UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
FACULDADE DE AGRONOMIA
PROGRAMA DE PÓS-GRADUAÇÂO EM ZOOTECNIA

# COMPORTAMENTO INGESTIVO DE OVINOS MANEJADOS SOB DIFERENTES MÉTODOS DE PASTOREIO E INTENSIDADES DE PASTEJO EM SISTEMA INTEGRADO DE PRODUÇÃO AGROPECUÁRIA

RICARDO PEREIRA GONÇALVES
Engenheiro Agrônomo/UFRGS

Dissertação apresentada como um dos requisitos à obtenção do grau de Mestre em Zootecnia
Área de Concentração Plantas Forrageiras

Porto Alegre (RS), Brasil.
Março, 2017

CIP - Catalogação na Publicação

Gonçalves, Ricardo Pereira
Comportamento ingestivo de ovinos manejados sob diferentes métodos de pastoreio e intensidades de pastejo em sistema integrado de produção agropecuária / Ricardo Pereira Gonçalves. -- 2017.
112 f.

Orientadora: Carolina Bremm.
Coorientador: Paulo César de Faccio Carvalho.

Dissertação (Mestrado) -- Universidade Federal do Rio Grande do Sul, Faculdade de Agronomia, Programa de Pós-Graduação em Zootecnia, Porto Alegre, BR-RS, 2017.

1. Escalas de pastejo. 2. Estrutura do pasto. 3. Ganho médio diário. 4. Lolium multiflorum. 5. Rebaixamento do pasto. I. Bremm, Carolina, orient. II. Carvalho, Paulo César de Faccio, coorient. III. Título.

Elaborada pelo Sistema de Geração Automática de Ficha Catalográfica da UFRGS com os dados fornecidos pelo(a) autor(a).

RICARDO PEREIRA GONÇALVES
Engenheiro Agrônomo

**DISSERTAÇÃO**

Submetida como parte dos requisitos
para obtenção do Grau de

**MESTRE EM ZOOTECNIA**

Programa de Pós-Graduação em Zootecnia
Faculdade de Agronomia
Universidade Federal do Rio Grande do Sul
Porto Alegre (RS), Brasil

Aprovada em: 21.03.2017
Pela Banca Examinadora

Homologado em: 17.05.2017
Por

CAROLINA BREMM
PPG Zootecnia/UFRGS
Orientadora

PAULO CÉSAR DE FACCIO CARVALHO
Coordenador do Programa de
Pós-Graduação em Zootecnia

CÉSAR HENRIQUE ESPIRITO CANDAL POLI
PPG Zootecnia/UFRGS

HENRIQUE M.N. RIBEIRO FILHO
PPGCA/UDESC

OLIVIER BONNET
PPGBA/UFPEL

CARLOS ALBERTO BISSANI
Diretor da Faculdade de Agronomia

# DEDICATÓRIA

*Aos meus pais, que me apoiaram incondicionalmente nesta jornada.*
*A todos os que buscam no conhecimento uma forma de evolução.*

**Dedico.**

*"...*
*Tenho saudade*
*De pessoas que fui conhecendo*
*lembranças que fui esquecendo*
*amigos que acabei perdendo*
*Mas continuo vivendo e aprendendo."*

**Marta Medeiros**

## AGRADECIMENTOS

*Meu eterno agradecimento a Deus pela proteção e por sempre guiar meus passos.*

*Aos meus familiares, meus pais Renato e Sandra, minhas irmãs Renata e Roberta e a pequena Valentina (a alegria da nossa família) pelo carinho e fundamental apoio que sempre me deram.*

*À Carol por me "amadrinhar", pela confiança em mim depositada e por ter sido um exemplo de orientadora, amiga, paciente e muito presente, obrigado por plantar em mim o gosto pela pesquisa científica.*

*Ao professor Paulo, pela generosidade, inspiração e grande oportunidade de fazer parte de seu grupo de pesquisa.*

*A todos do GPEP, bolsistas, mestrandos, doutorandos e pós-doutorandos pelo acolhimento, amizade, dedicação e suporte que fazem a excelência desse grupo, com certeza cresci muito ao lado de vocês nesses dois anos.*

*Ao professor Poli e às gurias do CEPOV, Jalise, Mariana e Gabi pela ajuda de sempre, pela amizade e grande incentivo que me fizeram encarar mais esta etapa da vida.*

*Ao meu irmão de coração Wagner, que me acompanhou e enfrentou poucas e boas durante a realização do experimento.*

*A todos os estagiários da EEA, Dani, Gentil, Ricardo, as meninas do Paraná, Natalí, Carolina, Ana, Kamila e Lariane pelo imenso prazer em conhecê-los, vocês também foram fundamentais para a realização deste trabalho.*

*A todos os funcionários da EEA pelo primordial suporte sempre que necessário durante o período experimental.*

*À Universidade Federal do Rio Grande do Sul e aos professores da Faculdade de Agronomia e do Programa de Pós-Graduação em Zootecnia, pelo ensino de alta qualidade.*

*A CAPES, pela concessão da bolsa de estudos, tornando meu sonho possível durante esses anos.*

*Meus sinceros agradecimentos à Edilene, ao Antonio e ao José por estar ao meu lado nas horas que mais precisei e por sempre acreditar no meu potencial.*

*MUITO OBRIGADO!*

**COMPORTAMENTO INGESTIVO DE OVINOS MANEJADOS SOB DIFERENTES MÉTODOS DE PASTOREIO E INTENSIDADES DE PASTEJO EM SISTEMA INTEGRADO DE PRODUÇÃO AGROPECUÁRIA**[1]

Autor: Ricardo Pereira Gonçalves

Orientadora: Carolina Bremm

Coorientador: Paulo César de Faccio Carvalho

**Resumo** – O entendimento das relações entre as características do pasto e as respostas do comportamento ingestivo animal é fundamental para o aprimoramento de inovações no manejo de pastagens, tornando os sistemas pastoris mais eficientes e competitivos. Neste estudo comparamos dois métodos de pastoreio (Rotativo x Contínuo) e duas intensidades de pastejo (Moderada e Baixa) a fim de compreendermos como as características de pastos de azevém anual (*Lolium multiflorum* Lam.*)* influenciam o comportamento ingestivo e o ganho médio diário de ovinos. Observamos que o método de pastoreio afeta a quantidade de folhas e inflorescências, influenciando a composição química da forragem, além da taxa de bocados e o tempo de pastejo dos ovinos. Por outro lado, as intensidades de pastejo influenciaram os bocados por estação alimentar e o número de refeições. Além disso, variáveis como: estação alimentar por minuto, duração das refeições e tempo de pastejo foram positivamente correlacionadas com o ganho médio diário dos animais, assim, podem ser utilizadas como preditoras do ganho médio diário de ovinos. Encontramos evidências de que em pastoreio rotativo, ambas as intensidades de pastejo estudadas promoveram um rebaixamento em torno de 45% da altura pré-pastejo. A estrutura do pasto e a composição química da forragem foram adequadas para o pastejo de ovinos até o início do estádio reprodutivo do azevém anual. No entanto, ao final do estádio reprodutivo da pastagem, ambas as intensidades de pastejo restringiram os padrões de comportamento ingestivo dos ovinos nas maiores escalas espaço-temporais. Essa restrição é acentuada durante o rebaixamento do pasto, em decorrência da redução no percentual de lâminas foliares, alterando o comportamento ingestivo de ovinos. Logo, a resposta comportamental de ovinos depende de: (i) taxa de lotação, (ii) nível de desfolha do dossel, (iii) período do estádio reprodutivo do azevém anual e composição estrutural da forragem durante o rebaixamento.

**Palavras–chave:** escalas de pastejo, estrutura do pasto, ganho médio diário, *Lolium multiflorum,* rebaixamento do pasto.

---

[1] Dissertação de Mestrado em Zootecnia – Plantas forrageiras, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil (p.112), Março, 2017.

**INGESTIVE BEHAVIOR OF SHEEP MANAGED UNDER DIFFERENT STOCKING METHODS AND GRAZING INTENSITIES ON INTEGRATED CROP-LIVESTOCK SYSTEM**[1]

Author: Ricardo Pereira Gonçalves

Advisor: Carolina Bremm

Co-advisor: Paulo César de Faccio Carvalho

**Abstract** – The understanding of the relationships between sward characteristics and the animals' ingestive behavior responses is fundamental for the improvement of sward management innovations, making pastoral systems more efficient and competitive. In this study, we compared two stocking methods (Continuous and Rotational) and two grazing intensities (Moderate and Low) to understand how the sward characteristics of annual ryegrass (*Lolium multiflorum* Lam.) influence the ingestive behavior and the average daily gain of sheep. We observed that the stocking method affect the quantity of leaf blades and inflorescences influenced forage chemical composition, as well as the bite rate and grazing time of sheep. On the other hand, grazing intensities had influence the bites by feeding station and meals number. Moreover, variables as feeding station per minute, meals duration and grazing time were positively correlated with the average daily gain, thus, they can be used as predictors for the average daily gain of sheep. We found evidence that both grazing intensities studied promote a grazing down around 45% of pre-grazing sward height in rotational stocking. Sward structure and forage chemical composition, were adequate for sheep grazing until the beginning of the sward reproductive stage. However, from the stage 2 of grazing down at the end of the sward reproductive stage, both grazing intensities apparently restricted the sheep's ingestive behavior patterns in the larger spatial and temporal scales of grazing. Therefore sheep's behavioral response depends on: (i) stocking rate, (ii) canopy defoliation level, (iii) period of sward reproductive stage and forage structural composition during grazing down.

**Keywords**: average daily gain, grazing down, grazing scales, *Lolium multiflorum* sward structure.

---

[1] Master of Science dissertation in Forage Science – Faculty of Agronomy, Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil. (p.112), March, 2017.

# SUMÁRIO

## RELAÇÃO DE TABELAS

### CAPÍTULO II

### INGESTIVE BEHAVIOR OF SHEEP MANAGED UNDER DIFFERENT STOCKING METHODS AND GRAZING INTENSITIES AND THEIR INFLUENCE ON THE AVERAGE DAILY GAIN



### CAPÍTULO III

### GRAZING DOWN PROCESS: IMPLICATIONS FOR SWARD MANAGEMENT THROUGH SHEEP'S INGESTIVE BEHAVIOR

# RELAÇÃO DE FIGURAS

## CAPÍTULO II

### INGESTIVE BEHAVIOR OF SHEEP MANAGED UNDER DIFFERENT STOCKING METHODS AND GRAZING INTENSITIES AND THEIR INFLUENCE ON THE AVERAGE DAILY GAIN



## CAPÍTULO III

### GRAZING DOWN PROCESS: IMPLICATIONS FOR SWARD MANAGEMENT THROUGH SHEEP'S INGESTIVE BEHAVIOR

## RELAÇÃO DE APÊNDICES

# LISTA DE ABREVIATURAS

| Abreviatura | Descrição |
|---|---|
| ADG | average daily gain |
| BFS | bites by feeding station |
| BR | bite rate |
| C | carbono |
| CP | crude protein |
| cm | centímetros |
| DM | dry mass |
| EA | estação alimentar |
| EU | experimental unit(s) |
| FAR | forage accumulation rate |
| FA | forage allowance |
| FM | forage mass |
| FSM | feeding stations per minute |
| GT | grazing time |
| ha | hectares |
| K | potássio |
| $km^2$ | quilômetros quadrados |
| kg | quilogramas |
| ICLS | Integrated Crop-Livestock Systems |
| LLS | leaf life span |
| LW | live weight |
| m | metros |
| N | nitrogênio |
| NDF | neutral detergent fiber |
| MD | meals duration |
| MN | meals number |
| O | Oxigênio |
| OMD | organic matter digestibility |
| P | fósforo |
| PC | plant coverage |
| PC1 | first principal component |
| PC2 | second principal component |
| RT | rumination time |
| S | South |
| SIPA | Sistema(s) Integrado(s) de Produção Agropecuária |
| SFS | steps by feeding station |
| SM | steps per minute |
| SPD | Sistema de Plantio Direto |
| SR | stocking rate |
| TOA | time of other activities |
| W | West |

# 1 CAPÍTULO I

# INTRODUÇÃO

## 1.1 INTRODUÇÃO GERAL

No cenário atual da produção mundial de alimentos, nota-se cada vez mais a necessidade de utilizar sistemas sustentáveis de produção. Dentro desta ótica, os Sistemas Integrados de Produção Agropecuária (SIPA) são reconhecidos pela *"Food and Agriculture Organization"* - FAO (2010) como sistemas produtivos promissores e sustentáveis, capazes de aumentar a produção de alimentos com responsabilidade ambiental, devido às interações espaço-temporais entre animais, plantas e o meio no qual estão inseridos (MORAINE *et al.,* 2016).

Em SIPA o uso de gramíneas durante a fase de pastagem é um fator de grande importância, pois o sistema radicular agressivo e a alta produção de biomassa são características que contribuem para a manutenção do solo, considerado a base de todo o sistema de produção (CAVALLINI *et al*., 2010; LOSS *et al*., 2011). Atrelado a isso, a utilização adequada de intensidades de pastejo pode contribuir para bons resultados (BONETTI *et al*., 2015). Assim, a adoção de SIPA, com o uso de práticas adequadas de manejo racional dos recursos naturais e de insumos, é primordial para uma agricultura eficiente. Com a sua utilização é possível diversificar áreas cultivadas, promovendo a implantação de pastagens destinadas à engorda e terminação de animais com menor custo de produção total (BALBINOT JR. *et al*., 2009).

Nos sistemas de produção animal a pasto, as relações planta-herbívoro devem ser contextualizadas em novas formas de manejo, visto que a forma como o animal reage às variações estruturais da pastagem compõe o comportamento de pastejo (CARVALHO & MORAES, 2005). Nesse sentido, a eficiência da utilização e conversão da forragem em produto animal (VALADARES FILHO *et al*., 2006), bem como o manejo do animal em seu ambiente de pastejo exige novos conceitos de gestão e novas ferramentas para fazer frente aos paradigmas que envolvem a produção alimentar contemporânea (CARVALHO, 2009). Para tanto, o estudo do comportamento animal tem grande importância para racionalizar a exploração zootécnica (ÍTAVO *et al*., 2008). Além de preocupar-se com a quantidade de alimento ofertado aos animais, o manejador deve estar atento ao controle e ao monitoramento da estrutura do pasto, com vistas a construir ambientes pastoris adequados, que possibilitem um consumo elevado de forragem e de nutrientes pelo herbívoro (CARVALHO *et al*., 2013).

Vários estudos descrevem o processo de pastejo em diferentes escalas hierárquicas espaciais e temporais que variam do bocado a grandes regiões de pastejo, onde cada uma delas caracteriza-se por um padrão de comportamento e, consequentemente, por fatores bióticos e abióticos que influenciam as decisões no processo de pastejo por diferentes relações de causa-efeito (SENFT *et al*., 1987; LACA & DEMMENT 1992; BAILEY *et al*. 1996). De acordo com Santos (2010), a compreensão adequada da dinâmica temporal e espacial do processo de pastejo, bem como os graus de alterações e de complexidade que os integram, é imprescindível para uma produção sustentável e eficiente. Portanto, o entendimento dos mecanismos e das estratégias utilizadas pelos animais durante o processo de pastejo tem suma importância para a obtenção de maiores benefícios na utilização desses ambientes, promovendo uma melhor identificação da qualidade da forragem ingerida pelos animais (CARVALHO *et al*., 2013) e que irá beneficiar o desempenho animal (SANTOS et al., 2010). A aplicabilidade desses conceitos ao sistema produtivo da ovinocultura, por exemplo, é fundamental para a construção de um ambiente adequado de produção de carne de cordeiro (BARBOSA *et al*. 2007).

Com base nessas informações, este trabalho objetivou definir de que maneira variáveis do comportamento ingestivo nas maiores escalas espaços-temporais (bocado, estação alimentar, *patch* e sítio de pastejo) podem ser usadas como preditoras acuradas para o desempenho individual de ovinos em pastagem de azevém anual (*Lolium multiflorum* Lam.), sendo consideradas na definição de metas de manejo de métodos de pastoreio e intensidades de pastejo. Para tanto, no Capítulo II será exposto como a combinação de dois métodos de pastoreio e duas intensidades de pastejo, interferem nas características estruturais do pasto, no comportamento ingestivo e, consequentemente, no ganho médio diário dos ovinos. Ademais, no Capítulo III será avaliada a relação entre as características estruturais do azevém anual, em estágio reprodutivo, e as respostas do comportamento ingestivo desses pequenos ruminantes ao longo do rebaixamento do pasto, em pastoreio rotativo.

## 1.2 HIPÓTESES DE ESTUDO

O presente estudo foi desenvolvido com base nas seguintes hipóteses: (1) variáveis do comportamento ingestivo nas diferentes escalas espaços-temporais (estação alimentar, *patch*, sítio de pastejo e campo de pastejo) podem ser usadas como preditoras do ganho médio diário de ovinos em pastagem de azevém anual (*Lolium multiflorum* Lam.) e deveriam ser consideradas para definir metas de manejo baseadas em métodos de pastoreio e intensidades de pastejo; (2) no método de pastoreio rotativo, a composição estrutural e química do azevém anual, ao final do período de rebaixamento do pasto, restringe o padrão de comportamento ingestivo de ovinos em intensidade de pastejo moderada, enquanto que em intensidade de pastejo baixa o padrão de comportamento ingestivo desses animais não é restringido.

## 1.3 OBJETIVOS

Objetivou-se com esse estudo: (1) definir como as alterações na estrutura e qualidade de uma pastagem de azevém anual (*Lolium multiflorum* Lam.), promovidas por métodos de pastoreio e intensidades de pastejo, afetam o comportamento ingestivo de ovinos; (2) avaliar de que forma alterações no comportamento ingestivo podem ser usadas para entender o ganho médio diário de ovinos, bem como estabelecer metas de manejo em pastagem de azevém anual; e (3) identificar e avaliar a relação entre as características estruturais do azevém anual e as respostas do comportamento ingestivo de ovinos durante o rebaixamento do pasto, a fim de promover melhorias no manejo sustentável do método de pastoreio rotativo.

## 1.4 REVISÃO BIBLIOGRÁFICA

### 1.4.1 Sistemas Integrados de Produção Agropecuária: promovendo o futuro da nutrição do planeta

O cenário agrícola atual apresenta o paradoxo de ter que produzir alimentos em elevada quantidade e qualidade, enquanto garantindo a segurança alimentar com o mínimo distúrbio ambiental possível e ainda promovendo benefícios sociais (BALBINOT Jr. *et al*., 2009). De acordo com o relatório "*Long Shadow*" da FAO (2006), a continuação da intensificação e especialização da produção agrícola, realizada de forma marcante nos países industrializados, é incapaz de produzir alimentos em âmbito mundial de forma sustentável, devido aos impactos causados sobre os recursos hídricos, as alterações climáticas e os ecossistemas em geral.

Diante dessa situação, destaca-se a importância de melhorar o funcionamento dos sistemas produtivos a base de forragem para garantir a sustentabilidade da produção de alimentos (CARVALHO *et al*., 2013; BOTREAU *et al*., 2014). , por meio da viabilidade econômica, sustentabilidade ambiental e respeito social, associados à ecoeficiência (RAO *et al*., 2014). De acordo com Rao *et al*. (2015) a intensificação sustentável em sistemas a base de forragens, pode ser estabelecida a partir de três processos de intensificação inter-relacionados: (i) intensificação genética - desenvolvimento e uso de gramíneas superiores e leguminosas para aumento da produção pecuária; (ii) intensificação ecológica - desenvolvimento e aplicação de melhores práticas de gestão das explorações e dos recursos naturais; e (iii) intensificação socioeconômica - a melhoria das instituições e políticas locais e nacionais, que permitem aperfeiçoar as tecnologias e apoiar o seu uso duradouro. Logo, para suprir a demanda nutricional de uma população crescente, que chegará a 9,2 bilhões de pessoas em 2050, o aumento da produção mundial de alimentos e fibras deverá ocorrer 90% através da "intensificação sustentável" e apenas 10% a partir da expansão das áreas agrícolas (FAO, 2010). A alternativa mais apropriada para isso é o uso de sistemas de produção que promovam intensa utilização dos recursos disponíveis nos agrossistemas, concomitante à melhoria da qualidade do solo (base da produção vegetal e animal), reduzindo o consumo de insumos e gerando maior renda por área (DORAN & PARKIN, 1994). Portanto, os países em desenvolvimento têm maior potencial para aumentar a produção alimentar através da restauração de terras degradadas do que os países desenvolvidos (SMITH *et al*., 2008; MURGUEITIO *et al.,* 2011).

As integrações de sistemas pastoris com sistemas de cultivo ajudam a mitigar impactos ambientais negativos resultantes da intensificação dos cultivos e melhoraram a qualidade desses sistemas através de restauração periódica (LEMAIRE *et al*., 2014). Nesse sentido, os Sistemas Integrados de Produção Agropecuária (SIPA) já são vistos como alternativa sustentável e apresentam potencial para suprir a demanda mundial crescente. Os SIPA podem ser implantados com sucesso em pequenos e grandes estabelecimentos rurais, ademais, quando utilizados nos trópicos, são diversificados e dinâmicos, com base em condições agroecológicas e de mercado distintas (BYERLEE & COLLINSON, 1988; GILLER *et al*., 2010). A adoção dos SIPA tem crescido bastante no Brasil e apresenta particularidades em cada região do país. Enquanto na região do Cerrado e centro-sul do país o enfoque da integração está voltado para a rotação de culturas e na recuperação de áreas degradadas, no caso da região Sul do Brasil a integração também se destaca como alternativa de renda e utilização das áreas nos períodos entre as lavouras de verão (CARVALHO *et al*., 2005). Logo, no Sul do Brasil a produção vegetal é constituída por culturas como: soja, fumo, feijão e milho (sendo este último destinado à produção de silagem e grãos) enquanto que a produção animal é, em geral, representada por bovinos destinados à produção de carne e de leite, mas também por ovinos e caprinos para produção de carne (BALBINOT JR *et al*., 2009).

É evidente que um dos objetivos dos SIPA é melhorar o metabolismo do sistema agrícola, mas não necessariamente através de um processo de integração apenas entre culturas e a pecuária. As vantagens dos SIPA estão baseadas, justamente, na associação de características positivas presente em cada um dos sistemas utilizados. Sabe-se que sistemas como o plantio direto (SPD), em que se tem aporte de resíduo no solo, há aumento do carbono orgânico total, podendo interferir na redução da densidade do solo e no aumento da porosidade total, macro e microporosidade, na camada superficial (MARCOLAN & ANGHINONI, 2006). Com o uso de gramíneas para pastoreio animal os benefícios característicos do SPD podem ser potencializados, pois o sistema radicular agressivo e a alta produção de biomassa dessas plantas contribuem para a manutenção da boa estrutura física do solo (CAVALLINI *et al*., 2010; LOSS *et al*., 2011). Esses benefícios são refletidos no rendimento das culturas sucessoras, na redução da incidência de pragas, doenças e plantas daninhas, além do aumento da diversificação temporal da exploração econômica na propriedade rural (FLORES *et al*., 2007; BALBINOT JR *et al*., 2009). Assim, os SIPA apresentam produtividade e sustentabilidade superiores aos sistemas que não incluem o componente animal na fase de pastejo, devido à maior eficiência de uso dos nutrientes, diversidade microbiana, ciclagem de nutrientes, agregação do solo e sequestro de carbono, contribuindo também para a mitigação da emissão de gases de efeito estufa (MORAES *et al*., 2014). Além disso, as pastagens de médio e longo prazo constituem um tipo de uso da terra com um papel específico na prestação de serviços ecossistêmicos (BRETAGNOLLE *et al*., 2011; LEMAIRE *et al*., 2014; RODRÍGUEZ-ORTEGUA *et al*., 2014). A natureza dos serviços ecossistêmicos prestados à sociedade é frequentemente classificada como: abastecimento (produtos nutricionais, materiais e energéticos dos ecossistemas), regulador (de processos naturais como erosão e controle de pragas) e provedor de serviços culturais (oferecendo recursos espirituais, inspiradores e experiências educacionais) (MORAINE *et al,* 2016).

O conceito de SIPA vai além da simples rotação ou sucessão da lavoura integrada com a pecuária, tendo em vista que esta terminologia não abrange a diversidade de interações que os sistemas integrados podem alcançar (CARVALHO *et al*., 2014). Conforme Moraine *et al.* (2016), as complementaridades e sinergias entre as culturas e a pecuária podem melhorar o ciclo de nutrientes e a prestação de serviços ecossistêmicos em sistemas agrícolas. Portanto, o conceito de SIPA assemelha-se mais ao proposto por Anghinoni *et al.* (2013), os quais referem-se aos SIPA como sistemas planejados para explorar sinergismos e propriedades emergentes, frutos de interações nos compartimentos solo-planta-animal-atmosfera de áreas que integram atividades de produção agrícola e pecuária. Assim, para melhor entendimento dos SIPA é de grande importância considerar interações espaço-temporais entre animais, plantas (pastagens e culturas) e o meio em que estes estão inseridos (MORAINE *et al.,* 2016). Essas interações dependem de recursos econômicos, institucionais e sociais, tais como: infraestrutura, mercados, instituições e capital social de pessoas envolvidas direta ou indiretamente no funcionamento do sistema. Os SIPA também podem ser conceituados como sistemas sócio-ecológicos (CABELL & OELOFSE, 2012), em que o sistema social influencia a maneira como a terra é utilizada, bem como a natureza dos serviços ecossistêmicos que ela fornece (DÍAZ *et al*., 2011; SCHOUTEN *et al*., 2012; POCCARD-CHAPUIS *et al*., 2014). Contudo, vale esclarecer que os SIPA não são e nem devem ser considerados como uma novidade temática. Já que os primeiros sistemas agrários da história humana derivam da revolução agrícola neolítica (MAZOYER *et al*., 2010). Em uma escala temporal, os SIPA se originaram, provavelmente, de uma combinação de propósitos, em que herbívoros domesticados consumiam plantas que o homem não conseguia aproveitar (CARVALHO *et al*., 2014). A partir disso, os animais geravam nutrientes consumíveis pelos humanos, e seus excrementos geravam a fonte de nutrientes necessária para a prática da agricultura (ANGHINONI *et al*., 2013). Portanto, os sistemas integrados são tão antigos quanto à domesticação das plantas e dos animais. Porém, sempre estiveram em evolução, através do conhecimento de suas propriedades progredindo em paralelo ao desenvolvimento humano (CARVALHO *et al*., 2014).

Atualmente, os SIPA estão presentes em mais de 25 milhões de $km^2$ (BELL & MOORE, 2012), produzindo alimentos tanto de origem vegetal quanto animal. A maior parte da carne e do leite produzidos no mundo em desenvolvimento, e quase metade da produção mundial de cereais provém desses sistemas (HERRERO *et al*., 2010). Entretanto, mesmo com todas as características promissoras que os SIPA apresentam, são inúmeros os desafios para o seu desenvolvimento. Tendo em vista que para o adequado funcionamento de um SIPA alguns fundamentos devem ser atendidos, tais como: uso de rotação de culturas e sistema plantio direto, a correção da acidez e fertilidade do solo, o emprego de genótipos melhorados, bem como o manejo correto da pastagem, em especial no que se refere à sua fertilização e à manutenção de altura adequada. (BALBINOT JR *et al*., 2009). Segundo Moraine *et al* (2016), o desenvolvimento de interações entre as explorações agrícolas e a pecuária levanta questões metodológicas importantes, em função da complexidade envolvida na investigação científica desse sistema. Nesse seguimento, Tanaka *et al*. (2008), descreveram a dificuldade de integrar múltiplos objetivos e analisar as trocas entre os desempenhos numa abordagem experimental. Balbinot Jr *et al*., 2009 e Randrianasolo *et al*. (2010), mostraram a importância da análise e da avaliação multicriteriosa para a concepção dos SIPA, onde vários fatores biológicos, econômicos e sociais estão relacionados e determinam a sua sustentabilidade. Para Anghinoni et al. (2013), o grau de interações sinérgicas inerentes aos SIPA é dependente do quão complexo é o sistema, com relação à diversificação, temporalidade e espacialização. Essa complexidade exige o desenvolvimento de políticas governamentais adaptadas, baseadas na participação e no aprendizado social, as quais determinarão a aceitabilidade e a implementação final dos SIPA nas propriedades rurais de forma geral (MORAINE *et al*.,2016).

Desse modo, a avaliação da produção animal no contexto dos SIPA deve representar tema de grande interesse nos tópicos de pesquisa voltados à produção de alimentos mundial. Tendo em vista que quanto mais diversos são os sistemas, mais eles se aproximam dos processos ecossistêmicos naturais, mimetizando seu funcionamento e equilíbrio (KIRSCHENMANN, 2007). Dentre os principais objetivos dessas pesquisas específicas, deve estar: (i) o aumento da intensificação sustentável de alimentos nos próximos dez anos (em regiões específicas de poucos países onde as políticas incentivem a produção e o fornecimento de serviços ecossistêmicos); (ii) aumento da participação de pequenos e médios produtores aos mercados formais e (iii) a aplicação de intervenções resilientes em cadeias de valor cultural e agropecuário, assegurando ganhos econômicos e reduzindo a pobreza (RAO *et al*., 2015).

### 1.4.2 Sistemas pastoris: o uso de diferentes estratégias de manejo da pastagem e suas implicações no desempenho animal

O potencial dos sistemas pastoris não foi considerado uma opção viável até a década de 1970, quando os ecologistas introduziram a hipótese de otimização do pastoreio (BRISKE *et al*., 2008). Nesse seguimento, os ruminantes apresentam excelência na capacidade de transformar a biomassa de baixa qualidade em alimento de alta densidade e valor nutricional (SMITH *et al*., 2013). Para tanto, a eficiência da produção animal a pasto resulta de três processos correlacionados, sendo eles: produção de forragem; consumo de forragem e conversão da forragem em produto animal (VALADARES FILHO *et al*., 2006). Através disso, os herbívoros contribuem com aproximadamente 15% do total da energia alimentar humana, 25% da proteína dietética e alguns micronutrientes não disponíveis facilmente a partir de plantas para consumo humano (FAO, 2009). Desse modo, os ruminantes acabam sendo responsáveis por aproximadamente 50% da produção de alimentos no mundo (65% dos bovinos, 75% do leite e 55% dos cordeiros nos países em desenvolvimento) (HERRERO *et al*., 2010). Em contraste, a pecuária pode ter efeitos negativos substanciais sobre o meio ambiente, incluindo o aquecimento global (BOUWMAN *et al.,* 2006), a poluição por nitrogênio (N) (STEINFELD *et al*., 2006; HERRERO *et al*., 2013), alto consumo de água e contaminação dos recursos hídricos (HERRERO *et al*., 2012). Portando, o estudo do animal em seu ambiente de pastejo possui um papel de grande complexidade, exigindo novos conceitos de manejo e novas ferramentas para fazer frente aos paradigmas que envolvem a produção alimentar contemporânea (CARVALHO, 2009).

A utilização da pastagem pelo animal implica em explorar e promover a heterogeneidade do ambiente seja pelo próprio pastejo (através da seleção da forragem pelo animal), ou pela distribuição de dejetos (que não é constante nem uniforme) (MCNAUGHTON,1985; CHÁVEZ *et al*., 2011). A escolha correta da espécie ou cultivar forrageira acaba promovendo o equilíbrio do ambiente pastoril e, ao longo do tempo, determina os índices de produtividade e de qualidade (BAUER *et al*., 2011). Aliado a isso, os herbívoros são os principais agentes reguladores da estrutura e da composição dos ecossistemas pastoris, definindo o padrão espacial das comunidades vegetais nesse ambiente (DUMONT *et al*., 2012). Esse padrão espacial é determinado por “feedbacks” entre o animal pastejador e a qualidade das plantas à sua disposição (ADLER *et al*., 2001). Nesse sentido, é possível elevar o consumo do animal de acordo com a quantidade e qualidade da forragem oferecida, podendo ser expresso pela altura do pasto, tempo de vida da folha, massa de forragem, índice de área foliar, teor de proteína bruta, entre outros (VAN SOEST, 1994; PONTES *et al*., 2004). Para tanto, é fundamental a utilização de espécies forrageiras de alto valor nutritivo, além de trabalhar com ofertas de forragem adequadas às demandas dos animais (BARBOSA *et al*. 2007). Dentre os fatores que são influenciados pela forragem, Hodgson (1990) citou a maturidade, concentração de nutrientes do material ingerido e estrutura física da forragem. O avanço na idade da planta interfere na qualidade, mesmo em condições de alta oferta para os animais, pois altera a participação de seus componentes estruturais, principalmente a relação folha/colmo e material senescente (BORTOLO *et al*., 2001). Animais alimentados com forragens com alto teor de fibra têm menor taxa de passagem das partículas no rúmen, o que acarreta em redução do consumo de matéria seca (VAN SOEST, 1994). Com base nisso, destaca-se o azevém anual (*Lolium multiflorum* Lam.), uma gramínea forrageira hibernal muito utilizada em pastagens na Região Sul do Brasil para melhorar a oferta e a qualidade da forragem, além de favorecer o desenvolvimento dos animais na estação de menor produção das pastagens nativas (BARBOSA *et al*., 2007). O azevém anual é muito cultivado em diversos países do mundo, dentre estes o Uruguai, Argentina, Estados Unidos e Nova Zelândia. Os pastos de azevém destacam-se pela facilidade de estabelecimento, eles apresentam crescimento vigoroso, especialmente nos meses da primavera, alto valor nutritivo e alta produtividade de forragem, o que contribui para o bom desempenho animal individual e por área (SANTOS *et al*., 2009).

Em sistemas de produção animal a pasto, as plantas estão sujeitas a desfolhas sucessivas, cuja frequência e intensidade são dependentes do método de pastoreio a que estão submetidas (LEMAIRE & CHAPMAN, 1996). O emprego de métodos de pastoreio como ferramenta de manejo baseia-se, predominantemente, nos tradicionais métodos contínuo e/ou rotativo. De forma simplificada, enquanto em pastoreio contínuo o animal não tem restrição de deslocamento dentro da área de pastejo, no método rotativo a estratégia, geralmente utilizada, é de uma elevada lotação instantânea em subdivisões pré-estabelecidas dos piquetes (HODGSON, 1990). Isso também promove traços característicos nas respostas dos animais em pastejo sob esses dois métodos. Vários estudos descrevem que em pastoreio contínuo, a capacidade de seleção de estruturas do pasto com melhor qualidade pelo herbívoro é maior, consequentemente, pode haver maior desempenho individual (Barrett et al., 2001; Ungar et al., 2001; CARVALHO, 2007). Por outro lado, segundo os mesmos autores, em pastoreio rotativo, muitas vezes há uma restrição da seletividade do animal (elevadas taxas de lotação), havendo aumento na densidade aparente, com drástica diminuição da relação folha/colmo ao longo do rebaixamento do pasto, prejudicando o desempenho animal individual.

É provável que a comparação entre pastoreio contínuo e rotativo seja muito ampla para ter implicações práticas significativas (LACA, 2009). A complexidade desse tema está no amplo conjunto de variáveis de confusão que tornam quase impossível uma comparação direta entre métodos de pastoreio (HEADY, 1961). O que se sabe de forma consolidada, é que uma pastagem abundante em folhas jovens com certa proporção de lâminas expandidas intactas (para pastoreio contínuo) ou uma massa de folhas residuais que não seja pequena (para pastoreio rotativo) completariam o cenário de um ambiente alimentar confortável para o animal (CARVALHO & MORAES, 2005). A complexidade relativa do processo de tomada de decisão no manejo de pastagens levou a importantes tentativas de desenvolver indicadores simples ou ferramentas que os agricultores podem aplicar na sua gestão diária (CHAPMAN *et al*., 2012). Exemplos desses objetivos de manejo incluem o conceito do uso adequado das intensidades de pastejo em pastoreio contínuo e, mais recentemente, das alturas de pré e pós-pastejo em pastoreio rotativo, os quais têm um grande impacto no desempenho animal e na rentabilidade de sistemas pastoris (AMARAL *et al*., 2012; SAVIAN *et al*. 2014). No caso do azevém anual, que depende da produção de sementes produzidas para a manutenção do banco de sementes e posterior estabelecimento por ressemeadura natural, a utilização de métodos de pastoreio e intensidades de pastejo que favoreçam o desenvolvimento de perfilhos reprodutivos para a manutenção deste banco, é de extrema importância. Barhlomew *et al*. (2009) inferiram que os perfilhos reprodutivos em azevém anual em pastoreio contínuo são formados pelos mosaicos de exclusão ao pastejo proveniente da seleção dos animais. Em pastoreio rotativo, estas áreas de exclusão ao pastejo também ocorrem, assim, os perfilhos reprodutivos podem ser originários destas áreas. Em maiores intensidades de pastejo, os mosaicos de exclusão são menores, resultado da menor seleção imposta pelos animais na pastagem, consequentemente a produção de sementes pode ser menor, caso esta seja insuficiente para a manutenção do banco de sementes do solo, o restabelecimento no ano seguinte poderá ser comprometido.

Apesar da grande complexidade do tema, há inúmeras evidências geradas a partir de experimentos de pastejo nos últimos 60 anos indicando que o pastoreio rotativo não parece conseguir consistentemente resultados que diferem muito do pastoreio contínuo (BRISKE *et al*., 2008). Segundo os mesmos autores a produção vegetal é igual ou maior em pastoreio contínuo em comparação ao pastoreio rotativo em 87% (resultado encontrado em 20 de 23 experimentos analisados), a produção por animal e por área também é igual ou maior na comparação do pastoreio contínuo com o rotativo em 92% (resposta em 35 de 38 experimentos) e 84% (resposta em 27 de 32 experimentos), respectivamente. Portanto, ambos os métodos de pastoreio são definidos de tal forma que eles podem facilmente se aproximar e até mesmo complementar uns dos outros em termos de fatores causais próximos, tais como a frequência e a intensidade de desfolha das plantas ao longo do processo de pastejo (LACA, 2009). É evidente que um sistema pastoril bem manejado, seja ele rotativo ou contínuo, sempre irá atingir os objetivos de produção desejados mais eficazmente do que um sistema mal gerido. O que se torna essencial em qualquer estratégia de manejo é o oferecimento da forragem em uma quantidade que potencialize o consumo dos animais, além de criar condições de solo favoráveis à ressemeadura de espécies forrageiras (CARVALHO *et al*., 2004). De acordo com Briske *et al*. (2008), a taxa de lotação emergiu como a variável de manejo mais consistente que influencia tanto as respostas de plantas como de animais em pastoreio. Da mesma forma acontece em SIPA, pois a taxa de lotação afeta indiretamente a quantidade de biomassa presente ao longo do ciclo da pastagem e, consequentemente, na que será transferida para o ciclo de lavoura (CARVALHO *et al*., 2005). Nesse sentido, a taxa de lotação deve ser monitorada de acordo com a capacidade de suporte de carga de cada solo, produção de forragem e demanda de forragem dos animais, minimizando assim, as alterações na sua estrutura física (BONETTI *et al*., 2015). Mckown *et al*. (1991) compararam os efeitos do pastoreio rotativo e contínuo com a intensidade de pastejo na ingestão de nutrientes e concluíram que as diferenças na ingestão de nutrientes entre os tratamentos foram atribuídas, principalmente, às diferenças na taxa de lotação em vez do método de pastoreio. Assim como Mezzalira *et al*. (2014), que constataram que independentemente da espécie forrageira e do método de pastoreio estudados, a massa de bocados e, consequentemente, a taxa de ingestão são os componentes mais importantes para o desempenho animal e, geralmente, aumentam em paralelo à altura do pasto. Por sua vez, resultados como esses podem ser alcançados através da redução da taxa de lotação, promovendo estabilidade ao sistema planta-animal.

Apesar das variações de vegetação induzidas pelo pasto esteja bem compreendida, pouca atenção é dada aos efeitos do comportamento dos herbívoros na distribuição espacial da vegetação e seus consequentes efeitos sobre as comunidades de plantas e métodos de pastoreio (REN *et al*., 2015). Para Laca (2009) o comportamento dos sistemas pastoris pode ser mais bem entendido como uma série de respostas a eventos específicos em determinados momentos. Há necessidade de maior compromisso com a capacidade de manejo, a fim de promover eficácia do sistema, já que os sistemas pastoris não possuem propriedades únicas que lhes permitam compensar a ineficácia da gestão (BRISKE *et al*., 2008). Novas possibilidades de direcionamento das habilidades dos animais devem ser criadas através da adoção de técnicas de manejo que visem o estabelecimento de um maior equilíbrio entre a produção e o ambiente (SANTOS, 2010). Portanto, constatações relativas ao adequado manejo da pastagem a partir do uso de métodos de pastoreio e intensidades de pastejo são de grande relevância para manter a sustentabilidade de ecossistemas específicos no atual cenário científico forrageiro.

### 1.4.3 O estudo do comportamento ingestivo de herbívoros relacionado às características do pasto

Durante um longo processo evolutivo os herbívoros se especializaram na utilização de um recurso complexo para a sua alimentação, a forragem, a qual se apresenta de forma dinâmica no tempo e no espaço (CARVALHO & MORAES, 2005). Evidências experimentais, tais como as de Prache *et al*. (1998), definiram que o fundamento básico do processo de pastejo é a otimização, onde o custo de aquisição de energia é sempre contraposto ao benefício de obtê-la. Então, para serem eficientes na aquisição de nutrientes os animais têm a capacidade de adaptar o tempo dedicado ao pastejo, alterando suas decisões comportamentais gerais (NEWMAN *et al*., 1994). Nesse sentido, os herbívoros desenvolveram estratégias de otimização do uso do tempo na busca e na colheita da forragem com qualidade superior à média existente em toda a área de pastoreio (CARVALHO *et al*., 2013). Assim, esses animais são capazes de explorar, de forma positiva, a heterogeneidade natural do ambiente pastoril (LACA & DEMMENT,1991), através de alterações nos padrões de deslocamento, preferência e ingestão em resposta às variações da oferta de forragem, da estrutura e da composição química do pasto (CARVALHO *et al*., 2013).

Fundamentos como estes foram obtidos por meio do acompanhamento e compreensão do comportamento ingestivo animal, apresentando crucial importância na área da forragicultura. Uma vez que o entendimento das relações existentes entre as características estruturais do pasto e o comportamento dos animais é fundamental para se definir as estratégias de manejo das pastagens (GONÇALVES *et al*., 2009). Através da modulação do comportamento alimentar e espacial, os animais adaptam-se a diferentes fatores ambientais, na busca da satisfação de suas necessidades e da realização de suas funções vitais (SANTOS, 2010). Com o conhecimento do comportamento ingestivo e das estratégias dos animais no ambiente pastoril é possível conhecer as relações de causa-efeito que determinam o consumo, permitindo inferências sobre a qualidade do ambiente e o estado nutricional dos animais em pastejo (CARVALHO *et al*., 2008), tendo em vista que o comportamento dos animais nada mais é do que o reflexo das características do pasto moldadas pelo próprio animal (via pastejo) e associadas às decisões do manejador (HIRATA *et al*., 2010). Nessa lógica, o primeiro procedimento quantitativo para avaliar o efeito do pastejo sobre a composição do ambiente pastoril baseou-se no reconhecimento de que o pastejo seletivo afeta desproporcionalmente alguns grupos vegetais mais do que outros (BRISKE *et al*., 2008). Da mesma forma, a alteração da apreensibilidade da forragem apresenta grande influência sobre o comportamento ingestivo do animal por meio da intensidade de desfolha aplicada à pastagem (GLIENKE *et al*., 2008). Entretanto, a altura das plantas durante os vários estádios do desenvolvimento fenológico é o que mais influencia tanto a frequência e a intensidade da desfolhação, como a localização correspondente e o número de meristemas restantes (perfilhos) determinam a taxa de substituição da área foliar (BRISKE & RICHARDS, 1995; DI´AZ *et al*., 2001). De acordo com Garcez Neto *et al*. (2002), a produção de novos perfilhos é um processo contínuo que pode ser acelerado pela desfolhação da planta e consequente melhoria do ambiente luminoso na base do dossel. A manutenção da população de perfilhos ocorre por uma contínua reposição dos perfilhos mortos pelos vivos, sendo esse comportamento essencial para a perenidade das gramíneas (SILVA *et al*., 2016). A resposta das plantas forrageiras a esse processo depende, portanto, da espécie, da severidade do processo de remoção de tecidos e da sua adaptação ao pastejo (GROFF *et al*., 2002).

É importante destacar que as ações comportamentais dos herbívoros não sofrem influência exclusiva das características do pasto, mas também das experiências individuais dos animais, e como elas interagem com seu ambiente físico e social (BAILEY & PROVENZA, 2008). Neste seguimento, Provenza & Launchbaugh (1999) consideraram que os genes compõem a memória cumulativa do ambiente na formação de uma espécie através de milênios, considerando que os animais adquirem através dos tempos uma grande bagagem de aprendizado passado de geração a geração. Assim, a experiência adquirida pelo animal tem um efeito determinante no processo de construção do comportamento alimentar em pastoreio (SANTOS, 2010). Numa escala temporal mais reduzida, a memória consiste em outro fator que influencia os movimentos dos animais em pastejo. Segundo Bailey *et al*. (1996), existem dois tipos de memória, uma memória de referência ou radial (que diz respeito à localização espacial dos animais em relação ao alimento, o que possibilita a estes lembrar os locais com maior ou menor abundância de forragem) e outra de trabalho ou paralela (que refere-se à lembrança dos locais já pastejados, evitando assim o retorno aos mesmos, em períodos de aproximadamente 8 horas).

Descobertas como estas, baseadas no comportamento animal, promoveram uma mudança no enfoque da pesquisa. Deixou-se de enfatizar apenas a produtividade animal e passou-se a investigar os processos e as razões envolvidas no ato do animal buscar o alimento, com vistas a aperfeiçoar o uso e consumo do pasto (CARVALHO & MORAES, 2005). No seguimento do processo de otimização do pastejo, Senft *et al*. (1987) propuseram um modelo conceitual de forrageamento para herbívoros, apresentando o processo de pastejo de forma hierárquica e em diferentes escalas espaço-temporais. Essas escalas também foram apresentadas de forma hierárquica por Laca & Ortega (1995) e por Bailey *et al*. (1996), variando da planta ou estação alimentar (menor escala), passando pela comunidade de plantas ou grandes "*patches"* (escala intermediária) até a escala de sistema regional (maior escala). Em cada escala, observam-se padrões de forrageamento distintos e, consequentemente, fatores bióticos e abióticos que influenciam as decisões no processo de pastejo por diferentes relações de causa-efeito (LACA & ORTEGA, 1995; BAILEY *et al*., 1996).

Sob essa visão, faz-se necessário que os manejadores de sistemas pastoris tenham o conhecimento de que uma das características do comportamento forrageiro dos animais é seu padrão diurno. A partir disso, Carvalho *et al.* (2005) propuseram que o controle do consumo de forragem devesse ser focado em sua dinâmica dentro das refeições (definida como uma ação contínua de pastejo; GIBB, 1998) e entre refeições ao longo do dia, coordenando períodos de atividade de ingestão e ruminação. Entender os fatores que controlam o número e a duração das refeições em relação ao estado do pasto é importante para predizer a aquisição de nutrientes pelos animais em pastejo (BAUMONT *et al*., 2000). Assim, as horas mais próximas ao nascer e ao pôr do sol tendem a ser de pastejo mais longo e contínuo, em contraste, no restante do dia, o pastejo tende a ser mais intermitente e os animais descansam ou ruminam (FRASER & BROOM, 1990). Além disso, fatores fisiológicos e metabólicos, a termorregulação, a necessidade de socialização, descanso, regulação do consumo de água, vigilância, distância da água e topografia do terreno constituem fatores bióticos e abióticos que também controlam os padrões de pastejo em escalas em longo prazo (SENFT *et al*., 1987; LACA & DEMMENT, 1992; BAILEY *et al*., 1996). Por outro lado, sobre as menores escalas do comportamento ingestivo, que compreendem desde o bocado até a estação alimentar, fatores como a oferta de forragem, a estrutura do pasto, a composição química da forragem e a variabilidade espacial, tornam-se mais relevantes (CARVALHO *et al*., 2013).

Para Santos (2010), o adequado entendimento do processo de hierarquização do pastejo em escala temporal e espacial torna-se fundamental para o manejo correto dos herbívoros. Na escala de bocado, a variável resposta de maior importância é a massa do bocado (BAILEY & PROVENZA, 2008). Ao realizar bocados, o animal defronta-se continuamente com a seleção das partes mais nutritivas do pasto (por exemplo: folhas, colmos, inflorescências e material senescente), com o intuito de obter uma dieta com elevada qualidade (CARVALHO *et al*., 2013). Esse mecanismo estratégico dos herbívoros visa à profundidade do bocado, tendo relação positiva e proporcional à altura das plantas, fenômeno este definido como “proporcionalidade constante de remoção de forragem” (HODGSON *et al*., 1994). À medida que ocorre a depleção das lâminas, chega um momento em que os animais irão despender maior tempo na procura por folhas verdes dentro de um dossel repleto de colmos e material morto, contexto este que resulta em efetiva redução na taxa de bocados (ORR *et al*., 2004). A redução da taxa de bocados indica o aumento de movimentos mandibulares de mastigação e manipulação à medida que a massa do bocado diminui (HODGSON *et al*., 1997). Portanto, para aumentar a eficiência na formação dos bocados é necessário proporcionar estruturas de pasto que possibilitem ao animal colher elevadas massas de bocados, visando minimizar o efeito dos “custos fixos” relacionados à colheita de forragem em cada bocado (CARVALHO *et al*., 2013).

Por outro lado, na escala de estação alimentar (EA), definida como o espaço correspondente ao pastejo sem movimento das patas dianteiras (ALLEN *et al*. 2011), os animais tomam decisões de quanto tempo permanecer, e quantos bocados apreender, por EA (STUTH, 1991). A ingestão em nível de EA é um importante indicativo de atributos quanti-qualitativos e estruturais do pasto, quanto melhor a qualidade estrutural do pasto na EA (e.g., massa de forragem, altura do pasto, densidade de forragem e relação folha/colmo), maior será o tempo de permanência dos animais até que a relação custo/benefício em explorá-la passe a ser menos interessante (CARVALHO *et al*., 2013). Allden & Whittaker (1970) definiram a ingestão de forragem como o efeito combinado do comportamento ingestivo, da massa de bocados, da taxa de bocados e do tempo de pastejo. Nesse sentido, para atender suas exigências de ingestão de matéria seca, os herbívoros alteram o tempo de pastejo, bem como a taxa e o tamanho de bocados (GLIENKE *et al*., 2008). Assim, a alta disponibilidade de forragem, possibilita que os animais acessem as melhores EAs, colham bocados de alta massa e caminhem maiores distâncias entre EAs acessadas (ROUGUET *et al*., 1998). O que por sua vez, promove eficiência do processo de pastejo e, consequentemente, reflete em excelente desempenho animal.

Nas escalas maiores do processo de pastejo (sítio e campo de pastejo), a organização temporal envolve turnos, podendo apresentar várias refeições, as quais são interrompidas por intervalos de duração variada (intermitências superiores a 5 minutos; GIBB et al., 1999). O tempo diário que os animais dedicam ao pastejo também se configura como um indicador qualitativo do ambiente alimentar (CARVALHO *et al*., 2005) e que pode ser afetado pela duração da atividade de ruminação (relacionada à características físico-químicas da dieta) e outras atividades (relacionadas com o status nutricional e social, por exemplo) (HODGSON et al., 1997). Em situações de abundância de forragem, os animais executam, ao longo do dia, maior número de refeições de curta duração (BAGGIO et al., 2008), promovido pela elevada taxa de ingestão e, consequentemente, rápido estado de saciedade (CARVALHO & MORAES, 2005). Por outro lado, em situações limitantes ao consumo de forragem, o tempo diário dedicado ao pastejo pode exceder a 10 horas, e o deslocamento em pastejo pode alcançar valores superiores a 4 km $dia^{-1}$, o que acaba prejudicando o desempenho dos animais (DA TRINDADE, 2011).

### 1.4.4 Padrões de comportamento ingestivo animal ao longo do rebaixamento do pasto

Sistemas de produção animal com uso do método de pastoreio rotativo são projetados de forma a redistribuir a pressão de pastejo no tempo e no espaço, com maior controle sobre a frequência, intensidade e uniformidade de desfolha durante o período de pastejo (GILLEN *et al*., 1990). Nesse seguimento, o processo de pastejo ocorreria com remoção de camadas sucessivas de pasto, correspondentes a 50% da altura da planta (BAUMONT *et al.*, 2004), provocando uma mudança estrutural no dossel caracterizada pelo aumento da presença de barreiras à desfolhação e maior teor fibroso da forragem (BENVENUTTI *et al*., 2015; SILVA *et al*., 2015).

Dentre as modificações estruturais da pastagem, a quantidade de folhas é o principal componente que afeta a qualidade da forragem (ORR *et al*., 2004 BENVENUTTI *et al*., 2015), refletindo negativamente no consumo diário de forragem pelo animal em pastejo (BENVENUTTI *et al*., 2015; MACEDO *et al*., 2015). Nesse sentido, diversos estudos voltados ao entendimento do que ocorre ao longo do rebaixamento do pasto (LACA *et al*., 1992; UNGAR *et al*., 2001; AMARAL *et al*., 2012; BENVENUTTI *et al*., 2015) descreveram que as modificações estruturais do dossel, como a diminuição da relação folha/colmo, podem restringir os padrões de comportamento ingestivo dos herbívoros, levando a utilização de estratégias de compensação do pastejo, como a progressiva redução nas dimensões do bocado e, consequentemente, na taxa de ingestão de forragem. Estratégias de compensação como essas se tornam mais evidentes, por exemplo, ao final do período de ocupação de um piquete, pois os animais se deparam mais frequentemente com componentes estruturais do pasto (inflorescências e colmos) complicadores do processo de formação do bocado (BENVENUTTI *et al*., 2015; ROCHA *et al*., 2016). Assim, há menor eficiência dos movimentos de apreensão, resultando em maior tempo de manipulação na boca desses componentes estruturais do pasto, quando comparado aos movimentos de apreensão de folhas (HODGSON, 1990; LACA *et al*., 1994). Entretanto, é importante destacar que o animal não se motiva a pastejar a porção colmos antes de ter removido a maior parte das folhas, pois isso exigiria maior gasto de energia para colheita, prejudicando a profundidade do bocado e, por consequência, a massa do bocado (BARRE *et al*., 2006).

Com o objetivo de maximizar a taxa de ingestão ou a ingestão diária de forragem durante a desfolhação, estudos indicam que a altura ideal pós-pastejo depende da altura inicial do pasto, uma vez que em pastoreio rotativo a entrada dos animais em um novo piquete caracteriza-se pela presença de plantas intactas e com predominância de folhas na porção superior do dossel (FONSECA *et al*., 2012; MEZZALIRA *et al*., 2014). Portanto, a manutenção de uma taxa de ingestão alta é função do tempo de permanência do animal em pastejo no primeiro horizonte do dossel, onde há maior proporção de folhas (LACA & DEMMENT, 1996; FONSECA *et al*., 2012; MEZZALIRA *et al*., 2014; BENVENUTTI *et al*., 2015). Segundo Bailey *et al*. (1996), em pastoreio rotativo o animal pode utilizar a chamada memória de trabalho para comparar informações referentes a disponibilidade de forragem com o seu valor nutritivo durante as últimas oito horas e, até mesmo, ao longo de vinte e um dias. De acordo com Ribeiro Filho *et al*. (2003) e Amaral *et al*. (2012), no pastoreio rotativo o animal diminui o tempo de pastejo e/ou a taxa de bocados ao longo do rebaixamento do pasto por desestímulo à estrutura apresentada, percebendo que possui a opção de esperar para ser trocado de piquete. Sendo assim, as estratégias de compensação do pastejo podem não se expressar na mesma intensidade sob esse método de pastoreio.

Em função de todas as considerações descritas anteriormente, entende-se que o pastoreio é um processo fundamental que afeta a dinâmica e o funcionamento dos ecossistemas pastoris (CARVALHO, 2013). Portanto, o manejo adequado da pastagem deve ser baseado nos princípios da interação planta-animal, considerando os processos envolvidos na produção, utilização e sustentabilidade das pastagens, bem como nas respostas comportamentais e produtividade animal (BENVENUTTI *et al*., 2015; LEMAIRE *et al*., 2011).

## 2 CAPÍTULO II

# INGESTIVE BEHAVIOR OF SHEEP MANAGED UNDER DIFFERENT STOCKING METHODS AND GRAZING INTENSITIES AND THEIR INFLUENCE ON THE AVERAGE DAILY GAIN[1]

[1] Artigo elaborado conforme as normas da revista *Grassland Science* (Apêndice 1).

# Ingestive behavior of sheep managed under different stocking methods and grazing intensities and their influence on the average daily gain

Ricardo Pereira Gonçalves[2], Carolina Bremm[1], Jalise Fabíola Tontini[1], Fernanda Gomes Moojen[1], Luis Fernando Picasso Quadros[1], Sylvio Solom Santana Mendina[1], Thainá Soares de Freitas[1] and Paulo César de Faccio Carvalho[1]

**Abstract**

The relationship between sward characteristics and animal ingestive behavior is essential for the development of livestock production in pastoral systems. In light of this, we performed visual observation of sheep and compared two stocking methods (continuous and rotational) under low-to-moderate grazing intensities to understand the animals' average daily gain in annual ryegrass (*Lolium multiflorum* Lam.). We verified that the stocking method affects the leaf blades and inflorescences' quantity, which were the main sward characteristics, which influenced forage chemical composition, as well as promoted the bite rate increase and grazing time of sheep. On the other hand, grazing intensities influenced the bites by feeding station and the number of meals. Besides, variables as feeding station per minute, duration of meals and grazing time were highlighted for the principal components, explaining 67.3% of total data variation. These variables were positively correlated with the average daily gain, thus, they can be used as predictors for the average daily gain of sheep. Therefore, changes in behavior responses in scales as feeding station and range were compensation sources used by the sheep to maintain their average daily gain when exposed to a grazing condition limited, due to a high inflorescences' percentage.

**Keywords**

Bite rate; grazing time; *Lolium multiflorum;* scales of grazing; sward characteristics.

[2] Grazing Ecology Research Group, Faculty of Agronomy, Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, RS, Brazil

## 2.1 Introduction

Herbivorous face a complex nutritional environment during grazing process, and they exploit it by a series of nested processes which include bite formation and gathering (Laca 2008). Thus, sward management in pastoral systems aims to create sward structures which optimize the forage apprehension by the animal (Carvalho *et al*. 2009) with high intake rate (Mezzalira *et al*. 2014) to decrease the daily grazing time (Villalba and Provenza 2009) and concurrently many other factors which influence animal performance (Santos *et al*. 2010).

The relative complexity of sward management decision-making in most pasture-based livestock farming areas has led to important attempts to develop simple indicators or tools who farmers can apply in their day-to-day management (Chapman *et al*., 2012). Examples of these management targets include the concept that grazing intensities in continuous stocking and pre- and post-grazing sward heights in rotational stocking has a major impact on animal performance and profitability of grazing livestock systems (Amaral *et al*., 2012; Savian *et al*., 2014). But rotational stocking does not seem to consistently achieve results that differ greatly from continuous stocking since the stocking rate is not too high (Briske *et al*. 2008).

According to Laca (2009), regardless of stocking method, stocking rate, and other management factors, the grazing process can be interpreted as a spatial and temporal scale, formed by a series of bites removing a set of plants per animal unit. These scales range from bite to home range, and biotic and abiotic factors influence grazing in every scale by different cause-effect relationships (Bailey *et al*. 1996).

By doing so, the knowledge about animal ingestive behavior in pastoral systems allows adequate uses for sward management strategies besides promote the livestock system success (Hao *et al*. 2013). Animal ingestive behavior can generate, maintain, or reduce the sward heterogeneity by the best patches selection, and animals can partially compensate for the sward heterogeneity effect (Laca 2009). Thus, the monitoring and understanding of the animals' ingestive behavior can help clarify the relationship among the sward characteristics, behavior pattern and animal's individual performance.

This study hypothesizes that the ingestive behavior variables in larger spatial and temporal scales (such as feeding station, patch, feeding site and range) can be used as predictors for the average daily gain of sheep in annual ryegrass and should be considered to define management goals of stocking methods and grazing intensities. This research aims to (i) define how the changes in the sward structure and annual ryegrass quality, promoted by stocking methods and grazing intensities, affect the ingestive behavior of lambs; and (ii) evaluate how behavioral pattern changes can be used to establish management goals which provide better average daily gain of sheep in annual ryegrass.

## 2.2 Materials and methods

This study is part of a long-term experimental protocol and composes an integrated crop-livestock system (ICLS) started in 2003. This system integrates soybean (*Glycine max* L.) and corn (*Zea mays*) during summer/autumn and sward of annual ryegrass (*Lolium multiflorum* Lam.) during winter/spring. The present study was developed in winter/spring, from July to October 2015.

### 2.2.1 Experimental area and procedures

The experiment was conducted at the Research Station of the Federal University of Rio Grande do Sul (RS/UFRGS), which is located in Southern Brazil (30° 05' 22" S, 51° 39' 09" W). The climate is humid subtropical, Cfa, according to Köppen and Geinger (1928). The soil was classified as Paleudult Typical (USDA, 1999) with a slightly wavy relief and free of restrictions for annual crops.

According to the experimental protocol, the annual ryegrass was sow on May 8th, 2015, using 30 kg $ha^{-1}$ of seed ("Common" cultivar). It was applied 200 kg $ha^{-1}$ N-$P_2O_5$-$K_2O$ (5-30-15 formula) and 200 kg potassium chloride (according to the need of the system set: 60 kg phosphorus $ha^{-1}$ and 60 kg $ha^{-1}$ potassium) was applied. Nitrogen fertilization in urea form was applied in amount of 150 kg $ha^{-1}$ N, with half dose applied to when the ryegrass plants had the 4th leaf (June 26th, 2015) and the rest of, at the beginning of spring (September 25th, 2015), as recommended by the Soil Fertility Commission (1995).

### 2.2.2 Experimental design

The experimental design was a randomized complete block design with three replications corresponding to 3.2 hectares (ha), while was divided into 12 paddocks, ranging from 0.23 to 0.41 ha. The experiment was arranged in a two-level factorial design, with two stocking methods (continuous and rotational) and two grazing intensities for sheep: forage allowance of 2.5 and 5 times (namely moderate and low, respectively) the potential daily dry matter intake (DMI) according to the NRC (1985).

### 2.2.3 Establishment of stocking cycle

The variable leaf life span (LLS) is a morphogenic variable and indicative of the optimum time period of defoliation (how many days – in thermal time – a leaf remains available to grazing before senescing) and it was used to determine the interval of each stocking rate adjustment to maintain predefined forage allowance. This interval corresponds to stocking cycles described below. Data from Pontes *et al*. (2003) in the same experimental area were used: 500ºC leaf$^{-1}$, from June to August, and 410ºC leaf$^{-1}$, from September to November. Thus, these values were divided by the average air temperature of the months from June to November, obtained from climatic series of the last twenty-five years of the meteorological station located 800 m from the experimental site. Therefore, the number of days of each stocking cycle was derived as follows: 36, 27, 24, and 21 days for paddocks under the low grazing intensity and 33, 24, and 31 days for paddocks under the moderate grazing intensity (differences due to a delayed establishment of sward in the paddocks under the moderate grazing intensity). During stocking cycles, the annual ryegrass coverage percentage of the paddocks was 91.6 ± 1.8% for all treatments, and the criteria adopted for the initial of stocking cycle was the value of forage mass (FM) between 1500 and 2000 kg DM ha$^{-1}$(Ramon *et al*. 2007; Confortin *et al*. 2013).

Animals were on a three-day period in each strip, thus, the size and number of the strip was determined based on the minimum area to keep three tester-animals; the optimum time period of sward defoliation; the available area of each paddock; and the number of days of each stocking cycle.

### 2.2.4 Parameters related to animals

The experimental animals were *Corriedale* breed lambs with approximately 27 ± 2 kg of live weight (LW) and average age of 10 ± 2 months (yearling-lambs). Each paddock as experimental unit (EU) received three tester-animals (permanent animals that remained throughout the experimental period) and a variable number of animals, periodically adjusted to maintain the desired forage allowance ("put-and-take" method was used, based on variable animal numbers during a stocking cycle with a periodic adjustment in animal numbers, in an attempt to maintain a desired quantity of forage, according to Allen *et al*. 2011). The stocking rate was obtained by the relationship between the number of animals and the total area of the paddocks. The average daily gain (ADG, kg animal$^{-1}$ day$^{-1}$) was obtained by the difference of the final LW with the initial LW of tester-animals divided by the number of days of each stocking cycle. Animals weighing was always performed after 12 hours of fasting.

### 2.2.5 Determining forage production

The forage production (forage mass, forage accumulation rate, and forage allowance) was performed at the end of each stocking cycle. The forage mass was determined by clipping six quadrates by paddock (0.5 x 0.5 m) representative of the average sward height. All forage samples were oven dried, in an air forced ventilation at 65°C for 72 hours to determine the dry matter content.

Four grazing exclusion cages were used to obtain the forage accumulation rate in the paddocks under continuous stocking. Two similar areas were chosen for each cage; one of the areas was clipped, and in the other area, the grazing exclusion cage was allocated. The forage accumulation rate was estimated by the difference between the forage mass in the previous stocking cycle outside the cage, and the forage mass inside the cage in the present stocking cycle. We also clipped three quadrates within the same strip of each paddock under rotational stocking. Then, the forage accumulation rate was estimated by the difference between the post-grazing forage mass in the previous stocking cycle, and the pre-grazing forage mass in the present stocking cycle.

The forage allowance (FA, % LW) was calculated according to the following equation: FA (%LW) = ((FMd$^{-1}$ + FAR)/SR)*100. Where: LW = live weight, FM = average forage mass of each stocking cycle (kg DM ha$^{-1}$), n = number of days of stocking cycle, FAR = forage accumulation rate (kg ha$^{-1}$ DM day$^{-1}$), SR = stocking rate of each stocking cycle (kg LW ha$^{-1}$). The total forage production (TFP; kg DM ha$^{-1}$) was obtained by the sum of the initial FM (beginning of the experiment) with the FAR of each stocking cycle.

### 2.2.6 Animal ingestive behavior evaluations and sward characteristics

The ingestive behavior evaluations were performed in two periods, representing the second and the fourth stocking cycle. Visual observation of tester-animals occurred from dawn (6:30am) to dusk (6:30pm) on September 6th and October 24th in the continuous stocking, and from September 5th to 8th and October 23rd to 26th in the rotational stocking (according to the strip occupation). Every 5 minutes, the animal's grazing activities were recorded, being distributed in: grazing time, rumination time, and time of other activities. These were used to calculate the variables: meals duration and meals number (a meal was defined as a continuous grazing action, Gibb *et al*. 1999). In addition, in the peak grazing activity, i.e. in the early hours of the morning and between late afternoon and early evening (Hodgson 1990), it was assessed the time spent by the animal to complete 20 bites, and the time at which the animals completed 10 feeding stations was collected (Forbes and Hodgson 1985). According to Ruyle and Dwyer (1985), feeding station is a hypothetical semicircle, referring to the area that is within reach of the animal, where it takes multiple bites without moving its front feet. These data were used to calculate the variables: time per bite (second), bite rate (bites per minute), time per feeding station (second), bites by feeding station, feeding station per minute, steps per minute, and steps by feeding station.

The variables of sward characteristics as sward height, percentages of leaf blades, stems, inflorescences and the forage apparently consumed by the animals were evaluated during the same days as animals' ingestive behavior assessments, according to the stocking method. The sward height was measured at 200 points per paddock evaluated in continuous stocking and 100 points per strip evaluated of the rotational stocking, using a “sward stick” (Barthram 1985). The frequency whereby plants were touched by the “sward stick” was used to determine the percentages of leaf blades, stems, and inflorescences. The forage apparently consumed by the animals was collected by “hand plucking” (Bonnet *et al*. 2011). These samples were ground in a “Wiley mill”, with a 1 mm sieve, for chemical analysis of sward composition according to the Near infrared reflectance spectroscopy (NIRS) technique, which was coined for the indirect prediction of dietary attributes, i.e., crude protein (CP), neutral detergent fiber (NDF), and organic matter digestibility (OMD), using calibrations based on pairs of known diets (reference values) and resulting faecal spectra (Lyons and Stuth 1992)

### 2.2.7 Statistical analysis

Data were submitted to analysis of variance (ANOVA) considering 5% of significance level (*P* < 0.05). The normal distribution of data was tested using the Shapiro-Wilk test (*P* > 0.05) and only the feeding station per minute variable was transformed by logarithmic function. Two statistical models were defined, one for animal analysis and other for the sward analysis. We included in both statistical models the fixed effects of stocking method, grazing intensity and their interactions. We tested different random effects and the non-significant effects were identified and removed. Thus, for the sward analysis, the final model included the random effect of block, while for the animal analysis; the animal within the block was included as random effect. We used the average data of the three-day assessments in rotational stocking to compare the stocking methods. Means were compared using the Tukey test (*P* < 0.05). Pearson correlation analysis was performed between sward characteristics and animals' responses, and the principal component analysis (PCA) was used to define relationships among the variables of the sward, ingestive behavior and average daily gain of animals. The statistical software JMP® (v.12.2.0) by SAS® was used in this research.

## 2.3 Results

### 2.3.1 Forage production and sward characteristics

There was a significant effect of interaction between stocking method and grazing intensity (*P* < 0.05) for the forage mass and leaf blade percentage (Table 1). The forage mass was higher in a low grazing intensity, independent of the stocking method. Continuous stocking under moderate grazing intensity presented lower forage mass and leaf blade percentage, but in rotational stocking these variables did not differ between grazing intensities. The sward height, forage accumulation rate and the forage allowance (Table 1) were statistically higher ($P < 0.05$) in low grazing intensity. Stems percentage (Table 1) also did not differ between treatments ($P > 0.05$). Stocking method and grazing intensity affected ($P < 0.05$) inflorescence percentage (Table 1) being higher in continuous stocking and low grazing intensity. Contents of CP, NDF and OMD of forage apparently consumed by the animals (Table 1) were affected by the stocking method ($P < 0.05$). Continuous stocking presented higher NDF content, while rotational stocking had higher CP and OMD contents.

**2.3.3 Animal performance and ingestive behavior responses**

Stocking rate and average daily gain did not differ between treatments ($P > 0.05$; Table 2). On the other hand, the animal ingestive behavior differed between the stocking methods ($P < 0.05$; Table 2). The continuous stocking promoted longer grazing time and bite rate, in contrast, the rotational stocking promoted longer rumination time (Table 2). The time of other activities differed between the stocking methods and grazing intensities, rotational stocking and moderate intensity promoted longer time of other activities. The number of meals were affected by grazing intensities ($P < 0.05$; Table 2), the moderate grazing intensity promoted higher number of meals than low grazing intensity. The duration of meals did not differ between the treatments ($P > 0.05$, Table 2). The variables: bite by feeding station, feeding stations per minute, steps per minute and steps by feeding station (Table 3) were analyzed by grazing intensity in each stocking method, because the area of paddocks under continuous stocking was larger than the area of strip in rotational stocking (and this could mix up the results). The grazing intensities only affected ($P < 0.05$) the bites by feeding station in the continuous stocking method. Higher bites by feeding station were found in low grazing intensity. The other variables did not differ for the grazing intensity in the stocking method.

First and second principal components (*Biplot* CP 1 xCP 2, Figure 1) explain 67.3% of total data variation. Feeding station per minute, and the duration of meals were highlighted for the first principal component (PC 1). It was verified by the variables which have the longest vector and were closest to the PC 1 axis. They explain 47.2% of total data variation. In the second principal component (CP 2) grazing time and average daily gain were highlighted, which have the longest vector and were closest to the CP 2 axis. These variables explain 20.1% of the total data variation. There are high correlations between average daily gain and grazing time (because they formed acute angles). Average daily gain is positively correlated with the variables of the duration of meals, feeding station per minute and steps per minute (because they are in the same quadrant), and negatively correlated with the variables time of other activities and rumination time (because they are in opposite quadrants).

## 2.4 Discussion

### 2.4.1 Forage production and sward structure during stocking cycles

The responses of sward height and forage mass in continuous stocking (Table 1) were as expected due to the grazing intensities influences during stocking cycles. Similar responses were observed by Pontes *et al*. (2003), which concluded that lower sward heights were obtained in lower forage mass values, and resulted in lower forage allowances, consequently. However, in rotational stocking, the sward forage mass and leaf blade percentage did not differ between the studied grazing intensities (Table 1). In this stocking method, there is a better control of variation light availability and defoliation frequency due to the periods of grazing down and the subsequent post-grazing (Barbosa *et al*. 2007). Thus, the plants have time to recover after the grazing down and produce more photosynthetic structures (leaf blades), as well as a higher population density of tillers (Bullock 1996). Therefore, the differences in those sward characteristics of the rotational stocking could have been masked by the post-grazing period.

The forage allowance responses (Table 1) were also expected due to the stocking rate adjustment during the stocking cycles. According to Groff et al. (2002), grazing intensity interferes with the sward structure formation and the forage allowance. We expected a higher stocking rate in moderate grazing intensity, but it was not observed (Table 2). According to O'Reagain *et al*. (2014), the stocking rate is dependent on the forage mass, thus, it is possible to assume that the lower forage mass of the moderate grazing intensity (Table 1) influenced the stocking rate, which was similar in both grazing intensities in this study.

### 2.4.2 Sward characteristics and ingestive behavior responses

Among the sward structural modifications, the leaf blade amount is the main component that affects the forage quality (Orr *et al*., 2004; Benvenutti *et al*., 2015), which is shown by the correlations between the leaf blades percentage with the contents of NDF ($r$ = -0.83, $P$ < 0.0001), CP ($r$ = 0.80, $P$ < 0.0001), and OMD ($r$ = 0.81, $P$ < 0.0001). Confortin *et al*. (2010) found the animal ingestive behavior patterns depend on the sward structural characteristics, which are subject to change throughout the stocking cycle. In the present study only feeding station and range scales (bite rate and grazing time, rumination time and time of other activities, respectively, Table 2) were influenced by different stocking methods. In fact, this response is related to the differences in the sward structure and their chemical composition (Table 1). We verified that the forage chemical composition indicated good forage quality (Table 1). However, the high inflorescences' percentage (Table 1) may have represented a restrictive sward structure on animals' ingestive behavior patterns, influencing the grazing time and bite rate (Table 2). As grazing time was negatively correlated with the leaf blade percentage ($r$ = -0.65, $P$ = 0.0012) and positively correlated with the inflorescences' percentage ($r$ = 0.73, $P$ = 0.0002), the sward structural (i.e., leaves proportion) influence under the animal ingestive behavior is confirmed by this study. This reinforces the idea that the longer bite rate and grazing time by sheep were caused by the inflorescences' percentage.

According to Santos *et al*. (2010), grazing time is a variable directly related to forage availability and intake. Therefore, the decline in the intake rate during the grazing process is compensated, to a certain point, by the prolongation of the meals (Ungar 1998; Ungar and Ravid 1999), which occurs concomitantly with the decrease in daily number of meals (Carvalho *et al*. 2013). In the present study, the duration of meals presented similar values between treatments, but the number of meals increased under moderate grazing intensity (Table 2). This response may be associated to the longer time required for the construction of the bites (due to high percentage of inflorescences), which could constrain the intake rate (Mezzalira *et al*. 2014). In a similar way, the effect of grazing intensity on the bites by feeding station (Table 3) was due to the high inflorescences amount in the continuous stocking (Table 1). Thus, under low grazing intensity, the animals took more bites by feeding station, due to the sward structure constrain, in attempt to maintain a constant intake rate (Fonseca *et al.* 2012). It was also associated to positive correlation of the bites by feeding station with the leaf blades percentage ($r$ = 0.6, $P$ = 0.0002); as well as the negative correlation of the feeding stations per minute with the leaf blades percentage ($r$ = -0.74, $P$ < 0.0001); their positive correlation with the inflorescences percentage ($r$ = 0.51, $P$ = 0.00102); and with the average daily gain of the animals (Figure 1). Although the other variables in the feeding station scale did not differ between grazing intensities, the steps per minute was positively correlated with the animals average daily gain. (Figure 1). According to Gonçalves *et al*. (2009), the animals move more by feeding stations in intermediate sward heights, where were also observed a higher intake rate and, consequently, higher average daily gain.

### 2.4.3 Ingestive behavior responses used to establish sward management goals that provide better individual sheep performance

Herbivores performance is dependent of ingestive behavior and it is affected by the alteration in sward characteristics and by forage apprehensibility (Groff *et al*. 2002). We expected a stocking method effect in relation to the sheep average daily gain, since the animals have a greater opportunity for diet selection under continuous stocking (Laca 2009) a factor related to animal productivity (Soder *et al*. 2009), but it was not observed in the present study (Table 1). In contrast, we expected the average daily gain would not be affected by the grazing intensities and this fact was observed (Table 2), because both grazing intensities were similar in terms of sward structure. Based on these results, we verified that the possible effect of the stocking method in the average daily gain of sheep was neutralized by the compensation sources of the animal ingestive behavior, as bite rate and grazing time, in different spatial and temporal scales of grazing (i.e., feeding station and range, respectively). According to Laca (2009), productivity and sward conditions can be affected by stocking methods; however, average daily gain will only be affected if spatial-temporal sequences of the animal ingestive behavior are also affected.

Therefore, the main implication of this research is the use of the feeding station and range scales (as feeding station per minute, meals duration and grazing time), as accurate predictors to understand the average daily gain of sheep in annual ryegrass. According to the principal components analysis (figure 1), these variables were positively correlated with the average daily gain, so, they should be considered to define management goals. We can observe an association between high average daily gain with the continuous stocking method and moderate grazing intensity. However, we did not observe difference in animal average daily gain between treatments. Consequently, the choice of the stocking method would be a sward manager's decision, prioritizing the stocking method which best suits, or the complementary use of both strategies, as sustainable sward management strategies of the livestock system. On the other hand, it is important that the sward manager have attention, especially in low grazing intensity, with the high percentage of inflorescences. Though high inflorescences' percentage is important to promote a better sward establishment with high forage production during the subsequent years (Barth Neto *et al*. 2013), high inflorescences' percentage also can represent a grazing condition limited in the end of grazing period, changing animal's bite rate, grazing time and reflecting in low average daily gain (Table 2). Establishing a percentage of inflorescences threshold level to maintain animals grazing would be a next step to improve sward management in annual ryegrass and the profitability of the pastoral system.

## 2.5 Conclusions

The ingestive behavior responses in the larger spatial and temporal scales of grazing could be used to establish sward management goals. The stocking method affect the quantity of leaf blades and inflorescences, which were the main sward characteristics that influenced forage chemical composition, as well as promoted the increase in bite rate and grazing time of sheep. Moreover, variables as feeding station per minute, the duration of meals and grazing time were highlighted for the principal components, explaining 67.3% of total data variation. These variables were positively correlated with the average daily gain, thus, they can be used as predictors for the average daily gain of sheep. Therefore, behavior responses changes in scales as feeding station and range were compensation sources used by the sheep to maintain their average daily gain when exposed to a grazing condition limited, due to a high inflorescences percentage.

## 2.6 Acknowledgements

Special thanks to students from Grazing Ecology Research Group (UFRG/Brazil) and collaborators who assisted in the experiment. This study was supported by CNPq, CAPES.

## 2.7 References

Allen VG, Batello C, Berretta EJ *et al*. (2011) An international terminology for grazing lands and grazing animals. *Grass Forage Sci*. 66, 2–28.

Amaral MF, Mezzalira JC, Bremm C, Da Trindade JK, Gibb MJ, Silva R, Carvalho PCF (2012) Sward structure management for a maximum short-term intake rate in annual ryegrass. *Grass Forage Sci*. 68, 271–277.

Bailey DW, Gross JG, Laca EA *et al.* (1996) Mechanisms that result in large herbivore grazing distribution patterns. *J. Range Manage*., Denver, v. 49, n. 5, p. 386–400.

Barbosa CMP, Carvalho PCF, Cauduro GF, Lunardi R, Kunrath TR, Gianluppi GDF (2007) Finishing of grazing lambs on ryegrass swards (*Lolium multiflorum* Lam.) under different grazing intensities and methods. *Brazilian J. Anim. Sci*. 36 (6): 1953–1960. (in Portuguese with English abstract.)

Barth Neto A, Savian JV, Tres Schonsb RMT *et al*. (2013) Italian ryegrass establishment by self-seeding in integrated crop-livestock systems: Effects of grazing management and crop rotation strategies. *Europ. J. Agronomy*, 53: 67– 73

Barthram GT (1985) Experimental techniques: the HFRO sward stick. In*:* Barthram GT, The hill farming research organization/biennial report. Penicuik: HFRO. 29–30.

Benvenutti MA, Pavetti DR, Poppi DP, Gordon IJ, Cangiano CA (2015) Defoliation patterns and their implications for the management of vegetative tropical pastures to control intake and diet quality by cattle. John Wiley and Sons Ltd. *Grass Forage Sci.* 71, 424–436.

Bonnet O, Hagenah N, Hebbelmann L, Meuret M, Shrader AM (2011) Is hand plucking an accurate method of estimating bite mass and instantaneous intake of grazing herbivores? *Rangeland Ecol. Manage*. 64(4): 366–374.

Briske D, Derner J, Brown J *et al.* (2008) Rotational grazing on rangelands: reconciliation of perception and experimental evidence. *Rangeland Ecol. Manage*. 61: 3–18.

Bullock JM (1996) Plant competition and population dynamics. In*:* Hodgson J, Illius AW (Eds.). The Ecology and management of grazing systems. *Wallingford: CAB International*, 69–100.

Carvalho PCF, da Trindade JK, Mezzalira JC *et al.* (2009) From the bite to precision grazing: Understanding the plant-animal interface to exploit the multi-functionality of grasslands. *Brazilian J. Anim. Sci*. 38: 109–122. (in Portuguese with English abstract.)

Carvalho PCF, da Trindade JK, Bremm C *et al*. (2013) Comportamento Ingestivo de Animais em Pastejo. In: *Forragicultura: Ciência, Tecnologia e Gestão dos Recursos Forrageiros*. Viçosa: UFV, 525–545. (in Portuguese)

Champman DF, Tharmara JJ, Agnusdei M, Hil LJ (2012) Regrowth dynamics and grazing decision rules: further analysis for dairy production systems based on perennial ryegrass (*Lolium perenne* L.) pastures. *Grass Forage Sci.,* 67, 77–95.

Confortin ACC, Bremm C, Rocha MG *et al.* (2010) Ingestive behavior patterns of ewe lambs receiving or not supplement on Pearl millet pasture. *Rural Sci*. 40: 2555–2561. (in Portuguese with English abstract.)

Confortin A.C.C., da Rocha M.G., Machado J.M., Roman J., de Quadros F.L.F., and Pötter L. (2013) Different herbage masses on morphogenetic and structural traits of Italian ryegrass. *Rural Sci*. Santa Maria, 43(3): 496–502. (in Portuguese with English abstract.)

Forbes TDA; Hodgson J (1985) Researching the plant-animal interface: The investigation of ingestive behavior of cows and sheep. *Grass Forage Sci*. 40: 69–77.

Gibb MJ, Huckle CA, Nuthall R, Rook AJ (1999) The effect of physiological state (lactating or dry) and sward surface height on grazing behaviour and intake by dairy cows. *Appl. Anim. Behav. Sci*. Amsterdam, 63: 269–287.

Gonçalves EN, Carvalho PCF, Devincenzi T, *et al.* (2009) Plant-animal relationships in a heterogeneous pastoral environment: displacement patterns and feeding station use. R. Bras. Zootec., Viçosa, v. 38 (11):  2121–2126. (in Portuguese with English abstract.)

Groff AM, Moraes A, Soussana JF, Carvalho PCF, Louault F (2002) Interval and Intensity of Defoliation on the Growth, Senescence and Defoliation Fluxes and Equilibrium of Associated Grasses. *Brazilian J. Anim. Sci*. 31(5): 1912–1923. (in Portuguese with English abstract.)

Hao J, Dickhoefera U, Lina L *et al.* (2013) Effects of rotational and continuous grazing on herbage quality, feed intake and performance of sheep on a semi-arid grassland steppe. *Arch. Anim. Nutr*. 67: 62–76.

Hodgson J (1990) Grazing management: science into practice. London: Longman Group, 203.

Köppen W, Geinger R (1928) Klimate der erde. Verlag justus perthes, Gotha (Wall-map).

Laca EA (2009) New Approaches and Tools for Grazing Management. *Rangeland Ecol. Manage*. 62: 407–417.

Laca EA (2008) Foraging in a heterogeneous environment: intake and diet selection. In 'Resource ecology: spatial and temporal dynamics of foraging'. (Ed. V Bels) (CAB International: Wageningen,The Netherlands) 81–100.

Lyons RK, and Stuth JW (1992) Fecal NIRS equations for predicting diet quality of free-ranging cattle. *J. Range Manage.* 45, 238–244.

Mezzalira JC, Carvalho PCF, Fonseca L *et al.* (2014) Behavioural mechanisms of intake rate by heifers grazing swards of contrasting structures. *Appl. Anim. Behav. Sci*. 153: 1–9.

National Research Concil–NRC (1985) Nutrient requirement of sheep. $6^{th}$.ed. *Washington: National Academy Press*., 99.

O'Reagain P, Scanlan J, Hunt L, Cowley R, and Walsh D (2014) Sustainable grazing management for temporal and spatial variability in north Australian rangelands – a synthesis of the latest evidence and recommendations. *Rangeland J.* 36: 223–232.

Orr RJ, Rutter SM, Yarrow NH (2004) Changes in ingestive behaviour of yearling dairy heifers due to changes in sward state during grazing down of rotationally stocked ryegrass or white clover pastures. *Appl. Anim. Behav. Sci*. 87: 205–222.

Pontes LS, Nabinger C, Carvalho PCF, da Trindade JK, Montardo DP, dos Santos RJ (2003) Morphogenetic and structural traits of ryegrass (*Lolium multiflorum* Lam.) managed under different sward heights. *Brazilian J. Anim. Sci.* Viçosa, 32 (4): 814–820. (in Portuguese with English abstract.)

Ramon J, da Rocha MG, Pires CC, Elejalde DAG, Kloss MG, and Oliveira Neto RA (2007) Ingestive behaviour and performance of sheep grazing Italian ryegrass (*Lolium multiflorum* Lam.) pasture with different herbage masses. *Brazilian J. Anim. Sci*.Viçosa, MG, 36(4): 780–788. (in Portuguese with English abstract.)

Ruyle GB, Dwyer DD (1985.) Feeding stations of sheep as an indicator of diminished forage supply. *J. Anim. Sci*., Champaign, 61, 349-353.

Santos BRC, Votolini TV, Salla LE (2010) Behavior of grazing. *Elect. J. Vet. Medic*. 11 (4): 1–33. (in Portuguese with English abstract.)

Savian JV, Barth Neto A, de David DB et al. (2014) Grazing intensity and stocking methods on animal production and methane emission by grazing sheep: Implications for integrated crop-livestock system. *Agric. Agric. Ecosyst. Environ*. 190: 112–119.

Soder KJ, Gregorini P, Scaglia G, Rook AJ (2009) Dietary selection of domestic grazing ruminants: current state of the knowledge. *Rangeland Ecol. Manage*. 62: 389–398.

Soil Fertility Commission (1995) Fertilizer and Liming Recommendations for States of Rio Grande do Sul and Santa Catarina. Passo Fundo, Brazilian Society of Soil Science /Embrapa CNPT, 3, 223. (in Portuguese)

Ungar ED (1998) Changes in bite area and bite depth during patch depletion by cattle, in: Gibb, M.J. (Ed.), Proceedings of the IX$^{th}$ European Intake Workshop on Techniques for Investigating Intake and Ingestive Behaviour by Farm Animals, IGER, North Wyke, 81–82.

Ungar ED, Ravid N (1999) Bite horizons and dimensions for cattle grazing herbage to high levels ofdepletion. *Grass Forage Sci*. 54: 357–364.

United States Department of Agriculture - USDA (1999) Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys. *USDA*,Washington, DC, 1–87.

Villalba JJ, Provenza FD (2009) Learning and dietary choice in herbivores. *Rangeland Ecol. Manage*. 62 (5): 399–406.

**Table 1** Data of the annual ryegrass (*Lolium multiflorum* Lam.) structural and chemical composition of the forage apparently consumed during ingestive behavior assessments of sheep managed under different stocking methods (continuous and rotational) and grazing intensities (moderate and low).

| Variables | Continuous | | Rotational | | Mean ± SEM | *P*M | *P*I | *P*M×I |
|---|---|---|---|---|---|---|---|---|
| | Moderate | Low | Moderate | Low | | | | |
| FA* | 10.7[b] | 18.5[a] | 9.4[b] | 15.7[a] | 13.6 ± 4.2 | 0.2455 | 0.0008 | 0.6742 |
| FAR* | 56.3[b] | 90.3[a] | 47.5[b] | 73.4[a] | 66.9 ± 27 | 0.2595 | 0.0146 | 0.7189 |
| FM* | 1508.8[c] | 2684.4[a] | 1692.1[bc] | 1994.6[b] | 1970 ± 311.3 | 0.0626 | <0.0001 | 0.0032 |
| SH | 13.8[b] | 19.1[a] | 17.4[b] | 18.4[a] | 17.2 ± 3.3 | 0.2825 | 0.0337 | 0.1307 |
| LB | 29.3[c] | 36.7[b] | 48.9[a] | 45.7 [a] | 40.1 ± 6 | <0.0001 | 0.4048 | 0.0472 |
| S | 12.3 | 9.2 | 17.6 | 14.6 | 13.4 ± 6.2 | 0.0507 | 0.2519 | 0.9807 |
| I | 45.6[Ab] | 50.9[Aa] | 29.7[Bb] | 36.5[Ba] | 40.7 ± 6.7 | <0.0001 | 0.0414 | 0.7926 |
| NDF | 52.7[a] | 51.9[a] | 50[b] | 48.9[b] | 50.9 ± 1.8 | 0.0017 | 0.2227 | 0.8018 |
| CP | 16.2[b] | 16.5[b] | 17.2[a] | 18[a] | 17 ± 1.1 | 0.0142 | 0.2401 | 0.6124 |
| OMD | 74.9[b] | 74.4[b] | 77.6[a] | 78.6[a] | 76.4 ± 3.1 | 0.0149 | 0.8531 | 0.5716 |

*Data regarding the stocking cycle in which animal ingestive behavior evaluation was performed; FA = forage allowance (kg DM/100kg LW); FAR = forage accumulation rate (kg DM day $^{-1}$); FM = forage mass (kg DM ha$^{-1}$); SH = sward height (cm); LB = leaf blade (%); S = stems (%); I = inflorescences (%); NDF = neutral detergent fiber (%); CP = crude protein (%);OMD = organic matter digestibility (%); SEM = standard error of the mean; *P*M = probability of stocking method; *P*I = probability of grazing intensity; *P*M×I = probability of interaction between stocking method and grazing intensity. Means followed by lowercase letters in line differ by Tukey test ($P < 0.05$) for *P*M, *P*I or *P*M × I. Means followed by upper and lowercase letters in line differ by Tukey test ($P < 0.05$) for *P*M and *P*I, respectively.

**Table 2** Data of animal performance and ingestive behavior of sheep managed under different stocking methods (continuous or rotational) and grazing intensities (moderate and low) in annual ryegrass sward (*Lolium multiflorum* Lam.).

| Variables | Continuous | | Rotational | | Mean ± SEM | *P*M | *P*I | *P*M×I |
|---|---|---|---|---|---|---|---|---|
| | Moderate | Low | Moderate | Low | | | | |
| SR* | 955.1 | 1012.4 | 1101.7 | 1061.5 | 1033.2 ± 153.5 | 0.1119 | 0.8939 | 0.3948 |
| ADG* | 0.110 | 0.080 | 0.105 | 0.076 | 0.092 ± 0.06 | 0.8349 | 0.0002 | 0.7755 |
| GT | 585.4$^{a}$ | 570.9$^{a}$ | 468.8.5$^{b}$ | 474$^{b}$ | 520.7 ± 52 | 0.0002 | 0.7755 | 0.5415 |
| RT | 75.3$^{b}$ | 100$^{b}$ | 136.5$^{a}$ | 175.5$^{a}$ | 121.8 ± 33.7 | 0.0062 | 0.1246 | 0.7121 |
| TOA | 124.6$^{Ba}$ | 90.4$^{Bb}$ | 176$^{Aa}$ | 126.8$^{Ab}$ | 128.7 ± 33.6 | 0.0327 | 0.0399 | 0.6723 |
| MD | 93.3 | 99.5 | 73.3 | 92 | 89.4 ± 21.5 | 0.0692 | 0.0956 | 0.3682 |
| MN | 6.4$^{a}$ | 5.8$^{b}$ | 6.7$^{a}$ | 5.3$^{b}$ | 6.2 ± 1.1 | 0.6076 | 0.0093 | 0.3001 |
| BR | 35.3$^{a}$ | 32.3$^{a}$ | 30.1$^{b}$ | 29.8$^{b}$ | 31.9 ± 3.8 | 0.0280 | 0.2888 | 0.3707 |

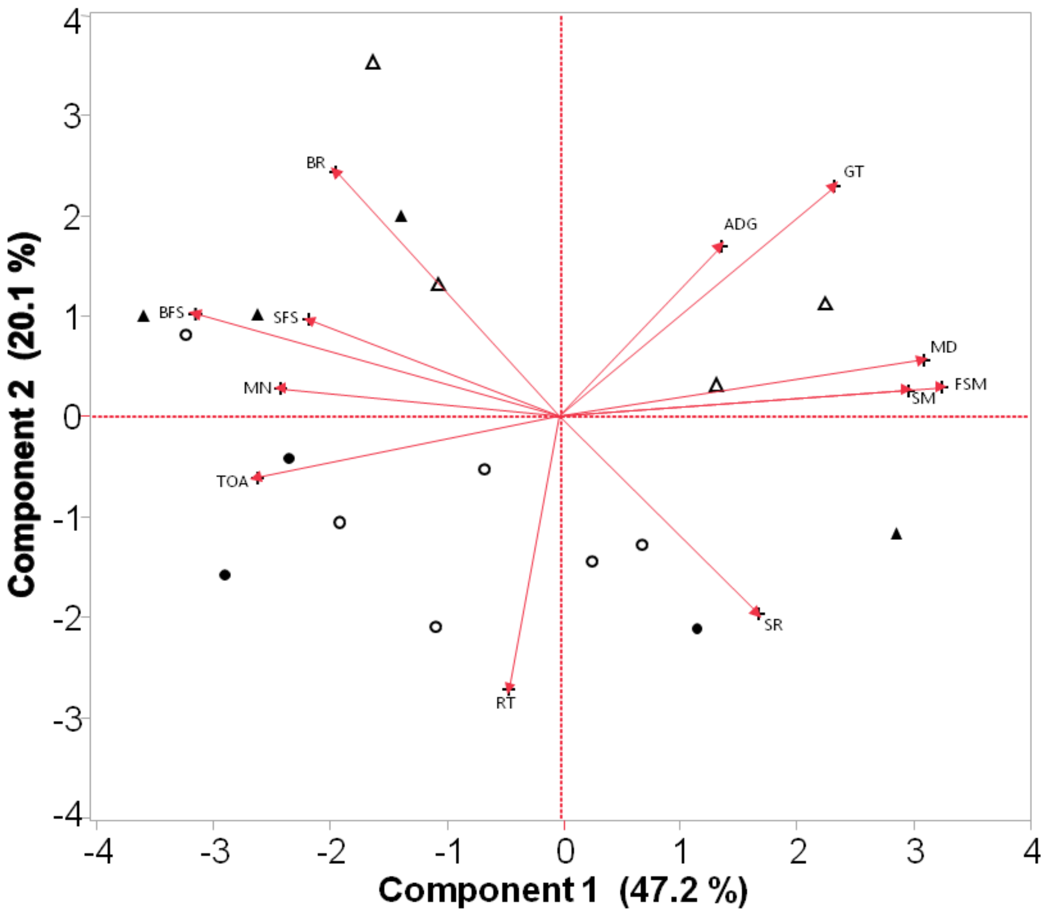
*Data regarding the stocking cycle in which animal ingestive behavior evaluation was performed; SR = stocking rate (kg LW ha$^{-1}$); ADG = average daily gain (kg animal$^{-1}$ day$^{-1}$); GT = grazing time (minute); RT = rumination time (minute); TOA = time of other activities (minute); MD = meals duration (minute); MN = meals number; BR = bite rate (bites per minute); SEM = standard error of the mean; *P*M = probability of stocking method; *P*I = probability of grazing intensity; *P*M×I = probability of interaction between stocking method and grazing intensity. Means followed by lowercase letters in line differ by Tukey test ($P < 0.05$) for *P*M, *P*I or *P*M×I. Means followed by upper and lowercase letters in line differ by Tukey test ($P < 0.05$) for *P*M and *P*I, respectively.

**Table 3** Variables compared by grazing intensity (moderate and low) in each stocking method (continuous or rotational) of the ingestive behavior daily data of sheep in sward of annual ryegrass (*Lolium multiflorum* Lam.).

| Variables | Continuous | | Mean ± SEM | *P*I | Rotational | | Mean ± SEM | *P*I |
|---|---|---|---|---|---|---|---|---|
| | Moderate | Low | | | Moderate | Low | | |
| BFS | 6.5[b] | 9[a] | 7.6 ± 2.5 | 0.0445 | 8.6 | 8.4 | 8.5 ± 2.1 | 0.9080 |
| FSM | 6.2 | 5.1 | 5.7 ± 1.4 | 0.1677 | 4.2 | 4.3 | 4.3 ± 0.9 | 0.9154 |
| SM | 10 | 8 | 8.9 ± 2.1 | 0.1019 | 6.7 | 7.6 | 7.2 ± 1.2 | 0.1568 |
| SFS | 1.8 | 1.7 | 1.7 ± 0.3 | 0.1055 | 1.6 | 1.7 | 1.7 ± 0.2 | 0.1626 |

BFS = bites by feeding station (number); FSM = feeding stations per minute (number); SM = steps per minute (number); SFS = steps by feeding stations (number); SEM = standard error of the mean; *P*I = probability of grazing intensity. Means followed by lowercase letters in line differ by Tukey test ($P$ <0.05) for *P*I.

**Figure 1** Principal components analysis (*Biplot* CP1xCP2) for 11 variables of the animal ingestive behavior and the average daily gain of sheep managed under different stocking methods (continuous or rotational) and grazing intensities (moderate and low) in annual ryegrass (*Lolium multiflorum* Lam.).




Components 1 and 2 explain 67.3% of the total data variation; ADG = average daily gain (kg animal$^{-1}$ day$^{-1}$); GT = grazing time (minute); MD = meals duration (minute); FSM = feeding stations per minute (number); SM = steps per minute (number); SR = stocking rate (kg LW ha$^{-1}$); RT = rumination time (minute); TOA = time of other activities (minute); BFS = bites by feeding station; SFS = steps by feeding station (number); MN = meals number; BR = bite rate (bites per minute); ( △) = continuous stocking method and moderate grazing intensity; ( ▲ ) = continuous stocking method and low grazing intensity; ( ○ ) = rotational stocking method and moderate grazing intensity; ( ● ) = rotational stocking method and low grazing intensity.

# 3 CAPÍTULO III

## GRAZING DOWN PROCESS: IMPLICATIONS FOR SWARD MANAGEMENT THROUGH SHEEP'S INGESTIVE BEHAVIOR[3]

[3] Artigo elaborado conforme as normas da revista *Grass and Forrage Science* (Apêndice 2).

## Grazing down process: implications for sward management through sheep's ingestive behavior

**R.P. Gonçalves*[4], C. Bremm*, F.G. Moojen*, D. Marchi†[5], G. Zubricki*, L.A.M. Caetano*, A. Barth Neto*, and P.C.F. Carvalho***

**Abstract**

Foraging behavior studies have supported innovations in sward management, making pastoral systems more sustainable and competitive. Based on this, we evaluated the sheep's ingestive behavior responses and the changes in sward structure during four stages of grazing down in rotational stocking, indicating the threshold level of grazing down for sheep grazing in reproductive stage of annual ryegrass (*Lolium multiflorum* Lam.) managed under two grazing intensities (low and moderate). We found evidences that both grazing intensities studied promote a grazing down around 45% of non-limiting pre-grazing sward height. Thus, it could be expected that sward structure and forage chemical composition were adequate for sheep grazing during all grazing down of the sward in the reproductive stage. However, during grazing down stages in the end of the sward reproductive stage, both grazing intensities restricted the sheep's ingestive behavior patterns in the larger spatial and temporal scales of grazing (e.g. bite rate by feeding station, steps per minute, and grazing time). Therefore, sheep's behavioral response depends on: (i) grazing intensity, (ii) period of sward reproductive stage, and (iii) forage structural composition during grazing down.

**Keywords:** Grazing intensity; *Lolium multiflorum;* reproductive stage; rotational stocking; sward structure.

[4] * Grazing Ecology Research Group, Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil.
[5] † Department of Animal Science, Federal University of Santa Maria, Palmeira das Missões, RS, Brazil.

## 3.1 Introduction

Grazing is a substantial process that affects the dynamics and functioning of the pastoral ecosystems (Carvalho, 2013). Therefore, sward management should be based on the plant-animal interaction principles, considering the processes involved in the production, utilization and sustainability of the sward, as well as in the behavioral responses and animal performance (Benvenutti *et al*., 2015; Lemaire *et al*., 2011).

The rotational stocking method was designed to redistribute the grazing pressure in time and space, with greater control over the frequency, intensity, and uniformity of the sward defoliation during a stocking cycle (Gillen *et al*., 1990). Combining these characteristics with management actions that promote a high forage intake rate (Fonseca *et al*., 2012; Mezzalira *et al*., 2014), and consequent reduction in the grazing time (Villalba and Provenza, 2009), are essential to promote efficiency animal gains of these systems.

The grazing process observation can help to clarify the herbivore's behavioral components concerning the forage search and forage intake by the animal in different spatial and temporal scales (Carvalho *et al*., 2013). As well as certain sward management strategies, based on principles of plant-animal interaction, can be easily applied in rotational stocking systems (Benvenutti *et al*., 2015), since the animals' ingestive behavior is a result of sward characteristics, shaped by the animal itself (by grazing) and associated with the management decisions (Hirata *et al*., 2010).

The grazing down process influences the sward structure and, consequently, the animal's ingestive behavior through the short-term forage intake rate (Fonseca *et al*., 2012). However, the animal's responses may be different depending on the intensity of grazing, since in the short-term, sward characteristics at/in intensive stocking rates impose severe constraints to bite formation (Gregorini *et al*., 2011). During the sward reproductive stage, which is composed by high proportion of inflorescences, the responses of animal behavior/performance can have more changes due to the fact of the inflorescences present worse nutritive value than the leaves (Camargo *et al*., 2012; Benvenutti *et al*., 2015).

Therefore, this study hypothesizes that in the final stage of grazing down; sward structure and the forage chemical composition of annual ryegrass (*Lolium multiflorum* Lam.) managed in rotational stocking will constrain the sheep’s ingestive behavior pattern in moderate grazing intensity, whilst in low grazing intensity the sheep’s ingestive behavior pattern will not be constrained. This study aims to promote a better understanding of the relationship among the sward structural characteristics, the sheep’s ingestive behavior responses during grazing down process and their implications to indicate the threshold level of sheep's grazing in reproductive stage of annual ryegrass in rotational stocking system.

## 3.2 Materials and methods

This study is part of a long-term experimental protocol and composes an integrated crop-livestock system (ICLS) started in 2003. This system integrates soybean (*Glycine max* L.) and corn (*Zea mays*) during summer/autumn and sward of annual ryegrass (*Lolium multiflorum* Lam.) during winter/spring. The present study was developed in winter/spring, from July to October 2015.

### 3.2.1 Experimental area and procedures

The experiment was conducted at the Research Station of the Federal University of Rio Grande do Sul (RS/UFRGS), which is located in Southern Brazil (30° 05' 22'' S, 51° 39' 09" W). The climate is humid subtropical, Cfa, according to Köppen and Geinger (1928). The soil was classified as *Paleudult Typical* (USDA, 1999) with a slightly wavy relief and with no restrictions for annual crops.

According to the experimental protocol, the annual ryegrass was sow on May 8$^{th}$, 2015, using 30 kg ha$^{-1}$ of seed ("Common" cultivar). It was applied 200 kg ha$^{-1}$ N-$P_2O_5$-$K_2O$ (5-30-15 formula) and 200 kg potassium chloride (according to the need of the system set: 60 kg phosphorus ha$^{-1}$ and 60 kg ha$^{-1}$ potassium) was applied. Nitrogen fertilization in urea form, was applied in amount of 150 kg ha$^{-1}$ N, with half dose applied when the ryegrass plants had the 4$^{th}$ leaf (June 26$^{th}$, 2015) and the rest in the beginning of spring (September 25$^{th}$, 2015), as recommended by the Soil Fertility Commission (1995).

### 3.2.2 Experimental design

The experimental design was a randomized complete block with three replications corresponding to six paddocks ranging from 0.23 to 0.41 ha. The experiment was arranged in a rotational stocking method with two grazing intensities for sheep: forage allowance of 2.5 and 5 times (namely moderate and low, respectively) the potential daily dry matter intake (DMI) according to the NRC (1985).

### 3.2.3 Establishment of the stocking cycle

The variable leaf life span (LLS) is a morphogenic variable and indicative of the optimum time period of defoliation (how many days – in thermal time – a leaf remains available to grazing before senescing) and was used to determine the interval of each stocking rate adjustment to maintain pre-defined forage allowance. This interval corresponds to stocking cycles described below. Data from Pontes et al. (2003) in the same experimental area were used: 500ºC leaf$^{-1}$, from June to August, and

410ºC leaf$^{-1}$, from September to November. Thus, these values were divided by the average air temperature of the months from June to November, obtained from climatic series of the last twenty-five years of the meteorological station located 800 m from the experimental site. Therefore, the number of days of each stocking cycle was derived from as follows: 36, 27, 24, and 21 days for paddocks under the low grazing intensity and 33, 24, and 31 days for paddocks under the moderate grazing intensity (differences due a delayed establishment of sward in the paddocks under the moderate grazing intensity). The criteria adopted for the initial of stocking cycle was the value of forage mass (FM) between 1500 and 2000 kg DM ha$^{-1}$ (Ramon *et al*. 2007; Confortin *et al*. 2013).

Animals were on a three-day period in each strip, thus, the size and number of the strip was determined based on the minimum area to keep the three tester-animals; the optimum time period of sward defoliation; the available area of each paddock and the number of days of each stocking cycle.

### 3.2.4 Parameters related to animals

The experimental animals were Corriedale breed lambs with approximately 27 ± 2 kg of live weight (LW) and mean age of 10 ± 2 months (yearling-lambs). Each paddock as experimental unit (EU) received three tester-animals (permanent animals that remained throughout the experimental period) and a variable number of animals periodically adjusted to maintain the desired forage allowance ("put-and-take" method was used, based on variable animal numbers during a stocking cycle with a periodic adjustment in animal numbers in an attempt to maintain a desired quantity of forage, according to Allen *et al*. 2011). The stocking rate was obtained by the relationship between the number of animals and the total area of the paddocks. The forage allowance (FA, % LW) was calculated according to the following equation: FA

(%LW) = ((FMd$^{-1}$ + FAR)/SR) *100. Where: LW = live weight, FM = average forage mass of each stocking cycle (kg DM ha$^{-1}$), n = number of days of stocking cycle, FAR = forage accumulation rate (kg ha$^{-1}$ DM day$^{-1}$), SR = stocking rate of each stocking cycle (kg LW ha$^{-1}$).

### 3.2.5 Animal ingestive behavior evaluation

The ingestive behavior evaluations occurred in two periods, one representing second stocking cycle (beginning of reproductive stage of annual ryegrass, on September 5$^{th}$ to 8$^{th}$), and the other representing the fourth stocking cycle (end of reproductive stage of annual ryegrass, on October 23$^{rd}$ to 26$^{th}$), in order to obtain representation of this phenological stage of the sward. Visual observation period was divided in four stages (grazing down stage). The initial stage occurred from 2:00 p.m. (strip exchange) to dusk (6:30 p.m.). Stage two and three occurred from dawn (6:30 a.m.) to dusk (6:30 p.m.) of the second and third day, respectively; and the final stage occurred from dawn (6:30 am) until 2:00 pm of the last grazing down day, when another strip exchange occurred. Every 5 minutes, the animal's grazing activities were recorded, being distributed in: grazing time, rumination time, and time of other activities. These were used to calculate the variables: time per meal and number of meals (a meal was defined as a continuous grazing action, Gibb *et al*. 1999). In addition, in the peak grazing activity, i.e. in the early hours of the morning and between late afternoon and early evening (Hodgson 1990), it was assessed the time spent by the animal to complete 20 bites, and the time in which the animals completed 10 feeding stations was collected (Forbes and Hodgson 1985). According to Ruyle and Dwyer (1985), feeding station is a hypothetical semicircle, referring to the area that is within reach of the animal, where it takes multiple bites without moving its front feet. These data were used to calculate the variables: bite rate (bites per minute), bites by feeding station (number), feeding stations per minute (number/min), steps per minute (number/min), and steps by feeding station (number).

### 3.2.6 Sward characterization

The sward characterization was performed on the strip occupied by the animals during the ingestive behavior evaluations. We measured the forage mass, sward height, and the forage apparently consumed by the animals.

The forage mass was determined in three moments (initial, intermediate, and final) by clipping three quadrants (0.26 x 0.26 m), representative of the average sward height. Samples were oven dried in an air forced ventilation at 65°C for 72 hours to determine the dry matter content.

The sward height was measured in the four stages of grazing down (initial, two, three, and final stages) by measuring 100 points per strip using a “sward stick” (Barthram 1985). The frequency whereby plants were touched by the “sward stick” was used to determine the percentages of leaves, stems, and inflorescences.

The forage apparently consumed by the animals was collected in two moments (initial and final stages) by “hand plucking” methodology (Bonnet *et al*. 2011). These samples were ground in a “Wiley mill”, with a 1 mm sieve, for chemical analysis of sward composition according to the Near infrared reflectance spectroscopy (NIRS) technique, which was coined for the indirect prediction of dietary attributes, i.e., crude protein (CP), neutral detergent fiber (NDF), and organic matter digestibility (OMD), using calibrations based on pairs of known diets (reference values) and resulting *faecal spectra* (Lyons and Stuth, 1992).

### 3.2.7 Statistical analysis

Data were submitted to analysis of variance (ANOVA) considering 5% of significance level (*P* < 0.05). The normal distribution of data was tested using the Shapiro-Wilk test (*P* > 0.05). Two statistical models were defined, one for lambs' ingestive behavior analysis and other for the sward analysis. We included in both statistical models the fixed effects of grazing intensity, grazing down stage, evaluation period and their interactions. We tested different random effects and the non-significant effects were identified and removed. Thus, for the sward analysis, the final model included the random effect of block, while for the animal analysis; the animal within the block was included as random effect. Variables of animal's ingestive behavior was transformed to the daily basis (e.g. minutes per day), for the purposes of comparison of grazing down stages. Means were compared using the Tukey test (*P* < 0.05) and Pearson correlation analysis was performed between sward characteristics and animals' ingestive behavior data. It was used the statistical software JMP® (v.12.2.0) by SAS®.

## 3.3 Results

### 3.3.1 Sward characterization

The responses of forage allowance were also expected, 15.7 ± 2.3 and 9.4 ± 2.3 kg DM/100kg LW day$^{-1}$ to low and moderate grazing intensity, respectively. The grazing intensity and grazing down stage affected (*P* <0.05) forage mass in the first evaluation period (Figure 1). The average forage mass had a decrease of 55 ± 5.6% of the initial value, it was higher in moderate than in low grazing intensity. In the second period, the initial forage mass was lower than in the first evaluation period in both grazing intensities, and only grazing down stage affected (*P* < 0.05) the forage mass (Figure 1). Forage mass had a decrease of 45 ± 8.8 % of the initial value in both grazing intensities.

Sward height (Figure 2a) was affected by grazing down stage in both periods ($P$ < 0.05), which had 11 ± 1.8 cm decrease of the pre-grazing sward height (23 ± 1.8 and 23.7 ± 1.8 cm to moderate and low grazing intensity, respectively). There was effect of the interaction between grazing downstage and evaluation period ($P$ < 0.05) for the grazing down percentage (Figure 2b). The grazing down percentage was similar for moderate and low grazing intensities in the first evaluation period (44 ± 5% of the pre-grazing sward height). In the second period, the grazing down percentage was more expressive in moderate grazing intensity in the stages 2 and 3, but, in final stage, both grazing intensities presented similar grazing down percentages (46 ± 5%).

Grazing down stage and evaluation period also affected ($P$ < 0.05) the percentages of leaves and stems during grazing down (Figure 3), whilst there was not observed effect of grazing intensity ($P$ > 0.05). In the first evaluation period, the initial stage presented frequency of leaves of 67 ± 4% this value had a decrease of 14 ± 4% until the final stage (staying constant for both grazing intensities). In contrast, in the second evaluation period, the initial stage presented leaves frequency around 54 ± 4%, and in the final grazing down stage the leaves' frequency was approximately 32 ± 4% for both grazing intensities. The stems' frequency had an increase of approximately 17 ± 3% and 40 ± 3% in the first and second periods, respectively, for both grazing intensities.

Inflorescences frequency (Figure 3) was affected by grazing intensity ($P$ = 0.0158), grazing down stage ($P$ = 0.0227), and evaluation period ($P$ = 0.0006). The initial stage, in first period, presented inflorescences' frequency around 15 ± 5 and 27 ± 5% to moderate and low grazing intensities, respectively, there was observed an increase around 10 ± 4% between the initial stage and stage 2. In contrast, the initial grazing down stage in the second evaluation period had inflorescences frequency around 42 ± 5%; and it had a decrease of 26 ± 5% during grazing down, for both grazing intensities. The contents of CP, NDF, and OMD of the forage apparently consumed by the animals (Table 1) were similar between the grazing intensities ($P > 0.05$), but it was affected by the grazing down stage and evaluation period ($P < 0.05$). CP and OMD contents were higher in the first evaluation period, whilst the NDF content was higher in the second period. The CP and OMD contents decreased between the initial and final stages of grazing down, whilst NDF content increased.

### 3.3.2 Animal ingestive behavior responses

The number of meals and the steps by feeding station differed between the grazing intensities ($P < 0.05$). The other responses of sheep's ingestive behavior were not affected by the grazing intensities studied (P > 0.05). Moderate grazing intensity promoted longer meals number and low grazing intensity promoted longer steps by feeding station (Table 2)

There was effect of the evaluation period for most of the studied behavior variables: meals duration, meals number, bite rate, feeding stations per minute, bites by feeding station and steps per minute. Longer duration of meals, meals number, bite rate and bites by feeding station were observed in the first period. In contrast, longer feeding stations per minute and steps per minute were observed in the second period ($P < 0.05$, Tables 2 and 3). There was effect of the interaction between grazing intensity and evaluation period only to feeding stations per minute ($P > 0.05$, Table 2).

On the other hand, all responses of sheep's ingestive behavior were affected by the interaction between grazing down stage and evaluation period ($P < 0.05$, Tables

3). Initial grazing down stage promoted longer grazing time, meals duration, and bite rate, which decreased gradually during grazing down. In contrast, final stage promoted longer rumination time, time of other activities, and meals number, which increased gradually during grazing down. These responses were most expressive in the second period. In the first period, feeding stations per minute had similar responses during grazing down, but in the second period this variable decreased gradually during grazing down. Bites by feeding station had a decreased gradually during grazing down stage in the first period, and similar responses during grazing down in the second period. Steps per minute has increased gradually during final stage in first period and similar responses during grazing down in second period.

## 3.4 Discussion

### 3.4.1 Sheep's ingestive behavior influenced by the sward structure during grazing down in the evaluation periods

Responses of forage mass (Figure 1), sward height, grazing down percentage (Figure 2), and percentages of leaves, inflorescences, and stems (Figure 3) indicate a limiting sward structure for the sheep's behavioral patterns in the second evaluation period (end of the reproductive stage of annual ryegrass). It was due to the defoliation level caused by both grazing intensities studied during grazing down in a condition that had high inflorescences' percentage and low leaves percentage. Baumont *et al*. (2004) proposed a theoretical model where grazing process would occur with removal of canopy successive horizons, equivalent to half the sward height. Thus, during grazing down, the animal is faced with cost-benefit decisions for forage apprehension (Prache and Peyraud, 2001). In the final grazing stage is expected that this process become complicated, because the animals are confronted with sward structural components (inflorescences and stems) complicating for the bite formation process (Gordon and Benvenutti, 2006, Benvenutti *et al*., 2015, Rocha *et al*., 2016, Figure 3). Thereby, there is less efficiency in the apprehension movements of these swards structural components, resulting in a longer time of manipulation in the mouth, when compared to the apprehension movements of leaves and sheaths (Hodgson 1990, Laca *et al*., 1994, Table 3).

The response found in the present study indicates that the grazing down percentage did not exceed 45% of the pre-grazing sward height in both grazing intensities and in both evaluation periods (Figure 2b). According to Fonseca *et al.* (2012) grazing down above 40% of the optimal pre-grazing sward height constrain the forage intake rate. Therefore, it could be expected that both grazing intensities studied would not constrain animal's ingestive behavior patterns. Ungar (1998) suggested that the animal changes their preference for the second horizon when remain 15 to 30% of the horizon that being grazed. Baumont *et al*. (2004) estimated this change in 25% and Mezzalira *et al*. (2014) observed values of 23 and 24% of non-grazed area with grazing down of around 40% of the pre-grazing sward height. Thus, considering that the leaves' frequency remained consistently higher than that of inflorescences (around 60%) during all grazing down in the first evaluated period (Figure 3), it is possible to affirm that both grazing intensities did not restrict the pattern of animal behavior in the larger spatial and temporal scales. However, in the second evaluation period, the leaf frequency remained lower than that of inflorescences and close to 20% since grazing down stage 2, indicating that the animals were facing a restrictive situation in that period. Therefore, animals used a compensation strategy to deal with changes in sward conditions. There was gradual increase in the number of feeding station per minute and steps per minute during the grazing down stages (Table 3), showing that sheep spent more time searching and selecting the best patches (Laca, 2009). Moreover, the reduction in meals duration and in bite rate (Table 3) shows a change in the time of apprehension and manipulation process of stems and inflorescences to maintain daily forage intake constant until the final grazing down stage (Benvenutti *et al*., 2015). As observed in studies that aimed to understand what occurs during grazing down (Laca *et al*., 1992; Ungar *et al*., 2001, Amaral *et al*., 2012), the sward structural modifications between the grazing strata (decrease in the leaf/stem ratio) interfere negatively with the herbivores' ingestive behavior, considering the progressive decrease in the bite mass and the forage intake rate.

### 3.4.2 Animals' ingestive behavior influenced by the forage chemical composition during grazing down in the evaluation periods

Among the sward structural modifications, the amount of leaves is the main component that affects the forage quality (Orr *et al*., 2004; Benvenutti *et al*., 2015). Thus, forage quality determines the amount of energy and nutrients that the herbivores can acquire from the forage intake (Carvalho, 2013). The increase in NDF content during grazing down and, especially, in the second period (Table 1), contributed to the increase in bite rate by sheep (Tables 2 and 3). Therefore, maintenance of a high intake is a function of the grazing time and the animal's permanence in the upper stratum, where there is higher leaves proportion (Laca and Demment, 1996; Fonseca *et al*., 2012; Mezzalira *et al*., 2014, Benvenutti *et al*., 2015). In the present study, the animals did not increase the grazing time at the final grazing down stage, especially in the second period (Figure 3; Table 3). This indicates that they could not compensate the grazing discouragement probably caused by a limiting condition in both grazing intensities. According to Bailey *et al*. (1996), in rotational stocking, the animal uses a working memory to compare information of the forage available with the intake nutritional value in the last eight hours and even over the twenty-one days. Thus, the animal can decrease the bite rate and grazing time along the grazing down by discouragement to the presented sward structure, realizing that it has the option of waiting to be changed of strip (Ribeiro Filho *et al*., 2003; Amaral *et al*. 2012). In addition, the increase in the inflorescences' frequency in the second evaluation period, from grazing down stage 2 (Figure 3), led to an increased in the meals number with reduced the duration of meals (Table 3). According to Briske *et al*. (2008), the increase in forage fibrousness influences the reduction in the proportion of cell soluble components (amino acids, proteins, lipids, starch) and increase in the proportion of cell structural components (hemicelluloses, cellulose, lignin, silica). It has accelerated the "rumen filling", since the higher fiber content of forage (Table 1) increase digestive processing by the animal (Van Soest, 1994; Filho *et al*., 2016). Consequently, an increase in the rumination time was observed (Table 3).

### 3.4.3 Implications of the grazing intensities in the rotational stocking management of annual ryegrass at reproductive stage

The changes in the chemical and structural composition of the forage during grazing down, and their implications on the sheep's ingestive behavior were verified by our results in two evaluation periods, reinforcing the theory that the herbivorous seek, until a certain point, to optimize their grazing activities in time and space (Charnov, 1976). Thus, we should prioritize adequate forage allowance in a sward structure composed by high proportion of leaves, since they present better nutritive value than the stems and inflorescences (Camargo *et al*., 2012; Benvenutti *et al*., 2015). Our results support the fact that the moderate and low grazing intensities are suitable for sheep grazing until the beginning of the reproductive stage of annual ryegrass (first period). However, during grazing down in the end of the reproductive stage of annual ryegrass (second period), both grazing intensities constrained the sheep's ingestive behavior patterns in the larger spatial and temporal scales (e.g. bite rate by feeding station, steps per minute, and grazing time, Table 3). Therefore, the greatest implication of this research is the use of a management strategy that indicates the threshold level of grazing in reproductive stage of annual ryegrass, contributing in the decision-making of the sward management in rotational stocking. Considering from the point of view of the plant, what really matters is the intensity and timing of defoliation, a concept that is well-established in grazing science (Chapman *et al*., 2007).

## 3.5 Conclusions

The sward structure and the forage chemical composition of annual ryegrass sward (*Lolium multiflorum* Lam.) managed under low and moderate grazing intensities in rotational stocking are suitable for sheep grazing in the beginning of the sward reproductive stage. However, during grazing down in the end of the sward reproductive stage, both grazing intensities constrain the sheep's ingestive behavior patterns in the larger spatial and temporal scales (e.g. bite rate by feeding station, steps per minute and grazing time). Therefore, sheep's behavioral responses during grazing down of annual ryegrass depend on: (i) grazing intensity, (ii) period of the sward reproductive stage, and (iii) forage structural composition during grazing down.

## 3.6 Acknowledgements

Special thanks to students from Grazing Ecology Research Group (UFRG/Brazil) and collaborators who assisted in the experiment. This study was supported by CNPq, CAPES.

### 3.7 References

ALLEN V.G., BATELLO C., BERRETTA E.J., HODGSON J., KOTHMANN M., LI X., MCIVOR J., MILNE J., MORRIS C., PEETERS A., and SANDERSON M. (2011) An international terminology for grazing lands and grazing animals. *Grass and Forage Science*, 2–28.

AMARAL M.F., MEZZALIRA J.C., BREMM C., DA TRINDADE J.K., GIBB M.J., SILVA R., and CARVALHO P.C.F. (2012) Sward structure management for a maximum short-term intake rate in annual ryegrass. *Grass and Forage Science*, **68**, 271–277.

BAILEY D.W., GROSS J.E., LACA E.A., RITTENHOUSE L.R., COUGHENOUR M.B., SWIFT DM, and SIMS P.L. (1996) Mechanisms that result in large herbivore grazing distribution patterns. *Journal of Range Management*, Arizona, **49** (5), 386–400.

BARTHRAM G.T. (1985) Experimental techniques: the HFRO sward stick. In*:* BARTHRAM G.T., The hill farming research organization/biennial report. *Penicuik: HFRO*, pp.29–30.

BAUMONT R., COHEN-SALMON D., PRACHE S., and SAUVANT D. (2004) A mechanistic model of intake and grazing behaviour in sheep integrating sward architecture and animal decisions. *Animal Feed Science and Technology*, Amsterdan, **112** (1), 5–28.

BENVENUTTI M.A., PAVETTI D.R., POPPI D.P., GORDON I.J., and CANGIANO C.A. (2015) Defoliation patterns and their implications for the management of vegetative tropical pastures to control intake and diet quality by cattle. John Wiley and Sons Ltd. *Grass and Forage Science*, **71**, 424–436.

BONNET O., HAGENAH N., HEBBELMANN L., MPADDOCKSRET M., and SHRADER A.M, (2011) Is hand plucking an accurate method of estimating bite mass and instantaneous intake of grazing herbivores? *Rangeland Ecology and Management*, **64** (4), 366–374.

BRISKE D.D., DERNER J.D., BROWN J R., FUHLENDORF S.D., TEAGUE W.R., HAVSTAD K.M., GILLEN R.L., ASH A.J., and WILLMS W.D. (2008) Rotational grazing on rangelands: reconciliation of perception and experimental evidence. *Rangeland Ecology and Management*, **61**, 3–18.

CAMARGO D.G., ROCHA M.G., SILVA J.H.S, GLIENKE C.L., CONFORTIN A.C.C., and MACHADO J.M. (2012) Characteristics of forage intake of lambs at phenological stages of Italian ryegrass pasture. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, Belo Horizonte, **46** (2), 403–410. (in Portuguese)

CARVALHO P.C.F. (2013) Can grazing behaviour support innovations in sward management? *Proceedings...* of the 22nd International Sward Congress. 1134–1148.

CARVALHO PCF, DA TRINDADE JK, BREMM C, MEZZALIRA JC, FONSECA L. (2013) Comportamento Ingestivo de Animais em Pastejo. In: *Forragicultura: Ciência, Tecnologia e Gestão dos Recursos Forrageiros*. Viçosa: UFV, 525–545. (in Portuguese)

CHARNOV E.L. (1976) Optimal foraging: the marginal value theorem. *Theor Popul Biol*. **9**, 129–136.

CHAPMAN D.F., PARSONS A.J., COSGROVE G.P., BARKER D. J, MAROTTI D. M., VENNING K. J., RUTTER S. M., HILL J., and THOMPSON A. N. (2007) Impacts of spatial patterns in pasture on animal grazing behavior, intake, and performance. *Crop Sci.* **47**, 399–415.

CONFORTIN A.C.C., DA ROCHA M.G., MACHADO J.M., ROMAN J., DE QUADROS F.L.F., and PÖTTER L. (2013) Different herbage masses on morphogenetic and structural traits of Italian ryegrass. *Ciência Rural*, Santa Maria, **43** (3), 496–502. (in Portuguese)

FILHO A.E., CARVALHO G.G.P., PIRES A.J.V., SILVA R.R., SANTOS P.E.F., MURTA R.M., PEREIRA F.M., CARVALHO, B.M.A., MARANHÃO C.M.A., RUFINO L.M.A., SANTOS S.A., and PINA D.S. (2016) Intake and ingestive behavior in lambs fed low-digestibility forages. *Tropical Animal Health Production,* **48**, 1315–1321.

FONSECA L., MEZZALIRA J.C., BREMM C., FILHO R.S.A., GONDA H.L., and CARVALHO P.C.F. (2012) Management targets for maximising the short-term herbage intake rate of cattle grazing in Sorghum bicolor. *Livestock Science*, **145**, 205–211.

FORBES T.D.A., and HODGSON J. (1985) Researching the plant-animal interface: The investigation of ingestive behavior of cows and sheep. *Grass and Forage Science*, **40**, 69–77.

GREGORINI P., GUNTER S.A., BOWMAN M.T., CALDWELL J.D., MASINO C.A., COBLENTZ W.K., and BECK P.A. (2011) Effect of herbage depletion on short-term foraging dynamics and diet quality of steers grazing wheat pastures. *J. Anim. Sci*. **89**, 3824-3830.

GIBB M.J., and TREACHER T.T. (1976) The effect of herbage allowance on herbage intakeand performance of lambs grazing perennial ryegrass and red clover swards. *Journal of Agricultural Science,* **86**, 355–365.

GIBB M.J, HUCKLE C.A., NUTHALL R., and ROOK A.J. (1999) The effect of physiological state (lactating or dry) and sward surface height on grazing behaviour and intake by dairy cows. *Appl. Anim. Behav. Sci*. Amsterdam, **63**, 269–287.

GILLEN R.L., MCCOBUM F.T., and BRUMMER J.E. (1990) Tiller defoliation patterns under short duration grazing in tallgrass prairie. *Journal of Range Management*, **43**, 95–99.

GORDON I.J., and BENVENUTTI M.A. (2006) Food in 3D: how ruminant livestock interact with sown sward architecture at bite scale. In: BELS V. (Ed.). Feeding in domestic vertebrates: from structure to behavior. *CAB International Wallingford*, pp.263–277.

HIRATA M., KUNIEDA E., and TOBISA M. ( 2010.) Short-term ingestive behaviour of cattle grazing tropical stoloniferous grasses with contrasting growth forms. *Journal of Agricultural Science*, **148**, 615–624.

HODGSON J. (1990) Grazing management: science into practice. London: *Longman Group*, pp.203.

KÖPPEN W., and GEINGER R. (1928) Klimate der erde. Verlag justus perthes, Gotha (Wall- map).

LACA E.A. (2009) New Approaches and Tools for Grazing Management. *Rangeland Ecology and Management*, **62**, 407–417.

LACA E.A., and DEMMENT M.W. (1996) Foraging strategies of grazing animals. In: HODGSON J., and ILLIUS A.W. (Ed). The Ecology and Management of Grazing Systems. *CAB International, Wallingford,* pp.137–157.

LACA E.A., UNGAR E.D., and DEMMENT M.W. (1994) Mechanisms of handling time and intake rate of a large mammalian grazer. *Applied Animal Behaviour Science*, Amsterdan, **39** (1), 3–19.

LACA E.A., UNGAR E.D., SELIGMAN N.G., RAMEY M.R., and DEMMENT M.W. (1992) An integrated methodology for studying short-term grazing behavior of cattle. *Grass and Forage Science*, **47**, 81–90.

LEMAIRE G., HODGSON J., and CHABBI A. (2011) 'Sward productivity and ecosystems services'. *CABI international: Wallingford*, pp.286.

LYONS R.K., and STUTH J.W. (1992) Fecal NIRS equations for predicting diet quality of free-ranging cattle. Journal of Range Management 45, 238–244.

MEZZALIRA J.C., CARVALHO P.C.F., FONSECA L., BREMM C., CANGIANO C., GONDA H.L., and LACA E.A. (2014) Behavioural mechanisms of intake rate by heifers grazing swards of contrasting structures. *Applied Animal Behaviour Science*, **153**, 1–9.

NATIONAL RESEARCH CONCIL-NRC (1985) Nutrient requirement of sheep. 6$^{th}$.ed. Washington: *National Academy Press*, pp.99.

ORR R.J., RUTTER S.M., and YARROW N.H. (2004) Changes in ingestive behaviour of yearling dairy heifers due to changes in sward state during grazing down of rotationally stocked ryegrass or white clover pastures. *Applied Animal Behaviour Science*, **87**, 205–222.

PONTES L.S., NABINGER C., CARVALHO P.C.F., DA TRINDADE J.K., MONTARDO D.P. and DOS SANTOS R.J. (2003) Morphogenetic and Structural Traits of Ryegrass (*Lolium multiflorum* Lam.) Managed under Different Sward Heights. *Brazilian Journal of Animal Science*, Viçosa, **32** (4), 814–820. (in Portuguese)

PRACHE S., and PEYRAUD J. (2001) Foraging: behaviour and intake in temperate cultivated sward. In: International Sward Congress, 19. *Proceedings*… São Pedro. pp.309–319.

RIBEIRO FILHO H.M.N., DELAGARDE R., and PEYRAUD J.L. (2003) Inclusion of white clover in strip-grazed perennial ryegrass swards: herbage intake and milk yield of dairy cows at different ages of sward regrowth*. Animal Science*, **77**, 499–510.

ROCHA, C.H., SANTOS, G.T., PADILHA, D.A., SCHMITT, D., MEDEIROS-NETO, C., and SBRISSIA A.F. (2016) Displacement patterns of cattle grazing on Kikuyugrass swards under intermittent grazing. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, **68**(6), 1647–1654. (in Portuguese)

RUYLE G.B., and DAWYER D.D. (1985) Feeding station s of sheep as an indicator of diminished forage supply*. Journal of Animal Science*, Champaign, **61**, 349–353.

SOIL FERTILITY COMMISSION (1995) Fertilizer and Liming Recommendations for States of Rio Grande do Sul and Santa Catarina. Passo Fundo, *Brazilian Society of Soil Science /EmbrapaCNPT*, **3**, pp.223. (in Portuguese)

UNITED STATES DEPARTMENT OF AGRICULTURE - USDA (1999) Soil Taxonomy: A BasicSystem of Soil Classification for Making and Interpreting Soil Surveys. USDA,Washington, DC. pp.1–87.

UNGAR E.D. (1998) Changes in bite area and bite depth during patch depletion by cattle. In: GIBB M.J. (Ed.). Paddocksropean intake workshop on techniques for investigating intake and ingestive behaviour by farm animals 10. *Proceedings...* North Wyke. pp.81–82.

UNGAR E.D., RAVID N., and BRUCKENTAL I. (2001) Bite dimensions for cattle grazing herbage at low levels of depletion. *Grass and Forage Science*, Oxford, **56**(1), 35–45.

VAN SOEST P.J. (1994) Nutritional ecology of the ruminant. *Ithaca: Cornell University Press*, pp.476.

VILLALBA J.J. and PROVENZA F.D. (2009) Learning and dietary choice in

herbivores. *Rangeland Ecology and Management*, **62**(5), 399–406

.

**Figure 1**2Forage mass of the annual ryegrass (*Lolium multiflorum* Lam.) in two evaluation periods (1 and 2), corresponding to the ingestive behavior assessments of lambs managed under rotational stocking under two grazing intensities (Moderate and Low).

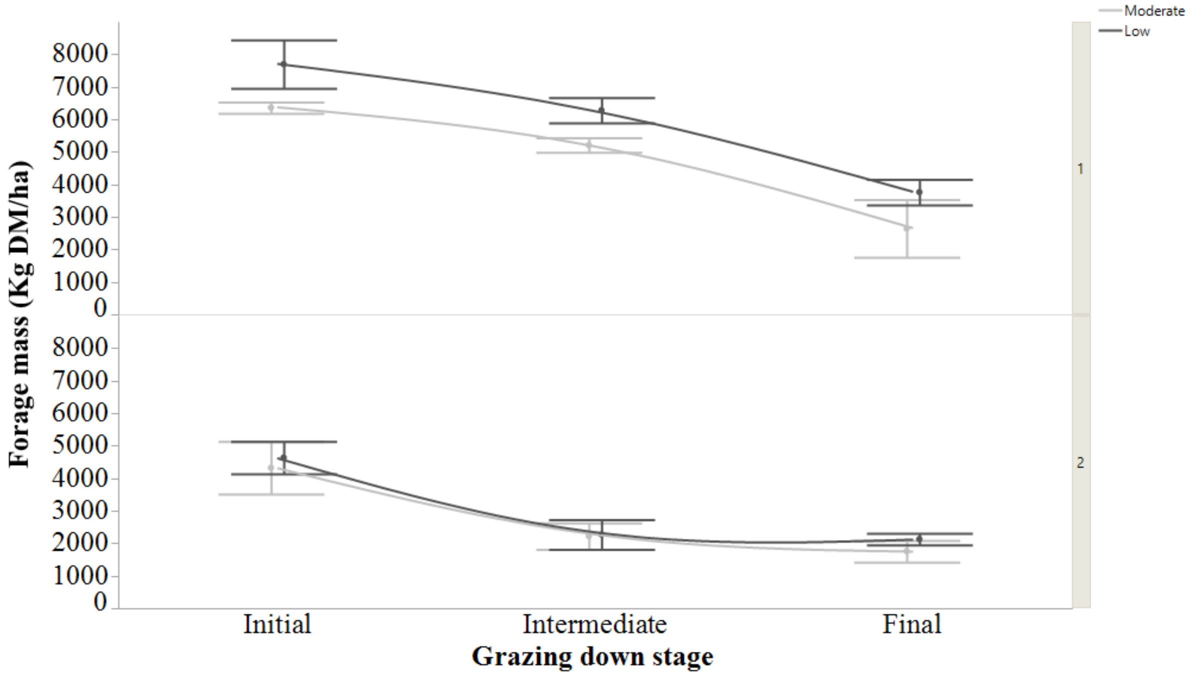


**Figure 23**Average sward height (centimeters) (a) and grazing down percentage (b) of the annual ryegrass (*Lolium multiflorum* Lam.) in two evaluation periods (1 and 2), corresponding to the grazing down in rotational stocking under two grazing intensities (Moderate and Low).

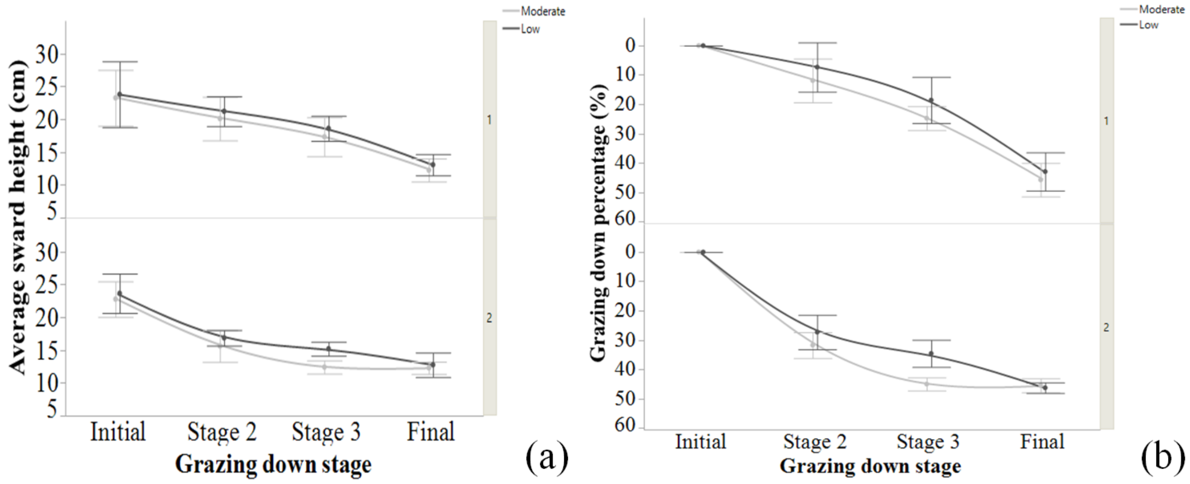


**Figure 34**Frequency of leaves (○ —) (● —); inflorescences (◇ —) (◆ —); and stems (+ ---) (✳ ---) under the grazing intensities moderate and low, respectively, of the annual ryegrass (*Lolium multiflorum* Lam.) in two evaluation periods (1 and 2), corresponding to the grazing down in rotational stocking.

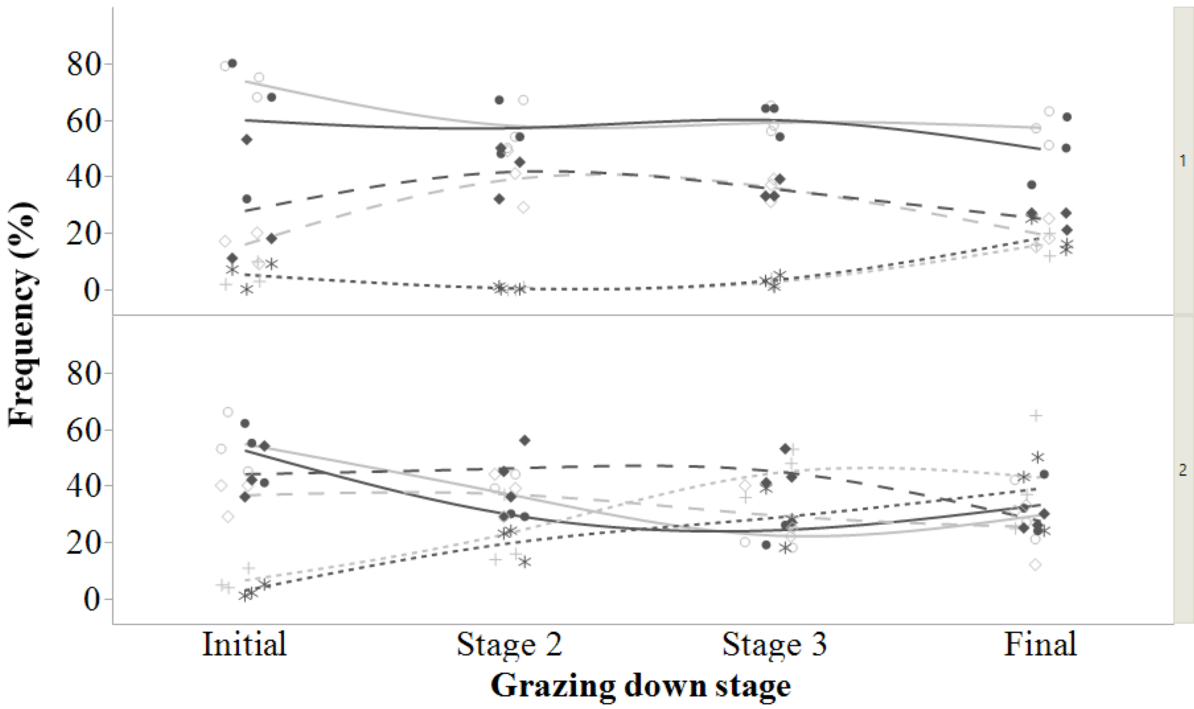


**Table 14**Chemical composition of the annual ryegrass (*Lolium multiflorum* Lam.) forage apparently consumed by sheep in two evaluation periods (1 and 2), corresponding to the initial and final of grazing down stages in rotational stocking under two grazing intensities (moderate and low).

| Variables | Evaluation period 1 | | | | Mean | Evaluation period 2 | | | | Mean | *P*I | *P*S | *P*I×S | *P*E | *P*I×E | *P*S×E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Moderate | | Low | | | Moderate | | Low | | | | | | | | |
| | Grazing down stage | | | | | Grazing down stage | | | | | | | | | | |
| | Initial | Final | Initial | Final | | Initial | Final | Initial | Final | | | | | | | |
| NDF | $41.5^{b}$ | $46.9^{a}$ | $41.5^{b}$ | $46.9^{a}$ | $44.2^{B}$ | $53.1^{b}$ | $58.6^{a}$ | $50.4^{b}$ | $56.7^{a}$ | $54.7^{A}$ | 0.2926 | <0.0001 | 0.8665 | <0.0001 | 0.2989 | 0.7745 |
| CP | $21.9^{a}$ | $18.3^{b}$ | $22.9^{a}$ | $20.2^{b}$ | $20.8^{A}$ | $16.3^{a}$ | $12.3^{b}$ | $16.9^{a}$ | $12^{b}$ | 14 $4^{B}$ | 0.1943 | <0.0001 | 0.9877 | <0.0001 | 0.2723 | 0.2812 |
| OMD | $88.9^{a}$ | $82.6^{b}$ | $88.8^{a}$ | $83.1^{b}$ | $85.8^{B}$ | $75^{a}$ | $64^{b}$ | $76.7^{a}$ | $65.9^{b}$ | $70.4^{B}$ | 0.5238 | <0.0001 | 0.8812 | <0.0001 | 0.6120 | 0.1266 |

NDF = neutral detergent fiber (%); CP = crude protein (%); OMD = organic matter digestibility (%); *P*I = probability of grazing intensity; *P*S = probability of grazing stage; *P*I×S = probability of interaction between grazing intensity and grazing stage; *P*E = probability of evaluation period; *P*I×E = probability of interaction between grazing intensity and evaluation period; *P*S×E = probability of interaction between grazing stage and evaluation period; *P*I×S×E = probability of interaction between grazing intensity, grazing stage and evaluation period. Means followed by lowercase letters in line differ by Tukey test ($P < 0.05$) for *P*S. Means followed by upper letters in line differ by Tukey test ($P < 0.05$) for *P*E.

**Table 2**5Ingestive behavior (adjusted means) of sheep managed under two grazing intensities (moderate and low) in rotational stocking, in two evaluation periods (1 and 2) of the annual ryegrass sward (*Lolium multiflorum* Lam.).

| | Evaluation period 1 | | | Evaluation period 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Moderate | Low | Mean | Moderate | Low | Mean | *P*I | *P*E | *P*I×E |
| GT | 474.5 | 473.9 | 474.2 | 469.8 | 487 | 478.4 | 0.7691 | 0.7529 | 0.5031 |
| RT | 115.1 | 158.5 | 136.8 | 142.5 | 163.3 | 152.9 | 0.3967 | 0.0612 | 0.1858 |
| TOA | 190.3 | 125.5 | 157.9 | 167.6 | 129.7 | 148.6 | 0.1134 | 0.4116 | 0.2354 |
| MD | 111.3 | 116.8 | 89$^{A}$ | 85.3 | 92.6 | 114.1$^{B}$ | 0.6695 | 0.0173 | 0.9336 |
| MN | 6.6$^{a}$ | 6.2$^{b}$ | 6.4$^{A}$ | 6$^{a}$ | 5.2$^{b}$ | 5.6 $^{B}$ | 0.0414 | 0.0186 | 0.4331 |
| BR | 32 | 31.4 | 31.7$^{A}$ | 26.2 | 28.4 | 27.3 $^{B}$ | 0.7744 | <0.0001 | 0.0922 |
| FSM | 3.4$^{b}$ | 2.8$^{b}$ | 3.1$^{B}$ | 5.4$^{a}$ | 6.1$^{a}$ | 5.7 $^{A}$ | 0.9126 | <0.0001 | 0.0019 |
| BFS | 11.2 | 11.8 | 11.5$^{A}$ | 5.3 | 5.1 | 5.2 $^{B}$ | 0.9073 | <0.0001 | 0.5031 |
| SM | 5.3 | 5.7 | 5.5$^{B}$ | 8.7 | 10.2 | 9.4 $^{A}$ | 0.1371 | <0.0001 | 0.1337 |
| SFS | 1.7$^{b}$ | 2.1$^{a}$ | 1.9 | 1.7$^{b}$ | 1.8$^{a}$ | 1.7 | 0.0260 | 0.1717 | 0.1949 |

GT = grazing time (minute); RT = rumination time (minute); TOA = time of other activities (minute); MD = meals duration (minute); MN = meals number; BR = bite rate (bites per minute); FSM = feeding stations per minute (number); BFS = bites by feeding station; SM = steps per minute (number); SFS = steps by feeding station (number); *P*I = probability of grazing intensity; *P*E = probability of evaluation period; *P*I×E = probability of interaction between grazing intensity and evaluation period. Means followed by lowercase letters in line differ by Tukey test ($P < 0.05$) for *P*I. Means followed by upper letters in line differ by Tukey test ($P < 0.05$) for *P*E.

**Table 3**6 Ingestive behavior (adjusted means) of sheep during grazing down stages (initial, stage 2, stage 3, and final) of rotational stocking in two evaluation periods (1 and 2) of the annual ryegrass sward (*Lolium multiflorum* Lam.).

| | Evaluation period 1 | | | | | Evaluation period 2 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Initial | Stage 2 | Stage 3 | Final | Mean | Initial | Stage 2 | Stage 3 | Final | Mean | *P*S | *P*E | *P*S×E |
| GT | 594.4$^{a}$ | 454.4$^{bc}$ | 441$^{bc}$ | 407.1$^{c}$ | 474.2 | 699.9$^{a}$ | 492.3$^{b}$ | 419.5$^{c}$ | 301.9$^{d}$ | 478.4 | <0.0001 | 0.7529 | <0.0001 |
| RT | 61.2$^{c}$ | 141.2$^{b}$ | 148.9$^{ab}$ | 196$^{ab}$ | 136.8 | 31.2$^{c}$ | 179.1$^{b}$ | 218.5$^{a}$ | 183$^{b}$ | 152.9 | <0.0001 | 0.0612 | 0.0001 |
| TOA | 124.3$^{b}$ | 162.8$^{ab}$ | 168.4$^{ab}$ | 176.2$^{a}$ | 157.9 | 48.8$^{d}$ | 108.6$^{c}$ | 142$^{bc}$ | 295.1$^{a}$ | 148.6 | <0.0001 | 0.4116 | <0.0001 |
| MD | 148.3$^{a}$ | 61.7$^{b}$ | 75.4$^{b}$ | 70.5$^{b}$ | 89$^{A}$ | 245.5$^{a}$ | 95.1$^{b}$ | 63.8$^{bc}$ | 51.8$^{c}$ | 114.1$^{B}$ | <0.0001 | 0.0173 | 0.0003 |
| MN | 5.7$^{b}$ | 7.5$^{a}$ | 5.7$^{b}$ | 6.6$^{ab}$ | 6.4$^{A}$ | 3.4$^{c}$ | 5.4$^{b}$ | 7.1$^{a}$ | 6.4$^{ab}$ | 5.6 $^{B}$ | <0.0001 | 0.0186 | 0.0003 |
| BR | 42.6$^{a}$ | 36.8$^{b}$ | 28.2$^{c}$ | 19.1$^{d}$ | 31.7$^{A}$ | 32.1$^{a}$ | 28.1$^{b}$ | 24.7$^{c}$ | 24.4$^{c}$ | 27.3 $^{B}$ | <0.0001 | <0.0001 | <0.0001 |
| FSM | 3.2$^{a}$ | 3$^{a}$ | 3$^{a}$ | 3.2$^{a}$ | 3.1$^{B}$ | 7$^{a}$ | 5.1$^{b}$ | 5.7$^{b}$ | 5.1$^{b}$ | 5.7 $^{A}$ | 0.0022 | <0.0001 | 0.0051 |
| BFS | 15.1$^{a}$ | 13.7$^{a}$ | 11$^{b}$ | 6.2$^{c}$ | 11.5$^{A}$ | 4.8$^{a}$ | 5.2$^{a}$ | 5.3$^{a}$ | 5.4$^{a}$ | 5.2 $^{B}$ | <0.0001 | <0.0001 | <0.0001 |
| SM | 5.2$^{b}$ | 4.6$^{b}$ | 5$^{b}$ | 7.4$^{a}$ | 5.5$^{B}$ | 10.2$^{a}$ | 7.8$^{b}$ | 10.1$^{a}$ | 9.7$^{a}$ | 9.4 $^{A}$ | 0.0015 | <0.0001 | 0.0409 |
| SFS | 1.7$^{bc}$ | 1.5$^{c}$ | 1.7$^{bc}$ | 2.5$^{a}$ | 1.9 | 1.5$^{b}$ | 1.5$^{b}$ | 1.9$^{ab}$ | 2$^{a}$ | 1.7 | <0.0001 | 0.1727 | 0.0380 |

GT = grazing time (minute); RT = rumination time (minute); TOA = time of other activities (minute); MD = meals duration (minute); MN = meals number; BR = bite rate (bites per minute); FSM = feeding stations per minute (number); BFS = bites by feeding station; SM = steps per minute (number); SFS = steps by feeding station (number); *P*S = probability of grazing stage; *P*E = probability of evaluation period; *P*S×E = probability of interaction between grazing stage and evaluation period. Means followed by lowercase letters in line differ by Tukey test ($P$ < 0.05) for *P*S or *P*S×E. Means followed by upper letters in line differ by Tukey test ($P$ < 0.05) for *P*E.

# 4 CAPÍTULO IV

# CONSIDERAÇÕES FINAIS

## 4.1 CONSIDERAÇÕES FINAIS

Este estudo possibilitou definir como as alterações na estrutura e qualidade de uma pastagem de azevém anual (*Lolium multiflorum* Lam.), promovidas por métodos de pastoreio e intensidades de pastejo, afetam o comportamento ingestivo de ovinos, o ganho médio diário desses animais, bem como auxiliou a estabelecer metas de manejo dessa pastagem.

No Capítulo II, constatamos que o método de pastoreio afeta a quantidade de folhas e inflorescências, que foram as principais características do pasto que influenciaram a composição química da forragem, além de promover o aumento da taxa de bocados e no tempo de pastejo dos ovinos. Por outro lado, as intensidades de pastejo estudadas influenciaram o aumento dos bocados por estação alimentar e diminuição do número de refeições. Além disso, variáveis como estação alimentar por minuto, duração das refeições e tempo de pastejo foram destaque para os componentes principais, explicando 67,3% da variação total dos dados. Essas variáveis foram positivamente correlacionadas com o ganho médio diário dos animais, assim, podem ser utilizadas como preditoras do ganho médio diário de ovinos. Portanto, as mudanças nas respostas do comportamento ingestivo, em escalas como estação alimentar e campo de pastejo foram fontes de compensação utilizadas pelos ovinos para manter seu ganho médio diário quando expostos a uma condição de pastejo limitada, devido ao elevado percentual de inflorescências na pastagem.

No Capítulo III, encontramos evidências de que em pastoreio rotativo, ambas as intensidades de pastejo estudadas promovem um rebaixamento em torno de 45% da altura pré-pastejo em método rotativo. Assim, a estrutura do pasto e a composição química da forragem foram adequadas para o pastejo de ovinos até o início do estádio reprodutivo do azevém anual. No entanto, partir da fase de rebaixamento 2, ao final do estádio reprodutivo da pastagem, ambas as intensidades de pastejo aparentemente restringiram os padrões de comportamento ingestivo dos ovinos nas maiores escalas espaço-temporais do pastejo. Logo, a resposta comportamental de ovinos depende de: (i) taxa de lotação, (ii) nível de desfolha do dossel, (iii) período do estádio reprodutivo do azevém anual e composição estrutural da forragem durante o rebaixamento.

De acordo com as respostas obtidas, fica evidente a necessidade do aprimoramento de práticas de manejo sustentáveis que visem oferecer aos animais estruturas de pasto de qualidade, e que aperfeiçoem o processo de pastejo. Portanto, em pastoreio contínuo, devem-se manter os "*patches*" explorados pelos animais em condições adequadas que priorizem elevado percentual de folhas. Alterar o critério adotado para a entrada dos animais na pastagem (redução do valor da massa de forragem inicial para 1.500 kg MS $ha^{-1}$, por exemplo) pode ser uma alternativa para atingir o objetivo da situação descrita. Tendo em vista que o critério atual do protocolo experimental promove um alto acúmulo de forragem pré-pastejo (podendo ser maior que 2.000 kg MS $ha^{-1}$), levando ao aumento das áreas de rejeição na pastagem, e dificultando o controle sobre o precoce e alto percentual de inflorescências. Ademais, no método de pastoreio rotativo, deve-se considerar um percentual de rebaixamento que não ultrapasse 45% da altura inicial do pasto. Além disso, a tomada de decisão do limite do pastejo de ovinos em azevém anual deve considerar até o início do estádio reprodutivo da pastagem. Como descrito na literatura citada nesse trabalho, é fundamental que os novos estudos continuem mudando os rumos da pesquisa científica, devido à complexidade das relações existentes entre clima, solo, planta e animal. Estabelecer uma percentagem do nível de inflorescência para manter os animais pastando, seria um próximo passo para melhorar o manejo da pastagem de azevém anual e a rentabilidade do sistema pastoril. Entretanto, para a realização dos procedimentos básicos que compõem esse protocolo experimental, torna-se fundamental o investimento em infraestrutura e capital social de pessoas envolvidas direta ou indiretamente no funcionamento do sistema.

# 5 REFERÊNCIAS


ADLER, P.B.; RAFF, D.A.; LAUENROTH, W.K. The effect of grazing on the spatial heterogeneity of vegetation. **Oecologia**, Berlin, v. 128, n. 4, p. 465–479, 2001.

ALLDEN, A.G.; WHITTAKER I.A. The determinants of herbage intake by grazing sheep: The interrelationship of factors influencing herbage intake and availability. **Aust. J. Agric. Res.**, Victoria, v. 21, n. 5, p. 755–766, 1970.

ANGHINONI, I.; CARVALHO, P.C.F.; COSTA, S.E.V.G.A. Abordagem sistêmica do solo em Sistemas Integrados de Produção Agrícola e Pecuária no subtrópico brasileiro. **Tópicos Ci. Solo**, Viçosa, v. 8, p. 325–380, 2013.

AMARAL, M.F. et al. Sward structure management for a maxi- mum short-term intake rate in annual ryegrass. **Grass. Forage Sci.,** Oxford, v. 68, n. 2, p. 271–277, 2012.

BAGGIO, C. et al. Padrões de uso do tempo por novilhos em pasta- gem consorciada de azevém anual e aveia. **R. Bras. Zoot**., Viçosa, MG, v. 37, p.1912-1918, 2008.

BALBINOT, JR. A.A. et al. Integração lavoura-pecuária: intensificação de uso de áreas agrícolas. **Ciên. Rural**, v. 39, n. 6, p. 1925–1933, 2009.

BAILEY, D.W. et al. Mechanisms that result in large herbivore grazing distribution patterns. **J. Range Manage**., Denver, v. 49, n. 5, p. 386–400, 1996.

BAILEY, D.W.; PROVENZA, F.D. Mechanisms determining large-herbivore distribution. In: PRINS, H.H.T.; VAN LANGEVELD, F. (Ed.). **Resource ecology**: spatial and temporal dynamics of foraging. Wageningen: UR Frontis Series, 2008. p. 7–29. v. 2A,

BAUMONT, R. et al. A mechanistic model of intake and grazing behaviour in sheep integrating sward architecture and animal decisions. **Anim. Feed Sci. Techn.**, Amsterdam, v. 112, n. 1, p. 5–28, 2004.

BAUMONT, R. et al. How forage characteristics influence behaviour and intake in small ruminants: a review. **Livestock Prod. Sci.**, Amsterdam, v. 64, n. 1, p. 15–28, 2000.

BAUER, M.O. et al. Produção e características estruturais de cinco forrageiras do gênero Brachiaria sob intensidades de cortes intermitentes [Herbage yield and structural characteristics of five Brachiaria genus forages under intermittently defoliation sward]. **Ciên. Anim. Bras**., Goiânia, v. 12, n. 1, p. 17–25, 2011.

BARBOSA, C.M.P. et al. Terminação de cordeiros em pastagens de azevém anual manejadas em diferentes intensidades e métodos de pastejo. **R. Bras. Zootec**., Viçosa, v. 36, n. 6, p. 1953–1960, 2007.

BARRE, P. et al. Morphological Characteristics of Perennial Ryegrass Leaves that Influence Short-Term Intake in Dairy Cows. **Agron. J.**, Madison, v. 98, n. 1, p. 978-985, 2006.

BARRETT, P.B. et al. Pattern of herbage intake rate and bite dimensions of rotationally grazed dairy cows as sward height declines. **Grass. Forage Sci**., Oxford, v. 56, n. 4, p. 362–373, 2001.

BARTHOLOMEW, P. W.; WILLIAMS, R. D. Establishment of Italian Ryegrass (Lolium Multflorum Lam.) by Self-Seeding as Arrected by Cutting Date and Degree of Herbage Removal in Spring in Pastures of the Southern Great Plains of the United States. **Grass Forage Sci.,** v. 64, p. 177–186, 2009.

BELL, L.W.; MOORE A.D. Integrated crop-livestock systems in Australian agriculture: Trends, drivers and implications. **Agric**. **Syst**., Essex, v. 111, p. 1–12, 2012.

BENVENUTTI, M.A. et al. Defoliation patterns and their implications for the management of vegetative tropical pastures to control intake and diet quality by cattle. John Wiley and Sons Ltd. **Grass Forage Sci.**, Oxford, v. 71, n. 3, p. 424–436, 2015.

BENVENUTTI, M.A.; GORDON, I.J.; POPPI, D.P. The effect of the density and physical properties of grass stems on the foraging behaviour and instantaneous intake rate by cattle grazing an artificial reproductive tropical sward. **Grass Forage Sci.**, Oxford, v. 61, n. 3, p. 272–281, 2006.

BONETTI, J.A. et al. Influência do sistema integrado de produção agropecuária no solo e na produtividade de soja e braquiária. **Pesq. Agropec. Trop.**, Goiânia, v. 45, n. 1, p. 104–112, 2015.

BORTOLO, M. et al. Desempenho de Ovelhas, Composição Química e Digestibilidade in Vitro em uma Pastagem de Coastcross-1 (*Cynodon dactylon* (L.) Pers) sob Diferentes Níveis de Matéria Seca Residual. **R. Bras. Zootec.**, Viçosa, v. 30, n. 3, p. 636–643, 2001.

BOUWMAN, L. et al. Exploring global changes in nitrogen and phosphorus cycles in agriculture induced by livestock production over the 1900−2050 period. **Proceedings of the National Academy of Sciences of the United States of America**, Washington, v. 110, n. 52, p. 20882–20887, 2013.

BOTREAU, R. et al. Towards an agroecological assessment of dairy systems: Proposal for a set of criteria suited to mountain farming. **Anim**., Cambridge, v. 8, n. 8, p. 1349–1360, 2014.

BRETAGNOLLE, V. et al. The role of grassland areas within arable cropping systems for conservation of biodiversity at the regional level. In: LEMAIRE, G.; HODGSON, J.; CHABBI, A. (Ed.). **Grassl. Product. Ecosyst. Serv**. Wallingford: CABI, 2011. p. 251–260.

BRISKE, D.D.; RICHARDS, J.H. Plant responses to defoliation: a morphological, physiological and demographic evaluation. In: BEDUNAH, D. J.; SOSEBEE, R. E. (Ed.). **Wildland plants**: physiological ecology and developmental morphology. Denver, CO, USA: Soc. Range Manage., 1995. p. 635–710.

BRISKE, D. et al. Rotational grazing on rangelands: reconciliation of perception and experimental evidence. **Rangeland Ecol. Manage.**, Lawrence, v. 61, n. 1, p. 3–18, 2008.

BYERLEE, D.; COLLINSON, M.P. **Planning technologies appropriate to farmers**: Concepts and procedures. Mexico, DF: CIMMYT, 1988.

CABELL, J.F.; OELOFSE, M. An indicator framework for assessing agroecosystem resilience. **Ecol. Soc.**, Brooklyn, v. 17, n. 1, p. 1–18, 2012.

CARVALHO, P.C.F. et al. O estado da arte em integração lavoura-pecuária. In: CICLO DE PALESTRAS EM PRODUÇÃO E MANEJO DE BOVINOS, 10., 2005, Canoas. **Anais**... Canoas: Ed. ULBRA, 2005. p. 7–44.

CARVALHO, P.C.F.; CANTO, M.W.; MORAES, A. Fontes de perdas de forragem sob pastejo: forragem se perde? In: PEREIRA, O.G. et al. (Org.). **Manejo Estratégico da Pastagem**. Viçosa: [s.n.], 2004. p. 387–410. v. 1.

CARVALHO P.C.F.; MORAES A. Comportamento ingestivo de ruminantes: bases para o manejo sustentável do pasto. In: MANEJO SUSTENTÁVEL EM PASTAGEM, 1., 2005, Maringá. **Anais**... Maringá: UEM, 2005. p. 1–20.

CARVALHO, P.C.F. et al. Avanços metodológicos na determinação do consumo de ruminantes em pastejo. **R. Bras. Zootec.**, Viçosa, v. 36, p. 151–170, 2007.

CARVALHO, P.C.F. et al. Características estruturais do pasto e o consumo de forragem: o quê pastar, quanto pastar e como se mover para encontrar o pasto In: PEREIRA O.G. et al. (Ed.). **Manejo estratégico da pastagem**. Viçosa: UFV, 2008. p.101–130. v. 1.

CARVALHO, P.C.F. Can grazing behaviour support innovations in grassland management? In: INTERNATIONAL GRASSLAND CONGRESS, 22., Sydney. **Proceedings**... Sydney: [s.n.], 2013. p. 1134–1148.

CARVALHO, P.C.F. et al. Comportamento Ingestivo de Animais em Pastejo. In: **Forragicultura**: Ciência, Tecnologia e Gestão dos Recursos Forrageiro. [Viçosa]: UFV, 2013. p. 525–545.

CARVALHO, P.C.F. et al. Definições e terminologias para Sistema Integrado de Produção Agropecuária. **Rev. Cienc. Agron.**, Fortaleza, v. 45, n. 5, p. 1040–1046, 2014.

CAVALLINI, M.C. et al. Relações entre produtividade de *Brachiaria brizantha* e atributos físicos de um Latossolo do Cerrado. **Rev. Bras. Cienc. Solo**, Viçosa, v. 34, n. 4, p. 1007–1015, 2010.

CHÁVEZ, L.F. et al. Diversidade metabólica e atividade microbiana em sistema de integracão lavoura-pecuária em plantio direto sob intensidades de cultivo. **Pesqui. Agropec. Bras.**, Brasília, v. 46, n. 10, p. 1254–1261, 2011.

CHAPMAN, D.F. et al. Regrowth dynamics and grazing decision rules: further analysis for dairy production systems based on perennial ryegrass (*Lolium perenne* L.) pastures. **Grass Forage Sci.,** Oxford, v. 67, n. 1, p. 77–95.

DA TRINDADE, J.K. **Comportamento e consumo de forragem diário por bovinos de corte em pastagem natural complexa**. 2011. 148 f. Tese (Doutorado) - Universidade Federal do Rio Grande do Sul, Faculdade de Agronomia, Porto Alegre, 2011.

DÍAZ, S.; NOY-MEIR I.; CABIDO, M. Can grazing response of herbaceous plants be predicted from simple vegetative traits? **J. Appl. Ecol.**, v. 38, n. 3, p. 497–508, 2001.

DÍAZ, S. et al. Linking functional diversity and social actor strategies in a framework for interdisciplinary analysis of nature's benefits to society. **Proceedings of the National Academy of Sciences of the United States of America**, Washington, v. 108, n. 3, p. 895–902, 2011.

DORAN, J.W.; PARKIN, T.B. Defining and assessing soil quality. In: DORAN, J.W. et al. **Defining soil quality for a sustainable environment**. Madison: Soil Sci. Soc. Am. J., 1994. p. 3–22.

DUMONT, B. et al. When does grazing generate stable vegetation patterns in temperate pastures? **Agric. Ecosyst. Environ.**, Amsterdam, v. 153, p. 50–56, 2012.

FLORES, J.P.C. et al. Atributos físicos do solo e rendimento de soja em sistema plantio direto em integração lavoura pecuária com diferentes pressões de pastejo. **Rev. Bras. Ciên. Solo**, Viçosa, v. 31, n. 4, p. 771–780, 2007.

FONSECA, L. et al. Effect of sward surface height and level of herbage depletion on bite features of cattle grazing Sorghum bicolor swards. **J. Anim. Sci.**, v. 91, n. 9, p. 1–9, 2013.

FAO. **Livestock's Long Shadow**. Rome: FAO, 2006. 390 p. (Collection: Environmental Issues and Options).

FAO. **The state of food and agriculture**: Livestock in the balance. Rome, Italy: FAO, 2009.

FAO. **An international consultation on integrated crop-livestock systems for development**: the way forward for sustainable production intensification. FAO: Rome, 2010. 63 p. (Integrated Crop Management, v.13).

FRASER, A.F.; BROOM, D.M. **Farm animal behaviour and welfare**. London: Bailliere Tindall, 1990. 437 p. v. 3.

GARCEZ NETO, A.F. et al. Respostas morfogênicas e estruturais de Panicum maximum cv. Mombaça sob diferentes níveis de adubação nitrogenada e alturas de corte. **R. Bras. Zootec.**, Viçosa, v. 31, n. 5, p. 1890–1900, 2002.

GIBB, M.J. et al. The effect of physiological state (lactating or dry) and sward surface height on grazing behav- iour and intake by dairy cows. **Appl. Anim. Behav. Sci.,** Amsterdam, v. 63, n. 4, p. 269–287, 1999.

GILLEN, R.L.; MCCOBUM, F.T.; BRUMMER, J.E. Tiller defoliation patterns under short duration grazing in tallgrass prairie. **J. Range Manage.**, Lawrence, v. 43, n. 2, p. 95–99, 1990.

GILLER, K.E. et al. Communicating complexity: Integrated assessment of trade-offs concerning soil fertility management within farming systems to support innovation and development. **Agric.Syst.**, Essex, v. 104, n. 2, p. 191–203, 2010.

GLIENKE, C.L. et. al. Comportamento ingestivo de cordeiras em pastagem consorciada de inverno sob diferentes intensidades de desfolha. **R. Bras. Zootec.**, Viçosa, v. 37 n. 11, p. 1919–1927, 2008.

GONÇALVES, E.N. et al. Relações planta-animal em ambiente pastoril heterogêneo: padrões de deslocamento e uso de estações alimentares. **R. Bras. Zootec.**, Viçosa, v. 38, n. 11, p. 2121–2126, 2009.

GORDON, I.J.; BENVENUTTI, M.A. Food in 3D: how ruminant livestock interact with sown sward architecture at bite scale. In: BELS, V. (Ed.). **Feeding in domestic vertebrates**: from structure to behavior. Wallingford: CAB International, 2006. p. 263–277.

GROFF, A.M. et al. Intervalo e intensidade de desfolhação nas taxas de crescimento, senescência e desfolhação e no equilíbrio de gramíneas em associação. **R. Bras. Zootec.,** Viçosa, v. 31, n. 5, p. 1912–1923, 2002.

HART, R.H. et al. Grazing systems, pasture size, and cattle grazing behavior, distribution, and gains. **J. Range Manage.**, Lawrence, v. 46, p. 81–87, 1993.

HEADY, H.F. Continuous vs. specialized grazing systems: a review and application to California annual type. **J. Range Manage.**, Lawrence, v. 14, p. 182–193, 1961.

HERRERO, M. et al. Smart investments in sustainable food production: revisiting mixed crop-livestock systems. **Science**, Washington, v. 327, n. 5967, p. 822–825, 2010.

HERRERO, M. et al. **Drivers of change in crop-livestock systems and their potential impacts on agro-ecosystems services and human wellbeing to 2030**: A study commissioned by the CGIAR Systemwide Livestock Programme. Nairobi, Kenya: ILRI, 2012.

HERRERO, M. at al. Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. **Proceedings of the National Academy of Sciences of the United States of America**, Washington, v. 110, n. 52, p. 20888−20893, 2013.

HIRATA, M.; KUNIEDA, E.; TOBISA, M. Short-term ingestive behaviour of cattle grazing tropical stoloniferous grasses with contrasting growth forms. **J. Agr. Sci.**, Cambridge, v. 148, n. 5, p. 615–624, 2010.

HODGSON, J. **Grazing Management**: Science into Practice. New York: John Wiley & Sons, Inc., 1990. 203 p. (Longman Handbooks in Agriculture).

HODGSON, J.; CLARCK, D.A.; MITCHELL, R.J. Foraging behaviour in grazing animals and its impact on plant communities. In: NATIONAL CONFERENCE ON FORAGE QUALITY, EVALUATION AND UTILIZATION, 1994, Nebraska. **Proceedings**... Nebraska: University of Nebraska, 1994. p. 796–827.

HODGSON, J.; COSGROVE, G.P.; WOODWARD, S.J.R. Research on foraging behavior: progress and priorities. In: INTERNATIONAL GRASS- LAND CONGRESS, 18., 1997. Calagary. **Proceedings**... Calagary: Association Management Centre, 1997.

ILLIUS, A.W. et al. Costs and benefits of foraging on grasses varying in canopy structure and resistance to defoliation. **Functional Ecol.**, Oxford, v. 9, n. 6, p. 894–903, 1995.

ÍTAVO, L.C.V. et al. Comportamento ingestivo diurno de bovinos em pastejo contínuo e rotacionado. **Archivos de Zootecnia**, Cordoba, Colombia, v. 57, n. 217, p. 43–52, 2008.

KIRSCHENMANN, F.L. Potential for a new generation of biodiversity in agroecosystems of the future. **Agron. J.**, Madison, v. 99, n. 2, p. 373–376, 2007.

LACA, E.A. New Approaches and Tools for Grazing Management. **Rangeland Ecol Manage**., Lawrence, v. 62, n. 5, p. 407–417, 2009.

LACA, E.A.; DEMMENT, M.W. Foraging strategies of grazing animals. In: HODGSON, J.; ILLIUS, A.W. (Ed.). **The Ecology and Management of Grazing Systems**. Wallingford: CAB International, 1996. p. 137–157.

LACA, E.A.; DEMMENT, M.W. Herbivory: the dilemma of foraging in a spatially heterogeneous food environment. In: PALO, R.T.; ROBBINS, C.T. (Ed.). **Plant defenses against mammalian herbivory**. Boca Raton: CRC, 1991. p. 29–44.

LACA, E.A. et al. An integrated methodology for studying short-term grazing behavior of cattle. **Grass Forage Sci.**, Oxford, v. 47, n. 1, p. 81–90, 1992.

LACA, E.A.; ORTEGA, I.M. Integrating foraging mechanisms across spatial and temporal scales. In: INTERNATIONAL RANGELAND CONGRESS, 5., 1995, Salt Lake City. **Proceedings**... Salt Lake City: Society for Range Management, 1995. p. 129–132.

LEMAIRE, G.; CHAPMAN. D. Tissue flows in grazed plant communities. In: HODGSON, J.; ILLIUS, A.W. (Ed.). **The ecology and management of grazing systems**. Wallingford: CAB International, 1996. p. 3–36.

LEMAIRE, G.; HODGSON, J.; CHABBI, A. **Grassland productivity and ecosystems services**. Wallingford: CABI international, 2011.

LEMAIRE, G. et al. Integrated crop-livestock systems: Strategies to achieve synergy between agricultural production and environmental quality. **Agric. Ecosyst. Environ.**, v. 190, p. 4–8, 2014.

LOSS, A. et al. Agregação, carbono e nitrogênio em agregados do solo em plantio direto com integração lavoura-pecuária. **Pesqu. Agropec. Bras.**, Brasília, DF, v. 46, n. 10, p. 1269–1276, 2011.

MACEDO, E.O. et al. Consumo e comportamento ingestivo de cabras em pasto de capimmarandu. **Semina: Ciên. Agrárias**, Londrina, v. 36, n. 3, p. 2175–2184, 2015.

MARCOLAN, A.L.; ANGHINONI, I. Atributos físicos de um Argissolo e rendimento de culturas de acordo com o revolvimento do solo em plantio direto. **Rev. Bras. Ciên. Solo**, Viçosa, v. 30, n. 1, p. 163–170, 2006.

MCNAUGHTON, S.J. Ecology of a grazing ecosystem: the Serengeti. **Ecol. Monogr.**, Lawrence, v. 55, n. 3, p. 259–295, 1985.

MEYNARD, J.M.; DEDIEU, B.; BOS, B. Redesign and codesign of farming systems: An overview of methods and practices. In: DARNHOFER, I.; GIBBON, D.; DEDIEU, B. (Ed.). **Farming Systems Research into the 21st century**: The New Dynamic. Dordrecht: Springer, 2012. p. 407–431.

MEZZALIRA, J.C. et al. Behavioural mechanisms of intake rate by heifers grazing swards of contrasting structures. **Appl. Anim. Behav**. **Sci.**, Amsterdam, v. 153, p. 1–9, 2014.

MORAINE, M.; DURU, M.; THEROND, O. A social-ecological framework for analyzing and designing integrated crop–livestock systems from farm to territory levels. **Renew. Agric. Food Syst.**, [Cambridge], v. 1, n. 1, p. 1–14, 2016.

MORAES, A. et al. Integrated crop – livestock systems in the Brazilian subtropics. **European Journal of Agronomy,** [Amsterdam], v. 57, p. 4–9, 2014.

MURGUEITIO, E. et al. Native trees and shrubs for the productive rehabilitation of cattle ranching lands. **Forest Ecol. Manage.**, Amsterdam, v. 261, n. 10, p. 1654–1663, 2011.

NEWMAN, J.A.; PARSONS, A.J.; PENNING, P.D. A note on the behavioural strategies used by grazing dairy animals to alter their intake rates. **Grass Forage Sci.**, Oxford, v. 49, n. 4, p. 502–505, 1994.

ORR, R.J.; RUTTER, S.M.; YARROW, N.H. Changes in ingestive behaviour of yearling dairy heifers due to changes in sward state during grazing down of rotationally stocked ryegrass or white clover pastures. **Appl. Anim. Behav. Sci.**, Amsterdam, v. 87, n. 3-4, p. 205–222, 2004.

PRACHE, S.; PEYRAUD, J. Foraging: behaviour and intake in temperate cultivated grassland. In: INTERNATIONAL GRASSLAND CONGRESS, 19., 2001, São Pedro. **Proceedings**… São Pedro: [s.n.], 2001. p. 309–319.

POCCARD-CHAPUIS, R. et al. Landscape characterization of integrated crop–livestock systems in three case studies of the tropics. **Renew. Agric. Food Syst.**, v. 29, n. 3, p. 218–229, 2014.

PONTES, L. S.; CARVALHO, P.C.F.; NABINGER, C. Variáveis morfogênicas e estruturais de azevém anual (*Lolium multiflorum* Lam.) manejado em diferentes alturas. **R. Bras. Zootec.**, Viçosa, v. 33, n. 3, p. 529-537, 2004.

PRACHE, S.; GORDON, I.J.; ROOK, A.J. Foraging behavior and diet selection in domestic herbivores. **Annales de Zootechnie**, Versailles, v. 47, p. 335–345, 1998.

PROVENZA, F.D.; LAUCHBANUGH, K.L. Foraging on the edge of chaos. In: LAUCHBANUGH, K.L.; MOSLEY, J.C.; SANDERS, K.D. (Ed.). **Grazing behavior of livestock and wildlife**. Moscow: University of Idaho, 1999. p. 1–12.

RANDRIANASOLO, J. et al. Modeling crop-livestock integration systems on a regional scale in Reunion Island: Sugar cane and dairy cow activities. **Advances in Animal Biosciences**, v. 1, n. 2, 498-498 p., 2010.

RAO, I. et al. Climate-smart crop-livestock systems for smallholders in the tropics: Integration of new forage hybrids to intensify agriculture and to mitigate climate change through regulation of nitrification in soil. **Trop**. **Grassl.** Brisbane, v. 2, p. 130–132, 2014.

RAO, I. et al. **LivestockPlus–The sustainable intensification of forage-based agricultural systems to improve livelihoods and ecosystem services in the tropics**. Cali, CO: Centro Internacional de Agricultura Tropical (CIAT), 2015. (Report number: CIAT Publication, n. 407).

REN, H. et al. Do sheep grazing patterns affect ecosystem functioning in steppe grassland ecosystems in Inner Mongolia? **Agric. Ecosys. Environ.**, v. 213, p. 1–10, 2015.

RIBEIRO FILHO, H.M.N.; DELAGARDE, R.; PEYRAUD, J.L. Inclusion of white clover in strip-grazed perennial ryegrass swards: herbage intake and milk yield of dairy cows at different ages of sward regrowth. **Anim. Sci**., Penicuik, v. 77, n. 3, p. 499–510, 2003.

ROCHA, C.H. et al. Padrões de deslocamento de bovinos em pastos de capim-quicuiu sob lotação intermitente. **Arq. Bras. Med. Vet. Zootec**., Belo Horizonte, v. 68, n. 6, p. 1647–1654, 2016.

RODRÍGUEZ-ORTEGA, T. et al. Applying the ecosystem services framework to pasture- based livestock farming systems in Europe. **Anim.**, Cambridge, v. 8, n. 8, p. 1361–1372, 2014.

ROUGUET, C.; DUMONT, B.; PRACHE, S. Selection and use of feeding sites and feeding station s by herbivores: A review. **Annales Zootechnia**, Madrid, v. 47, n. 4, p. 225–244, 1998.

SANTOS, B.R.C.; VOTOLINI, T.V.; SALLA, L.E. Comportamento de Pastoreio. **Rev. Elect. Vet.**, v. 11, n. 4, p. 1–33, 2010.

SANTOS, H. P. et al. Gramíneas anuais de inverno. In: SANTOS, H. P.; FONTANELI, R. S.; FONTANELI, R. S. (Ed.). **Forrageiras para integração lavoura-pecuária**. Passo Fundo: Embrapa Trigo, 2009.

SAVIAN, J.V. et al. Grazing intensity and stocking methods on animal production and methane emission by grazing sheep: Implications for integrated crop-livestock system. **Agric. Ecosyst. Environ**. v. 190, p. 112–119, 2014.

SCHOUTEN, M.A.H. et al. A resilience-based policy evaluation framework :Application to European rural development policies. **Ecol. Econ.**, Amsterdam, v. 81, p. 165–175, 2012.

SENFT, R.L. et al. Large herbivore foraging and eco- logical hierarchies. **BioSci.**, Washington, v. 37, n. 11, p. 789–799, 1987.

SILVA, J.L. *et al*. Massa de forragem e características estruturais e bromatológicas de cultivares de *Brachiaria* e *Panicum.* **Cienc. anim. bras**., Goiânia, v. 17, n. 3, p. 342–348, 2016.

SILVA, T.P.D. et al. Ingestive behaviour of grazing ewes given two levels of concentrate. **S. Afr. J. Anim. Sci.**, Pretoria, v. 45, n. 2, p. 180–187, 2015.

SMITH, P. et al. Greenhouse gas mitigation in agriculture. **Philosophical Transactions of the Royal Society B**, London, v. 363, n. 1492, p. 789–813, 2008.

SMITH, J. et al. Beyond milk, meat, and eggs: Role of livestock in food and nutrition security. **Anim. Front.**, v. 3, n. 1, p. 6–13, 2013.

STEINFELD, H.; WASSENAAR, T.; JUTZI, S. Livestock production systems in developing countries: Status, drivers, trends. **Revue Scientifique et Technique de L'office International des Epizooties**, Paris, v. 25, n. 2, p. 505–516, 2006.

STUTH, J.W. Foraging behavior. In: HEITSCHMIDT, R.K.; STUTH, J.W. (Ed.). **Grazing management**: an ecological perspective. Oregon: Timber Press, 1991. p. 85–108.

TANAKA, D.L.; KARN, J.R.; SCHOLLJEGERDES, E. Integrated crop-livestock systems research: Practical research considerations. **Renew. Agric. Food Syst.**, v. 23, n. 1, p. 80–86, 2008.

UNGAR, E.D.; RAVID, N.; BRUCKENTAL, I. Bite dimensions for cattle grazing herbage at low levels of depletion. **Grass Forage Sci.**, Oxford, v. 56, n. 1, p. 35–45, 2001.

VALADARES FILHO, S.C. et al. Perspectivas do uso de indicadores para estimar o consumo individual de bovinos alimentados em grupo. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA - SBZ, 43., 2006, João Pessoa **.** **Anais**... João Pessoa: [s.n.], 2006. 1 p.

VAN SOEST, P.J. **Nutricional ecology of the ruminant**. 2. ed. Ithaca: Cornell University Press, 1994. 476 p.

# 6 APÊNDICES

**6.1 APÊNDICE 1** Normas para elaboração e submissão de trabalhos científicos à revista *Grassland Science*.

## Grassland Science




Edited By: Toshihiko Yamada

Impact Factor: 0.82

ISI Journal Citation Reports © Ranking: 2015: 22/57 (Agriculture Multidisciplinary); 44/83 (Agronomy)

Online ISSN: 1744-697X

### *Author Guidelines*

### EDITORIAL REVIEW AND ACCEPTANCE

The acceptance criteria for all papers are the quality and originality of the research and its significance to our readership. Except where otherwise stated, manuscripts are peer reviewed by a member of the Editorial Board and two anonymous referees. Final acceptance or rejection rests with the Editor-in-Chief, who reserves the right to refuse any material for publication.

Manuscripts should be written in a clear, concise, direct style. Where contributions are judged as acceptable for publication on the basis of scientific content, the Editor-in-Chief and the Publisher reserve the right to modify typescripts to eliminate ambiguity and repetition and improve communication between author and reader.

Further details are available here.

### SUBMISSION OF MANUSCRIPTS

All articles submitted to the journal must comply with these instructions. Failure to do so will result in return of the manuscript and possible delay in publication.

A submission template in MS word is available from here.
Manuscripts should be submitted online at https://mc.manusciptcentral.com/grssci

For Authors unable to submit their manuscript online, please consult with the Managing Editor at the Editorial Office. Email:grassl-sci@naro.affrc.go.jp; Tel: 81 287 37 7684; Fax: 81 287 37 7684.
Manuscripts should be prepared as a Word (.doc or .docx) file, double-spaced on A4 paper with top, bottom and side margins of at least 30 mm. All pages should be numbered consecutively, beginning with the title page. Text pages should have numbered lines. Please use only standard fonts, such as Times, Times New Roman, or Arial for text; in particular, please do not use Japanese or other Asian fonts. Do not use automated or manual hyphenation. Figures should be uploaded as separate files whereas tables should be included in the manuscript file.

**Covering Letter**

Papers are accepted for publication in the Journal on the understanding that the content has not been published or submitted for publication elsewhere. This must be stated in the covering letter.

The covering letter must also contain an acknowledgment that all authors have contributed significantly, and that all authors are in agreement with the content of the manuscript.

Authors must declare any financial support or relationships that may pose conflict of interest.

If tables or figures have been reproduced from another source, a letter from the copyright holder (usually the Publisher), stating authorization to reproduce the material, must be attached to the covering letter.

**Pre-acceptance English-language editing**

Authors for whom English is a second language may choose to have their manuscript professionally edited before submission to improve the English. Visit our site to learn about the options. All services are paid for and arranged by the author. Please note using the Wiley English Language Editing Service does not guarantee that your paper will be accepted by this journal.

**Author material archive policy**

Authors who require the return of any submitted material that is accepted for publication should inform the Editorial Office (at submission) or the Publisher (after acceptance). If no indication is given that author material should be returned, the Editorial Office and Wiley will dispose of all hardcopy and electronic material two months after publication.

**ETHICAL CONSIDERATIONS**

In taxonomic papers, type specimens and type depositories must be clearly designated and indicated. Authors are required to deposit the name-bearing type material in internationally recognized institutions (not private collections).

When the research is carried out in areas for which research permits are required (e.g. nature reserves), or when it deals with organisms for which collection or import/export permits are required (e.g. protected species), the authors must clearly detail obtaining these permits in the Acknowledgments section.

## PUBLICATION ETHICS GUIDELINES

Grassland Science is committed to integrity in scientific research and recognizes the importance of maintaining the highest ethical standards. Please find attached the Best Practice Guidelines on Publication Ethics. Further information at COPE http://publicationethics.org/

English: http://exchanges.wiley.com/ethicsguidelines
Chinese: http://www.wiley.co.jp/journals/learning/PublicationEthic_Simplified_Chinese_low.pdf
Japanese: http://www.wiley.co.jp/blog/pse/?p=29489

## STYLE OF THE MANUSCRIPT

**Spelling:** The Journal uses US spelling and authors should therefore follow the latest edition of the Merriam-Webster's Collegiate Dictionary.

**Units:** All measurements must be given in SI or SI-derived units.

**Abbreviations:** Abbreviations should be used sparingly – only where they ease the reader's task by reducing repetition of long, technical terms. Initially use the word in full, followed by the abbreviation in parentheses. Thereafter use the abbreviation only.

**Trade names:** Chemical substances should be referred to by the generic name only. Trade names should not be used.

**Scientific names:** Upon its first use in the title, abstract and text, the common name of a species should be followed by the scientific name (genus, species and authority) in parentheses. However, for well-known species, the scientific name may be omitted from the article title. If no common name exists in English, the scientific name should be used only.

## PARTS OF THE MANUSCRIPT

The length of an article (including references, tables and appendices) should not exceed 6 pages for research papers, 3 pages for short reports and 12 pages for review papers.
Manuscripts should be presented in the following order: (i) title page, (ii) abstract and key words, (iii) text, (iv) acknowledgments, (v) references, (vi) appendices, (vii) figure legends, (viii) tables (each table complete with title and footnotes) and (ix) figures.

Footnotes to the text are not allowed and any such material should be incorporated into the text as parenthetical matter.
A submission template in MS word is available from here.

**Title page**
The title page should contain (i) the title of the paper, (ii) the full names of the authors and (iii) the addresses of the institutions at which the work was carried out together with (iv) the full postal and email address, plus facsimile and telephone numbers, of the author to whom correspondence about the manuscript should be sent. The present address of any author, if different from that where the work was carried out, should be supplied in a footnote.
The title should be short and informative. Do not use abbreviations in the title. A short running title (less than 40 characters) should also be provided.

**Abstract and key words**
All articles must have a brief unstructured abstract that states in 200-300 words (100-150 words for short report) or fewer the purpose, basic procedures, main findings and principal conclusions of the study. The abstract should not contain abbreviations or references.
Five or fewer key words (three or fewer for short report) should be supplied (for the purposes of indexing) below the abstract in alphabetical order.

**Text**
Authors should use the following subheadings to divide the sections of their manuscript: Introduction, Materials and Methods, Results and Discussion.

**Statistics**
Whenever possible, researchers should consult a statistician before designing an experiment and when analyzing results to avoid inappropriate descriptions. Describe statistical methods with enough detail to enable the reader to verify the reported results. Indicate the computer program used, if any.

**Acknowledgments**
The source of financial grants and other funding must be acknowledged, including a frank declaration of the authors' industrial links and affiliations. The contribution of colleagues or institutions should also be acknowledged. Personal thanks and thanks to anonymous reviewers are not appropriate.

**References**
The Harvard (author, date) system of referencing is used (examples are given below). In the text give the author's name followed by the year in parentheses: Smith (2000). If there are two authors use 'and': Smith and Jones (2001); (Smith and Jones 2001). When reference is made to a work by three or more authors, the first name followed by *et al.* should be used: MacDonald *et al.* (2002). In the reference list, references should be listed in alphabetical order.

In the reference list, cite the names of all authors when there are six or fewer; when seven or more, list the first three followed by *et al.* Do not use *ibid.* or *op cit.* Reference to unpublished data and personal communications should not appear in the list but should be cited in the text only (e.g. Smith A, unpublished data). All citations mentioned in the text, tables or figures must be listed in the reference list. Authors are responsible for the accuracy of the references.

*Journals*
Hirata M, Sato R, Ogura S (2002) Effects of progressive grazing of a pasture on the spatial distributions of herbage mass and utilization by cattle: a preliminary study. *Ecol Res* 17: 381–393.
*Online article not yet published in an issue*
An online article that has not yet been published in an issue (therefore has no volume, issue or page numbers) can be cited by its Digital Object Identifier (DOI). The DOI will remain valid and allow an article to be tracked even after its allocation to an issue.
Souter NJ, Milne T (2009) Grazing exclusion as a conservation measure in a South Australian temperate native grassland. *Grassl Sci,* doi: 10.1111/j.1744-697X.2009.00142.x
*Books*
Chapman GP (1996) *The Biology of Grasses*. CAB International, Wallingford, 1-288.
*Chapter in a book*
Moser LE, Jennings JA (2007) Grass and legume structure and morphology. In: *Forages, Volume II, The Science of Grassland Agriculture*, 6th edn (Eds Barnes RF, Nelson CJ, Moore KJ, Collins M), Wiley-Blackwell, Ames, 15-35.
*Website*
FAO (1999) Guidelines on social analysis for rural area development planning. Agricultural policy support service, FAO, Rome, available from
URL: http://www.fao.org/tc/Tca/pubs/tmap34/tmap34.htm [cited 2 November 2004].

**Appendices**
These should be placed at the end of the paper, numbered in Roman numerals and referred to in the text. If written by a person other than the author of the main text, the writer's name should be included below the title.

**Tables**
Tables should be self-contained and complement, but not duplicate, information contained in the text. Number tables consecutively in the text in Arabic numerals. Type tables on a separate sheet with the legend above. Legends should be concise but comprehensive – the table, legend and footnotes must be understandable without reference to the text. Vertical lines should not be used to separate columns. Column headings should be brief, with units of measurement in parentheses; all abbreviations must be defined in footnotes. Footnote symbols: †, ‡, §, ¶, should be used (in that order) and *, **, *** should be reserved for P-values. Statistical measures such as SD or SEM should be identified in the headings.

**Figure legends**

Type figure legends on a separate sheet. Legends should be concise but comprehensive – the figure and its legend must be understandable without reference to the text. Include definitions of any symbols used and define/explain all abbreviations and units of measurement.

**Figures**

All illustrations (line drawings and photographs) are classified as figures. Figures should be cited in consecutive order in the text. Each figure page should have name of author(s) and figure number in the bottom margin. Figures should be sized to fit within the column (80.5mm), intermediate (110mm) or the full text width (168mm). Line figures should be supplied as sharp, black and white graphs or diagrams, drawn professionally or with a computer graphics package. Lettering must be included and should be sized to be no larger than the journal text. Individual photographs forming a composite figure should be of equal contrast, to facilitate printing, and should be accurately squared.

Magnifications should be indicated using a scale bar on the illustration. If supplied electronically, graphics must be supplied as high resolution (at least 300 d.p.i.).

More advice on figures can be found at Wiley's guidelines for preparation of figures: http://authorservices.wiley.com/bauthor/illustration.asp

**Supporting Information**

Supporting Information may be attended to the manuscript at the submission stage. The material, the length of which is judged to be reasonable by the Editor-in-Chief, will be considered acceptable. It should be clearly referred to in other sections of the manuscript. Supporting Information will only be published with the online version of the article. Material will be posted online as is supplied by the author. There is no editing or proofreading during the production process. Wiley will not be responsible for the contents or functionality of any supporting materials supplied by the author.

**MANUSCRIPTS FOR SHORT REPORTS**

Manuscripts for short papers should be organized basically in the same style as a research paper. However, the arrangement of the main text (introduction, materials and methods, results and discussion) need not necessarily follow that for a research paper, as long as the essence of the study or observation is properly described within the page allowance. The specific requirements for a short report are as follows:

- The abstract should be in 100-150 words or fewer.
- Three or fewer key words should be supplied.
- The length of an article (including references, tables and appendices) should not exceed 3 pages.

**WORD PROCESSING**

- Do not use the carriage return (enter) at the end of lines within a paragraph.
- Turn the hyphenation option off; include only those hyphens that are essential to the meaning.
- Specify any special characters used to represent non-keyboard characters.
- Take care not to use l (ell) for 1 (one), O (capital o) for 0 (zero) or ß (German esszett) for β (Greek beta).

- Use a tab, not spaces, to separate data points in tables. If you use a table editor function, ensure that each data point is contained within a unique cell (i.e. do not use carriage returns within cells).

**PUBLICATION CHARGES**

All articles except invited articles are subject to the following publication charges. Extra publication charge will apply when an article exceeds the page limit specified for each article type (Original articles maximum of 6 typeset pages; Short reports maximum of 3 typeset pages; Review papers maximum of 12 typeset pages).

For articles submitted by 30 June 2016

A publication fee of ¥20,000 is required for each review paper/original article/practical report and ¥10,000 for each short report. All papers requiring extra publication costs are charged ¥19,000 for each additional page.

**For articles submitted after 1 July 2016** (To join JSGS, please visit here for details.)

**Articles where a corresponding author is a JSGS member**
A publication fee of JPY16,000 is required for each review paper/original article/practical report and JPY8,000 for each short report. All papers requiring extra publication costs are charged JPY16,000 for each additional page.

**Non-JSGS members**
A publication fee of JPY18,000 is required for each review paper/original article/practical report and JPY9,000 for each short report. All papers requiring extra publication costs are charged JPY30,000 for each additional page.
Authors will be requested to fill in the payment form at the time of the acceptance of their manuscript by the Publisher.

**PUBLICATION PROCESS AFTER ACCEPTANCE**

Accepted papers will be passed to Wiley's production team for publication. The author identified as the formal corresponding author for the paper will receive an email prompting them to login into Wiley's Author Services, where via the Wiley Author Licensing Service (WALS) they will be asked to complete an electronic license agreement on behalf of all authors on the paper. More details on the copyright and licencing options for the journal appear below.

**Wiley's Author Services**

Author Services enables authors to track their article through the production process to publication online and in print. Authors can check the status of their articles online and choose to receive automated e-mails at key stages of production. The corresponding author will receive a unique link that enables them to register and have their article automatically added to the system. Please ensure that a complete e-mail address is provided when submitting the manuscript. Visit Author Services (https://authorservices.wiley.com/bauthor/default.asp) for more details on online production tracking. and for a wealth of resources including FAQs and tips on article preparation, submission and more.

**Proofs**

Once the paper has been typeset the corresponding author will receive an e-mail alert containing instructions on how to provide proof corrections to the article. It is therefore essential that a working e-mail address is provided for the corresponding author. Proofs should be corrected carefully; responsibility for detecting errors lies with the author.

**Early View**

The journal offers rapid speed to publication via Wiley's Early View service. Early View articles are complete full-text articles published online in advance of their publication in a printed issue. Early View articles are complete and final. They have been fully reviewed, revised and edited for publication, and the authors' final corrections have been incorporated. Because they are in final form, no changes can be made after online publication. Early View articles are given a Digital Object Identifier (DOI), which allows the article to be cited and tracked before allocation to an issue. After print publication, the DOI remains valid and can continue to be used to cite and access the article. More information about DOIs can be found at http://www.doi.org/faq.html.

**Offprints**

A PDF reprint of the article will be supplied free of charge to the corresponding author. Additional printed offprints may be ordered online for a fee. Please click on the following link and fill in the necessary details and ensure that you type information in all of the required fields: http://offprint.cosprinters.com/cos. If you have queries about offprints please e-mail: offprint@cosprinters.com.

**Author Marketing Toolkit**

The Wiley Author Marketing Toolkit provides authors with support on how to use social media, publicity, conferences, multimedia, email and the web to promote their article.

**COPYRIGHT, LICENSING AND ONLINE OPEN**

Accepted papers will be passed to Wiley's production team for publication. The author identified as the formal corresponding author for the paper will receive an email prompting them to login into Wiley's Author Services, where via the Wiley Author Licensing Service (WALS) they will be asked to complete an electronic license agreement on behalf of all authors on the paper.

Japanese guidelines on how to use WALS are available here.

Authors may choose to publish under the terms of the journal's standard copyright transfer agreement (CTA), or under open access terms made available via Wiley OnlineOpen.

**Standard Copyright Transfer Agreement:** FAQs about the terms and conditions of the standard CTA in place for the journal, including standard terms regarding archiving of the accepted version of the paper, are available at: Copyright Terms and Conditions FAQs.
Note that in signing the journal's licence agreement authors agree that consent to reproduce figures from another source has been obtained.

**OnlineOpen – Wiley's Open Access Option:** OnlineOpen is available to authors of articles who wish to make their article freely available to all on Wiley Online Library under a Creative Commons license. With OnlineOpen, the author, the author's funding agency, or the author's institution pays a fee to ensure that the article is made open access. Authors of OnlineOpen articles are permitted to post the final, published PDF of their article on their personal website, and in an institutional repository or other free public server immediately after publication. All OnlineOpen articles are treated in the same way as any other article. They go through the journal's standard peer-review process and will be accepted or rejected based on their own merit.

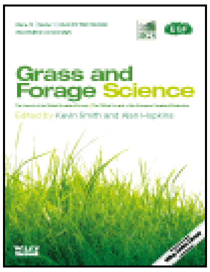
***Online Open licenses.*** Authors choosing OnlineOpen retain copyright in their article and have a choice of publishing under the following Creative Commons License terms: Creative Commons Attribution License (CC BY); Creative Commons Attribution Non-Commercial License (CC BY NC); Creative Commons Attribution Non-Commercial-NoDerivs License (CC BY NC ND). To preview the terms and conditions of these open access agreements please visit the Copyright Terms and Conditions FAQs.

**Funder Open Access and Self-Archiving Compliance:** Please click here for more information on Wiley's compliance with specific Funder Open Access and Self Archiving Policies, and click here for more detailed information specifically about Self-Archiving definitions and policies.

**6.2 APÊNDICE 2** Normas para elaboração e submissão de trabalhos científicos à revista *Grass and Forage Science*.

**Grass and Forage Science**






Edited By: Alan Hopkins and Kevin Smith

Impact Factor: 1.617

ISI Journal Citation Reports © Ranking: 2015: 22/83 (Agronomy)

Online ISSN: 1365-2494

***Author Guidelines***

**Author Guidelines**

Content of Author Guidelines: 1. General, 2. Ethical Guidelines, 3. Submission of Manuscripts, 4. Manuscript Types Accepted, 5. Manuscript Format and Structure, 6. after Acceptance.

Relevant Document: Colour Work Agreement Form

Useful Websites: Submission Site, Articles published in Grass and Forage Science, AuthorServices, Wiley Blackwell's Ethical Guidelines, Guidelines for Figures

**1. GENERAL**

*Grass and Forage Science* publishes the results of research and development in all aspects of grass and forage production, management and utilization, reviews of the state of knowledge on relevant topics and book reviews. Authors are also invited to submit papers on non-agricultural aspects of grassland management such as recreational and amenity use and the environmental implications of all grassland systems. The Journal considers papers from all climatic zones. Originality is required in papers submitted for publication but this does not preclude the publication of material of a developmental nature.
*Grass and Forage Science* is covered by Wiley Blackwell's Early View service. Early View articles are complete full-text articles published online in advance of their

publication in a printed issue. Articles are therefore available as soon as they are ready, rather than having to wait for the next scheduled print issue. Early View articles are complete and final. They have been fully reviewed, revised and edited for publication, and the authors' final corrections have been incorporated. Because they are in final form, no changes can be made after online publication. The nature of Early View articles means that they do not yet have volume, issue or page numbers, so Early View articles cannot be cited in the traditional way. They are therefore given a Digital Object Identifier (DOI), which allows the article to be cited and tracked before it is allocated to an issue. After print publication, the DOI remains valid and can continue to be used to cite and access the article.
Please read the instructions below carefully for details on the submission of manuscripts, the journal's requirements and standards as well as information concerning the procedure after a manuscript has been accepted for publication in *Grass and Forage Science*. Authors are encouraged to visit Wiley Blackwell's Author Services for further information on the preparation and submission of articles and figures.
Note to NIH Grantees
Pursuant to NIH mandate, Wiley Blackwell will post the accepted version of contributions authored by NIH grant-holders to PubMed Central upon acceptance. This accepted version will be made publicly available 12 months after publication. For further information, see www.wiley.com/go/nihmandate

## 2. ETHICAL GUIDELINES

*Grass and Forage Science* adheres to the below ethical guidelines for publication and research.

### 2.1. Authorship and Acknowledgements

**Authorship:** Authors submitting a paper do so on the understanding that the manuscript has been read and approved by all authors and that all authors agree to the submission of the manuscript to the Journal. ALL named authors must have made an active contribution to the conception and design and/or analysis and interpretation of the data and/or the drafting of the paper and ALL must have critically reviewed its content and have approved the final version submitted for publication. Participation solely in the acquisition of funding or the collection of data does not justify authorship and, except in the case of complex large-scale or multi-centre research, the number of authors should not exceed six.
It is a requirement that all authors have been accredited as appropriate upon submission of the manuscript. Contributors who do not qualify as authors should be mentioned under Acknowledgements.

**Acknowledgements:** Under Acknowledgements please specify contributors to the article other than the authors accredited. Please also include specifications of the source of funding for the study. Suppliers of materials should be named and their location (town, state/county, country) included.

### 2.2. Ethical Approvals

All studies using animals should include an explicit statement in the Material and Methods section identifying the review and ethics committee approval for each study, if applicable.
If appropriate, experiments should be carried out in accordance with the Guidelines laid down by the National Institute of Health (NIH) in the USA regarding the care and use of animals for experimental procedures or with the Paddocksropean Communities Council Directive of 24 November 1986 (86/609/EEC) and in accordance with local laws and regulations. The Editor reserves the right to reject papers if there is doubt as to whether appropriate procedures have been used.

### 2.3 Source of Funding

Authors are required to specify the source of funding for their research when submitting a paper. As of 1st March 2008, this information will be a requirement for all manuscripts submitted to the Journal and will be published in the Acknowledgements.. Suppliers of materials should be named and their location (town, state/county, country) included.

### 2.4 Appeal of Decision

Authors who wish to appeal the decision on their submitted paper may do so by e-mailing the Editor with a detailed explanation for why they find reasons to appeal the decision.

### 2.5 Permissions

If all or parts of previously published illustrations are used, permission must be obtained from the copyright holder concerned. It is the author's responsibility to obtain these in writing and provide copies to the Publishers.

### 2.6 Copyright Transfer Agreement.

If your paper is accepted, the author identified as the formal corresponding author for the paper will receive an email prompting them to login into Author Services; where via the Wiley Author Licensing Service (WALS) they will be able to complete the license agreement on behalf of all authors on the paper.

**For authors signing the copyright transfer agreement**
If the Online Open option is not selected the corresponding author will be presented with the copyright transfer agreement (CTA) to sign. The terms and conditions of the CTA can be previewed in the samples associated with the Copyright FAQs below:

CTA Terms and Conditions http://authorservices.wiley.com/bauthor/faqs_copyright.asp

**For authors choosing Online Open**

If the Online Open option is selected the corresponding author will have a choice of the following Creative Commons License Open Access Agreements (OAA):

Creative Commons Attribution License OAA

Creative Commons Attribution Non-Commercial License OAA

Creative Commons Attribution Non-Commercial -NoDerivs License OAA

To preview the terms and conditions of these open access agreements please visit the Copyright FAQs hosted on Wiley Author Services http://authorservices.wiley.com/bauthor/faqs_copyright.asp and visit http://www.wileyopenaccess.com/details/content/12f25db4c87/Copyright--License.html.
If you select the Online Open option and your research is funded by The Wellcome Trust and members of the Research Councils UK (RCUK) or the Austrian Science Fund (FWF) you will be given the opportunity to publish your article under a CC-BY license supporting you in complying with your Funder requirements. For more information on this policy and the Journal’s compliant self-archiving policy please visit: http://www.wiley.com/go/funderstatement.

**3. SUBMISSION OF MANUSCRIPTS**

Manuscripts should be submitted electronically via the online submission site http://mc.manuscriptcentral.com/gfs The use of an online submission and peer review site enables immediate distribution of manuscripts and consequentially speeds up the review process. It also allows authors to track the status of their own manuscripts. Complete instructions for submitting a paper is available online and below. Further assistance can be obtained from office@britishgrassland.com.

**3.1. Getting Started**

• Launch your web browser (supported browsers include Internet Explorer 6 or higher, Netscape 7.0, 7.1, or 7.2, Safari 1.2.4, or Firefox 1.0.4) and go to the journal's online Submission Site: http://mc.manuscriptcentral.com/gfs
• Log-in or click the 'Create Account' option if you are a first-time user.
• If you are creating a new account.
- After clicking on 'Create Account', enter your name and e-mail information and click 'Next'. Your e-mail information is very important.
- Enter your institution and address information as appropriate, and then click 'Next.'

- Enter a user ID and password of your choice (we recommend using your e-mail address as your user ID), and then select your area of expertise. Click 'Finish'.

• If you have an account, but have forgotten your log in details, go to Password Help on the journals online submission system http://mc.manuscriptcentral.com/gfs and enter your e-mail address. The system will send you an automatic user ID and a new temporary password.

• Log-in and select 'Author Center'.

### 3.2. Submitting Your Manuscript

• After you have logged in, click the 'Submit a Manuscript' link in the menu bar.

• Enter data and answer questions as appropriate. You may copy and paste directly from your manuscript and you may upload your pre-prepared covering letter.

• Click the 'Next' button on each screen to save your work and advance to the next screen.

• You are required to upload your files.

- Click on the 'Browse' button and locate the file on your computer.
- Select the designation of each file in the drop-down menu next to the Browse button.
- When you have selected all files you wish to upload, click the 'Upload Files' button.

• Review your submission (in HTML and PDF format) before sending to the Journal. Click the 'Submit' button when you are finished reviewing.

### 3.3. Manuscript Files Accepted

Manuscripts should be uploaded as Word (.doc) or Rich Text Format (.rft) files (not write-protected) plus separate figure files. GIF, JPEG, PICT or Bitmap files are acceptable for submission, but only high-resolution TIF or EPS files are suitable for printing. The files will be automatically converted to HTML and PDF on upload and will be used for the review process. The text file must contain the entire manuscript including title page, abstract, text, references, tables, and figure legends, but no embedded figures. Figure tags should be included in the file. Manuscripts should be formatted as described in the Author Guidelines below.

### 3.4. Suspension of Submission Mid-way in the Submission Process

You may suspend a submission at any phase before clicking the 'Submit' button and save it to submit later. The manuscript can then be located under 'Unsubmitted Manuscripts' and you can click on 'Continue Submission' to continue your submission when you choose to.

### 3.5. E-mail Confirmation of Submission

After submission you will receive an e-mail to confirm receipt of your manuscript. If you do not receive the confirmation e-mail after 24 hours, please check your e-mail address carefully in the system. If the e-mail address is correct please contact your IT department. The error may be caused by spam filtering software on your e-mail server. Also, the e-mails should be received if the IT department adds our e-mail server (uranus.scholarone.com) to their white list.

### 3.6. Manuscript Status

You can access Scholar One Manuscripts (formerly known as Manuscript Central) any time to check your 'Author Center' for the status of your manuscript. The Journal will inform you by e-mail once a decision has been made.

### 3.7. Submission of Revised Manuscripts

Revised manuscripts must be submitted within 30 days of authors being notified of the need to revise their paper. Locate your manuscript under 'Manuscripts with Decisions' and click on 'Submit a Revision' to submit your revised manuscript.

## 4. MANUSCRIPT TYPES ACCEPTED

**Original Articles:** Full papers or Research Notes may be submitted. Research Notes should not normally exceed 1500 words or their equivalent in length.

**Review Articles:** Review articles are welcomed. They should be of an equivalent length to full papers.

**Book reviews:** Short book reviews of less than 1000 words are commissioned by the Deputy Editor.

## 5. MANUSCRIPT FORMAT AND STRUCTURE

**Note: Authors submitting papers to *Grass and Forage Science* are strongly urged to read *An international terminology for grazing lands and grazing animals* by the Forage and Grazing Terminology Committee. The article should be used as a guide to the correct use of terminology in grazing studies, and can be accessed for free here.**

### 5.1. Format

**Language:** The language of publication is English. Authors for whom English is a second language must have their manuscript professionally edited by an English speaking person before submission to make sure the English is of high quality. It is preferred that manuscripts are professionally edited. A list of independent suppliers of editing services can be found at http://authorservices.wiley.com/bauthor/English_language.asp. All services are paid for and arranged by the author, and use of one of these services does not guarantee acceptance or preference for publication.

**Abbreviations, Symbols and Nomenclature:** All numerical data must be presented in System International (SI) units. The 24-hour clock should be used for time. Abbreviations should be used for all units and numerical values should be given in figures except where the number begins a sentence. If a number does not refer to a unit of measurement, it should be spelled out if it is ten or less. Abbreviations may be used for other physical quantities (e.g. DM for dry matter) provided that they are given in full when first mentioned in the paper and are followed by the abbreviation in brackets, e.g. dry matter (DM). Particular attention should paid to the composition of fertilizers: the abbreviations N, P, P2O5, K and K2O may be used without definition at the first occurrence, but P should not be used to indicate phosphate (P2O5) nor K to indicate potash (P2O). Proportions, rather than percentages, should be used except where there is a scientific convention to use percentages, e.g. cover and germination rate.

**5.2. Structure**

All manuscripts submitted to *Grass and Forage Science* should include: Abstract, Keywords, Introduction, Materials and methods, Results and Discussion.

**Title Page:** The title page should give the title of the article, the names and initials of each author, the department and institution to which the work should be attributed and the name, address, and the e-mail address of the author for correspondence. The author should also provide up to six keywords to aid indexing.

**Abstract:** should be a brief (not exceeding 200 words) and comprehensive summary of the contents of the manuscript.

**Optimizing Your Abstract for Search Engines**

Many students and researchers looking for information online will use search engines such as Google, Yahoo or similar. By optimizing your article for search engines, you will increase the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in another work. We have compiled these guidelines to enable you to maximize the web-friendliness of the most public part of your article.

**Main Text of Original Research Article**

**Introduction:** The Introduction of the paper should explain briefly the reasons for conducting the investigation and its nature: a full review of the literature is not necessary.

**Material and Methods:** The Materials and methods section of the paper should describe the experimental details so that the study could be repeated.

**Results:** Experimental results should be presented in either tabular or diagrammatic form but not in both forms.

**Discussion:** The Discussion of the results should conclude with a clear statement of their importance and application.

**Acknowledgements:** This must include a statement of the sources of funding used for the work.

**5.3. References**

**APA – American Psychological Association**
References should be prepared according to the Publication Manual of the American Psychological Association (6th edition). This means in text citations should follow the author-date method whereby the author's last name and the year of publication for the source should appear in the text, for example, (Jones, 1998). The complete reference list should appear alphabetically by name at the end of the paper.

A sample of the most common entries in reference lists appears below. Please note that a DOI should be provided for all references where available. For more information about APA referencing style, please refer to the APA FAQ. Please note that for journal articles issue numbers are not included unless each in the volume begins with page one.>

**Journal article**

Beers, S. R. , & De Bellis, M. D. (2002). Npaddocksropsychological function in children with maltreatment-related posttraumatic stress disorder. The American Journal of Psychiatry, 159, 483–486. doi:10.1176/appi.ajp.159.3.483

**Book edition**

Bradley-Johnson, S. (1994). Psychoeducational assessment of students who are visually impaired or blind: Infancy through high school (2nd ed.). Austin, TX: Pro-ed.

**OSCOLA** (used for legal citations)

Citations: OSCOLA is a ‘footnote style’, so all citations appear in footnotes. OSCOLA does not use endnotes or in-text citations, such as ‘(Brown, 2007)’. Longer works, such as books and theses, also include citations in tables of cases and legislation, and bibliographies.

When citing any source either directly as a quotation or indirectly by paraphrasing referring to ideas in cite the reference footnote indicated oscola.>

Indicate footnotes with a superscript number which should appear after the relevant punctuation in text if any put footnote marker at end of sentence unless for sake clarity it is necessary to directly word or phrase relates. Relates brackets before closing bracket. Quotation need not be footnoted separately from name source derived two same sentence. Otherwise separate notes used. Close full stop question exclamation mark where more than one citation given single reference them semi-colons.>

**Sample references follow:**
Citing cases>
It is well represented in the case law, perhaps most notably in the expression of the no-conflict rule advocated by Lord Upjohn in Phipps v Boardman,[31]
The relevant footnotes would appear as follows :>[31] [1967] 2 AC 46 (HL).
Citing legislation>

A citation in a footnote is not required when citing legislation if all the information the reader needs about the source is provided in the text, as in the following sentence: This case highlights the far-reaching judicial role ushered in by the Human Rights Act 1998.
Where the text does not include the name of the Act or the relevant section, this information should be provided in a footnote.

British courts must only consider Strasbourg jurisprudence: they are not bound by it.>[1]
The relevant footnotes would appear as follows:>
[1] Human Rights Act 1998, s 2.
Citing secondary sources>

If relying on or referring to a secondary source, such as a book or an article, provide a citation for the work in a footnote.

Hart wrote that the doctrine of precedent is compatible with two types creative or legislative activity : distinguishing earlier case by narrowing rule extracted from and widening discarding a restriction found in as formulated>[34]
The relevant footnotes would appear as follows:>
[34] HLA Hart, The Concept of Law (2nd edn, Clarendon Press 1994) 135.
When citing more than one source of the same kind for a single proposition put sources in chronological order with oldest first.>

Full details about how to cite and style in OSCOLA can be found here - OSCOLA (Oxford University Standard for the Citation of Legal Authorities - 4th Edition)

## 5.4. Tables, Figures and Figure Legends

**Tables:** should only be used to clarify important points. Tables must, as far as possible, be self-explanatory. The tables should be on a separate page and numbered consecutively with Arabic numerals.
**Figures:** All graphs, drawings and photographs are considered figures and should be numbered in sequence with Arabic numerals. If all or parts of previously published illustrations are used, permission must be obtained from the copyright holder concerned. It is the author’s responsibility to obtain these in writing and provide copies to the Publisher.

### Preparation of Electronic Figures for Publication

Although low quality images are adequate for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented programmes. Scans (TIFF only) should have a resolution of at least 300 dpi (halftone) or 600 to 1200 dpi (line drawings) in relation to the reproduction size (see below). Please submit the data for figures in black and white or submit a Colour Work Agreement Form (see Colour Charges below). EPS files should be saved with fonts embedded (and with a TIFF preview if possible).

For scanned images, the scanning resolution (at final image size) should be as follows to ensure good reproduction: line art: >600 dpi; halftones (including gel photographs): >300 dpi; figures containing both halftone and line images: >600 dpi.

Further information can be obtained at Wiley Blackwell's guidelines for figures: http://authorservices.wiley.com/bauthor/illustration.asp

Check your electronic artwork before submitting it: http://authorservices.wiley.com/bauthor/eachecklist.asp

**Permissions:** If all or parts of previously published illustrations are used, permission must be obtained from the copyright holder concerned. It is the author's responsibility to obtain these in writing and provide copies to the Publisher.

**Colour Charges:** It is the policy of *Grass and Forage Science* for authors to pay the full cost for the reproduction of their colour artwork. Therefore, please note that if there is colour artwork in your manuscript when it is accepted for publication, Wiley Blackwell require you to complete and return a Colour Work Agreement Form before your paper can be published. The form can be downloaded from the link at the top of the page. If you are unable to download the form, please contact the Production Editor at GFS@wiley.com.

Please post or courier all pages of your completed form to:

Customer Services (OPI)
John Wiley & Sons Ltd, Paddocksropean Distribution Centre
New Era Estate
Oldlands Way
Bognor Regis
West Sussex
PO22 9NQ

**Figure Legends:** Each figure should have a legend which makes the material comprehensible without reference to the text and all legends should be typed together on a separate sheet and numbered correspondingly.

## 6. AFTER ACCEPTANCE

### 6.1 Proof Corrections

The corresponding author will receive an e-mail alert containing a link to a website. A working e-mail address must therefore be provided for the corresponding author. The proof can be downloaded as a PDF (portable document format) file from this site. Acrobat Reader will be required in order to read this file. This software can be downloaded (free of charge) from the following website: www.adobe.com/products/acrobat/readstep2.html
This will enable the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof. Hard copy proofs will be posted if no e-mail address is available; in your absence, please arrange for a colleague to access your e-mail to retrieve the proofs. Proofs must be returned to the Editor within three days of receipt. Excessive changes made by the author in the proofs, excluding typesetting errors, will be charged separately. Other than in exceptional circumstances, all illustrations are retained by the publisher. Please note that the author is responsible for all statements made in their work, including changes made by the copy editor.

### 6.2 Author Services

Online production tracking is available for your article through Wiley Blackwell's Author Services. Author Services enables authors to track their article - once it has been accepted - through the production process to publication online and in print. Authors can check the status of their articles online and choose to receive automated e-mails at key stages of production. The author will receive an e-mail with a unique link that enables them to register and have their article automatically added to the system. Please ensure that a complete e-mail address is provided when submitting the manuscript. Visit http://authorservices.wiley.com/bauthor for more details on online production tracking and for a wealth of resources including FAQs and tips on article preparation, submission and more. For more substantial information on the services provided for authors, please see Wiley Blackwell's Author Services.

### 6.3 Online Open

Online Open is available to authors of primary research articles who wish to make their article available to non-subscribers on publication, or whose funding agency requires grantees to archive the final version of their article. With Online Open, the author, the author's funding agency, or the author's institution pays a fee to ensure that the article is made available to non-subscribers upon publication via Wiley Online Library, as well as deposited in the funding agency's preferred archive.

For the full list of terms and conditions, see http://authorservices.wiley.com/bauthor/onlineopen.asp.
Any authors wishing to send their paper OnlineOpen will be required to complete the payment form available from our website.

Prior to acceptance there is no requirement to inform an Editorial Office that you intend to publish your paper OnlineOpen if you do not wish to. All OnlineOpen articles are treated in the same way as any other article. They go through the journal's standard peer-review process and will be accepted or rejected based on their own merit.

**6.4 Author Material Archive Policy**

Please note that unless specifically requested, Wiley
Blackwell will dispose of all hardcopy or electronic material submitted two months after publication. If you require the return of any material submitted, please inform the editorial office or production editor as soon as possible.

**6.5 Offprints and Extra Copies**

Authors can retrieve the final PDF proof of their article via Author Services. Details on Author Services can be found here; http://authorservices.wiley.com/bauthor
Additional paper offprints may be ordered online. Please click on the following link, fill in the necessary details and ensure that you type information in all of the required fields.If you have queries about offprints please e-mail offprint@cosprinters.com.

# 7 VITA

Ricardo Pereira Gonçalves, filho de Sandra Regina Pereira Gonçalves e Clóvis Renato Marques Gonçalves, nasceu no dia 17 de julho de 1990 na cidade de Uruguaiana, Rio Grande do Sul. Cursou seu Ensino Fundamental e Médio no Colégio Metodista União, em Uruguaiana, onde concluiu seus estudos no ano de 2007. Em 2008 ingressou no curso de Medicina Veterinária na Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS) em Uruguaiana, porém não concluiu o curso. Em 2010 prestou vestibular novamente, mas agora para Agronomia na Universidade Federal do Rio Grande do Sul (UFRGS), onde iniciou suas atividades como bolsista de monitoria acadêmica na disciplina de Desenho Técnico para Agronomia, sob a orientação do professor Daniel Sergio Presta Garcia. Um ano e meio depois passou a ser bolsista de Iniciação Científica no Centro de Estudo e Pesquisa em Ovinocultura da UFRGS, onde trabalhou com comportamento materno-filial e sistemas de alimentação de cordeiros para produção de carne de qualidade no outono, sob a orientação do professor Cesar Henrique Espirito Candal Poli. No último ano do curso de Agronomia, voltou a trabalhar como bolsista de monitoria acadêmica, na disciplina de Produção e Manejo de Ovinos, também sob a orientação do professor Cesar Henrique Espirito Candal Poli. Formou-se Engenheiro Agrônomo em Março de 2015. Em abril de 2015, deu início ao curso de Mestrado no Programa de Pós-graduação em Zootecnia da Universidade Federal do Rio Grande do Sul (UFRGS), sob a orientação da professora Carolina Bremm, onde passou a fazer parte do Grupo de Pesquisa em Ecologia do Pastejo. Foi submetido à banca de defesa da Dissertação de Mestrado em março de 2017.