS – statistic analysis system

JMP – JMP software – SAS

CAPÍTULO I

1. INTRODUÇÃO

O rebanho de ovinos do Brasil em 2019 era de, aproximadamente, 19,7 milhões de cabeças (FAO, 2020), estando os maiores rebanhos ovinos localizados nas regiões Sul e Nordeste. O estado do Rio Grande do Sul possui em torno de 2,8 milhões de cabeças ovinas (RADIOGRAFIA DA AGROPECUÁRIA GAÚCHA, 2020).

No início do século XX, a produção lanífera possuía grande destaque entre as atividades pecuárias no estado do Rio Grande do Sul, e o rebanho ovino gaúcho era majoritariamente composto de raças para produção de lã (SILVA et al., 2013). Com a crise da lã no final da década de 80 e 90, o rebanho laneiro comercial diminui significativamente. Entretanto, o aumento do poder aquisitivo da população, levando a maior demanda por proteínas de origem animal e o abate de animais jovens trouxeram uma nova possibilidade de mercado para a ovinocultura. Esse novo cenário tornou possível o início da reestruturação da ovinocultura no Rio Grande do Sul, com a transição do sistema produtivo laneiro para o sistema de produção de cordeiros para abate (VIANA & SILVEIRA, 2008).

Na produção de carne ovina, o cordeiro é potencialmente a categoria de melhores características da carcaça e, consequentemente, de maior aceitabilidade pelo consumidor (RIBEIRO et al., 2005). Essa categoria apresenta maior eficiência de ganho e qualidade de carcaça, principalmente nos primeiros seis meses de vida e estas características podem ser otimizadas pelo uso de sistemas adequados de terminação (CARVALHO et al., 2007).

A ovinocultura gaúcha é marcada por sazonalidade de produção e, consequentemente de oferta, ocorrendo uma maior oferta de carne ovina nos meses de novembro a janeiro, e menor oferta de maio a julho no Rio Grande do Sul (CANOZZI et al, 2013). Uma alternativa para reduzir esta sazonalidade seria a terminação de animais no período de entressafra (janeiro a abril) utilizando forrageiras tropicais cultivadas. Essas forrageiras apresentam características interessantes para produção, sendo mais adaptadas às adversidades edafoclimáticas e por terem apresentado grande potencial para criação de ovinos na região Sul do Brasil (FARIAS, 2016).

O *Panicum maximum* Jacq. Cv. IZ-5, Capim Aruana, é um excelente exemplo de forrageira tropical, vem chamando a atenção, no Brasil, e tem sido utilizada por muitos produtores devido a sua alta produtividade e por aceitar diversas espécies em pastejo, como ruminantes e equídeos, por ser resistente ao pastejo e de fácil propagação (por semente). Essa forrageira produz em torno de 15 t MS ha^{-1}, apresentaboa cobertura de solo e boa qualidade nutricional, com níveis de PB próximos a 14% e digestibilidade da MS próximo a 60% (FAJARDO et al., 2015; FARIAS, 2016).

Os sistemas de produção baseados em pastagem apresentam uma grande oportunidade no aumento da produção sustentável de ruminantes. Nessa forma de produção, o desempenho produtivo dos animais depende da qualidade e quantidade da forragem colhida durante o pastejo (NEIVA et al. 2005). O comportamento ingestivo de um animal em pastejo pode ser descrito por variáveis que compõem o processo de pastejo. Esse comportamento poderá ser uma resposta entre outros fatores ao tipo de forragem oferecida ao animal. Portanto, a estrutura do pasto é uma característica central e determinante do comportamento ingestivo (CARVALHO et al., 2001).

Para sistemas de produção com pastagens tropicais, os estudos são escassos e os resultados existentes não são conclusivos para que se possa extrapolar para além da espécie e/ou ambiente estudado. Para que um sistema produtivo em que os animais permanecem em pastejo seja eficiente, é importante conhecer as variáveis de alterações no comportamento ingestivo desses animais. Esse conhecimento possibilita definir estratégias adequadas para o manejo do pasto e do animal e proporciona habilidade para interferir de forma positiva nos resultados da produção (NEGRI et al., 2013).

Para a maior eficiência dos sistemas de produção de cordeiros em pastejo, é essencial que se conheça o comportamento ingestivo desses animais, principalmente, por serem uma categoria de alto potencial produtivo e que possui particularidades em relação as demais categorias trabalhadas na ovinocultura. Torna- se fundamental, também, o conhecimento acerca das características nutricionais e fisiológicas das pastagens com as quais se trabalha, a fim de viabilizar e aperfeiçoar esses sistemas de produção que apresentam alto potencial.

Diante de tais informações, a realização deste trabalho possibilita trazer informações altamente relevantes para a produção de animais jovens em pastagens tropicais. Ele permite compreender com mais clareza o comportamento ingestivo dos cordeiros recém-desmamados em diferentes estruturas de uma gramínea tropical. Esse é um trabalho que auxilia a compreensão da relação da estrutura de uma pastagem de porte cespitoso com o comportamento ingestivo de animais de pequeno porte, auxiliando no uso e manejo de forrageiras de elevado crescimento por cordeiros.

2. HIPÓTESES E OBJETIVOS

2.1 Hipóteses

As diferentes estruturas do Capim Aruana (*Panicum maximum*) alteram o comportamento ingestivo de cordeiros recém desmamados.

2.2 General objective

O objetivo deste trabalho é avaliar o comportamento ingestivo de cordeiros em pasto de Capim Aruana (*Panicum maximum* cv. IZ-5) com diferentes estruturas.

2.3 Objetivos específicos

1. Avaliar o tempo de pastejo, tempo de ruminação, tempo de ócio e taxa de bocado de cordeiros recém desmamados em pastagem tropical de gramínea Capim Aruana;

2. Avaliar as características bromatológicas, produtivas e estruturais do capim Aruana em diferentes alturas de manejo;

3. Correlacionar as características estruturais da pastagem com o comportamento ingestivo de cordeiros recém desmamados;

4. Descrever o comportamento ingestivo dos cordeiros em pastagem tropical de gramínea cespitosa;

5. Avaliar, através de uma análise multivariada de "Decision Tree" fatores que mais afetam o comportamento de pastejo de cordeiros em pastagens tropicais de Capim Aruana;

CHAPTER II

Lamb production on Aruana grass (*Panicum maximum*): ingestive behavior and tropical pasture structure. A review.[1]

[1] Subject - Journal of Veterinary Behavior

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Lamb production on Aruana grass (*Panicum maximum)*: ingestive behavior and tropical pasture structure. A review.

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Abstract: Ruminant production on cultivated pasture is a low-cost system. Tropical pasture, such as Aruana grass (*Panicum maximum* Jacq. Cv. IZ-5), in certain regions has proved to be a viable option for sheep production due to its adaptability and productivity characteristics. However, for the viability and efficiency of these systems, it is essential to know about the animals' ingestive behavior and its relationship with pasture structure. Recent research shows that upright tropical pasture managed with sheep should have a leaf area index of approximately 85% solar radiation interception (pre-grazing height of 20 cm) and weaned lambs should not be ≤ 22 kg. We discuss research results of the latest studies focusing sheep production on Aruana grass pasture.

Keywords: grazing, forage, forage height, *Panicum maximum*, ruminant production, ruminants

Introduction

Pastures occupy 40% of the planet's land surface (Sbrissia & Da Silva, 2001) and their production systems present an opportunity for sustainable ruminant production. Ruminant productivity depends on the quality and quantity of forage harvested during grazing (Neiva et al. 2005). During growing seasons that coincide with elevated temperatures and rainfall, pastures represent the primary resource for finishing lambs in tropical and subtropical regions (Tontini et al., 2015).

Panicum maximum cv. IZ-5 (common name: Aruana grass) is a prime example of tropical forage that has been widely used due to its high productivity and for been accepted by different grazers, such as ruminants and equidae.

Aruana grass tolerates grazing and is easily propagated by seeds. This forage produces an average of 15 t DM ha^{-1} year^{-1} with adequate soil coverage. It´s nutritional value for grazing ruminants reaches CP levels close to 14% and DM digestibility close to 60% (Fajardo et al., 2015).

Pasture-based systems present an opportunity to increase sustainable ruminant production. Animal Performance on pastures depends on forage quality and quantity harvested during grazing (Neiva et al. 2005). These drive ruminant grazing behavior and can be described by variables that make up the grazing process. This behavior may be a response, among other factors, to the type of forage offered to the animal. Therefore, the structure of the pasture is a central characteristic to tropical ruminant production and determines ingestive behavior (Carvalho et al., 2001).

In order for a grazing productive system to be efficient, it is important to characterize ingestive behavior of grazing ruminants. This knowledge makes it possible to define appropriate strategies for the management of pasture and animals to foster maximum sustainable production (Negri et al., 2013).

Aruana grass (*Panicum maximum*) and forage structure

In regions with sub-tropical and tropical climates, there is widespread use of species within the genus *Panicum*, which stand out for their high production capacity of forage mass (Tontini et al., 2019). In Brazil, the knowledge of tropical pasture management for sheep and goats is still incipient and the productive indexes obtained are low (Neiva et al., 2005).

Aruana grass (*Panicum maximum* cv. IZ-5) is a cultivar introduced at the Instituto de Zootecnia, animal science research institute from São Paulo State, Brazil, in 1974, using seeds from Africa. In 1989 cv. IZ-5 (common name: Aruana grass) was introduced. Aruana grass was launched as an option for grazing pastures (Gerdes et al., 2005). It has high biomass productivity, acceptability by several grazing species, such as sheep, cattle and horses, resistance to grazing, and ease propagation from seed.

In Brazil, *P. maximum* is one of the most used forage grasses in animal production systems, due to its good adaptation to tropical and subtropical climates as well as high productivity. This forage produces an average of 15 Mg dry matter ha^{-1} year^{-1} and is characterized as a medium-sized plant with spittley clump growth, with good soil coverage, good nutritional quality, CP levels close to 14% and dry matter digestibility close to 60% (Farias., 2016). In more recent studies, higher values were found of CP (14.5 - 15.1%) and digestibility (> 65%) when grazed by sheep (Fajardo et al., 2015; Tontini et al., 2015; Tontini et al., 2019).

Silva et al. (2015) found that Aruana grass managed at a leaf area index that allowed 85% interception of photosynthetically active radiation had less stem and dead forage biomass and higher leaf/stem ratio, compared to a 95% interception. In that same study, when grazed by sheep, authors determined that Aruana grass should be ideally defoliated to a residual leaf area index of 1.0, which in their study was equivalent to a pre grazing height of 20.7 cm. When comparing the productive characteristics and chemical composition of different pastures, Tontini et al. (2019) found that the leaf production of Aruana grass is 30% greater in summer compared to autumn. According to Fajardo et al. (2015), plants in late growing season (March-April) showed larger differences in the proportion of leaves and stems (leaf:stem ratio = 0.6 ± 0.13) than during the previous growing season (January-February) (leaf:stem ratio = 1.2 ± 0.13). Aruana grass produces more inflorescence in autumn and has higher growth rates when the minimum average temperatures are above 25 to 30ºC and the greatest rainfall occurs (Pedreira & Mattos, 1981).

The leaf density within canopy architecture in which a forage is available to animal harvest is known as a forage structure and is ultimately responsible for the nutrients ingested by grazing animals (Carvalho et al., 2001). Forage availability, height, density, and botanical composition provide basic information on how much forage is available, ultimately characterizing pasture forage structure. This structure is an important factor in determining the ease with which forage is ingested by the grazing ruminant (Brâncio et al., 2003).

Forage structure can be described along vertical and horizontal planes. It is essential for understanding the relationships between forage plants and grazing animals because animals perceive it and base forage harvest choices on canopy structure (Palhano et al., 2005). The vertical plane ecompassed variables such as leaf and stem distribution, total volumetric density, morphological components along the canopy profile, leaf:stem ratio, forage mass and height (Cangiano et al., 2002; Da Silva et al., 2008). The horizontal plane can be characterized by the greater or lesser presence of a certain species or different proportions between parts of the plant, by the number and distribution of areas under or overgrazed, or by the proportion and distribution of pasture areas characterized by the presence and absence of clumps of differing sizes (Galli & Cangiano, 1998; Milne, 1991; Da Silva et al. 2008).

Carvalho (1997) demonstrated that pasture heterogeneity influences the quantity and quality of the forage eaten by the animals, determining different levels of animal production for the same forage allowance. However, the animal also affects the structure of a pasture through grazing mechanisms (Carvalho et al., 2001). For Negri et al. (2019), height of the pasture is an essential tool for managing upright tropical grasses. Pasture height in grazing systems equates to the amount of biomass available (Carvalho et al., 2001). According to Carvalho (2004), management height does not only affect the amount of food in the pasture, at a given moment, but also the amount of food that will be produced daily in the pasture. Forage structural characteristics guide management recommendation that maximize pasture forage conversion to animal product. Understanding dynamic pasture structures makes it possible to predict seasonal forage production curves and design management strategies for the production system.

Ingestive behavior and forage structure

Ruminant animal behavior has recently taken on importance due to growing societal demands in relation to animal welfare in addition to pasture management (Carvalho et al., 2005). According to Mezzalira et al. (2011), research has currently focus on the processes involved in the act of animal seeking its food when grazing, as well as the consequences of grazing on the environment. Moreover, the study of ingestive behavior becomes an important tool when characterizing ruminant productivity as driven by diet; adjusting feeding management of the animal can enhance their performance (Cardoso et al., 2006). Finally, knowledge about ingestive behavior brings light tothe relationships that control animal, plant and soil interactions in pastures (De Paula et al., 2010).

Pasture canopy structure is central to determining characteristics that affect growth and competition in plant communities and subsequent ruminant grazing behavior (Carvalho et al., 2001). When in a pasture, the animal must look for and choose its forage available according to different types of structure, which have variable quality and abundance in time and space (O'reagain & Schwartz, 1995). In the case of lamb production systems on pasture, productivity is a function of the animals' ability to harvest nutrients efficiently and effectively. Therefore, the understanding of grazing behavior provides an important tool for improving pasture system productivity and sustainability. Ingestive grazing behavior assumes importance because it has a direct effect on feed intake and, consequently, animal performance (Poli et al., 2009).

The grazing process is both a cause and a consequence of pastoral environment structure. Concomitantly, the resulting pasture structure affects the grazing process, leding toa continuous cycle of cause-effect relationship (Carvalho et al. 2016). This grazing process is considered by Laca & Ortega (1995) as the set of behavioral actions related to the bite taken by the animal in view of the structure of the pasture presented to it, the bite being the "atom of the grazing process grazing." The smallest decision scale of the animal is the bite, which means the action or the act of seizing the forage with the teeth (Gibb, 1996). The grazing time of an animal in the pasture is rarely less than 6 or more than 12 hours (Carvalho et al., 1999[a]). The increase in grazing time as a result of greater selectivity resulting from dispersed, low quality forage increases the diversion of net energy for maintenance which, together with low nutritional quality, results in low animal performance (Carvalho et al., 2005).

Factors influencing ruminant grazing time in pastures include environmental conditions, forage availability and quality of pasture to which animals are subjected (De Paula et al., 2010). According to Hodgson (1990), animals respond more consistently to changes in canopy height than in forage mass. Several studies have shown that height and apparent density are the main determinant characteristics of grazing animal ingestive behavior (Hirata et al., 2010).

Pasture character effect on bite dimensions have been well elucidated for temperate systems. Silveira (2001) concluded that, among the various structural characteristics, pasture height is what most influences a ruminant's decision to bite and has a positive and proportional relationship with the depth of the bite (Hodgson et al., 1994; Carvalho & Moraes, 2005). Small ruminant behavior in temperate climate pastures has been widely characterized (Baumont et al., 2000).

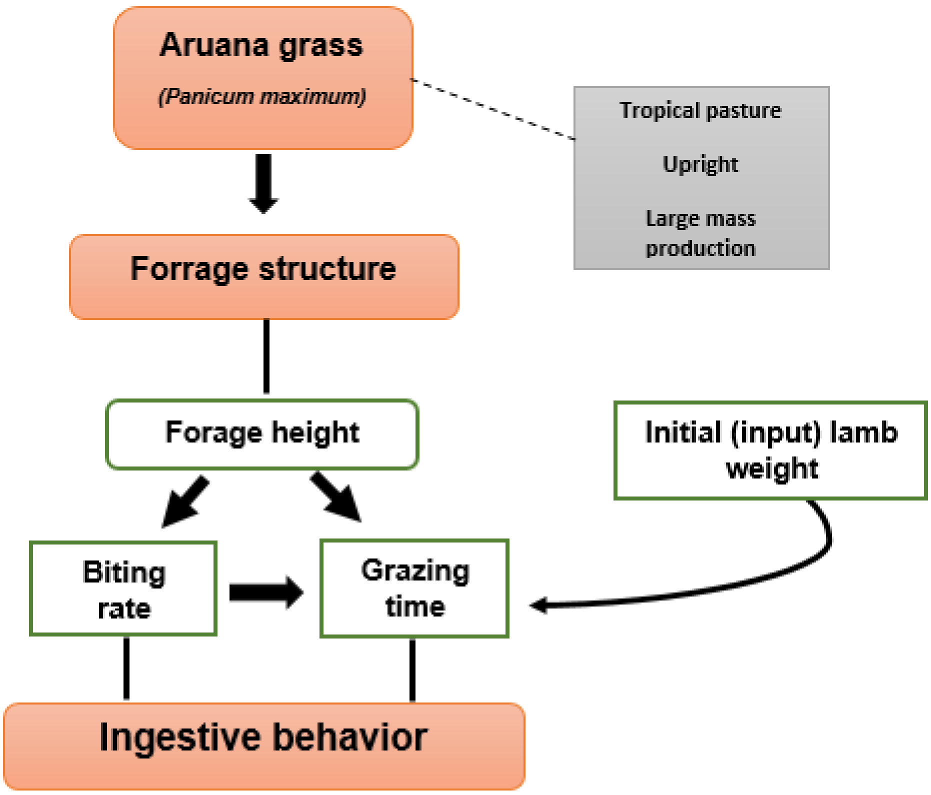
Compared to temperate pastures, little is known about ruminant grazing behavior in tropical grass pastures (Silva et al., 2015; Carvalho et al., 2005). Tropical pasture studies are scarce. Existing results are not conclusive so that the results are very often extrapolated beyond the species and/or environment studied. To complicate matters, diverse growth habits and morphology of tropical forage species result in greater structural variability in a shorter time period compared to temperate pastures. Therefore, it is difficult to synthesize and extrapolate ruminant ingestive behavior changes in tropical pasture using temperate pasture conceptual models or even the little existing information from other diverse tropical forage species.

Some tropical pastue research has contributed valuable information. Stobbs (1973) indicated that, in tropical pastures, volumetric density and leaf/stem ratio is more relevant in determining the animals' ingestive behavior than in temperate pastures. Sollenberger & Burns (2001) also stated that forage leaf density and proportion are the most important variables to be analyzed in tropical pastures. The way in which leaves are presented to the animals, the degree to which they can be apprehended separately from the stem, and the low digestible dead material all influence ruminant grazing behavior in C4 pastures. However, according to the authors, this difference is not in the total forage but, rather, in the uppermost pasture strata. For Carvalho et al. (2001) these characteristics are important in any type of the pasture, but in tropical pastures, the variations in structure are much greater.

In a study with lambs in tropical pasture of Aruana grass with contrasting heights, Silva et al. (2020) found that the behavioral variable that best reflects pasture structure differences is biting rate. Another important result of the same study is related to the effect of lamb weight. Initial lamb weight determines grazing time. Animals with an initial weight (entry into the pasture) of less than 22 kg become more susceptible to variations in forage height and are more prone to have problems harvesting feed. The model presented in the study demonstrates that lighter lambs would grazing for longer periods than the heavier lambs and highlights the importance of the structure of the tropical pasture for animals with low entry body weight.

Animal grazing behavior guides appropriate pasture and animal management strategies that change system productivity (Negri et al., 2013). For there to be efficiency in pasture production systems, it is essential that we study the ingestive behavior of animals and their modifications.

Conceptual model



The conceptual model represents a short form in relationship between a forage structure of Aruana Grass and the ingestive behavior of the animals. Among the structural characteristics, the most relevant for the study and addressed in the bibliographic review is the height of the pasture, which in turn mainly influences the behavioral variables of bit rate and grazing time. The greater the height of the pasture, the lower the bit rate. The behavioral variables of bit rate and grazing time are related.

The weight of animals entering the Aruana Grass pasture proved to be an important factor influencing the ingestive behavior of the animals through their influence on the grazing time behavior variable. The lower the weight of the animals entering the pasture, the more susceptible it is to variations and the longer the grazing time.

Conclusions

The study of tropical forages is crucial to understanding and managing sheep production on upright tropical grassland. Pasture structure and animal size are key variables to determining the best upright tropical pasture management for grazing sheep. The rapid change in tropical pasture structure from the beginning of growing seasons to the end and the small bite size of lambs dictate the importance of adjusting pasture height and animal body weight over time as plants mature and rainfall patterns change. For example, recent research has shown that Aruana grass grazed by sheep should have a leaf area index of 85% interception of solar radiation (pre-grazing 20-cm canopy height) and weaned lambs should not be ≤ 22 kg. Other similar pasture structure and ruminant behavior factors need to be characterized to guide optimal lamb production in pastures containing the numerous upright grass and forb species found throughout the tropics.

Conflict of interest

The authors declare no conflict of interest.

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CHAPTER III

Ingestive Behavior of Young Lambs on Contrasting Tropical Grass Sward Heights[1]

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Ingestive Behavior of Young Lambs on Contrasting Tropical Grass Sward Heights

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The efficiency of grazing ruminant production systems is directly associated to the animals' ingestive behavior, and to structural characteristics of the pastures. The objective of this study was to evaluate the ingestive behavior of young lambs grazing three different heights of Capim Aruana (*Panicum maximum*). The experiment was carried out in two consecutive years, in which 30 tester lambs (4–5 months old) were equally divided into three paddocks (treatments) corresponding to different average sward heights of Aruana grass: (1) Tall-75 cm; (2) Medium-50 cm; and (3) Short-25 cm in a randomized block design. Ingestive behavior assessments were carried out every 28 days through 10-min observations of the main activities of the animals (grazing, ruminating, idling) and biting rate, from sunrise to sunset. In addition, the productive and qualitative characteristics of the pastures were assessed. Despite differences in pasture structure, grazing time (GT) and idling time were similar among treatments (P = 0.4266 and P = 0.2939, respectively). The shortest ruminating time (RT, P =0.0181) was recorded in the treatment of lowest sward height. Lambs grazing on this treatment also showed 23% more bites per minute (P= < 0.0001) than animals in the Tall and Medium treatments. A Decision Tree analysis was performed for GT, identifying in a hierarchical order that the initial weight of the animals and sward height explained 62% (R^2 = 0.621) of the variation, representing the variables with the greatest influence on GT. Initial body weight explained 48% of the model. Thus, our research shows that the different sward heights of Capim Aruana mainly alter the lamb's RT and biting rate, and that the animals' initial body weight is a key factor influencing GT, given that this variable makes lambs more susceptible to changes in sward height.

Keywords: decision tree, grazing time, Capim Aruana, height, biting rate

INTRODUCTION

Pasture production systems represent a significant opportunity for increasing the sustainable production of ruminant animals worldwide. Under this scenario, animal performance depends of sward attributes such the quality and quantity of forage harvested during the grazing process (1). For instance, the ingestive behavior of young lambs kept on tropical pastures may be influenced by the different structures of swards at which they are exposed during grazing.

Sheep are highly selective animals, a trait that differentiates them from other, larger herbivores (2). This characteristic of selectivity inherent to the species is even more important in young lambs, as they progress through complex feeding periods and behavioral transitions. In addition, lambs are positioned at an optimal point on their growth curve, as they display high levels of intake and performance rates during this period (3). Because of these specific characteristics, it is necessary to understand the ingestive behavior of animals during this critical period, as it is one of the aspects that determines performance. In animal production systems, feeding is one of the most limiting factors for obtaining good results in productive performance (4). The way in which the forage is available to the animal is known as forage structure, which is responsible for the amount of nutrients ingested during the grazing process (5). According to Silva et al. (6) the structural characteristics of forage plants directly interfere with the ingestive behavior and performance of grazing animals, which, in turn alter the morphological (height, mass, and density) and physiological (photosynthetic rate and phenological stage) characteristics of the forage canopy, modifying subsequent animal and plant responses to grazing.

Tropical grasses are characterized by their high structure and growth rate (7, 8). These characteristics become a relevant issue when we think about the use of these forages for lamb production. Lambs are relatively small animals and seize food with their lips. In tall pastures with leaves above the animals' heads, lambs need to harvest practically leaf by leaf during the grazing process (5). The maintenance of the pasture structure is an important point to be analyzed when only this category is used in the pastoral system, since the growth rate of these pastures may be greater than the pasture harvesting capacity of young small ruminants. Consequently, there will be an accumulation of the most fibrous components of the sward with decreased nutritional quality of the forage on offer. For these reasons, proper management of the structure (height) is important to allow the best use of tropical grasses by young weaned lambs.

The ingestive behavior of grazers in temperate pastures is already well-known and described as the linear relationship between the decrease in height of the forage canopy and the increase in grazing time (9). Nevertheless, knowledge on such interaction is still scarce for tropical forage species and small ruminants. In order to obtain greater efficiency in the production systems of grazing ruminants, it is essential to know the animals' ingestive behavior and its relationships with forage structure. In addition to forage structure, it is necessary to understand how the nutritional composition of forages interact with their structural characteristics to influence foraging behavior and animal performance. Therefore, the objective ofthis study was to evaluate the ingestive behavior of young lambs grazing Capim Aruana (*Panicum maximum* cv. IZ-5) of different structures.

MATERIALS AND METHODS

Experimental Proceedings

The experiment was conducted during two consecutive years at the Experimental Agronomic Station of the Universidade Federal do Rio Grande do Sul, located at 46, Eldorado do Sul, Brazil—Latitude 29◦ 13 '26 "S, Longitude 53◦ 40 '45" W. The climate is subtropical humid "cfa" according to the Köppen (10) classification. The cfa classification is characterized by hot summers with temperature averages over 22◦C in the hottest month and well distributed rains (11). The experiment was carried out for 56 days during the summer in the years 2018 and 2019 (between January and March). Before this experimental period, an adaptation period of 7 days was performed to familiarize animals to their environment.

The treatments were characterized by different aimed structures of Capim Aruana (*Panicum maximum*), represented by different pasture heights: (1) Tall Treatment−75 cm of average height; (2) Medium Treatment −50 cm of average height; and (3) Short Treatment −25 cm of average height. To maintain the different pasture structures, strategic mowing was carried out before each experimental period. The pasture was mowed at 5 cm of residual height in all experimental paddocks, performed at different times before the beginning of the experiment (Tall −4 weeks; Medium −2 weeks; Short −1 week before the beginning of the experiment).

For experimental evaluations, 30 young weaned tester lambs with an average age of 4–5 months (at the beginning of the experiment), were used in each year of the study. Lambs were randomly distributed across groups and pastures, considering the variation of gender (female and castrated male) and weight, resulting in a uniform distribution of animals within each treatment group (N = 10 lambs/group). A continuous grazing method was used and all treatments had a 12%herbage allowance [12 kg total dry matter (DM) per 100 kg of animal bodyweight (BW)/day] adjusted in the day 1 of the experiment and every 28 days using the “put and take” technique (12). According to this technique, there were two groups of animals, one called “testers” that grazed continuously and showed the effect of the treatments, and another group name “put-and-take” lambs used only to maintain the sward height and regulate forage allowance. The lambs had access to shade, and water and mineral salt in *ad libitum* amounts. The average initial weight of the animals was similar between treatments (21 kg, P = 0.9401). Lambs were weighed every 28 days with a previous 12 h fasting of solids and liquids.

Pasture Assessments

Sward height was checked every 7 days using random sampling, using a 1.5m sward stick (13), taking measurements on 52 random points for each paddock, measuring the highest point of the leaf from the ground. The forage structure is composed not only by height, but also by density, forage mass and plant stage. Height, however, is a measure of high correlation with the forage structure and easy to measure, allowing for a high number of measurements during weekly intervals.

Evaluations to estimate herbage mass were carried out on day 1 of the experiment and every 28 days thereafter using a 0.25 m^2 frame, totaling six sample points per treatment, three at the average pasture height and three at random. These samples were cut close to the ground, collected and weighed.

The samples were homogenized, and two sub-samples were taken, one for determining the percentage of dry matter (DM), and another for botanical separation in leaf blade, stem + sheath, inflorescence, other grasses, other legumes, other species and senescent material. The separation of the plant's morphological components allows for the calculation of the leaf: stem ratio, which was the main variable that characterized the pasture. After botanical separation, all subsamples were placed in a forced air oven at an average temperature of 60◦C until constant weight, when samples were weighed on a 0.1-g precision balance.

The daily forage accumulation rate was measured every 28 days, using three grazing exclusion cages per paddock, according to Klingmann et al. (14). The objective of the evaluation was to measure the daily rate of pasture growth, enabling subsequente calculations of forage supply and adjustment of stocking rate. The daily forage accumulation was estimated by the difference between the sample cut inside the cage in the present period, and the forage mass cut in the previous period outside the cage, divided by the number of days in the period.

Forage samples were collected every 28 days using the grazing simulation technique (15) to assess the nutritional quality of forages. Bromatological analyses of forage samples were made to estimate the contents of dry matter (DM, method n◦ 930.15), mineral matter (MM, method n◦ 942.05) and crude protein (CP, method n◦ 984.13), according to the AOAC methodology (16). The analysis of apparent in vitro digestibility of organic matter (DIVMO) was performed according to Tilley and Terry (17). The neutral detergent fiber (NDF) concentration was analyzed according to Van Soest et al. (18), while acid detergent fiber (ADF) and acid detergent lignin (ADL) according to Goering and Van Soest (19). Determinations of insoluble nitrogen in neutral detergent (NIND) and insoluble nitrogen in acid detergent (NIAD) were also carried out according to the methodology described by Licitra et al. (20).

Ingestive Behavior Evaluation

The assessment of ingestive behavior was performed with continuous notes during the day (from sunrise to sunset) every 10min by trained people using the method described by Jamieson and Hodgson (21). The observations were performed only during daytime because most of the grazing activities of ruminants occur during this period (22–25) and nocturnal observations were not possible due to the difficulties to visualize the animals in tall pastures at night. In addition, the effect of sward height could certainly be visualized during the day. The animals were individually identified with fabric collars, in which each animal in the paddock received a collar with a different color. The activities of grazing, ruminating and idling were recorded individually for each tester animal. These assessments were carried out every 28 days. The temperature and relative humidity of the air were also measured.

The ruminating time (RT) was considered the period when the animal was not grazing but when it was chewing the ruminal bolus. The idling time (IT) represented the period when the animal was neither grazing nor ruminating. Grazing time (GT) was the period where the animal was actively grazing or selecting forage, including the period used for displacement during selection of the diet. Within the 10min of GT assessments, the biting rate was recorded using the “20 bites method” described by Forbes et al. (26), which counts the time spent by the animal to take 20 bites.

Meteorological Data From the Trial Period

In the first year of the experiment (2018), the average temperature was 23.2◦C, 75.6% average relative humidity and 106.1 millimeters of rain during the experimental period. In the second year of the experiment (2019), the average temperature was 24.1◦C, 74.8% relative humidity and 47.9 millimeters of rain. In the first behavioral assessment in 2018, the daily average temperature was 22.7◦C and in the second, 19.7◦C. In the year 2019, the average daily temperature in the first assessment was 25.5◦C and in the second 26.3◦C.

Statistical Analysis

The experimental design used was randomized blocks, in which each year represented a block. Animals were considered the experimental units for variables related to ingestive behavior, and paddocks were considered the experimental units for pasture variables. Analysis of variance were performed to determine the effects of the treatments using the Mixed procedure in SAS 9.4, and the means were compared by the Tukey test at the 5% significance level.

The variables evaluated over time, within each year, were considered as repeated measures. In addition to the analysis of variance, correlation analysis between the animal behavior and pasture variables were performed.

The ANOVA model included as fixed effects block, treatment, period (repeated measures over time within each year) and treatment x period interaction. The data of total GT and total IT were not normal (Shapiro-Wilk; $P \leq 0.05$) and were transformed by log and square root, respectively. The results are presented as means adjusted by the LSMEANS (least square means) procedure of SAS (version 9.4, SAS Institute Inc., Cary, NC, USA), ± standard error of the mean. The LSMEANS procedure was used because least square means are less sensitive to missing data (27).

The data were also submitted to multivariate Decision Tree analysis performed by JMP software (version 12, SAS Institute Inc., Cary, NC, USA). This analysis allows to understand a result obtained by investigating the degree of interference that the factors studied may have in a given process of interest. The statistical program generates an equation that explains (through R2 value) which factors most influence a certain variable like GT. The independent variables included as factors in the analysis were initial body weight, herbage mass (DM/ha), leaf:stem ratio, pasture accumulation rate, leaf/ha, stem/ha, senescence/ha, inflorescence/ha, sward height and biting rate.

RESULTS

Ingestive Behavior

The different structures of the Capim Aruana tropical pasture did not influence GT or IT by young lambs (P= 0.4266 and P= 0.2939, respectively), with averages for GT of 391.1 ± 15.44min in the Tall; 389.1±12.3min in the Medium and 428.1±24.3min per day in the Short treatment. For the variable IT (P= 0.2939) the averages were 174.3 ± 25.8min in the Tall; 152.9 ± 16.8min in the Medium and 144.1 ± 21.7min per day in the Short treatment. In relation to RT there was a significant (P= 0.0181) difference between treatments, being the longest times for the Medium treatment (174.4 ± 8.6 min/ day), which differed from the Short treatment (143.5 ± 7.2 min/ day). The RT in the Tall treatment (153.0 ± 7.3 min/day) did not differ from the other treatments (P > 0.05). There was an interaction between treatment and period (P = 0.0049) in relation to biting rate, in which the Short treatment had similar biting rates in both periods, 1 and 2 (30.0 ± 1.4 and 32.6 ± 1.2 bits/min, respectively). Animals under the Medium and Tall treatments showed lower biting rates during both periods, as shown in Table 1.

Table 1. Ingestive behavior of lambs recently weaned in different structures of tropical pasture Capim Aruana (*Panicum maximum)* a with period 1 being the initial instant of forage offered to the animals (summer) and period 2 the end of the pasture cycle (next to autumn).

VARIABLES[1]	Period	TREATMENTS			*P* value[2]		
		TALL	MEDIUM	SHORT	Treat	Per	Treat*Per
GT (min)	1	383.4 ± 17.5	383.7 ± 13.4	409.3 ± 38.4	0.4266	0.0941	0.2541
	2	399.4 ± 26.2	394.2 ± 20.7	446.8 ± 30.9			
	Mean	**391.1 ± 15.44**	**389.1 ± 12.3**	**428.1 ± 24.3**			
IT (min)	1	205.8 ± 19.4	172.0 ± 16.4	173.9 ± 36.5	0.2939	0.0003	0.4540
	2	142.9 ± 26.0	133.8 ± 18.0	114.3 ± 22.5			
	Mean	**174.3 ± 25.8**	**152.9 ± 16.8**	**144.1 ± 21.7**			
RT (min)	1	130.3 ± 8.2	160.0 ± 12.8	132.7 ± 9.1	0.0181	<.0001	0.2995
	2	177.0 ± 9.3	188.0 ± 11.1	154.3 ± 10.9			
	Mean	**153.0 ± 7.3AB**	**174.4 ± 8.6A**	**143.5 ± 7.2B**			
Bite Rate (bites/min)	1	19.8 ± 0.8c	25.6 ± 1.0b	30.0 ± 1.4ab	<.0001	0.0006	0.0049
	2	26.8 ± 1.5b	25.6 ± 1.0b	32.6 ± 1.2a			
	Mean	**23.2 ± 1.0B**	**25.6 ± 0.7B**	**31.3 ± 0.8A**			

[1] Variables = GT: grazing time; IT: Idling time; RT: ruminating time.

[2] Different capital letters differ on the line for each variable; Different lowercase letters differ from each other in the treatment * period interaction for each variable analyzed.

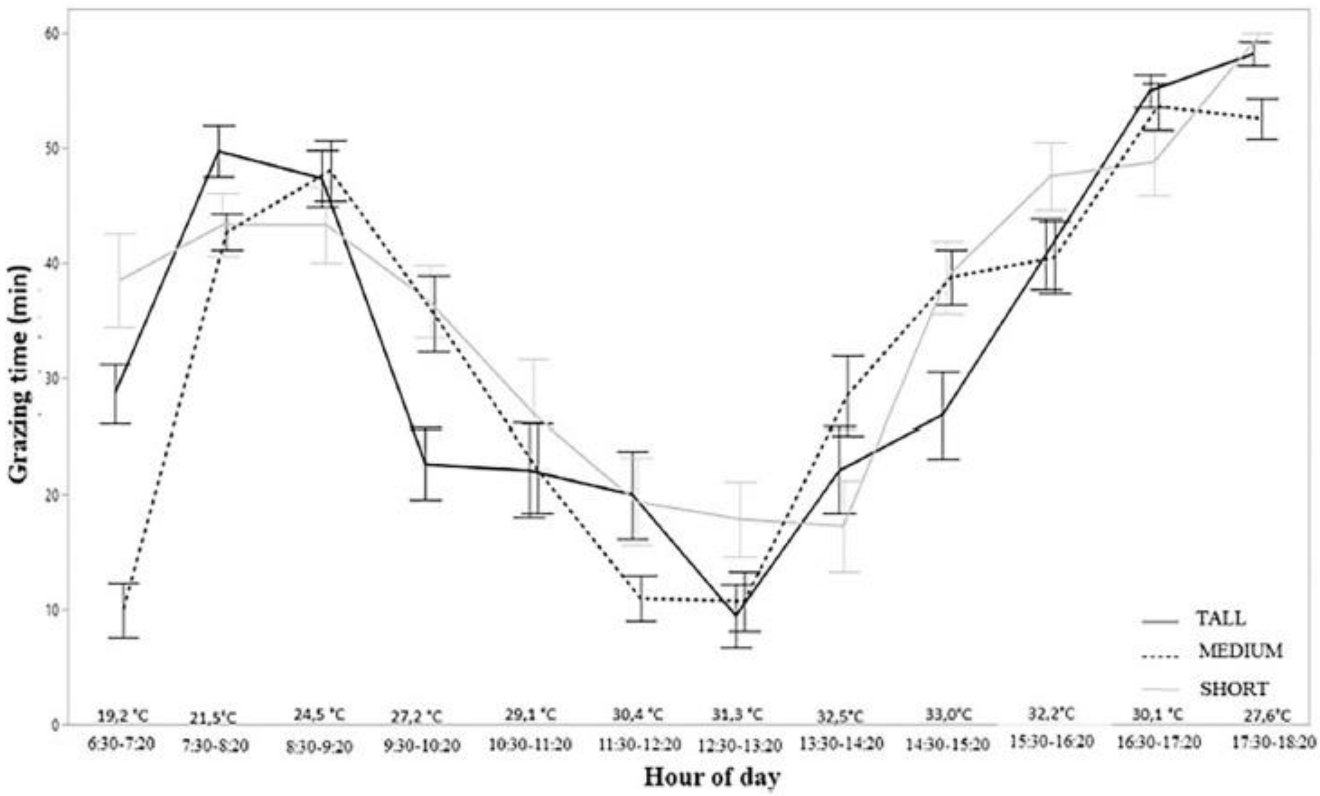

FIGURE 1 | Behavior of grazing activity during the day of freshly weaned lambs in different structures of tropical pasture Capim Aruana (*Panicum maximum*).

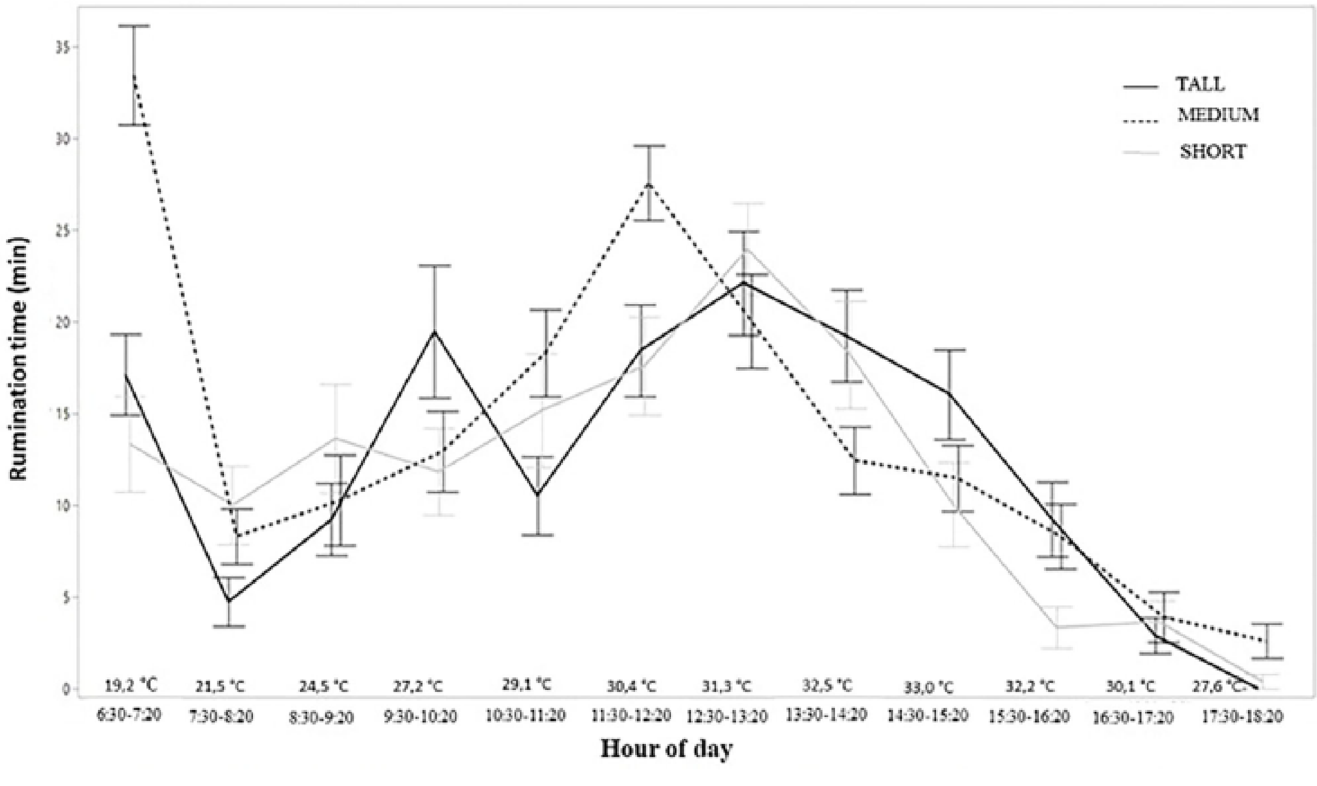

FIGURE 2 | Rumination behavior activity during the day of freshly weaned lambs in different structures of tropical pasture Capim Aruana (*Panicum maximum*).

When analyzing the GT of the animals over the different hours of the day, a similar pattern of behavior was observed in all treatments. In general, two grazing peaks occurred throughout the day. There was a peak in the morning with an average duration of 2 h between 07:30 am and close to 09:20 am. During this interval animals grazed more than 80% of the activities recorded. The animals returned to grazing activities after the hottest times of the day, around 02:20 pm, and the amount of time they spent grazing gradually increased, reaching almost 100% of the activities recorded after 05:20 pm (Figure 1).

Although the patterns of behavior were similar among treatments, it was possible to identify a different behavior of the Short treatment animals. While at the beginning of the behavior evaluation, at 6:30 am, the animals of this treatment were already in high grazing activity, almost 70% of the time, the animals on the Medium and Tall treatments were slowly starting their grazing activities. This behavior change shows that animals in the Low treatment started their grazing activities earlier in the day than in the other treatments, as shown in Figure 1. In addition to this behavior, animals under the Short treatment started to gradually reduce their grazing activity around 9:30 am, while this decline occurred for the other treatments at the same time but in a more pronounced manner. Another difference in behavior for animals in the Short treatment was that most of them did not cease their grazing activity in the hottest hours (11:30 am−02:20 pm), in contrast to animals assigned to taller structures (Figure 1).

There was a small difference between the Medium and the other treatments with regards to RT. During the first hour, the percentage of time spent ruminating by animals in the Medium treatment was greater than for the other two treatments, and greater rumination activity was observed by these animals in the hottest periods of the day (Figure 2).

Idling behavior across different hours of the day was similar for all treatments. In contrast to GT, idling behavior was less in the early morning and late afternoon, and there was an idling peak between 11:20 am 02:20 pm (Figure 3).

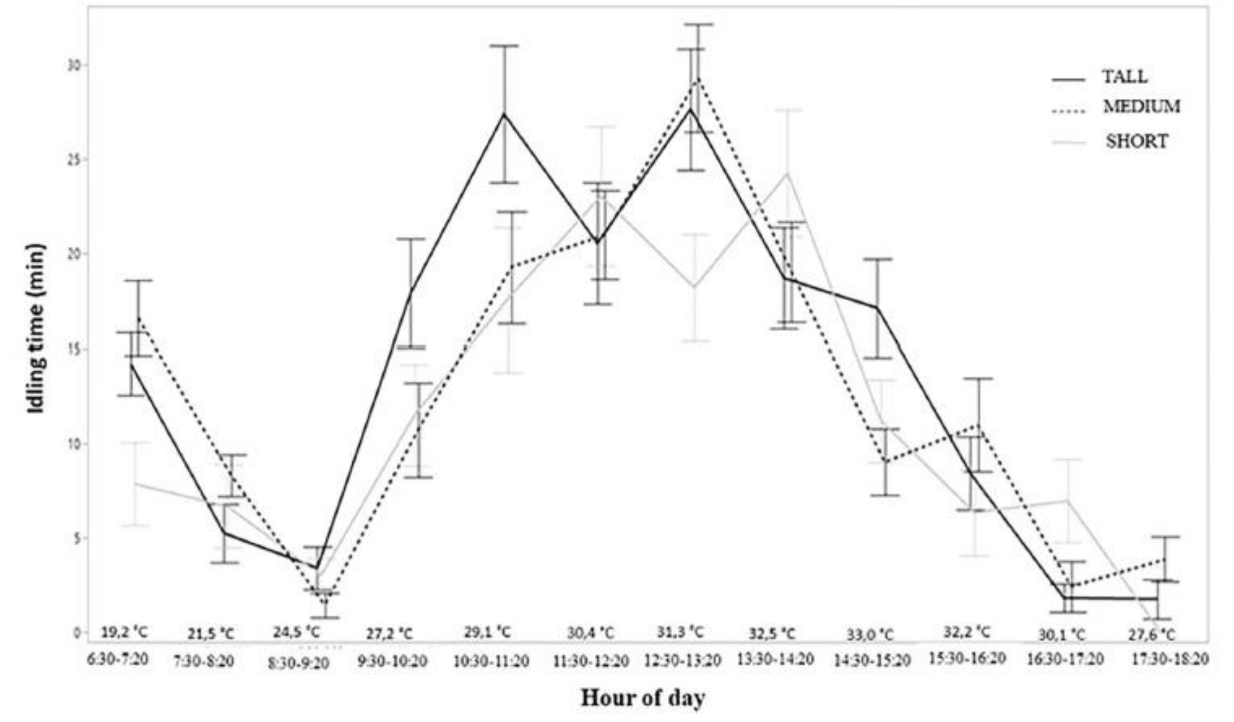

FIGURE 3 | Idling behavior activity during the day of freshly weaned lambs in different structures of tropical pasture Capim Aruana (*Panicum maximum*).

Decision Tree Analysis

According to this analysis, it was hierarchically identified that the initial weight of the animals and pasture height explained 62% (R^2 = 0.621) of the model, being the variables of greatest influence in the animals GT. The first division of the model showed that the factor of greatest interference in GT was the initial weight of the animals (Figure 4), explaining 48% of the variation in the model.

The model estimated that animals with an average initial weight >22.7 kg would have an average GT of 327.1min and animals weighing <22.7 kg would have an average GT of 470.2min. For animals of lower weight, the analysis showed that the factor with the greatest influence at explaining the observed variability in GT was forage height. This result demonstrates that the pasture height (structure) is more important for smaller animals.

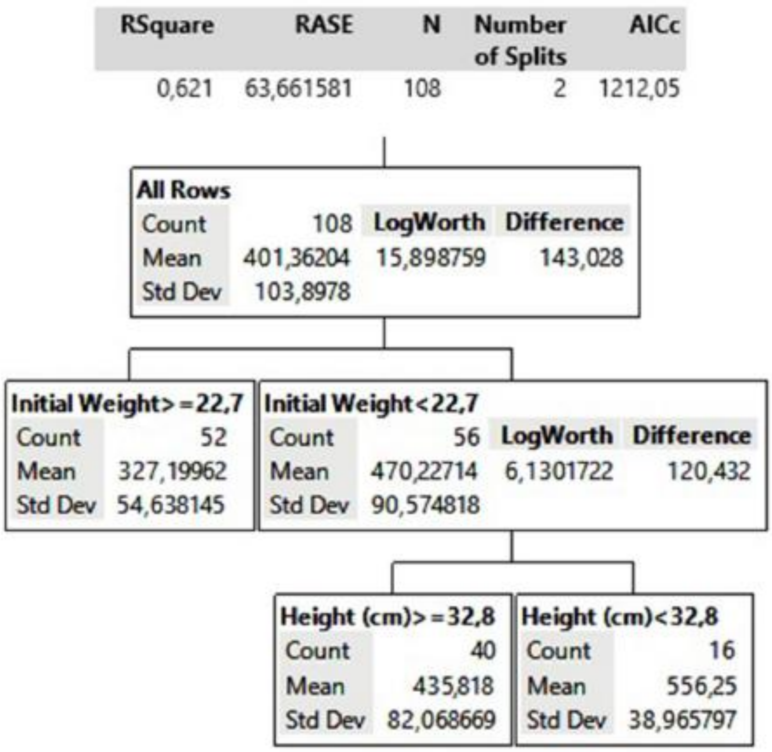

FIGURE 4 | Decision Tree model for grazing time behavior variable.

Pasture

The pasture height showed a negative correlation with biting rate (r = −0.46, *P* < 0.0001). Another characteristic of the pasture that showed a significant relationship with biting rate was the number of inflorescences per hectare (r = −0.51, *P* < 0.0001). There was a greater amount of inflorescence in the taller swards at the end of the experiment. On average, there was a trend (*P* = 0.0967) for greater amount of inflorescences in the Tall treatment. In fact, a high correlation was observed between sward height and percentage of inflorescence (r = 0.81, *P* < −0.0001).

The variables leaf/ha and dead matter/ha showed no significant difference between treatments. The variable herbage mass (DM/ha) differed significantly (*P* < 0.0001) between treatments, being greater for the Tall treatment (Table 2). The pasture accumulation rate showed a trend (*P* = 0.0513) for greater values in the Tall than in the Short treatment, and significant correlations with ingestive behavior variables, like IT (r = 0.63, *P* < 0.0001) and GT (r = −0.49, P < 0.0001). The leaf:stem ratio (*P* = 0.0006) was greater in the Medium and Short treatments than in the Tall treatment. In contrast, the stem/ha variable (*P* < 0.0001) was greater in the Tall treatment, as shown in Table 2.

Table 2. Grazing variables in different structures of Capim Aruana (*Panicum maximum)* with period 1 being the initial instant of forage offered to the animals (summer) and period 2 the end of the pasture cycle (near autumn).

VARIABLES[1]	**Period**	**TREATMENTS**			***P* value[2]**		
		TALL	**MEDIUM**	**SHORT**	**Treat**	**Per**	**Treat*per**
	1	4167.8 ± 111.1	2681.7 ± 129.6	1639 ± 37	**<.0001**	**0.0010**	**0.8141**
DM/ha (Kg)	**2**	5513 ± 143.18	3820.8 ± 85.3	2937 ± 51.4			
	Mean	**4840.1 ± 144.7^{a}**	**3251.3 ± 117.4B**	**2288 ± 120.6B**			
	1	195.1 ± 8.7	104.8 ± 5.3	127.1 ±! 20.5	**0.0513**		
Accumulation Rate (Kg/day)	**2**	-9.8 ± 0.2	4.8 ± 15.1	32.2 ± 22.2			
	Mean	**92.6 ± 17.8**	**54.8 ± 11.1**	**79.6 ± 17.1**			
	1	79.9 ± 1.2a	44.4 ± 2.7bc	23.8 ± 0.9d	**<.0001**	**0.7735**	**0.0120**
Height (cm)	**2**	67.2 ± 0.7ab	50.9 ± 0.4b	25.3 ± 0.6cd			
	Mean	**73.5 ± 1.2A**	**47.7 ± 1.4B**	**24.5 ± 0.5C**			
	1	1.4 ± 0.1	1.4 ± 0	3.7 ± 0.3	**0.0006**	**0.6946**	**0.2512**
L:S	**2**	0.3 ± 0	1.4 ± 0.1	1.4 ± 0.1			
	Mean	**0.8 ± 0.1B**	**1.4 ± 0A**	**2.6 ± 0.2A**			
	1	1455.6 ± 24.4a	1143.5 ± 66.4ab	805.5 ± 25.7b	**0.1438**	**0.4845**	**0.0322**
Leaf/ha (Kg)	**2**	1016 ± 15ab	1553.5 ± 120.3a	1223 ± 23.2ab			
	Mean	**1235.8 ± 39.7**	**1348.5 ± 75**	**1014.3 ± 41.2**			
	1	1964.1 ± 72.7	1080.1 ± 93.2	564.7 ± 38.8	**<.0001**	**<.0001**	**0.5855**
Stem/ha (Kg)	**2**	3685.2 ± 191.1	1992.5 ± 24.5	1378.1± 88.1			
	Mean	**2824.6 ± 176.9^{a}**	**1536.3 ± 85.6B**	**971.4 ± 87B**			
	1	323.9 ± 12	305.3 ± 28.7	167.5 ± 6.9	**0.4263**	**0.1984**	**0.0966**
Dead Matter/ha (Kg)	**2**	517.2 ± 6.7	167.4 ± 9.8	283.9 ± 11			
	Mean	**420.6 ± 17.8**	**236.3 ± 18.4**	**225.7 ± 12.2**			
	1	110.8 ± 7.8	17.2 ± 4	3.5 ± 0	**0.0967**	**0.7532**	**0.8529**
Inflorescence/ha (Kg)	**2**	39 ± 6.7	50 ± 1.9	0			
	Mean	**74.9 ± 7.2**	**33.6 ± 3.3**	**0.14 ± 0.04**			

[1] variables = DM/ha: dry matter per hectare; L:S: leaf:stem ratio.
[2] Different capital letters differ on the line for each variable; Different lowercase letters differ from each other in the treatment * period interaction for each variable analyzed.

Bromatological Composition of the Diet

The chemical composition of the diet did not differ among treatments ($P > 0.05$), with similar parameters, as shown in Table 3.

Table 3. Bromatological composition of the diet, based on the different structures of Capim Aruana (*Panicum maximum)*.

VARIABLES[1] (% /kg de MS)	TREATMENTS			*P* value[2]
	TALL	MEDIUM	SHORT	
Mineral matter	9.8 ± 0.1	11.9 ± 0.2	10.7 ± 0.1	**0.1068**
NDF	66.5 ± 0.9	69.9 ± 0.7	65.6 ±0.3	**0.3856**
ADF	35.7 ± 0.3	36.7 ± 0.2	35.2 ± 0.6	**0.7472**
CP	15.9 ± 0.4	17.2 ± 0.4	17.9 ± 0.2	**0.6599**
EE	2.2 ± 0	2.5 ± 0	2.6 ± 0	**0.0598**
NIND	1.6 ± 0	2.3 ± 0	2.3 ± 0	**0.4890**
NIAD	0.30 ± 0	0.31 ± 0	0.30 ± 0	**0.9748**
LIGNIN	3.8 ± 0.1	4.6 ± 0	3.9 ± 0	**0.2766**

[1] Variables = NDF: neutral detergent fiber; ADF: acid detergent fiber; CP: Crude Protein; EE: ethereal extract; NIND: nitrogen in neutral detergent; NIAD: nitrogen in acid detergent.

DISCUSSION

Ingestive Behavior

This experiment shows that young lamb grazing an upright tropical grass do not vary their GT due to the different sward heights, contrasting with what was discussed by Hodgson (9). This author, reviewing studies with temperate pastures, shows a linear increase in grazing time when the height or mass of the forage decreases. However, according to Sollenberger and Burns (28), this relationship in tropical pastures is not so consistent. Animals may graze taller or shorter tropical grasses for longer periods to compensate the limitations imposed either by pasture height, leaf size, number of stems or amount of herbage mass. However, rumination time in this study was longer in the Medium-height treatment, which demonstrates that factors other than structure can interfere in the GT of young animals grazing tropical pastures.

The leaf:stem ratio and the availability of green leaves in tropical pastures are key characteristics that affect animal ingestive behavior. For instance, Euclides et al. (29) studying *Panicum maximum* and Brachiaria spp. in southern Brazil showed that grazing time decreased with increments in the percentage of green leaves and leaf mass. Carvalho et al. (5) explains that the way leaves are presented to animals and how green leaves are apprehended, separately from stems and dead material, are important characteristics that should be considered in tropical pasture management in sheep production systems.

Despite the statistical difference in rumination time between treatments, it is important to consider that over 720min of daily evaluation, rumination time in the Medium-height treatment was only 30min greater than in the Short-height treatment. This small difference may then explain the lack of compensation observed for other activities in animals that exhibited shorter rumination times. In addition, these small differences in rumination time may not be physiological, since rumination activity is distributed throughout the day in periods ranging from 2min to more than 1 h (30). Other activities were similar between treatments, which reinforces the idea that difference for rumination time may be associated with a natural variation in animal behavior that occurs throughout the day.

Biting Rate

The greatest biting rates identified in this study occurred in animals exposed to the Short-height treatment (sward height of 25 cm). Biting rate and intake values by grazing animals are sensitive to variations in the mass and height of the pasture (31). In the case of an erect tropical grass, such as Capim Aruana, the shorter the pasture, the greater the biting rate. This response is consistent with observations in older lambs than those used in this study. Negri et al. (32) working with 120-day-old lambs grazing Capim Aruana (*Panicum maximum*) found that as sward height increased, animals spent more time (seconds) to achieve 20 mouthfuls. Stobbs (33) explains this behavior through the negative relationship between canopy height and density of the dry mass of green leaf blades, compromising the size of the bite due to increments in handling and chewing times. Similarly, Schwartz et al. (34) observed in sheep grazing pearl millet that at high pasture heights animals were forced to graze leaves individually due to leaf length, a behavior that decreased biting rate. Thus, there is a negative relationship between biting rate and height of tropical erect pastures (35). In fact, biting rate proved to be one of the variables that is most responsive to height variation of tropical erect grass.

A negative correlation was found between the rate of biting and the amount of inflorescence/ha in the pastures, whereas a positive correlation was detected between sward height and the presence of inflorescence. Likewise, Silva et al. (6) reported that the proportion of leaves in Aruana (*Panicum maximum*) and the presence of inflorescence influenced grazing strategy by lambs. This result shows the importance of avoiding the inflorescence in the pastures in order to facilitate lambs' grazing activities. Thus, the use of a mower or cattle grazing may contribute to manage pastures for grazing young lambs.

Behavior Throughout the day

When analyzed over the hours of the day, the animals' ingestive behavior showed a natural behavioral pattern (36, 37). There was a peak of grazing in the early morning and late afternoon, and a moderate increase in rumination and idling activities during the late morning and early afternoon. Despite a decrease in GT by lambs during the hottest hours of the day (11:30 am−2:20 pm) the activity, although less frequent, was still observed in this study, contrary to results reported by Starling et al. (38) in tropical conditions. These authors evaluated Corriedale ewes poorly adapted to warm conditions and observed that the animals abruptly stopped their grazing activity at high environmental temperatures. The observation of grazing activity in the hottest hours of the day in our study may be related to climatic conditions that did not trigger high thermal stress and thus allowed grazing to occur at those times. This behavior demonstrates the need for ruminants to be constantly ingesting food (39) and shows that temperature may have a limited effect on the grazing behavior of animals in subtropical conditions.

The Short-height treatment showed that animals were already grazing more intensely than lambs in the other treatments during the early hours of the day. During the first hour of evaluation, animals in the Tall-height treatment grazed on average for 30min and the Medium-height treatment for 10min, whereas the Short-height treatment grazed on average for 40min. Although there was not a significant difference in GT among treatments, the greater availability of leaves seems to prompt animals to graze earlier during the day.

In studies with sheep on bermudagrass pasture, Poli et al. (40) found that grazing was the activity that took up most of the lambs' time in the three production systems (lambs weaned on pasture; unweaned lambs exclusively on pasture; and unweaned lambs supplemented on pasture), consistent with results from the present study.

Decision Tree Behavior

The Decision Tree analysis allowed us to explore the factors that influenced GT. The initial weight of the lambs had a key influence on GT. Lighter lambs grazed for longer periods than heavier lambs. The model highlights the importance of the structure of tropical pasture for animals under lower initial body weights, as height appears as the second factor influencing grazing time. In support of this, Emerenciano Neto et al. (41) report that among various structural characteristics, pasture height was a key variable influencing animals' foraging decisions.

Although there were no significant differences in GT between the different pasture-height treatments, important variability was observed for initial body weights within treatments and between years. Such variation allowed for distinguishing the effect of pasture height on initial body weight. The importance of animal size was also mentioned by Carvalho et al. (5). They explain that young and light lambs can be largely affected by herbage components, mainly due to the difficulty of bite formation by a small mouth area, which in turn influences the animals' grazing capacity.

The longer grazing times by lighter animals can lead to greater energy expenditures, with potential negative effects on performance. Thus, increasing body weights would be an ideal scenario for early weaned lambs entering tropical pastures. For larger lambs, the structure of tropical pasture has less influence on the time invested in grazing, whereas young lighter lambs may benefit from grazing shorter pastures, given that for animals of lower weight forage height had the greatest influence on GT.

These are innovative results that highlight the importance of initial weight for a weaned lamb to enter an erect tropical grass pasture. It is important to wean animals at proper body weights and developmental conditions, so that they can face the challenges imposed by tropical grasses, characterized by their large structure of leaves and stems combined with a fast growth rate.

These results also show the importance of assessing ingestive behavior as a tool to understand the factors that have direct effect on animal productivity. Our study shows important relationships between erect tropical grass pasture and young lamb size, generating innovative management decisions. In fact, there is a need to have a minimal lamb weight to face the challenges promoted by a tropical pasture. In this study the structure of a tropical pasture becomes less of a concern as the animal is heavier than 23 kg.

CONCLUSIONS

Grazing time by young weaned lambs did not differ among different structures of an erect tropical grass sward, suggesting that other factors may influence foraging behavior. Biting rate proved to be the main variable that differed among the gradiente of grazing structures presented. Body weight and height of the upright tropical grass pasture had a strong influence on lambs' ingestive behavior. Maximum pasture height and minimum body weight should be considered when young lambs graze an erect tropical grassland.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The animal study was reviewed and approved by Universidade Federal do Rio Gande dos Sul Animal Care and Use Committee. Written informed consent was obtained from the owners for the participation of their animals in this study.

AUTHOR CONTRIBUTIONS

This study was developed by Animal Science Graduate Program at Universidade Federal do Rio Grande do Sul and it was financed by development agencies of the Brazilian Ministry of Education and Ministry of Science and Technology. Every author had important contributions on this manuscript. JS and LI developed the research project and fieldwork. CP is the head of the research project, being responsible for all parts of the study, from the project to the publication. JT was primarily responsible for the statistical analysis and results and discussion of the article. EM and JV contributed to the configuration of the manuscript and writing corrections. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest

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CAPÍTULO IV

3. CONSIDERAÇÕES FINAIS

O conhecimento acerca do comportamento ingestivo dos animais de produção é extremamente importante para que possamos atingir bons níveis de produtividade e bem-estar animal. Em sistemas de produção de ruminantes à base de pastagem, esse conhecimento torna-se fundamental para que se possa compreender esses sistemas e torná-los o mais eficiente possível.

Muitos são os estudos em relação ao comportamento ingestivo de ovinos e bovinos em pastagens temperadas, porém, não se pode extrapolar e generalizar esse conhecimento para as pastagens tropicais, devido a heterogeneidade característica dessas pastagens. Muito singular ainda é a dinâmica existente entre esse tipo de pastagem e o pastejo de cordeiros, devido ao tamanho desses animais (frente a uma pastagem tão heterogênea) e ao seu excelente potencial de desempenho.

Resultados de trabalhos anteriormente realizados mostraram a necessidade de entender essa relação cordeiro x pastagem tropical (estrutura). E o estudo do comportamento ingestivo, no presente trabalho, possibilitou a elucidação de algumas questões sobre essa relação. Trouxe, também, importantes resultados que auxiliarão não somente a comunidade científica, no âmbito de incrementar conhecimentos relacionados ao comportamento ingestivo e pastagem tropical, mas que irão auxiliar os produtores.

Mostrou-se que a taxa de bocado é a principal variável no processo de pastejo que reflete as diferenças entre as alturas da pastagem, e a mais influenciada por esta. Outro resultado importante é o padrão comportamental já descrito, que se manteve na pastagem estudada, de dois picos de pastejos principais ao longo do dia (no início da manhã e no entardecer).

As principais descobertas foram acerca do tempo de pastejo, variável que, por si só, não apresentou resposta significativa em relação as diferentes alturas. No entanto, o estudo dessa variável pela análise de Decision Tree possibilitou entender que o tempo de pastejo é influenciado principalmente pelo peso inicial dos animais. Ou seja, quanto menor o peso em que os animais forem introduzidos em um sistema a base de pastagem tropical, mais susceptíveis serão às modificações da pastagem e sua heterogeneidade. A altura (estrutura) do pasto é mais importante para animais menores. A altura máxima do pasto e o peso corporal mínimo devem ser considerados quando os cordeiros forem introduzidos em pastagens tropicais eretas.

A realização do estudo ocorreu das melhores formas possíveis de acordo com os recursos e ferramentas disponíveis. Contudo, para estudos futuros, que sigam essa linha de pesquisa, salientamos algumas alternativas que poderiam contribuir com as pesquisas, são elas: realização da avaliação do comportamento ingestivo por 24h (se houver recurso metodológico para tal) e maior número de avalições de comportamento ingestivo durante o período experimental.

No desfecho do estudo, solidifica-se a importância da preparação dos cordeiros anteriormente à desmama. Animais desmamados em boas condições (peso > 22 kg) terão melhor performance em sistema baseado em pastagem tropical. Portanto, esses resultados auxiliam na viabilização de sistemas de produção com essas pastegens, fornecendo informações relevantes sobre o manejo da altura do Capim Aruana e o peso de entrada dos animais jovens nesse sistema. Isso possibilitao aumento da eficiência produtiva de cordeiros no período de entressafra e colaborando com o avanço da ovinocultura em sistemas pastoris.

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5. APÊNDICE

Apêndice 1. Dados meteorológico durante as avaliações comportamento ingestivo 2018 e 2019.

Avaliação comportamento ingestivo		2018	
	ºC	**UR %**	**mm**
1º	22,7	78,7	0
2º	19,7	69,4	0
Avaliação comportamento ingestivo		**2019**	
	ºC	**UR %**	**mm**
1º	25,5	81,9	5,8
2º	26,3	65,1	0

Apêndice 2. Tabela variáveis da composição bromatológica da dieta, com base nas diferentes estruturas de Capim Aruana (Panicum maximum), sendo período 1 o instante inicial da forragem oferecida aos animais (verão) e o período 2 o final do ciclo da pastagem (próximo ao outono). Dados apresnetados por tratamento e período.

VARIABLE (% /kg de MS)	Period	TRATAMENTS TALL	MEDIUM	SHORT	*P* value Treat	Per	Treat*per
Mineral matter	1	9,4±0,2	10,6± 0	10,2± 0	**0.1068**	**0.0631**	**0.4878**
	2	10,3±0,1	13,1±0	11,2±0,2			
	Mean	**9,8±0,1**	**11,9±0,2**	**10,7±0,1**			
NDF	1	70,5±0,6	74,0±0,7	63,6±0,3	**0.3856**	**0.1515**	**0.1643**
	2	62,6±1,3	65,7±0,1	67,5±0			
	Mean	**66,5±0,9**	**69,9±0,7**	**65,6±0,3**			
ADF	1	33,6 ± 0	35,3 ± 0,1	36,4 ± 1,1	**0.7472**	**0.4103**	**0.2954**
	2	37,8 ± 0,1	38,0 ± 0,2	33,9 ± 0			
	Mean	**35,7 ± 0,3**	**36,7± 0,2**	**35,2 ± 0,6**			
CP	1	16,8 ± 0,5	18,7± 0,2	16,8 ± 0,1	**0.6599**	**0.6946**	**0.5067**
	2	15,0 ± 0,6	15,7 ± 2,8	19,0 ± 0,2			
	Mean	**15,9 ± 0,4**	**17,2 ± 0,4**	**17,9 ± 0,2**			
EE	1	2,4 ± 0	2,5 ± 0	2,5 ± 0	**0.0598**	**0.8945**	**0.1848**
	2	2,0 ± 0	2,6 ± 0	2,8 ± 0,1			
	Mean	**2,2 ± 0**	**2,5 ± 0**	**2,6 ± 0**			
NIND	1	1,8 ± 0	2,1 ± 0	2,3 ± 0,1	**0.4890**	**0.5679**	**0.9751**
	2	1,5 ± 0,1	1,8 ± 0,1	2,2 ± 0			
	Mean	**1,6 ± 0**	**2,3 ± 0**	**2,3 ± 0**			
NIAD	1	0,3 ± 0	0,3 ± 0	0,3 ± 0	**0.9748**	**0.4582**	**0.6008**
	2	0,2 ± 0	0,3 ± 0	0,2 ± 0			
	Mean	**0,30 ± 0**	**0,31 ± 0**	**0,30 ± 0**			
LIGNIN	1	3,7 ± 0	4,5 ± 0	3,5 ± 0	**0.2766**	**0.3244**	**0.8025**
	2	3,8 ± 0,2	4,8 ± 0	4,3 ± 0,1			
	Mean	**3,8 ± 0,1**	**4,6 ± 0**	**3,9 ± 0**			

* variables = NDF: neutral detergent fiber; ADF: acid detergent fiber; CP: Crude Protein; EE: ethereal extract; NIND: nitrogen in neutral detergent; NIAD: nitrogen in acid detergent.

6. VITA

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No decorrer da graduação participou de atividades extracurriculares, atuou como bolsista de monitoria, iniciação científica e tecnológica. Atuou no Laboratório de Nutrição Animal (LNA), durante um ano e meio, sob orientação da Professora Maitê de Moraes Vieira. E posteriormente no Centro de Ensino e Pesquisa em Ovinocultura (CEPOV), sob orientação do Professor Cesar Poli, desde 2015 até o término da graduação. Formou-se Zootecnista em 17 de março de 2019.

Em abril de 2019 ingressou no mestrado acadêmico no Programa de Pós-graduação em Zootecnia, Faculdade de Agronomia – UFRGS, sob orientação do Professor Cesar Poli e coorientação da Drª. Jalise Tontini. Permanecendo, assim, no grupo CEPOV e na sua principal área de atuação (ovinocultura). Foi bolsista CAPES durante o mestrado. Mestrado concluído em março de 2021.