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Émerson Mendes Soares

PRODUÇÃO E COMPORTAMENTO ANIMAL EM PASTAGEM NATURAL MANEJADA SOB PASTOREIO ROTATIVO – ANÁLISE CONJUNTA DE EXPERIMENTOS

Santa Maria, RS
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Tese apresentada ao Curso de Pós-Graduação em Zootecnia, da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para a obtenção do título de **Doutor em Zootecnia.**

Orientador: Fernando Luiz Ferreira de Quadros

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RESUMO

PRODUÇÃO E COMPORTAMENTO ANIMAL EM PASTAGEM NATURAL MANEJADA SOB PASTOREIO ROTATIVO – ANÁLISE CONJUNTA DE EXPERIMENTOS

AUTOR: Émerson Mendes Soares
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O objetivo deste trabalho foi estudar, através de uma análise conjunta de experimentos, o efeito do pastoreio rotativo, utilizando intervalos de descanso baseados na duração da expansão foliar de gramíneas nativas, na produção primária e secundária, bem como no comportamento ingestivo de novilhas de corte. Para isso, foi elaborada uma base de dados a partir de experimentos conduzidos com novilhas de corte manejadas em pastagem natural sob pastoreio rotativo, utilizando dois intervalos de descanso entre pastoreio: 375 e 750 graus-dia (GD). O arranjo experimental da área foi de blocos ao acaso, onde os tratamentos foram dois intervalos de descanso entre pastejo e três repetições de área para cada tratamento. Na base de dados, composta por oito experimentos realizados entre 2010 e 2014, foram considerados como efeitos fixos os tratamentos e as estações climáticas, e efeitos aleatórios o estudo e o erro experimental. A produção média por área foi de 411 kg PV/ha/ano, considerando uma taxa de lotação média de 915 kg PV/ha e um ganho médio diário de 0,276 kg PV/dia. A utilização do pastoreio rotativo, com intervalos de descanso baseados na duração da expansão foliar de gramíneas nativas, foi capaz de aumentar a eficiência de utilização das áreas de pastagens naturais, possibilitando ganhos individuais adequados para a recria de fêmeas de corte entre o desmame e o acasalamento aos 24 meses de idade. Novilhas de corte manejadas em pastagem natural sob pastoreio rotativo possuem um padrão de pastejo diurno. Entretanto, significativas atividades de pastejo acontecem durante períodos da noite bem como diferenças entre as estações no que tange ao momento que os animais realizam essas atividades. Avaliações de comportamento ingestivo de novilhas de corte em pastagens naturais, apenas durante o período diurno, não contemplam o tempo necessário para representar a totalidade das atividades de pastejo. Para que seja contemplada a totalidade das atividades de pastejo, é necessário realizar as avaliações de comportamento ingestivo entre o período do alvorecer e a meia-noite.

Palavras chave: Bioma Pampa. Comportamento ingestivo. Recria de novilhas. Métodos de pastejo. Eficiência de pastejo.

ABSTRACT

LIVESTOCK PRODUCTION AND ANIMAL BEHAVIOUR IN A NATURAL GRASSLAND MANAGED UNDER ROTATIONAL GRAZING - JOINT ANALYSIS OF EXPERIMENTS

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The aim of this work was to study, through a joint analysis of experiments, the effects of rotational grazing, using rest intervals based on duration of leaf expansion of native grasses, on the primary and secondary production as well as grazing behaviour of beef heifers. Then, it was elaborated a database from experiments conducted using beef heifers managed in a natural grassland under rotational grazing, using two rest intervals between grazing: 375 and 750 degree-day (DD). The experimental design of the area was randomized blocks where the two rest intervals were the treatments with three area replicates for each treatment. The database was composed by eight experiments performed between 2010 and 2014, it was considered as fixed effects the treatments and climatic seasons; studies and experimental error as random effects. The mean area production was 411 kg body weight/hectare/year, considering a mean stocking rate of 915 kg body weight *per* hectare and an average daily gain of 0,276 kg body weight *per* day. The use of rotational grazing, using grazing rest intervals based on duration of leaf expansion of native grasses, was able to increase the utilization efficiency of natural grasslands areas, making possible adequate individual gain for rearing beef heifers between weaning and breeding at 24 months old. Beef heifers have a diurnal grazing pattern when managed in natural grassland under rotational grazing. However, there are significant grazing activities during dark periods as well as climatic season differences in the moment when animals perform those activities. Grazing behaviour assessments in beef heifers managed in natural grasslands, performed only on diurnal period, do not contemplate the required period to represent all grazing activities. To contemplate all grazing activities, it is necessary to perform the grazing behaviour assessments between dawn and midnight.

Keywords: Pampa biome. Foraging behaviour. Beef cattle. Grazing methods. Grazing efficiency.

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Sumário

1. INTRODUÇÃO

A região de pastagens naturais da América do Sul (*"Río de la Plata grasslands"*) engloba uma região de 3,4 × 10^6 km² entre a porção oriental da Argentina, sul do Brasil e todo Uruguai, sendo uma das maiores áreas de pastagens temperadas/subtropicais do mundo (SORIANO, 1991). Dentro desse grande ecossistema, na porção brasileira, encontra-se o bioma Pampa, um dos seis biomas reconhecidos do Brasil, o qual ocupa 176,496 km^2 (2,07% do território nacional) em sua totalidade no Estado do Rio Grande do Sul (RS). As pastagens naturais do bioma Pampa caracterizam-se pela grande diversidade florística, compreendendo um total de mais de 3000 plantas vasculares sendo, destas, 450 espécies de gramíneas e 150 espécies de leguminosas (BOLDRINI et al., 2009). Essas áreas tem sido a base alimentar para a pecuária de corte desde o século XVII e, atualmente, apesar das mudanças dos arranjos produtivos, ainda é a região onde a ampla maioria de bovinos e ovinos de corte do RS estão localizados.

Essas áreas de pastagens tem sofrido nas últimas décadas, principalmente nos últimos 20 anos, uma substituição por cultivos anuais, sendo a soja o principal cultivo utilizado, aumentando sua área em 210% considerando os três países (MODERNEL et al., 2016) e, apenas no RS, ocorreu um aumento de 57% nos últimos 15 anos (SILVEIRA et al., 2017), reduzindo a área original de pastagens naturais do bioma Pampa a menos de 50% (PILLAR E VÉLEZ, 2010). Além da substituição por outros cultivos, o pastejo malconduzido (*i.e.*, sobrepastejo) associado à dominância de espécies invasoras (como capim annoni) são outras ameaças à manutenção das áreas de pastagens naturais e seus serviços ecossistêmicos (CARVALHO E BATELLO, 2009). A conversão de ecossistemas naturais para cultivos agrícolas tem sido relacionada, sistematicamente, com alguns problemas ambientais como emissão de gases de efeito estufa (SEARCHINGER et al., 2008), redução na diversidade de fauna e flora (OVERBECK et al., 2015) bem como redução na manutenção de reservas de água potável (GORDON et al., 2008). Nesse sentido, alguns autores propôem uma "agricultura ecologicamente intensiva" como uma eficiente maneira de aumentar a eficiência de utilização dos recursos naturais (BOMMARCO et al., 2013; TITTONEL, 2014), e sistemas pastoris baseados em pastagens naturais poderiam ser considerados nessa classe, desde que bem manejados (VIGLIZZO et al., 2001).

As informações de pesquisa com o manejo dessas áreas de pastagens naturais ainda são relativamente recentes e, devido à grande biodiversidade desses ecossistemas pastoris, torna-se ainda mais necessário a realização de experimentos de longo prazo e com prévio embasamento teórico para obtenção de informações sólidas. Nesse sentido, baseado no agrupamento funcional de gramíneas nativas do bioma Pampa (CRUZ et al., 2010) e nos resultados de morfogênese de algumas dessas espécies (EGGERS et al., 2004; MACHADO et al., 2013), Quadros et al. (2009) propuseram a utilização dessas informações para estabelecer intervalos de descanso entre pastejo em um sistema de pastoreio rotativo e, dentro desse sistema, realizar a recria de fêmeas de corte entre o desmame e o acasalamento. Teague et al. (2015) reforçam, em sua modelagem, a importância da definição de intervalos de descanso, que considerem características das plantas, para sistemas de pastoreio rotativo. Até então, os estudos de produção animal em pastagens naturais foram realizados, majoritariamente, em sistemas de pastoreio contínuo com ajuste da oferta de forragem (NABINGER et al., 2009) e, outros, em sistema contínuo com diferentes taxas de lotação fixa (LOBATO, 2009).

Entre as categorias mais representativas dentro do rebanho do RS estão terneiras e novilhas de corte (42% do total). Além disso, 25% do total do rebanho estão acima de um ano idade (ANUALPEC, 2015), ou seja, fisiologicamente aptas ao acasalamento (MORAN et al., 1989). Entretanto, em levantamento realizado por SENAR/SEBRAE/FARSUL (2005), foi constatado que as novilhas de corte no RS são acasaladas, majoritariamente, entre os 30 e 36 meses de idade. A manutenção de um grande número de fêmeas improdutivas no rebanho está entre as principais causas da baixa eficiência produtiva em sistemas de produção de bovinos de corte (FRIES E ALBUQUERQUE, 1999). Além disso, elevadas idades de acasalamento e baixas taxas de repetição de prenhez (LOBATO E PILAU, 2004) contribuem para ineficiência desses sistemas. Corroborando, Pötter et al. (1998) trabalhando em um sistema extensivo de produção, obtiveram uma redução de 21,61% para 14,48% do rebanho de fêmeas não produtivas quando reduzida a idade ao acasalamento de três para dois anos.

Nesse sentido, Nabinger (2006) afirma que a compreensão das interações entre a produção primária e a resposta animal são necessárias para o estabelecimento de padrões de produtividade potencial, os quais podem ser alterados, seja através de simples ações de manejo ou pelo uso de tecnologias/insumos com alto grau de alteração na produção animal. Canellas et al. (2013) citam como um dos principais limitantes da eficiência do processo produtivo, nesse ecossistema, a ausência de planejamento alimentar para a recria de novilhas. Esse planejamento acontece tanto em uma escala de propriedade como em escalas menores, como a avaliação do comportamento animal que, dentre outras respostas, informa o manejador sobre a qualidade do manejo que está sendo aplicado ao pasto (CARVALHO et al., 2015).

Dentre as avaliações possíveis de comportamento ingestivo, o tempo de pastejo é uma variável de, relativamente, simples observação e bastante eficiente como indicadora de eficiência no manejo da pastagem (MANNING et al., 2017). Vários protocolos experimentais, tanto em pastagens temperadas (HODGSON, 1982) quanto subtropicais (CARVALHO et al., 1999; PINTO et al., 2007; MEZZALIRA et al., 2012), avaliaram o tempo de pastejo e relacionaram com variáveis do pasto e sistemas de pastejo. Nesse sentido, a compreensão do comportamento ingestivo em diferentes estruturas de pasto, principalmente ambientes heterogêneos (LACA, 2008), é extremamente necessária para melhor definição de estratégias de manejo e suas relações com a disponibilidade de forragem (MEISSER et al., 2014).

Assim, é evidente a necessidade de protocolos experimentais que explorem a heterogeneidade das pastagens naturais do ponto de vista da produção primária, sua relação com o desempenho dos animais, e como os mesmos adaptam seu comportamento frente às mudanças nas características estruturais do pasto. Não menos importante, a utilização de ferramentas de avaliação da relação dos animais com o pasto, como o comportamento ingestivo, poderá elucidar de melhor maneira as relações de desempenho dos animais.

2. PROPOSIÇÃO

As hipóteses e objetivos que serão apresentadas, bem como os protocolos experimentais para avaliação das mesmas, encontram-se divididas em três partes. Em um primeiro momento, será apresentada a metodologia utilizada para realização dos experimentos e elaboração da base de dados. Posteriormente, são apresentados dois manuscritos intitulados: “A joint analysis of rotational grazing system on South America natural grasslands” e “Validity of the timing and duration of observation periods of beef heifers foraging behaviour in natural grasslands”.

3. MATERIAL E MÉTODOS

3.1 Elaboração da base de dados

A base de dados foi elaborada a partir de oito experimentos conduzidos ao longo de sete anos (entre 2010 e 2014) provenientes da área experimental do Laboratório de Ecologia de Pastagens Naturais (LEPAN), Departamento de Zootecnia da Universidade Federal de Santa Maria (UFSM). Os experimentos foram conduzidos em área de pastagem natural durante as diferentes estações do ano utilizando novilhas de corte em um sistema de pastoreio rotativo.

A partir dos dados coletados nos experimentos, foi elaborada uma base de dados comum utilizando o software EXCEL. Primeiramente, os dados foram tabulados integralmente na planilha de dados, incluindo todas as variáveis coletadas em cada experimento, em cada período experimental. Posteriormente, foram calculadas as médias de cada variável para cada estação climática (primavera, verão, outono e inverno); em média, em cada estação climática, foram realizados três períodos experimentais de 28 dias/cada e, portanto, cada unidade amostral foi composta pela média dos três períodos experimentais.

3.2 Área e manejo experimental

Todos os experimentos que compõem a base dados foram realizados em uma área de pastagem natural pertencente ao Departamento de Zootecnia, UFSM. Conforme Quadros e Pillar (2001), esta área vem sendo manejada desde a década de 70 com pastoreio contínuo de bovinos, não tendo histórico de conversão para fins agrícolas. A área experimental situa-se na região fisiográfica Depressão Central do Rio Grande do Sul, nas coordenadas 29º43’29,97”S 53º45’36,91”W. A altitude a nível do mar é de 95 m e o clima da região é subtropical úmido (Cfa), temperatura média anual de 19,2ºC e uma pluviosidade anual média de 1770 mm, conforme a classificação de Köppen. Nessa área experimental predominam dois tipos de solos: Planossolo Háplico Eutrófico (áreas de baixada) e Argissolo Vermelho Distrófico (áreas de topo e encosta) (STRECK et al., 2008).

A área experimental possui uma vegetação característica das pastagens naturais da Depressão Central com predominância de gramíneas, conforme contribuição na massa de forragem, a seguir descritas: *Andropogon lateralis* (37%), *Aristida laevis* (14%), *Saccharum trinii* (6%), *Shorgastrum nutans* (6%), *Paspalum plicatulum* (3%), *Axonopus affinis* (6%), *Paspalum notatum* (9%); espécies da família Umbelliferae, como *Eringium horridum* (3%), e 16% representando outras famílias (cada uma representando menos de 1%). Não menos importante, nessa área foram documentadas 117 espécies (33 gêneros de gramíneas); todos esses dados de composição e contribuição foram obtidos utilizando a metodologia BOTANAL (TOTHILL et al., 1978). A partir da primavera de 2007, a área foi manejada apenas entre setembro e maio, utilizada por bovinos de corte em pastoreio rotativo com taxa de lotação ajustada para um desaparecimento de 20 a 35% da massa de forragem existente. Na estação de crescimento 2009/2010 foi realizada uma queima controlada da área experimental e a mesma ficou em descanso até maio de 2010, quando foram aplicados dois intervalos entre pastoreios de 375 e 750 graus dia (GD), manejados com número fixo de animais (aproximadamente, 600 kg de PC/ha).

A área experimental possui 22,5 ha os quais foram subdivididos em 45 piquetes (0,5 ha cada) nos quais foram distribuídos os tratamentos. Todos os potreiros possuem bebedouros de água automatizados e cocho coberto para sal mineral e/ou suplementação. Além disso, a área foi dividida em três repetições de área agrupadas de maneira que as posições topográficas topo, encosta e baixada fossem contempladas de igual forma em cada tratamento. Os tratamentos 375 GD e 750 GD foram compostos por sete e oito potreiros por repetição, respectivamente. A divisão de potreiros nesse número foi realizada com o intuito de que fosse possível atingir os períodos de descanso estipulados mantendo no mínimo três animais teste durante toda a rotação, sem que houvesse a necessidade de se utilizar períodos de ocupação muito longos.

A partir de maio de 2010 foram definidos dois intervalos entre pastoreio (375 e 750 GD) como tratamentos aplicados na área experimental. A utilização dessas diferentes somas térmicas determina distintos intervalos entre pastoreios em método rotativo. O intervalo menor (375 GD) considera a soma térmica necessária para a elongação de duas folhas e meia da espécie *Axonopus affinis* e *Paspalum notatum*, gramíneas prostradas, competidoras por recursos, pertencente aos grupos A e B (QUADROS et al., 2009), com filocrono médio de 148,5 GD (EGGERS et al., 2004); enquanto isso, no intervalo maior (750 GD) considera a duração de elongação de duas folhas das espécies cespitosas dos grupos C e D (QUADROS et al., 2009), tais como: *Aristida laevis* e *Saccharum angustifolius*, com filocrono de 333 GD (MACHADO et al., 2013). A utilização da tipologia funcional (grupos A, B, C e D), propostos por Cruz et al., (2010), baseia-se na ideia de agrupar espécies de gramíneas de acordo com atributos como a área foliar específica (AFE) e teor de matéria seca (TMS), dividindo em grupos de captura de recursos (A e B) e outro de conservação de recursos (C e D). A soma térmica acumulada no período foi calculada pelo somatório da temperatura média diária (TM), a qual foi obtida a partir da seguinte fórmula: TM = [(TºMx + TºMn)/2]; onde TºMx é a temperatura máxima diária (ºC) e TºMn é a temperatura mínima diária (ºC). Os dados de temperatura utilizados para cálculos diários foram obtidos junto ao Instituto Nacional de Meteorologia (INMET), provenientes de uma torre de coleta de dados presente no campus da UFSM.

O manejo experimental foi o pastoreio rotacionado utilizando novilhas de corte, cuja idade variou entre 8 e 24 meses, durante os experimentos. Especificamente, durante o inverno de 2010, foram utilizadas seis novilhas teste por unidade experimental e as mesmas receberam uma suplementação mineral-protéica *ad libitum* (em cochos cobertos); durante esse período, não houve ajuste da taxa de lotação, mantendo o número de animais fixo ao longo do período. No período de primavera, verão e outono (estação quente) entre 2010 e 2011, foram utilizadas quatro novilhas teste por unidade experimental e, também, novilhas como animais reguladores da taxa de lotação. A taxa de lotação foi ajustada utilizando uma taxa de desaparecimento de 4,5% (HERINGER E CARVALHO, 2002) de 70% da porção verde da massa de forragem (como descrita abaixo); durante esse período, os animais tiveram acesso a suplementação mineral *ad libitum*. No inverno de 2011, foram utilizadas seis novilhas teste por unidade experimental (número de animais fixo ao longo do experimento), sendo que as mesmas receberam, diariamente às 14 horas, 0,5% do peso vivo de milho moído e suplemento mineral-protéico *ad libitum*. Na estação quente 2011/2012, foram utilizadas três novilhas teste por unidade experimental e, também, novilhas como animais reguladores da taxa de lotação. A taxa de lotação foi ajustada utilizando uma taxa de desaparecimento de 4,5% (HERINGER E CARVALHO, 2002) de 70% da porção verde da massa de forragem (como descrita abaixo); durante esse período, os animais tiveram acesso a suplementação mineral *ad libitum*. No inverno de 2012, foram utilizadas seis novilhas teste por unidade experimental (número de animais fixo ao longo do experimento), sendo que as mesmas receberam, diariamente às 14 horas, 0,5% do peso vivo de uma mistura de farelo de trigo e glicerol (85% farelo de trigo, 15% glicerol). No inverno de 2013, foram utilizadas cinco novilhas teste por unidade experimental (número de animais fixo ao longo do experimento), sendo que as mesmas receberam, diariamente às 14 horas, 1,0% do peso vivo de farelo de trigo (corrigido com 4% de calcário calcítico); enquanto isso, na estação quente de 2013/2014, foram utilizados os mesmos animais teste, porém com um número variável de novilhas para ajustar a taxa de lotação (ajustada da mesma maneira dos experimentos anteriores, nessa estação). No inverno de 2014, foram utilizadas seis novilhas teste por unidade experimental (número de animais fixo ao longo do experimento), as quais receberam uma suplementação mineral-protéica *ad libitum* (em cochos cobertos); além disso, as três novilhas mais leves de cada unidade experimental foram suplementadas, de segunda à sexta-feira, com 0,9% do peso vivo com milho moído.

Além desses manejos, foi realizado, constantemente, o controle sanitário de endoparasitas e ectoparasitas (pela utilização de medicamentos injetáveis e/ou via pour-on), bem como a aplicação de vacinas da febre aftosa e clostridioses. Não obstante, os animais tiveram acesso *ad libitum* à água em cochos de concreto com alimentação automática.

3.3 Variáveis utilizadas

As variáveis utilizadas para elaboração da base de dados foram separadas de acordo com a característica dos dados: variáveis referentes ao pasto, variáveis referentes ao desempenho dos animais, variáveis de relação pasto/animal e variáveis de comportamento ingestivo dos animais. As variáveis referentes ao pasto foram: massa de forragem média (MF; kg de matéria seca (MS) por hectare (ha)), massa de forragem de entrada no piquete (MFe; kg MS/ha), massa de forragem de saída (MFs; kg MS/ha), altura do dossel (Alt; cm), densidade volumétrica (Den; kg/cm), massa de forragem verde (MFv; kg MS/ha), massa de forragem morta (MM; kg MS/ha), proteína bruta (PB; %) e fibra em detergente neutro (FDN; %). As variáveis de relação pasto/animal foram a oferta de forragem (OF; expressa em % do peso corporal (PC)), taxa de lotação (TL; kg PV/ha), ganho de peso vivo (GPCe; kg PC/estação ou kg PC/ha/dia (GPCd)). A avaliação de desempenho individual dos animais foi estimada através do ganho médio diário (GMD; kg PV/dia); enquanto que as variáveis de comportamento animal foram tempo de pastejo (TP; min), tempo de ruminação (Rum; min) e tempo de outras atividades (Oci; min).

A MF foi obtida, em todos experimentos, a partir da realização de amostragem em um dos piquetes representativos de cada repetição. A amostragem da MF foi realizada pela técnica de estimativa visual de comparação a padrões, calibrada com dupla amostragem (HAYDOCK E SHAW, 1975), com 20 estimativas visuais e seis cortes rente ao solo, utilizando um quadrado de 0,25m². Enquanto isso, três subamostras dos cortes foram utilizadas para realizar a separação em componentes botânicos do pasto: folhas e colmos verdes (MFv; kg MS/ha), material morto (MM; kg MS/ha) e outras espécies (espécies não pertencentes à família Poaceae). Após separados, os componentes foram secos em estufa de ar forçado até atingirem peso constante para, posteriormente, serem pesados e os valores expressos em quilogramas de matéria seca por hectare. A massa de forragem foi avaliada em dois momentos, antes dos animais entrarem no piquete (MFe), em alguns experimentos, essa avaliação também foi realizada após a saída dos animais (MFs). Além disso, nos mesmos pontos de avaliação da MF, foram realizadas mensurações da altura do dossel utilizando uma régua graduada em centímetros (mensurando três pontos dentro do quadro de 0,25 m²); pela divisão da MF pela altura foi obtida a densidade volumétrica do pasto (Den; expressa em kg MS/cm).

Enquanto isso, os valores nutritivos do pasto foram determinados a partir de amostras de simulação de pastejo (EUCLIDES et al., 1992). Após a coleta das amostras de simulação, foi realizada a separação dos componentes botânicos da amostra (folhas, colmos, material morto e outras espécies), os quais foram encaminhados para estufa de ventilação forçada até atingirem peso constante, sendo que as folhas foram então moídas em moinho do tipo *Willey* com peneira de 2mm. A partir dessa amostra foram determinadas a FDN, conforme Van Soest (1967) e a PB a partir da determinação do nitrogênio total (AOAC, 1975).

As variáveis de relação pasto/animal foram a taxa de lotação (TL; kg PC/ha) calculada a partir da seguinte fórmula: TL = (PCt/área); onde "PCt" representa a quantidade em kg mantida na área da repetição durante o período e "área" representa a área total do módulo de pastoreio (piquete em ocupação e piquetes em descanso). A TL foi ajustada de acordo com a disponibilidade forrageira, mensalmente, durante as estações de primavera e verão; enquanto que, durante os períodos de outono e inverno, a taxa de lotação foi fixa, dependendo do experimento. A oferta de forragem (OF) expressa em percentual (kg MS/100 kg PC), obtida pela seguinte fórmula: OF = [(MFm/n)/(TLi)]*100; onde "MFm" representa a massa de forragem média no piquete durante o período de utilização, "n" representa o número de dias de ocupação do piquete e "TLi" representa a taxa de lotação instantânea do piquete. Também foram calculadas duas medidas de ganho por área: ganho de peso vivo (GPCd; expresso em kg PC/ha/dia), obtido pela multiplicação do ganho médio diário dos animais pelo número médio de animais mantidos na área; e o ganho de peso vivo durante a estação climática (GPCe; expresso em kg PC/ha), obtidos pela multiplicação do GPCd pelo número de dias de cada estação climática. Para obtenção dessas duas variáveis foram utilizadas as informações obtidas pela mensuração do ganho médio diário (GMD; kg PC/dia), calculado pela diferença de peso entre as pesagens dividido pelo número de dias entre as mesmas (todas pesagens foram realizadas sob jejum de sólidos e líquidos de 12 horas). Todas avaliações de desempenho individual dos animais foram realizadas em três animais por repetição, sendo os mesmos animais avaliados do início ao final do experimento.

3.4 Comportamento ingestivo

As avaliações de comportamento ingestivo foram realizadas por 24 horas consecutivas, iniciando no segundo dia de ocupação do piquete de cada repetição, independente do tratamento (375 ou 750 GD). Para todas avaliações, o valor médio de cada variável foi obtido pela média de quatro animais em cada piquete, sendo esse valor do piquete considerado o valor da unidade experimental. Para realização das avaliações, os avaliadores foram previamente treinados para realizar as mensurações com a menor interferência possível no comportamento natural dos animais. Os mesmos ficavam posicionados ao nível do solo, em uma distância entre 5 e 10 metros dos animais, para facilitar a visualização das atividades realizadas pelos mesmos. Além disso, de maneira geral, os animais apresentavam comportamento bastante calmo o que, por sua vez, facilitou a realização das avaliações. Como maneira de padronizar as avaliações, foram utilizados quatro avaliadores por piquete, ao longo de 24 horas, de maneira que os mesmos pudessem realizar períodos de descanso (normalmente, dois avaliadores estavam presentes no piquete cada vez).

As variáveis mensuradas foram o tempo total de pastejo (Past; expresso em minutos por dia, min/dia), tempo total de ruminação (Rum; expresso em min por dia, min/dia) e tempo de outras atividades (Out; expresso em min por dia, min/dia). As atividades dos animais foram visualmente avaliadas a cada dez minutos, ao longo de consecutivas 24 horas, seguindo as frequências previamente indicadas por Gary et al. (1970) e Mezzalira et al. (2011). A atividade de pastejo foi definida como o tempo dispendido para procura e apreensão do pasto através do bocado (HODGSON, 1990). O tempo de ruminação foi definido como o período de tempo em que, após cessamento da mastigação, os animais apresentavam movimentos mandibulares do bolo alimentar; enquanto que o tempo de outras atividades foi considerado o período que os animais não estavam em pastejo ou ruminação, exercendo atividades como interações sociais, ingestão de água ou suplementos, ou em inatividade (FORBES, 1988).

As avaliações de comportamento ingestivo foram realizadas sob a mesma metodologia durante os anos de 2010 (quatro avaliações), 2011 (seis avaliações) e 2012 (5 avaliações); dessas avaliações, três foram realizadas durante o verão, quatro durante o outono, cinco durante o inverno e três durante a primavera. As avaliações de comportamento foram realizadas com novilhas de corte, peso e idade variadas (entre 12 e 24 meses) (Tabela 1). Durante as estações de primavera e verão, os animais receberam apenas suplementação com sal mineral e água, ad libitum; enquanto que, durante as estações frias, os animais receberam suplementação, conforme descrito a seguir. Durante a estação fria de 2010, os animais tiveram livre acesso à uma suplementação mineral-protéica; na estação fria de 2011, os animais receberam milho moído, diariamente, em uma proporção de 0,5% do PC; já em 2012, os animais receberam, diariamente, uma mistura de glicerol e farelo de trigo (0,15 e 0,35% do PC, respectivamente).

Tabela 1. Peso médio inicial (kg), idade (meses), número de novilhas avaliadas durante o ano e datas de realização das observações de comportamento ingestivo em uma pastagem natural manejada sob pastoreio rotativo.

	2010	2011[1]	2012[1]
Peso vivo	215	177	185
Idade	18	12	12
Animais avaliados	24	36	24
Raça	Angus	Angus	Angus
Data de avaliação	11/06	20/01	16/01
	15/08	09/04	24/03
	30/09	04/06	26/05
	17/12	19/07	07/07
		03/09	12/09
		18/11	

[1]Nesses anos, as novilhas permaneceram nos piquetes entre 12 e 24 meses.

3.5 Análises estatísticas

3.5.1 Arranjo experimental da área

A área experimental compreende 22,5 hectares subdivididos em seis potreiros retangulares (3,5 ha/cada) os quais, cada um desses, foram divididos em sete piquetes no tratamento 375 GD (0,5 ha/cada) e oito piquetes no tratamento 750 GD (0,5 ha/cada), para realizar a rotação dos tratamentos. O arranjo experimental disposto na área foi de blocos ao acaso, sendo o relevo (baixada, encosta e topo) utilizado como critério de bloqueamento. Além disso, foram utilizados dois intervalos de descanso entre pastejo (375 e 750 GD) como tratamentos e três repetições de área para cada tratamento.

3.5.2 Análise estatística da base de dados

A análise conjunta foi realizada utilizando modelos mistos do programa estatístico SAS (v. 9.4 SAS Institute Inc., Cary, NC) em que considerou os efeitos fixos de formas de pastejo rotacionado e estações do ano e como efeitos aleatórios o estudo e o erro.

Diferenças entre as médias foram determinadas usando a opção P-DIFF do comando LSMEANS do proc MIXED, que é baseada no teste de Fisher com F-protegido. As diferenças foram declaradas a 5% de probabilidade. O efeito do bloco foi adicionado como co-variável no modelo quando este era significativo a 10% de probabilidade. Outliers foram removidos quando o seu erro normalizado eram > |3| e o número total de observações apresentados nas tabelas já consideram essa remoção de valores outliers. O coeficiente de correlação de Pearson entre variáveis foi obtido pelo procedimento CORR do SAS (v. 9.4 SAS Institute Inc., Cary, NC) e as significâncias foram declaradas a 5% de probabilidade.

Além destas, com o objetivo de relatar e identificar o padrão de distribuição das variáveis, foi realizada uma análise de correspondência Canônica demonstrada pela utilização de um diagrama de ordenação. Nesse diagrama foram apresentadas as médias das variáveis para ambos tratamentos e suas relações com as estações climáticas, sendo essa análise realizada com o software PAST (HAMMER et al., 2001)

Quanto aos dados do comportamento ingestivo, as avaliações de comportamento foram testadas por uma análise de variância (considerando 5% como nível de significância). Após essa análise, como não houveram diferenças significativas entre tratamentos (375 e 750 GD) para as variáveis tempo de pastejo e ruminação, todo conjunto de dados foi utilizado em um banco único de dados. Os dados foram agrupados por ano gerando quatro avaliações em 2010 (4 avaliações em seis potreiros; 24 réplicas); seis avaliações em 2011 (6 avaliações em 6 potreiros; 36 réplicas); e cinco avaliações em 2012 (cinco avaliações em seis potreiros; 30 réplicas). Posteriormente, a base de dados foi agrupada por estação climática, gerando 12 réplicas durante o verão, 24 réplicas no outono, 36 réplicas no inverno e 18 réplicas na primavera. Esse segundo agrupamento foi submetido, novamente, a uma análise de variância, utilizando o ano como bloco e, novamente, tempo de pastejo e tempo de ruminação não apresentaram diferenças significativas entre tratamentos (375 e 750 GD). Dessa maneira, pela similaridade no comportamento dos animais, independente de tratamento, ano ou estação climática, foi possível utilizar todo banco de dados para estudar a distribuição temporal e análise de suficiência amostral proposta nessa tese. Para isso, em todas avaliações, a unidade experimental utilizada é o valor médio das observações de todos animais que estavam alocados em cada piquete (quatro animais por piquete).

A partir desse banco de dados, foram estabelecidos cinco tratamentos a serem avaliados: controle (Control) baseado na avaliação do comportamento ao longo de 24 horas ininterruptas; tratamento “Sol” (DAY-SUN), baseado no período entre o nascer e o pôr do sol; tratamento “Luz do dia” (DAYLIGHT), baseado no período entre o alvorecer e o anoitecer; tratamento “Luz do dia + 2” (DAYLIGHT+2), baseado no tratamento anterior acrescido de duas horas; e tratamento “Amanhecer à meia-noite” (DAYLIGHTto0), baseado no período entre o alvorecer e a meia-noite.

Para determinação dos tratamentos, foram utilizados dados históricos do Instituto Nacional de Meteorologia (INMET) (média de 30 anos), para obtenção dos exatos horários do nascer e pôr do sol, em cada estação climática. Além disso, o horário de alvorecer e anoitecer foi estimado considerando a posição do sol como 6º acima (nascer do sol) e -6º abaixo (anoitecer) do horizonte, de acordo com Miguens (1996). O tratamento DAY-SUN foi adequado usando o horário do nascer do sol (horário inicial) e pôr do sol (horário final); o tratamento DAYLIGHT foi adequado usando os valores médios de alvorecer e anoitecer (em minutos, em cada estação), em que esse período foi adicionado aos horários de nascer e pôr do sol; o tratamento DAYLIGHT+2 foi estabelecido a partir do tratamento anterior e acrescido duas horas após o anoitecer; o tratamento DAILIGHTto0 foi adequado no horário entre o alvorecer e a meia-noite. Mesmo dentro dos mesmos tratamentos, houve diferença no período de tempo avaliado devido as diferenças entre as estações climáticas (fato esse devido as mudanças de fotoperíodo entre estações climáticas, alterando o horário de início e término das avaliações). Além disso, também foram avaliados os padrões de pastejo ao longo do dia em cada estação climática. Para isso, a base de dados foi separada por estação climática e os tempos médios de pastejo (minutos por hora), ao longo de 24 horas, foram comparados entre cada estação.

Para as análises estatísticas, foi utilizado um modelo em blocos onde cada ano foi considerado como bloco; cada potreiro foi considerado como uma réplica (média dos animais do potreiro), de um total de seis réplicas em cada avaliação (15 avaliações durante três anos). Devido as diferenças no comprimento do dia entre as estações, as quais tiveram diferentes números de réplicas (18 na primavera, 12 no verão, 24 no outono e 36 no inverno), os resultados são apresentados separados por estação. Enquanto isso, para as análises do tempo de pastejo (minutos por hora durante 24 horas), foram utilizados os valores de tempo de pastejo de todas réplicas da base de dados. Nessa análise, os dados foram separados por estação climática e, utilizando os valores médios de todas réplicas em cada estação climática, foi calculada o tempo de pastejo (minutos por hora) em cada hora do dia; e então, foram comparados os tempos de pastejo em cada hora para cada estação climática.

Inicialmente, os dados foram submetidos à análise de homogeneidade da variância e a normalidade dos resíduos, respectivamente (considerando 5% como nível de significância). Posteriormente, os dados foram submetidos à análise de variância e teste F, novamente utilizando 5% como nível de significância. As comparações de média foram realizadas utilizando o procedimento PROC MIXED (teste de Tuckey, $P<0,05$), incluindo no modelo os efeitos de bloco (anos) e tratamentos (períodos de avaliação). O critério utilizado para definir a suficiência amostral dos períodos de observação foi a equivalência do tratamento CONTROL com os demais tratamentos ($P>0{,}05$). Todas as análises estatísticas foram realizadas utilizando o software estatístico SAS (versão 9.4).

4. CAPÍTULO I

A joint analysis of rotational grazing system on South America natural grasslands

Capítulo baseado nas normas para submissão de artigo científico da revista Rangeland Ecology & Management

A joint analysis of rotational grazing system on South America natural grasslands

Abstract: Improving efficiency use of natural grasslands is a critical point to maintain these ecosystems. Defining a system of rotational grazing (RG) which considers plant traits will provide farmers an important tool to manage these areas. The aim of this article was to perform a joint analysis from a database of RG experiments in order to evaluate forage characteristics and animal performance in a natural grassland. It was used seven experiments performed under RG method, using beef heifers between 2011 and 2014, including climatic season effects. There were used two rest intervals as treatments: 375 and 750 degree-days, based on a morphogenic trait (duration of leaf expansion) from the main grasses species. Forage canopy characteristics were directly related to the individual and area gains, mainly described by canopy height, green forage mass and mean forage mass. Gains *per* area had direct effect from average daily gain leading to an increased gain *per* area during spring and summer seasons, despite lower forage allowances during these seasons. The utilization of RG for natural grasslands of Pampa biome, using these two rest intervals, was extremely effective in order to maximize gains *per* area, as demonstrated by body weight gains per climatic season. On an annual basis, it was produced around 410 kg BW ha^{-1} which were generated using mainly natural grasslands and small inclusion of by-products, upgrading both quantity and quality of protein to humans. If we simulate a rearing heifers system using the available data provided by continuous grazing research, it would be necessary around 62 ha to raise 100 heifers between weaning and breeding while using the RG here proposed, it would be necessary around 28 ha.

Keywords: Rangelands; Grazing methods; Livestock production; Beef heifers; Pampa biome;

Introduction

The area of the Río de la Plata grasslands, at the southern portion in eastern South America, comprises an area of 3.4 × 10^6 km² at the south of Brazil, Uruguay and center-east Argentina, and it is one of the largest area of temperate/subtropical grasslands of the world. Traditionally, these areas have been used for livestock meat production since XVI century, moving to an agricultural expansion during XIX century (Hall et al., 1991) and an accelerated transformation of agricultural system since 2003 (Vega et al., 2009). Particularly, at Río de la Plata area, between 2000 and 2010, soybean area increased 210% and the total arable cropping area by 28% (Modernel et al., 2016) and, at some regions as Rio Grande do Sul state (RS, Brazil), there was an increase of 57% in annual croplands in the last 15 years (Silveira et al., 2017), reducing the original rangelands area to less than 50% (Pillar and Vélez, 2010). These changes in lands use are a key factor for environmental problems, as increasing greenhouse gases (Searchinger et al., 2008) and changes in water dynamics (Gordon et al., 2008); thereby, ecologically intensive agriculture has been cited as a way to improve resources' use efficiency and reduce the use of external inputs, improving significance of functional biodiversity (Bommarco et al., 2013; Tittonel, 2014). In this sense, beef cattle systems based on species-rich rangelands, using negligible amounts of external inputs, can be considered ecologically intensive models (Viglizzo et al., 2001), mainly if these systems are well managed, maintaining or improving ecosystem services.

However, the management of these rangelands is very complex due to the high floristic diversity and structural heterogeneity, comprising around 4000 native plant species (Bilenca and Miñarro, 2004), as woody plants, shrubs and hundreds of grasses and legumes. Thereby, Cruz et al. (2010) proposed to cluster different grass species (main grazed species) according to their leaf characteristics (specific leaf area and leaf dry-matter content), establishing four functional groups (A, B, C and D). According to it, groups A and B are composed by species (mainly stoloniferous species) which use more quickly resources as water, nutrients and light (resource capture strategy); while groups C and D are composed by species (mainly tussock species) which tends to use resources more slowly, higher tissue density (conservative resource strategy). Then, Quadros et al. (2009; 2015) proposed to use morphogenic characteristics of these grasses (*i.e.* thermal sum for leaf expansion; Eggers et al., 2004; Machado et al., 2013) in order to define rest periods for the pasture, defining periods that would allow a physiological time for plants to recover after grazing. Rest intervals are a critical point generally not considered for rotational systems (Briske et al., 2008) and it is even more important to consider it for rotational systems in heterogeneous environments, as rangelands (Teague et al., 2015).

Rangelands have an extreme range of functional and spatial heterogeneity, and this complexity reflects to the managers and animals as highly variable forage canopy characteristics (Fuhlendorf et al., 2017). Animal performance of grazing animals is mainly determined by the nutritive value of plants available, botanical composition and animal intake (Dove and Mayes, 1996); Carvalho et al. (2015) concluded that a forage canopy characteristic (*i.e.* tussocks frequency), not included in the model, was one reason for failing to predict animal performance by intake rates and bite mass, once heifers take around 30% of their bites at tussocks (Bonnet et al., 2015). Several authors have used forage canopy characteristics traits to describe herbage and relate them with animal performance (Jochims et al., 2017; Henkin et al., 2015; Stephenson et al., 2013), both individual and gains *per* area; it emphasizes the need to explore forage structure, even more in heterogeneous environments as rangelands, to relate it with livestock performance.

Then, we have hypothesized that using morphogenic grasses traits to define a rotational grazing system, it would improve primary production, maximize grazing efficiency and increase animal performance. Therefore, the aim of this paper was to perform a joint analysis from a database of multiple rotational grazing experiments in order to evaluate herbage characteristics and animal performance in a natural grassland.

Materials and methods

Database elaboration

This database was elaborated from seven experiments carried out at experimental site of Natural Grasslands Ecology Laboratory (LEPAN), from Federal University of Santa Maria (UFSM) (Rio Grande do Sul state - RS, Brazil). The site has a 22.5 ha area of natural grassland located at Central Depression region of RS, in 29º43'30" S, 53º45'33" W coordinates. The climate is subtropical humid, with a mean annual temperature of 19.2ºC and mean annual rainfall of 1770 mm, at an elevation 95 m above sea level (Moreno, 1961).

The experiments were realized under rotational grazing method using beef heifers between 2011 and 2014. The experimental area was arranged in a randomized block design with two treatments (two rest intervals; *described below*) and three area replicates (six paddocks, three per treatment); the relief was used as criterion to block this area (lowland, convex slope and top). The area was divided in six paddocks (3.5-4.0 ha each) which were subdivided in sub-paddocks to perform the rotational management (seven sub-paddocks for treatment 375; eight sub-paddocks for treatment 750). The treatments were defined according to two different rest intervals between grazing, which were set according to the thermal sum accumulated over time (degree Celsius *per* day; DD) for leaf extension of grasses from two different groups (Cruz et al., 2010; *described below*).

The treatments were two rest intervals between grazing, these treatments were defined using the mean phyllocron from two functional grasses groups. The treatment 375 DD was based on the accumulated temperature for elongation of 2.5 leaves per tiller of grasses of functional groups A and B (e.g.: *Coelorhachis selloana* and *Paspalum notatum*; Eggers et al., 2004). While the treatment 750 DD was based on the accumulated temperature for elongation of 1.5 leaves per tiller of functional groups C and D (e.g.: *Aristida laevis* and *Saccharum trinii*; Machado et al., 2013). The occupation period of the sub-paddock was defined by dividing the rest interval of each treatment by the number of sub-paddocks decreased by one (sub-paddock under occupation); this way, it was generated a value, in Celsius degrees, of occupation from each sub-paddock. Over the experiments, the mean occupation period of the sub-paddocks were four days (ranging from two to five days, warm season) and seven days (ranging from five to ten days, cool season), these fluctuations were due to the different season temperatures over those years. Temperature data were obtained from a weather station (National Institute of Meteorology – INMET) located at UFSM campus.

The experimental management was the rotational grazing using beef heifers as experimental animals, which ranged from 8 to 24 months old, over the experiments (Table 1). The seven experiments used in this database were performed over the different climatic seasons, using different strategies: during the cool season (autumn/winter), the experimental area was managed under a fixed animal number each year and it was used different types of supplements; while that, during the other seasons (spring/summer), the experimental area was managed using variable stocking rates (using a put-and-take method), where the adjustments were made every time was completed a rotational cycle. The stocking rates adjustments were performed using 4.5% body weight herbage disappearance (Heringer and Carvalho, 2002) of 70% of the leaf blades from the total herbage mass (Confortin et al., 2016). Besides, during cool season, when animals were fed daily, they received the supplement around noon time; over all experiments, animals had free access to mineral supplements and water.

(Insert table 1 here)

The variables used in this database were separated according to the data source: forage canopy characteristics, animal performance and animal-herbage relation variables. The forage canopy characteristics were forage mass (FM; kg of dry matter (DM) per hectare (ha)), forage mass pre-grazing (FMe; kg DM^{-1} ha^{-1}), forage mass post-grazing (FMs; kg DM^{-1} ha^{-1}), canopy height (CH; cm), volumetric density (VD; kg^{-1} cm^{-1}), green forage mass (FMg; kg DM^{-1} ha^{-1}), senescent material mass (SM; kg DM^{-1} ha^{-1}), crude protein (CP; %) and neutral detergent fiber (NDF; %). The variable which expressed animal performance was the average daily gain (ADG; kg of body weight (BW) *per* day) while the animal-herbage variables were forage allowance (FA; expressed as % BW), stocking rate (SR; kg BW^{-1} ha^{-1}), body weight gain (BWGs; kg BW ha^{-1} *per* climatic season; or kg BW ha^{-1} day^{-1} (BWGd)).

Forage mass was evaluated, in all experiments, from sampling one representative sub-paddock of each replicate. The FM sampling was performed using the methodology proposed by Haydock and Shaw (1975), based on a visual estimative calibrated with a double sampling technique with 20 visual estimates and six cuts at the ground level, using a 0.25m² quadrat. From the cut samples, three subsamples were used to perform the forage canopy characteristics evaluation, through the separation of structural components of herbage as: green leaves and stems (FMg; kg DM^{-1} ha^{-1}), SM and other species (species not belonging to Poaceae family). After separated, structural components were taken to a forced air oven until reaching constant weight and, after that, samples were weighed and values expressed as kg DM per hectare. Besides, forage mass was evaluated at two moments: before the animals started to graze the representative sub-paddock (FMe) and after animals left the sub-paddock (FMs). Furthermore, at the same FM evaluation sites, it was performed the canopy height evaluations using a graduated rule (measuring three points inside the 0.25m² quadrat); the value of VD was obtained through the division between FM value and mean canopy height.

The forage nutritive values were determined from grazing simulation samples (Euclides et al., 1992). After collected samples, it was performed the separation of structural components (leaves, stems, senescent material and other species) which were dried at forced air oven until reaching constant weight; after that, leaves were grounded in *Willey* mil, using two millimeters sieve. From these samples, it was determined the NDF content (Van Soest and Robertson, 1985) and crude protein from the determination of total nitrogen (AOAC, 1975).

The herbage-animals relation variables were SR calculated as: SR = (BWt/area); where "BWt" represents the total amount of body weight kept in the paddock area and "area" represents the total area of each paddock. The SR was adjusted according to the forage availability, every time it was completed a paddock cycle in each replicate, during spring and summer seasons. The FA was calculated as: FA = [(FMm/n)/SRi)]*100; where "FMm" represents the mean forage mass; "n" represents the occupation period of the sub-paddock and "SRi" represents the instantaneous stocking rate of the sub-paddock. It was also calculated the area gain variables as BWGd obtained by multiplication of ADG by the mean number of animals kept in the area; and BWGs obtained by multiplication of BWGd by the number of days of each climatic season.

These last two variables were calculated using the data obtained by measuring the ADG (which was calculated by the weight difference between weighings by the number of days between them); for weighings, the animals were kept in water and solids fasting for an average of 12 hours, and measurements were performed early in the morning. All animal performance evaluations were realized in three animals per replicate, where it was used the same animals during each experiment.

From all these data, it was elaborated a common database using an electronic EXCEL spreadsheet. Initially, data were integrally tabulated in the spreadsheet, including all variables collected over the experiments from each experimental period. Following, it was calculated the averages for each variable for climatic season; generally, in each climatic season, it was realized three experimental periods which, in turn, the average of these periods composed the experimental unit. After that, it was chosen the variables previously described (which were common to all experiments) and all performed under the same methodology, then these were used to perform the statistical analyses and compare the treatments.

Experimental design

The experimental site has a 22.5 ha area subdivided in six rectangular paddocks (3.5-4.0 ha/each) which were subdivided in seven sub-paddocks (375 DD treatment; 0.5 ha/each) and eight sub-paddocks (750 DD treatment; 0.5 ha/each), in order to perform the rotational management. The experimental arrangement set in this area was a randomized block design, using the relief as blocking criteria (lowland, convex slope and top). Furthermore, it was used two grazing rest intervals as treatments (375 and 750 DD) and three area replicates for each treatment.

Data analyses

The data were analyzed using mixed models of SAS statistical software (v. 9.4 SAS Institute Inc., Cary, NC) in which rotational grazing and climatic seasons were considered fixed effects and experiments and experimental error random effects, as described in the following model:

$$Y_{ijk} = \mu + P_i + E_j + P_i \times E_j + \varepsilon_{ijk}$$

Where: Y_{ijk} = dependente variable; μ = overall mean; P_i = fixed effect of i^{th} rotational method; E_j = fixed effect of j^{th} climatic season; $E \times P_{ij}$ = interaction between treatments and climatic seasons; e ε_{ijk} = residual error, assuming ~ $_{iid}N(0, \sigma^2_e)$.

Due to the variations across experiments, the experiment effect was included in the model in the RANDOM statement of PROC MIXED (ST-PIERRE, 2001). Because the means were obtained from the same N across experiments and the experiments were conducted at the same facilities and pastures, under a similar experiment design, we did not weight the means in the analyses by the WEIGHT statement. Differences between means were determined using P-DIFF option of LSMEANS statement of PROC MIXED, which is based on Fisher´s F-protected at least significant difference test; all differences were considered significant at 5% of probability. The effect of relief blocks was included as co-variable in the model, when significant at 10% probability. Moreover, outliers were removed when its Studentized residual errors ploted against the predicted means were out of ± 3 (SAUVANT et al., 2008); the total number of observations presented in the descriptive tables considered the outliers exclusion. Pearson correlation coefficient between variables was tested using CORR procedure of SAS (v. 9.4 SAS Institute Inc., Cary, NC) and significances were considered at 5% probability.

Subsequently, multiple regression determined which parameter, among the variables with biological relationship, that better predicted the FMg, FA, SR, BWGd, BWGs and ADG. Analysis was performed using the REG stepwise statement of SAS (v. 9.4) and significance was considered at 5%. Prediction regressions were analysed using the MIXED procedure of SAS (v. 9.4), considering the experiments as a random effect. The equations' intercepts and slopes were estimated using the ESTIMATE statement from the MIXED procedure.

Furthermore, to identify and relate the distribution patterns of variables, it was performed a Canonical correspondence analysis onto the ordination diagram all variables used, treatments, and climatic season. The analysis was performed using PAST statistical software (Hammer et al., 2001).

Results

First, it was presented the summary of the studies used in the database, presenting number of observations (N), mean, median, minimum and maximum values, and standard error for each variable showed in this paper (Table 2). There were no treatments × climatic seasons interaction (P>0.05) for all forage canopy characteristics and forage nutritive values variables

(FMm, FMe, FMs, FMg, SM, CP, NDF, CH and VD; Table 3). There was a significant treatment effect for all variables that described forage mass (mean, pre-grazing, post-grazing, green components and senescent material) where these variables were always greater in 750 DD treatment. Besides, there was climatic season effect ($P<0.05$) for FMg and SM over the years, where FMg was decreasing from summer towards winter season and SM was lower during summer season and similar over the other seasons (both treatments). Otherwise, there was no climatic season effect for FMm, FMe, FMs, CP and FDN ($P>0.05$); however, there was a climatic season effect for CH and VD ($P<0.05$) where CH and VD had the same pattern for both treatments: greater during summer and autumn seasons, intermediate in spring and lower during winter.

(Insert table 2 here)

(Insert table 3 here)

There was a treatments × climatic seasons interaction ($P<0.05$) for FA and ADG (Table 4). Forage allowance was greater during autumn and winter seasons in 375DD treatment; similar values were obtained during spring and summer in 375DD treatment as well as in summer season for treatment 750DD. The FA was intermediate during spring season in 750DD treatment and the lowest FA values were achieved during autumn and winter for 750DD treatment. While that, ADG was greater during spring and summer seasons in 375DD treatment; intermediate ADG values were achieved during spring, summer and winter for 750DD treatment while reduced ADG values were achieved during winter season in 375DD treatment. The lowest ADG values were found during autumn season for both treatments.

Furthermore, there was no treatments × climatic seasons interaction ($P>0.05$) for the other animal and herbage-animal relation variables (SR, BWGs and BWGd; Table 4). There was a climatic season effect ($P<0.05$) for BWGs and BWGd; these variables had the same distribution pattern over climatic seasons, where these gains *per* area were greater during spring and summer seasons and lower during autumn and winter.

(Insert table 4 here)

Moreover, multivariate analysis, demonstrated through an ordination analysis, was used to show the distribution pattern of variables over climatic seasons (Fig. 1); in the ordination diagram, the variability of these effects was synthesized in the first two axis (78.9% axis X; 16% axis Y). Analyzing the ordination diagram, it was clearly possible to separate, through axis X (largest contribution), the warm from cool seasons; besides, seasons were allocated each one by quadrant and relative variables were also related by quadrant. The correlation coefficients of seasons with axis X were 0.41, 0.48, -0.37 and -0.49, respectively for spring, summer, autumn and winter; while the correlation coefficients of seasons with axis Y were -0.28, 0.35, 0.25 and -0.26, respectively for spring, summer, autumn and winter. During winter, SM was the variable most related with this season with a correlation with axis X of -0.15 and axis Y of -0.07; during autumn, variables as FA, FMm, FMs and CH were placed in the same quadrant, correlation with axis X of -0.31, -0.09, -0.009 and -0.03, respectively and, with axis Y of 0.02, 0.02, 0.003 and 0.13, respectively. Otherwise, variables as ADG, BWGs, BWGd, VD, CP and FMe were related to spring season, allocated in the same quadrant with correlations of 0.27, 0.59, 0.59, 0.05, 0.11 and 0.03, respectively (axis X) and -0.09, -0.02, -0.02, -0.10, -0.02 and -0.02, respectively (axis Y); while, during summer, FMg and NDF were the variables most related with this season, with correlations of 0.07 and 0.06, respectively (axis X) and 0.15 and 0.006, respectively (axis Y).

(Insert Figure 1 here)

Besides, it was calculated the Pearson correlation coefficients between all variables (Appendix A). The results that stood out were the significant correlations between BWGs and BWGd with CP (r=0.443, p=0.0002), NDF (r=0.266, p=0.032), VD (r=0.307, p=0.012), FMs

($r= -0.357$, $p=0.005$), CH ($r= -0.392$, $p=0.001$) and FA ($r= -0.341$, $p=0.003$); the correlations between SR and VD ($r=0.369$, $p=0.002$), CP ($r=0.390$, $p=0.001$), NDF ($r=0.321$, $p=0.009$), CH ($r= -0.277$, $p=0.026$) and FMs ($r= -0.434$, $p=0.001$). Other important correlations were between ADG and VD ($r=0.241$, $p=0.05$), FMm ($r= -0.249$, $p=0.05$) and CH ($r= -0.339$, $p=0.006$); FA had significant correlations with CP ($r=0.478$; $p<0.001$), CH ($r=0.235$, $p=0.05$; $r=0.437$, $p=0.0003$, respectively) and SM ($r=0.522$ and $r=0.563$, respectively; $p<0.01$). Moreover, FA had significant correlations with NDF ($r= -0.277$, $p=0.025$) and VD ($r=0.247$, $p=0.045$).

Furthermore, multiple regression were estimated to predict some response variables (FMg, FA, SR, BWGd, BWGs and ADG) (Table 5). The FMg had positive influence of CH and VD ($P<0.01$; r^2 model = 0.49), FA had positive influence of VD and negative of SM ($P<0.01$; r^2 model = 0.35) and SR had positive influence of VD, CP and NDF ($P<0.01$; r^2 model = 0.45). Moreover, gain *per* area variables had the better prediction models, where BWGd and BWGs were positively influenced by VD and FMg and negatively influenced by FMs ($P<0.01$; r^2 model = 0.63); while ADG was negatively influenced by FMe and positively influenced by FMg ($P<0.01$; r^2 model = 0.5).

(Insert table 5 here)

Discussion

Forage canopy characteristics were directly related to the individual and area gains in our database. For instance, the greater CH for 750DD treatment, which favors tussock grasses with low specific leaf area and high dry matter content, was linked to greater SM and FMg for 750DD treatment. However, the FMg ratio (FMg/FMm, %) was similar between treatments (38.6 and 37.9 %, 375 and 750DD, respectively), generating the equivalents SR between treatments, due to the use of green herbage allowance as stocking criteria, as preconized in other rotational grazing study (Badgery et al., 2017a). Furthermore, CH was mainly greater during autumn periods that, associated with those previous forage canopy characteristics

characteristics, may have influenced the optimization of animals diet, once factors as FMs (Fulkerson and Slack, 1994), spatial variability (Badgery et al., 2017b) and structure of FMg and SM (Cox et al., 2017) have negative impact on the animal performance. On the same line of thought, other forage canopy characteristics variables (FMe and FMg) were able to predict ADG in a model ($r^2 = 0.50$); interestingly, FMe had a negative influence on ADG, as claimed by Sollenberger and Vanzant (2011), but its influence was only 35 % of FMg.

Other forage canopy trait that had an important influence of treatments was FMm (as well as FMe and FMs), where FMm was greater in 750DD treatment as expected. The longest grazing interval favors the development of resource conservation species which, in turn, have high dry matter content and low specific leaf area and, moreover, this grazing interval encompass the necessary period to expand 2.5 leaves of groups A and B, increasing total herbage mass in these paddocks. However, FMg ratio was similar between treatments and high SM in 750DD treatment, which agrees with the results found, in this same experiment, by Confortin et al. (2016) where *Aristida laevis* (conservative resource specie) had the greatest leaf senescence; Machado et al. (2013) and Santos et al. (2013) also found similar results for conservative resources species. Even though, maintaining high FM is a very important management criterion, in doing so, it was possible to keep high SR during cool season. This high fiber volume (even with low forage quality) coupled with supplements, turns it possible to have reasonable individual gains (targeting gains for rearing heifers). Nonetheless, keeping high FM it is a relevant manner to sequestrate carbon in soil (Franzluebers and Stuedemann, 2009), fulfilling one of the natural grasslands ecosystem functions. There are reports of C sequestration rates around 0.48 Mg.ha^{1} per year (Bayer et al., 2006) in subtropical soils from Southern Brazil, using no-till management; Conceição et al. (2007) estimated a soil C content around 140 Mg.ha^{1} in an experiment performed in Pampa biome, using different FA for several years (FMm and FA values reported by these authors were lower than values reported in our database).

Furthermore, in an experiment conducted in our experimental site, between 2014 and 2015, net ecosystem productivity ranged among 181.52 $gC.m^{-2}.year^{-1}$ and 560.5 $gC.m^{-2}.year^{-1}$, indicating this system as a carbon sink (Acosta et al., 2016).

In order to balance these herbage shortcomings during cool season, using supplementation was the strategy to complement the animal nutrients requirements and supplements were chosen every year according to regional price availability, simulating a ranch-scale situation. Then, even CP was lower during cool season, it was not limiting to microbial rumen growth but the forage canopy characteristics and the high fiber content would limit to achieve the individual gains obtained, reinforcing the need to use nutritional supplementation during this period, either protein or energy supplements. Then, using this strategy enabled the ADG that, added to SR, promoted a body weight gain during the cool season above the RS state average and higher than values normally achieved in experimental sites (Soares et al., 2005; Neves et al., 2009; Mezzalira et al., 2012 and Soares et al., 2015). Livestock production has been directly accountable to be inefficient and misusing earth resources (HSI, 2011), however according to Godfray et al. (2010) and Gerber et al. (2013) the production efficiency *per* area (considering environmental and cultural factors) is a more appropriate strategy to pursue.

The utilization of rotational grazing for natural grasslands of Pampa biome, using two rest intervals (375 and 750DD), was extremely effective in order to maximize gains *per* area, as demonstrated by BWGs and BWGd. Natural grasslands of Pampa biome have been largely reduced over the last two decades, mainly replaced by annual crops (soybean, mostly), increasing its area in 57% from 2000/2001 to 2014/2015 (Silveira et al., 2017); furthermore, rangelands vegetation vigor over areas of Brazil and Uruguay have been reduced in the last two decades, mainly due to droughts and overgrazing (Wagner et al., 2013). These changes are mainly due to the low animal production indexes over this area combined with changing models of business, as replacement of land property from the beef cattle raising model to the land leasing model (Pizzato, 2013). However, there are several limitations about replacing these natural areas to annual croplands, either from ecological perspectives – mainly water provision and carbon storage (Overbeck et al., 2015) – as from social perspectives – property concentration, oppression against small farmers and enlarging migration of people to cities (Kohlhepp, 2010).

Then, our results represent an important tool for farmers to improve their animal production indexes using relatively small areas. Anyway, there were no differences between the treatments, only climatic season effects for gains *per* area, indicating that both treatments, regardless of season, were capable of increasing the current usage levels of these grasslands at a farm-scale (SENAR/SEBRAE/FARSUL, 2005). This similarity between treatments were due to the stocking rates adjustments that were realized at the same way for both treatments, considering the same levels of forage disappearance (4.5% of BW, using 70% of FMg), with no changes in floristic composition of the natural grassland (Seibert, 2015) . However, when it was evaluated the FA, there was a treatment effect where FA values were greater for 375DD treatment, demonstrating that the range of this variable in our data, made it not effective to explain the gains *per* area, also shown as negative Pearson correlation coefficients between gains per area and FA. Rouquette (2016) showed in his work that FA has a 2-plane relationship with ADG, showing that from a given point FA has no linear relation with gains, as shown in our work; besides, when multiple regressions were tested to predict ADG, forage allowance had any influence in ADG results, only FMg positively and FMe negatively.

Of course, gains *per* area are a function of SR and ADG; although SR had any effect of treatment or season, this result had a significant positive correlation with gains *per* area ($r=0.701$, $p<0.01$). Then, gains *per* area had direct effect from ADG (variable that had an interaction treatments × climatic seasons) leading to an increased gain *per* area during spring and summer seasons. Nonetheless, the lack of difference between SR over seasons it was a clearly effect of using supplementation during winter season that allowed to keep high SR with considerable ADG, even during a season where the forage canopy characteristics was worse than in other seasons, proven by the lowest value of FMg. Similar results also occurs in tropical grasses where swards under rotational grazing have lower leaf proportion and greater SM (Da Silva et al., 2009), reducing forage nutritive value and animal performance (Da Silva and Nascimento Júnior, 2007). Anyway, SR has to be carefully considered once it is considered a key management factor to maximize ranchers' profits and maintenance of rangeland functionality (Teague et al., 2009; Ritten et al., 2010).

While that, ADG had the lowest values during autumn periods for both treatments, although during this period there were no significant changes in forage canopy characteristics and/or forage nutritive values (as shown as FMg, CH, VD, CP and NDF). However, samples used to measure forage nutritive value were collected by grazing simulation and ruminants have a great selectivity capacity, where the forage nutritive value consumed is greater than that of total herbage offered (Sollenberger and Burns, 2001). Structural components could have a detrimental performance, during this season, due to the time spent to search and manipulate the diet, as hypothesized by Carvalho et al. (2015) (where it was also demonstrated low ADG during autumn season). Moreover, forage canopy characteristics described here may not be capable of describing accurately the changes that occurred during this season in a very heterogeneous sward as here described; in this type of grassland, heifers can perform 22 different bite types with bite masses ranging from 0.01 to 4.025 g DM^{-1} (Carvalho, 2013).

Briske et al. (2008) had concluded there was no advantage to use rotational grazing instead of continuous grazing in both plant and animal production. In contrast, Teague et al. (2013) claimed that rotational grazing was more effective when conducted at farm-scale and Wang et al. (2016), whose modeled grazing methods, claimed that rotational grazing could maintain or improve rangeland condition at higher stocking rates. However, most part of experiments used for Briske and coauthors did not consider herbage characteristics to define rotational criteria (rest and occupation periods, for instance) and, most part of them had no stocking rates adjustments. The results obtained in our database, from experiments which considered these points, as herbage physiological traits to manage the rangeland, turns it possible to considerably increase gains *per* area, which were predicted by multiple regressions through forage canopy characteristics (VD and FMg, positively; FMs, negatively; r^2=0.63). Particularly, FMg is directly related to rest intervals criteria (leaf expansion) for both treatments. As observed by Confortin et al. (2016), in the same experimental site indicated, FMg was an adequate variable to adjust stocking rates in a rotational grazing method using these rest intervals criteria. Another important result was the negative influence of FMs on gains *per* area, confirming the importance of the restricted occupation period through using an adjustable number of paddocks (Teague et al., 2015) to maximize rangelands' utilization efficiency.

Management Implications

There are important management implications that can be implied from our results, as relationships between forage canopy characteristics and individual performance as well as forage nutritive value and gains *per* area, for instance. However, the main management implication provided by our experimental design is a management strategy where farmers can increase the rangelands utilization efficiency providing ecosystem services, as maintaining biodiversity and carbon sequestration (Soussana et al., 2007; Kremen and Miles, 2012). On an annual basis, it was produced around 411 kg BW ha^{-1} which were generated using mainly natural grasslands (not edible for human consumption) and small inclusion of by-products, which upgrading of both quantity and quality of protein to humans compared to use plant materials directly as human foods (Patel et al., 2017). These facts are in agreement with some authors (Bommarco et al 2013; Tittonell, 2014) which indicated "ecologically intensive agriculture" as a way to increase resources' use efficiency and reduce the use of external inputs, by increasing reliability on functional diversity.

Despite all that, it is necessary to take this data to a farm-scale and simulate what could be done for farmers who managed these grasslands. For instance, if we simulate a rearing heifers system using the actual data provided by continuous grazing research (Soares et al., 2005; Neves et al., 2009; Mezzalira et al., 2012), it would be necessary around 62 hectares to raise 100 heifers between weaning (7 months old; 160 kg BW) and breeding (24 months old; 347 kg BW). On the other hand, if we simulate the same situation using the results demonstrated in our database, it would be necessary around 28 hectares; gains *per* area for continuous system would remain around 226 kg BW ha^{-1} $year^{-1}$ while using rotational system would represent around 411 kg BW ha^{-1} $year^{-1}$. Anyway, both methods are capable of greatly improving the current situation of animal production in these grasslands and, actually, these methods complement each other. There are considerable costs to implement a multi-paddock system which makes it not so simple to implement in a total farm-scale; however, our proposal is to give farmers a strategy to use on a portion of their farm, concentrating animals in small areas where, for instance, farmers could differ other areas to increase forage mass for drought periods or promote natural seeding (Lemaire et al., 2009; Anderson et al., 2011). Using the same situation simulated before, each hectare in the rotational grazing system would allow differing 2.21 ha in the remaining areas, providing an important strategy to manage rangelands in a farm-scale.

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Figures list:

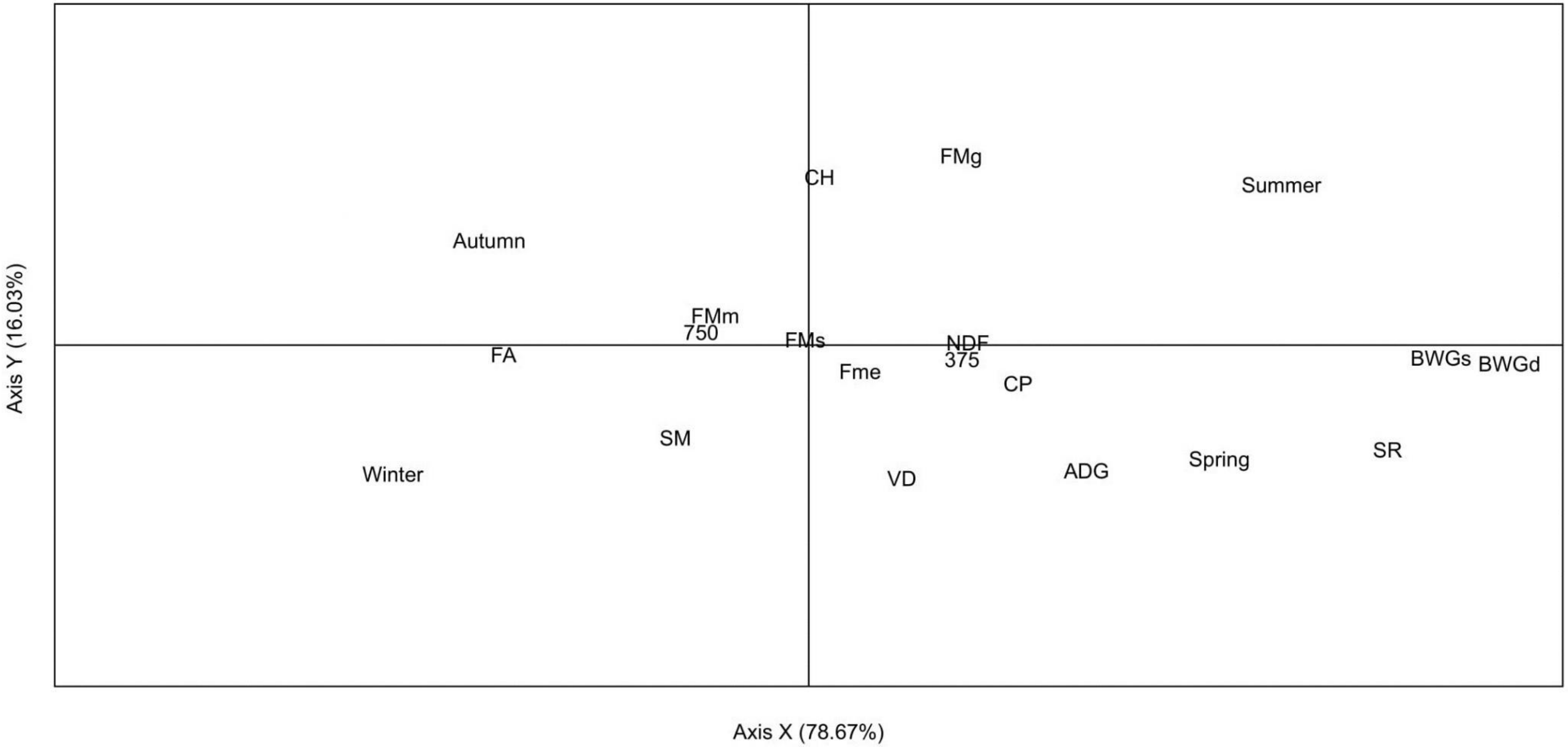

Figure 1 - Ordination diagram of response variables1 and environmental variables (treatments – 375 and 750 DD - and climatic seasons).

[1]FMm (Mean forage mass; kg DM^{-1} ha^{-1}); FMe (Forage mass pre-grazing; kg DM^{-1} ha^{-1}); FMs (Forage mass post-grazing; kg DM^{-1} ha^{-1}); FMg (Green forage mass; kg DM^{-1} ha^{-1}); SM (Senescent material; kg DM^{-1} ha^{-1}); CH (Canopy height; cm); VD (Volumetric density; kg DM^{-1} cm^{-1}); CP (Crude protein; %); NDF (Neutral detergent fiber; %); SR (Stocking rate; kg BW ha^{-1}); FA (Forage allowance; % BW); ADG (Average daily gain; kg BW day^{-1}); BWGd (Body weight gain per day; kg BW ha^{-1} day^{-1}); BWGs (Body weight gain per climatic season; kg BW)

Tables list:

Table 1 - Designation of performing year, climatic seasons, number of animals, supplement use and authors from the experiments used in the database.

Study	Year	Season	Animals/ paddock	Supplement	
				Level	Type
1[a]	2010/ 2011	Spr/Sum	Variable	Ad libitum	Mineral
2[b]	2011	Aut/Winter	Six	0.5% BW	Grounded corn
3[c]	2011/ 2012	Spr/Sum	Variable	Ad libitum	Mineral
4[d]	2012	Aut/Winter	Six	0.5% BW	Wheat bran + glicerol
5[e]	2013	Aut/Winter	Five	1% BW	Wheat bran
6[f]	2013/ 2014	Spr/Sum	Variable	Ad libitum	Mineral
7[g]	2014	Aut/Winter	Six	Ad libitum + 0.9% BW	Protein and grounded corn

[a]Garagorry, F.C., 2012; [b]Kuinchtner, B.C., 2013; [c]Barbieri, C.W., 2013; [d]Carvalho, T.H.N., 2014; [e]Kuinchtner, B.C., 2015; [f]Kuinchtner, B.C., 2015; [g]Casanova, P.T., 2016

*All heifers had access to the protein supplement, but only three were fed with grounded corn (0.9% BW)

Table 2 - Summary of variables from studies included in the database.

Variables[1]	N[2]	Mean	Median	Minimum	Maximum	Standard Error
FMm	71	3518	3272	1021	7108	142
FMe	60	4104	3965	1116	6800	141
FMs	60	3419	3277	925	5662	142
FMg	65	1569	1454	659	2875	64.8
SM	65	1988	1856	457	4428	115
CH	65	18.7	17.8	8.94	35.7	0.662
VD	65	199	208	93.8	352	8.11
CP	65	8.13	8.2	5.24	11.0	0.157
NDF	64	74.1	75.2	60.2	80.8	0.502
SR	72	857	595	358	3243	75.7
FA	72	20.6	18.0	3.29	54.4	1.56
ADG	72	0.265	0.265	-0.0564	0.540	0.0170
BWGd	72	1.04	0.905	-0.163	3.53	0.0909
BWGs	72	94.5	82.4	-14.8	321	8.27

[1]FMm (Mean forage mass; kg $DM^{-1}ha^{-1}$); FMe (Forage mass pre-grazing; kg $DM^{-1}ha^{-1}$); FMs (Forage mass post-grazing; kg $DM^{-1}ha^{-1}$); FMg (Green forage mass; kg $DM^{-1}ha^{-1}$); SM (Senescent material; kg $DM^{-1}ha^{-1}$); CH (Canopy height; cm); VD (Volumetric density; kg $DM^{-1}cm^{-1}$); CP (Crude protein; %); NDF (Neutral detergent fiber; %); SR (Stocking rate; kg BW ha^{-1}); FA (Forage allowance; % BW); ADG (Average daily gain; kg BW day^{-1}); BWGd (Body weight gain per day; kg BW $ha^{-1}day^{-1}$); BWGs (Body weight gain per climatic season; kg BW); [2]N= number of observations

Table 3 - Forage canopy characteristics and forage nutritive value of a natural grassland managed under two rest intervals in four different climatic seasons.

	Treatments													
	375				750									
	Climatic season									P -value			σ^{2}[3]	
Variables[1]	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	SEM[2]	Treatments	Season	Interaction	Exper.	Error
FMm[4]	4227	3178	3612	3394	4143	3936	3816	4269	8,59	0,0124[5]	0,174	0,182	1031435	482976
FMe[4]	3172	3876	3718	3210	4153	4778	4018	4358	465	<0,0001	0,163	0,531	351510	2075571
FMs[4]	2891	2981	3121	3032	3064	3951	3176	3918	548	0,009	0,272	0,128	654777	434077
FMg[4]	1715^{B}	992^{C}	1507^{B}	1898^{A}	1751^{B}	1122^{C}	1754^{B}	2275^{A}	217	0,0237[5]	<0,0001	0,537	121031	113432
SM[4]	2455^{A}	2317^{A}	1985^{A}	1328^{B}	2355^{A}	2564^{A}	2240^{A}	2023^{B}	384	0,0418[5]	0,0081	0,234	461994	272546
CP	7,75	7,93	8,91	8,74	7,76	8,05	8,55	8,39	0,598	0,557	0,182	0,824	0,908	0,883
NDF	76,1	74,2	73,2	72,7	75,4	73,9	72,8	72,2	2,39	0,550	0,180	0,999	18,6	9,79
CH	$20,5^{A}$	$12,3^{C}$	$17,2^{B}$	$18,8^{A}$	$24,7^{A}$	$14,5^{C}$	$20,0^{B}$	$23,1^{A}$	2,32	<0,0001[5]	<0,0001	0,663	17,3	8,32
VD[4]	207^{BC}	249^{A}	213^{B}	177^{C}	168^{BC}	251^{A}	210^{B}	195^{C}	27,2	0,570	0,0002	0,235	2322	1372

[1]FMm (Mean forage mass; kg DM^{-1}ha^{-1}); FMe (Forage mass pre-grazing; kg DM^{-1}ha^{-1}); FMs (Forage mass post-grazing; kg DM^{-1}ha^{-1}); FMg (Green forage mass; kg DM^{-1}ha^{-1}); SM (Senescent material; kg DM^{-1}ha^{-1}); CP (Crude protein; %); NDF (Neutral detergente fiber; %); CH (Canopy height; cm); VD (Volumetric density; kg DM^{-1}cm^{-1}); [2]Standar error of mean; [3]Variance; [4]Co-variable effect of blocks remained in the model, statistically significant (p<0,10); variável do efeito da blocagem para relevo de encosta, baixo e topo permaneceu no modelo pois foi estatisticamente significativo [5]Treatment 750 has greater FMg than treatment 375; [6]Treatment 750 was greater than treatment 375; [A-C]Different capital letters differ significantly for climatic seasons (P<0.05).

Table 4 - Animal performance and herbage-animal relation variables for beef heifers managed under two rest intervals over four different climatic seasons

	Treatments													
	375				750									
	Climatic Season									P -value			σ^2 [3]	
Variables[1]	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	SEM[2]	Treatments	Season	Interaction	Experim.	Error
FA[4]	$29,6^{a}$	$27,7^{a}$	$24,4^{ab}$	$25,2^{ab}$	$15,6^{d}$	$15,5^{d}$	$19,2^{c}$	$22,3^{b}$	5,52	<0,0001[5]	0,465	0,0004	151	34,6
SR	844	875	1010	864	834	813	1142	939	266	0,644	0,212	0,744	316874	88854
ADG	$0,0965^{d}$	$0,237^{c}$	$0,380^{ab}$	$0,441^{a}$	$0,0980^{d}$	$0,306^{b}$	$0,303^{b}$	$0,348^{b}$	0,0624	0,266	<0,0001	0,0237	0,0131	0,00851
BWGs[4]	$62,0^{B}$	$79,6^{B}$	144^{A}	163^{A}	$57,1^{B}$	$86,8^{B}$	100^{A}	129^{A}	24,1	0,0628	0,0004	0,182	1439	1703
BWGd[4]	$0,681^{B}$	$0,874^{B}$	$1,58^{A}$	$1,79^{A}$	$0,627^{B}$	$0,954^{B}$	$1,10^{A}$	$1,41^{A}$	0,264	0,0626	0,0004	0,0651	0,174	0,206

[1]FA (Forage allowance; % BW); SR (Stocking rate; kg BW ha^{-1}); ADG (Average daily gain; kg BW day^{-1}); BWGs (Body weight gain per climatic season; kg BW); BWGd (Body weight gain per day; kg BW $ha^{-1}day^{-1}$); [2]Standard error of mean; [3]Variance; [4]Co-variable effect of blocks remained in the model, statistically significant (p<0,10); [5]Treatment 375 has greater FA than treatment 750; [a-d]Different lowercase letters differ significantly for interaction (P<0.05); [A-C]Differente capital letters differ significantly for climatic seasons (P<0.05).

Table 5 - Multiple regressions for green forage mass (FMg; kg DM^{-1}ha^{-1}), forage allowance (FA; % BW), stocking rate (kg BW^{-1}ha^{-1}), body weight gain per day (kg BW ha^{-1}day^{-1}), body weight gain per season (kg BW per climatic season) and average daily gain (ADG; kg BW day^{-1}) in a natural grassland managed under rotational grazing with beef heifers

y[1]	Equation parameters	Estimates	r^2 partial	r^2 model	P-value	σ^2 error[2]	σ^2 study[3]
FMg	Intercept	-844 (±328)[4]					
	CH	87.8 (±9.29)	0.25	0.49	<0.01	89485	69455
	VD	3.81 (±0.913)	0.24				
FA	Intercept	17.6 (±8.09)					
	SM	-0.003 (±0.00170)	0.28	0.35	<0.01	35.7	258
	VD	0.05 (± 0.0221)	0.07				
SR	Intercept	-28.5 (±1012)					
	VD	2.71 (± 0.835)	0.23	0.45	<0.01	85645	368119
	CP	18.8 (±42.7)	0.15				
	NDF	3.12 (±12.2)	0.07				
BWGd	Intercept	-0.05 (±0.387)					
	VD	0.005 (±0.00140)	0.33	0.63	<0.01	0.248	0.0387
	FMg	0.0001 (±0.000181)	0.15				
	FMs	-0.0003 (±0.00009)	0.15				
BWGs	Intercept	-4.29 (±35.2)					
	VD	0.41 (±0.128)	0.33	0.63	<0.01	2058	320
	FMg	0.0881 (±0.0165)	0.15				
	FMs	– 0.0297 (± 0.0084)	0.15				
ADG	Intercept	0.287 (±0.0586)					
	FMe	-0.00007 (±0.0002)	0.24	0.5	<0.01	0.00787	0.00135
	FMg	0.0002 (±0.00003)	0.26				

[1]Variable response; [2]Error variance; [3]Study variance; [4]Standard error; CH (Canopy height, cm); VD (Volumetric density, kg DM^{-1}cm^{-1}); CP (Crude protein, %); NDF (Neutral detergent fiber, %); FMs (Forage mass post-grazing, kg DM^{-1}ha^{-1}); FMe (Forage mass pre-grazing; kg DM^{-1}ha^{-1})

Appendix A - Pearson correlation coefficients and P-values between variables.

Variables	FA[1]	FMe[2]	FMs[3]	FMm[4]	CH[5]	DV[6]	FMg[7]	SM[8]	CP[9]	NDF[10]	SR[11]	ADG[12]	BWGs[13]	BWGd[14]
FA	1	0,323	0,476	0,629	0,235	0,247	0,235	0,522	-0,478	-0,277	-0,356	0,085	-0,341	-0,341
		0,012	0,0001	<0,01	0,059	0,045	0,057	<0,01	<0,01	0,025	0,002	0,479	0,003	0,003
FMe		1	0,756	0,709	0,599	0,013	0,342	0,420	-0,210	-0,115	0,027	-0,249	-0,145	-0,145
			<0,01	<0,01	<0,01	0,925	0,011	0,002	0,132	0,411	0,839	0,055	0,269	0,268
FMs			1	0,599	0,610	-0,237	0,263	0,033	-0,225	-0,438	-0,434	-0,072	-0,357	-0,357
				<0,01	<0,01	0,084	0,054	0,814	0,105	0,001	0,001	0,583	0,005	0,005
FMm				1	0,370	0,486	0,673	0,855	-0,393	-0,106	-0,093	-0,016	-0,152	-0,152
					0,003	<0,01	<0,01	<0,01	0,001	0,405	0,440	0,896	0,207	0,206
CH					1	-0,429	0,464	0,031	-0,313	-0,121	-0,277	-0,339	-0,392	-0,392
						0,0004	0,0001	0,805	0,012	0,342	0,026	0,006	0,001	0,001
DV						1	0,274	0,784	0,092	0,011	0,369	0,241	0,307	0,307
							0,026	<0,01	0,467	0,928	0,002	0,051	0,012	0,012
FMg							1	0,423	-0,169	0,139	0,025	0,116	0,134	0,134
								0,0004	0,179	0,270	0,842	0,352	0,283	0,283
SM								1	-0,234	-0,083	0,169	-0,069	-0,085	-0,085
									0,061	0,513	0,176	0,580	0,500	0,499
CP									1	-0,060	0,390	0,129	0,443	0,443
										0,634	0,001	0,307	0,0002	0,0002
NDF										1	0,321	-0,202	0,266	0,266
											0,009	0,107	0,032	0,032
SR											1	-0,106	0,719	0,718
												0,375	<0,01	<0,01
ADG												1	0,439	0,439
													0,0001	0,0001
BWGs													1	1,00
														<0,01
BWGd														1

[1]Forage allowance (% BW); [2]Forage mass pre-grazing (kg $DM^{-1}ha^{-1}$); [3]Forage mass post-grazing (kg $DM^{-1}ha^{-1}$); [4]Mean forage mass (kg $DM^{-1}ha^{-1}$); [5]Canopy height (cm); [6]Volumetric density (kg $DM^{-1}cm^{-1}$); [7]Green forage mass (kg $DM^{-1}ha^{-1}$); [8]Senescent material (kg $DM^{-1}ha^{-1}$); [9]Crude protein (%); [10]Neutral detergente fiber (%); [11]Stocking rate (kg BW ha^{-1}); [12]Average daily gain (kg BW day^{-1}); [13]Body weight gain per climatic season (kg BW); [14]Body weight gain per day (kg BW $ha^{-1}day^{-1}$)

5. CAPÍTULO II

Validity of the timing and duration of observation periods of beef heifers foraging behavior in natural grasslands

Capítulo baseado nas normas para submissão de artigo científico da revista Animal Production Science

Validity of the timing and duration of observation periods of beef heifers foraging behavior in natural grasslands

Abstract: The goals of this work were to evaluate for how long foraging should be monitored over a 24 hour period to predict foraging behavior of beef heifers within a season and check the patterns of foraging activity over 24 hours. Database was collected between 2010-2012 with beef heifers managed under rotational grazing in natural grassland. Foraging, rumination and other activities times were assessed visually during 24 hours in 15 occasions. Data were classified according to climatic seasons, generating 12 replicates in summer, 18 in spring, 24 in autumn and 36 replicates in winter. Treatments were the evaluation of four distinct periods of time: from sunrise to sunset (DAY-SUN), daylight duration from dawn to nightfall (DAYLIGHT), DAYLIGHT plus two hours (DAYLIGHT+2), DAYLIGHT to midnight (DAYLIGHTto0) and the entire 24 hours (CONTROL). Differences for foraging, rumination and other activities were found for all seasons among evaluation periods tested. Sampling sufficiency was reached only between the DAYLIGHTto0 and CONTROL for all four climatic seasons. The DAYLIGHTto0 treatment covered 75% of a 24 hours period and 95% of the mean foraging time taking place during this time interval. About the foraging distribution over the day, in the warm seasons, the major foraging period during mornings occurred earlier than in the cool seasons and in cool seasons the foraging peak was observed during the afternoons. Visual observations starting at dawn until the mid-night hour were able to represent the total foraging time and it could be used to represent foraging activities during the entire day.

Keywords: grazing behavior; grazing distribution; foraging activities; monitoring behavior; grazing patterns

1 Introduction

Foraging behavior can be an important consideration when establishing management goals, because animals' behavior on pasture gives clues to judge if pasture management decisions are suitable or not (Gonçalves et al., 2009). Furthermore, the behavior of animals in controlled situations, such as grazing trials, gives insight into the production data collected.

Among variables of the foraging behavior, foraging time is the easiest variable to monitor, especially with Global Navigation Satellite System (GNSS) technology (Anderson et al., 2013), and it is the key variable to use as an indicator of management efficiency. According to Hodgson (1982), in temperate climate, ruminants commonly have a foraging time between 450 to 600 min/day. Under subtropical and tropical conditions, ruminants rarely forage less than 360 min/day up to intervals that may exceed 760 min/day (Carvalho et al., 1999). Evidently, these magnitudes in foraging time are due to the interaction of animal and plant factors including sward structure and available herbage. In the Southern Brazil Campos Grasslands (Allen et al., 2011), without limitations to inhibit potential intake (*e.g.* herbage mass or sward height), the time spent foraging may range between 500 – 650 min/day (Carlotto et al., 2010; Mezzalira et al., 2012; Pinto et al., 2007), regardless the grazing method used (Barbieri et al., 2014). Foraging time comparisons among experimental treatments, or even among different experiments, allow us to make conclusions about the management success of particular protocols. However, there are no records about the ideal period of foraging time evaluation that would be recommended to evaluate the pasture management success.

Despite the fact that foraging behavior studies have already been defined as an important evaluation, there are different propositions, by different research groups, in relation to the extent of the evaluations (*e.g.* during the daylight period or for 24h periods; Phillips and Schofield, 1989). This is due to three main factors: (i) availability and costs of skilled observers, (ii) circadian behavior rhythms associated to daylight, mainly in temperate climate, and (iii) needs for artificial light in sunlight absence.

The 24 hour visual evaluations could be less feasible in the 21ST century, in part because requires a large number of trained people. Furthermore, artificial light during dark periods may affect animals´ natural behavior (Gregorini et al., 2006). The introduction of GNSS technology to evaluate animal behavior in free ranging experiments is improving this type of evaluation. With limited labor, animals with GNSS system can be observed during daylight and their rate of movement during foraging recorded electronically besides, this system allows to identify similar foraging intervals during darkness and when observers are absent (Anderson et al., 2012). Other protocols have been reported including the IGER (Rutter et al., 1997) and bioacoustics (Alkon et al., 1989). However, all of these electronic devices should be calibrated with visual assessments to adapt the protocols to different environments around the world. Furthermore, continuous 24-hour assessments is the more accurate evaluation, mainly by evaluating a larger and fixed period, regardless of climatic season (1440 min/day).

Evaluations performed only during daylight periods, regardless of time interval, have been justified by ruminants' pattern of diurnal foraging behavior and based on labor requirements (Champion et al., 1994, Linnane et al., 2001). According to Phillips and Schofield (1989) and Gregorini et al. (2006), sources of supplementary light induce animals to eat, suggesting that animals prefer to consume forage when light is present, as shown when there is moonlight (Dulphy et al., 1980). Rumination and other activities occur between foraging bouts, probably due to the rumen dynamics (Dulphy et al., 1980; Phillips and Leaver, 1986).

During autumn and winter, restriction to daylight evaluations could be seriously biased due to the reduced day length (photoperiod) and, mainly, because in this period the quantity and quality of the forage are substantially different from other periods of the year, in the case of natural grasslands. Moreover, daylight observations do not consider animal behavior during nighttime, when heifers have been shown to forage (O'Connel et al., 1989), this observation was explained by lower temperatures during the night on tropical and subtropical conditions. Preference for foraging at night could be due to more comfortable air temperatures over this period (Gregorini et al., 2006). However, it was determined that nighttime foraging behavior has a shorter duration when compared to the daylight; furthermore, these foraging events could represent as much as 35% of the total foraging time over 24 hours in hot weather or during long nights (Dulphy et al., 1980, Hodgson, 1990; Gregorini, 2008). Besides, during these foraging events at night, Gregorini (2008) demonstrated that animals have a heavy bite mass (Gregorini, 2008).

Thus, considering Linnane et al. (2001) hypothesis (stating that foraging time occurs mainly during the daylight period and the need of visual observations to calibrate automatic registration methods for Southern Brazil Campos Grasslands), the objectives of this work were to evaluate for how long foraging should be monitored over a 24-hour period to predict foraging behavior of beef heifers within a season and check the patterns of foraging activity over 24 hours.

2 Material and Methods

2.1. Local, experimental area, climate and behaviour assessments

Fifteen experimental periods of behavior visual observations were analyzed from experiments conducted in natural grassland managed under rotational grazing method (with different rest intervals) using beef heifers, during three consecutive years. The experimental area is at the Federal University of Santa Maria (UFSM), Central Depression region of Rio Grande do Sul State (Brazil), with the center of the experimental area at approximately

29º43’30” S, 53º45’33” W. The climate has been described as subtropical humid, with a mean ambient annual temperature of 19.2ºC and mean annual rainfall of 1770 mm, at an elevation 95m above sea level (Moreno, 1961).

The experimental area of 22.5 ha was divided into six rectangular paddocks each one with 3.5 ha. Each of these six areas was subdivided into seven smaller sub-paddocks to perform the rotational grazing cycle. The criteria to define the rest period of sub-paddock was the thermal sum accumulated (degree Celsius *per* day; DD), for the duration of leaf elongation of two grasses groups which are classified according to the functional groups proposed by Cruz et al. (2010) (*as described below*).

Over the three years, three paddocks were managed using a rest interval of 375 DD of accumulated thermal sum and the other three paddocks were managed using 750 DD of accumulated thermal sum. The 375 DD rest interval is based on the accumulated temperature for elongation of 2.5 leaves *per* tiller of grasses of functional groups A and B (*e.g., Coelorhachis selloana* and *Paspalum notatum*; Eggers et al., 2004). The 750 DD rest interval is based on the accumulated temperature for elongation of 1.5 leaves *per* tiller of functional groups C and D (*e.g., Aristida laevis* and *Saccharum trinii;* Machado et al., 2013). For defining the rest intervals in each treatment, mean phyllocron (time in DD for complete leaf elongation) of each group (375 or 750DD) was multiplied by the number of expanding leaves *per* tiller, generating the rest periods of each sub-paddock. The number of expanding leaves of the grasses in the functional groups is intrinsic to the plants genetic traits and defines the time of rest intervals (Cruz et al., 2010). In this way, the occupation period was defined by dividing rest intervals (in thermal sum) of each treatment by the number of sub-paddocks less one (sub-paddock under occupation), resulting in the time, in Celsius degrees, of occupation of each sub-paddock.

Each year, a variable number between 24 and 36 beef heifers (at least four heifers *per* paddock) were evaluated with variable body weights (177 to 215 kg) and age (12 to 24 months)

(Table 1). Variations in weight and age were within the range for heifers rearing to breed at 2 years old. During the grass growing seasons (spring and summer), heifers were supplemented only with mineral salt and they had access *ad libitum* to water. In 2010 during the winter, heifers were supplemented with mineral protein salt *ad libitum* (Knorr et al., 2005). In 2011 during the winter, heifers were supplemented with grounded corn, in a basis of 5 grams *per* kg of body weight (0.5%). In 2012, during the winter, the heifers were supplemented, in the same percentage than the previous experiment, with wheat bran (85%) and glycerol (15%). The stocking rate adjustments were made each 28 days based on a 4.5% of disappearance of 70% of the grass leaf blades.

(Insert table 1 here)

The experimental area was arranged as a randomized block design with the two rest periods (described above) as the treatments (375 and 750 DD), using rotational grazing management and three area replicates (six paddocks, three for each rest period). The blocking criterion was the relief (top, convex slope and lowland). This arrangement was set at 2010 and managed all around the year for three years. Details about the management could be seen in Barbieri et al. (2014).

Behavior evaluations were tested through an analysis of variance model (considering $P \leq 0.05$ as the level of significance). Since there were no differences between foraging and rumination time between treatments (375 and 750 DD), we used all data to form a larger database. Data were clustered by year, generating four evaluations in 2010 (4×6 paddocks = 24 replicates); six evaluations in 2011 ($6 \times 6 = 36$ replicates); and five evaluations in 2012 ($5 \times 6 = 30$ replicates). Year was used as block in the statistical model to remove possible climatic differences among the years. After, data were clustered by season, regardless the year (blocked), what generate 12 area replicates in summer; 24 area replicates in autumn; 36 area replicates in winter; and 18 area replicates in spring. After clustering the data (years and climatic seasons), foraging and rumination time did not present significantly differences among the original treatments (375 DD and 750 DD), making possible to use all data to perform the timing and sample sufficiency analysis.

2.2 Natural grassland characterization

Experimental area was composed mostly by C_4 metabolic cycle grasses having a spring-summer growth period. Sward production is drastically reduced during the cool seasons (autumn and winter), concomitantly with a worsening in their chemical composition, mainly due to the high contribution of warm season grasses in the herbage mass. Cool seasons can be characterized by reduction in temperatures and photoperiods as well as occasional frosts occurrences (Carvalho et al., 2006). About the type of grassland, a major part of Campos grasslands (Allen et al., 2011) present a well-defined double layer canopy structure. In this case, lower strata was composed by short-grass species as *Axonopus affinis* and *Paspalum notatum*, mostly with a prostrate growth pattern. These species are highly preferred by free ranging cattle. In the upper strata were found grass species with a tussock-like growth habit, as *Andropogon lateralis* and *Aristida laevis* (Quadros et al., 2009).

The herbaceous vegetation consisted (mean contribution for green herbage mass in brackets) primarily of: *Andropogon lateralis* (±37%), *Aristida laevis* (±14%), *Saccharum trinii* (±6%), *Shorgastrum nutans* (±6%), *Paspalum plicatulum* (±3%), *Axonopus affinis* (±6%), *Paspalum notatum* (±9%); species within the Umbelliferae family, including *Eringium horridum* (±3%), and ±16% representing other plant families, including woody plants (each one with insignificant amounts; < 1%). Furthermore, 117 species, representing 33 grass genders have been documented in this experimental area (non-published data). The most abundant grass species were from A and B functional groups (*Andropogon lateralis*, *Axonopus affinis*, *Paspalum notatum;* see Cruz et al., 2010 for details of functional groups) which comprise 52%

of the mean green herbage mass; and from C and D groups (*Aristida laevis*, *Saccharum trinii*, *Shorgastrum nutans*, *Paspalum plicatulum*), comprising 29% of the herbage mass.

The individual contribution, for aboveground herbage biomass, of each specie is modified along the year, mostly due to the variations in environmental temperatures over time (seasons). However, there were no recorded changes in the presence or absence of species over the years. The quantity of senescent plant material in the paddocks also changed among seasons, being lower in the spring (±20% of total herbage mass) and greater in the winter season (±55% of total herbage mass). All these values (species contribution and botanical composition) were obtained using BOTANAL method as described by Tothill et al. (1978). Herbage mass (HM) was measured using a visual standard comparison, calibrated with double sampling technique (Haydock and Shaw, 1975), with 20 visual estimatives and six cuts at ground level, using 0.25 m^2 quadrats. All regression equations derived from visual assessments were above 0.7 of determination coefficient (R^2). In each evaluation of HM, sward height was measured with a sward stick, at the same points of HM evaluations. We did not consider the tall tussock grasses in sward height measurements.

2.3 Foraging behavior

Foraging behavior evaluations began on the second day of occupation of the sub-paddocks, regardless if the management was 375 or 750 DD (dates in Table 1). The mean time of occupation of the sub-paddocks was four days with a range between two to five days (spring and summer) and seven days with a range between five to ten days (autumn and winter). In all assessments, the mean value of the observations from all animals (at least four animals *per* sub-paddock) that were inside the sub-paddocks was considered the experimental unit.

For assessments, trained evaluators were placed at ground level approximately five to ten meters from the heifers to facilitate the visualization of animal's behavior. One evaluator was randomly assessed to each paddock for a change of shifts of two hours and four persons were required per 24 hours in each sub-paddock. Previously, heifers were exposed to night observations with flashlights to get used them to this type of lights. Animals were previously habituated to close handling by people using daily supplementation on grassland, so flashlights and close observations appeared to have minimal impact on the animal's behaviour.

Total foraging time, rumination and other activities time were visually recorded, every ten minutes, over 24 consecutive hours, and results were expressed in min/day. The recording frequency was chosen based on previous data reported by Gary et al. (1970) and Mezzalira et al. (2011). Foraging was defined to include the time spent by searching to select and gathering forage for biting similar to that previously described by Hodgson (1990). Rumination time was defined as the cessation of the foraging and the beginning of the jaw movements. Time of other activities was considered as the time when animals were not foraging or ruminating and it could be idling, in social activities, drinking water or eating supplements (Forbes, 1988).

2.4 Treatments for timing and sampling sufficiency evaluation

In a previous analysis of variance (as described before), there were no differences among treatments (375 DD and 750 DD rest intervals) and, then, data were recombined in five treatments regardless of rest intervals, which consisted the comparison between timing and duration of observation periods to test the sufficiency of sampling duration, for foraging time analysis. Due to the data similarity of the original treatments, each paddock was used as a replicate in each of the seasons, generating 12 replicates in summer; 24 replicates in autumn; 36 replicates in winter; and 18 replicates in spring. Differences between seasons were not compared because of the differences in day length among seasons and because the differences in green biomass availability and herbage quality.

Validation of the timing and duration of observation periods, in each season, were accounted for foraging, rumination and other activities times observed along uninterrupted periods of 24 hours. Treatments consist in evaluation of four distinct periods having different lengths based on the following selected intervals: sun duration - during the day from sunrise to sunset (DAY-SUN); day light duration - from dawn to dusk (DAYLIGHT); DAYLIGHT plus two hours (DAYLIGHT+2); DAYLIGHT to midnight (DAYLIGHTto0); and the entire 24 hours (CONTROL) (see details in Figure 1).

(Insert Figure 1 here)

To obtain the exactly times of sunrise and sunset, it was used historic data (mean of 30 years) registered by the National Institute of Meteorology (INMET) station in Santa Maria, Rio Grande do Sul State (the platform responsible to collect these data is situated around three kilometers of the experimental area). The mean time of sunrise and sunset was calculated, based on the INMET database, for each season. Using these times, it was identified the beginning and the end of the DAY-SUN treatment (Table 2). This information was used for dawn and dusk durations as described by Miguens (1996). In this description, sun position is 6º above (sunrise) and -6º below (sunset) the horizon (dusk or civil twilight). The mean values of dawn and dusk (in minutes, mean of each season) were added to the mean sunrise and sunset hour, to determine the start and the end of behavior evaluations that, in turn, defined the DAYLIGHT treatment (see Table 2).

(Insert table 2 here)

In the DAYLIGHT+2 treatment, animals were evaluated from dawn until two hours after dusk ended. For the DAYLIGHTto0 treatment, behavior was evaluated between dawn and midnight (00:00; midnight). For DAYLIGHT+2 and DAYLIGHTto0 treatments, the end of the evaluations were considered a fixed period of time, until sampling sufficiency was reached. The evaluation period (time), even within the same treatments (except in CONTROL treatment), was different between climatic seasons and this fact was due to the photoperiod changes among climatic seasons (Figure 1), influencing the time to begin the assessments.

2.5 Data analysis

The statistical analyzes used a block design model where each year was considered a block. Each paddock was considered a replicate (mean of animals inside the paddocks) and there were six replicates (paddocks number in the experimental area) in each trial (15 trials during three years). In spring, data were analyzed with 18 replicates, in summer with 12, in autumn with 24 and in winter with 36 replicates. Results were presented separately by season due to the differences in day length between seasons.

The analysis of foraging time (minutes *per* hour during 24 hours) was performed using the mean values of foraging time from all replicates of the database. For this analysis, data were separated by climatic seasons and, using mean values of all replicates in each climatic season, it was calculated the foraging time (minutes *per* hour) in each hour of the day. From this, it was compared the foraging time in each hour between climatic seasons.

Initially, data were submitted to a Bartlett test followed by a Shapiro-Wilk test to check the homogeneity of variance and normality of residuals, respectively, at $P<0.05$. After checking it, data were submitted to the analysis of variance and F test, again at $P<0.05$. Means comparison analyzes were made using PROC MIXED (Tukey test at $P<0.05$) from SAS 9.2 software, including in the model the effects of blocks (years) and treatments (evaluation periods). The criteria for sampling sufficiency of duration of observation periods was when comparisons between CONTROL and other treatments were similar (P>0.05).

3 Results

3.1 Sward characteristics

Mean herbage mass produced during the experimental years was 3871 kg/DM.ha (DM; dry matter), ranging from 3017 kg/DM.ha to 4242 kg/DM.ha. Besides, mean sward height, without tussock species, was 20 ± 3.9cm; ranging from 17.3 ± 3.3cm to 22.5 ± 4.1cm. Sward characteristics were similar among the paddocks and, besides, typical of this grassland formation.

3.2 Timing and duration of observation periods

There were differences (P<0.05) for foraging, rumination and other activities times among all seasons and treatments within 24h (Table 3). There were differences in foraging time between DAY-SUN and DAYLIGHT treatments (treatments with lower observation period) in summer and winter seasons. In summer, foraging time observed in the DAY-SUN treatment represented 82.7% of the total time spent foraging (time observed in CONTROL) and, this treatment evaluated 56.9% of day length. In DAYLIGHT, foraging time observed represented 88.1% of the total foraging time (time observed in CONTROL) and the DAYLIGHT evaluated 60.4% of day length. These treatments (DAY-SUN and DAYLIGHT) presented lower (P<0.05) foraging time than the time observed in the CONTROL.

(Insert table 3 here)

In winter, the DAY-SUN treatment covered 74.9% of the foraging time observed in the CONTROL and DAY-SUN treatment represented only 47.2% of a day length. In DAYLIGHT treatment, it was observed 79.7% of the foraging time observed in CONTROL and DAYLIGHT represented 50% of the day length. Rumination and other activities time were similar between DAY-SUN and DAYLIGHT treatments among all seasons. However, rumination time was lower in these treatments relative to the CONTROL.

In the DAYLIGHT+2 treatment, foraging time differences were observed in the spring, autumn and winter comparing with other evaluation periods (treatments). In this treatment, foraging time was greater than the time spent foraging in the two treatments that evaluating foraging time only on day clarity period (DAY-SUN and DAYLIGHT) and lower than grazing time observed in DAYLIGHTto0 and CONTROL treatments. In spring, foraging time in DAYLIGHT+2 represented 88% of the CONTROL and this treatment evaluated 68.1% of the day length. During autumn, foraging time of DAYLIGHT+2 represented 81.5% of the foraging time observed in the CONTROL and this treatment evaluated 57.5% of the day length. During winter, foraging time in DAYLIGHT+2 represented 84.1% of the CONTROL, evaluating 58.4% of the day length. Anyway, in any season, DAYLIGHT+2 treatment reached the foraging time representativeness of foraging time observed over the 24 hours of the day. In general, rumination and other activities time increased with the increase of the evaluated period in all seasons.

Sampling sufficiency of duration of observation periods for foraging time were achieved when the evaluations were realized until the midnight (DAYLIGHTto0 treatment) in the four seasons (treatment DAYLIGHTto0 *VS* CONTROL; Summer P=0.485; Spring P=0.278; Autumn P=0.212; Winter P=0.196).

Foraging time during summer season in the DAYLIGHTto0 treatment represented 97.8% of the foraging time measured in CONTROL, evaluating 77.1% of the day length. In spring, foraging time in the DAYLIGHTto0 represented 91.5% of the foraging time observed in CONTROL, evaluating 76.4% of day length. During winter, foraging time in the DAYLIGHTto0 represented 91.5% of foraging activity from CONTROL, evaluating 72.9% of the day length. In autumn, foraging time in the DAYLIGHTto0 represented 94.8% of activity from CONTROL, evaluating 73.6% of day length. Again, there was a change in the representativeness in the different treatments due to the differences in the time of dawn, in the different seasons. Despite that, there was an increase in the evaluation period until the time evaluated in the DAYLIGHTto0 treatment; time spent in rumination and other activities were different compared with CONTROL ($P<0.05$)

In a general way, in summer and spring, rumination time during periods of natural clarity (day), only represented 37.6% of rumination time compared with 24 hour period (CONTROL). The remaining rumination time (62.4%) was observed during dark periods (night). In the cool seasons (autumn and winter), 23.9% of rumination time was observed during light periods and 76.1% over the night. Furthermore, the remaining activities followed this same pattern: during summer and spring, 31.1% of other activities occurred during day period (natural light), while the remaining time (68.9%) was observed during the darkness. In the cool seasons (mean of autumn and winter), other activities were distributed 43% during day and 56.9% during darkness.

3.2 Diurnal foraging patterns

Distribution of foraging time over 24 hours presented some similarities among seasons, mainly when comparing warm seasons (summer and spring) with cool seasons (autumn and winter) (Figure 2).

(Insert figure 2 here)

During spring and summer, the first more intense foraging cycle (or peak) occurred earlier, around 4:00 in the morning. At 5:00, foraging activity was more intense on warm seasons than during cool seasons ($P<0.05$). In autumn and winter, the first foraging peak started around 6:00 hours. The difference ($P<0.05$) on foraging intensity between warm and cool seasons was observed until 8:00. In all seasons, after this more intense activity, foraging activity was reduced until 10:00 hours (more details in supplementary file; Table 4).

During late morning, around 11:00, a second more intense peak of foraging activity occurred in the summer and it was different from other seasons ($P<0.05$). In this same part of the day (late morning and early afternoon), cool seasons and spring had a more constant foraging distribution. Regardless the season, during late afternoon and in the beginning of the night (16:00 – 20:00 hours), a second foraging peak was observed. This peak in the foraging activity started earlier in the autumn and winter when comparing to spring and summer. In winter and autumn, this intense foraging activity started around 15:00 to 16:00 hours. This foraging peak had, approximately, a duration of three hours, one hour less than the duration of the foraging peak observed during the warm season. In summer and spring, the intense foraging activity happened between 17:00 – 21:00 hours.

After this foraging peak in late afternoon, foraging activity was reduced during the early evening. In cool seasons, this foraging activity reduction ranged from 19:00 - 22:00 hours. During spring, this reduction was shorter, and ranged from 21:00 to 22:00 hours and, in the summer season, foraging activity was evident from 21:00 - 0:00 hours. Furthermore, in spring, autumn and winter, heifers had another short foraging peak during the night (between 23:00 to 1:00 hours). Only during summer, heifers presented a low foraging activity during the night.

4. Discussion

Both plant and animal factors can influence animal's foraging behavior, among other factors as weather and quantitative and qualitative sward characteristics (Trindade et al., 2012). During the three years when foraging behavior was evaluated, herbage mass and sward height did not limit forage intake because these variables had not values in the range of sward structure considered to be limiting for beef heifers intake on natural grasslands (Gonçalves et al., 2009). Thus, the evaluation of these variables allowed us to claim that foraging behavior of beef heifers in this study was not influenced by these factors.

Recent ruminant behavior literature evaluating foraging behaviour has focused only on day light observations either in cool season pasture (Baggio et al., 2009), summer pasture (Silva et al., 2010) and natural grasslands (Mezzalira et al., 2012;; Trindade et al., 2012), in different types of weather. In temperate climates, weather is characterized by milder environmental temperatures during the day but cold environmental temperatures during the night (Champion et al., 1994). Thus, in this environment, foraging activity occurs predominantly during day light hours, probably due to the link with thermal comfort (Linnane et al., 2001). Major foraging events occur near sunrise and sunset, with the latter having greater intensity and longer duration (Gibb et al., 1998). However, in tropical and sub-tropical conditions, as it was demonstrated in this experiment, animals have more dispersed foraging activities over 24 hours, independently of the season. Supporting this, according with some authors (Phillips & Leaver, 1986; Gregorini et al., 2006; Gregorini et al., 2008), in subtropical and tropical climates, animals can take a significant part of foraging during non-daylight hours together with rumination and rest.

Another important fact is that hibernal grass species have a high nutritional quality (typical feature of the pastures in temperate climate), supporting the nutritional demands of the animals over the entire day. Due to this, night foraging activity is usually characterized as occurring in shorter intervals and in less intense bouts. Overall night foraging represents a small percentage of daily foraging time and contribute minimally to daily herbage intake in temperate climates (O'Connell et al., 1989; Krysl and Hess, 1993). Differently, in natural grasslands, as in our experiment, sometimes the nutrient concentrations of the pasture are not so high and, consequently, animals have to spend more time around the day to attend their energetic requirements.

According with our treatments, evaluations of foraging time which considered only day length (DAY-SUN and DAYLIGHT) were incomplete in representing foraging time of heifers over 24 hours (CONTROL). In these treatments, foraging time was significantly lower than foraging time evaluated in the CONTROL treatment. Even when two hours were added at the end of sunset (DAYLIGHT+2), the time spent foraging was significantly lower than foraging time measured over all 24 h (CONTROL). This definitively suggests there is a significant nighttime foraging (Figure 3).

Champion et al. (1994) and Gregorini et al. (2006; 2008) suggest that both sheep and cows may have significant meals at night. In temperate climates, ruminants have around three major grazing events *per* day: at sunrise, around 12:00 and at sunset (Gibb et al., 1998). However, this pattern is flexible and affected by external environment conditions, especially environmental temperatures. According to Gregorini et al. (2006), an adaptation could be an increase in the length of foraging events and a decrease in the number of meals during short days, or ruminants could increase meals number, including time at night to allocate these meals.

However, DAYLIGHTto0 treatment had, an average, 35 minutes less of total foraging time than the CONTROL, but this difference was not significant (P>0.05) between these treatments. So, it is possible to confirm that the time extent of foraging behaviour assessments that should be evaluated, because this period (DAYLIGHTto0) represented the total foraging time performed in the CONTROL treatment. Thus, with the evaluation of 75% of the entire day, all day light period and part of the dark period (in this case, until midnight), it was possible to evaluate a correspondent period to CONTROL treatment. Additionally, our data support, in a tropical climate situation, the affirmation that sunlight (including dawn and dusk) has a strong influence in the animal activity (Rutter et al., 2002). Besides, another important fact is that foraging events, which occur after sunset, should not be underestimated (Krysl and Hess, 1993). Nevertheless, trails assuming that foraging time observed only between sunrise and sunset (natural light) represents an accurate estimate of the foraging time, are underestimating the real time that animals spend foraging. This error can become magnified when this incomplete information is used to estimate/calculate other behaviour variables (*e.g.* bite mass) causing serious misunderstandings.

In some trials, bite mass is estimated through the division of daily animal intake by the daily bites number that, in turn, it is estimated by multiplying the bite rate by total foraging time. Our data suggest that it is possible to estimate more accurately by using foraging time recorded between dawn until midnight (0:00h). It is also recommended a preliminary trial for identifying main intervals of foraging activity. Using the results generated by our data, it is possible to reduce 25% in the total evaluation period with no effects in foraging representativeness [all seasons mean: 94% of the total grazing time observed in the CONTROL treatment ($P>0.05$)]. This protocol reduces possible overestimations of other dependent variables of foraging time and allows the comparison between trials conducted in similar conditions.

Besides, foraging distribution parameters observed over a 24 hour period (Figure 3) and daily patterns of foraging activity were validated with our data (Linnane et al., 2001). Clearly, foraging activity occurs mainly during day light and the influence of day length changes the animal's foraging pattern. Moreover, the different foraging peaks, during different seasons, demonstrate the animal's ability to adapt their foraging activity to variations in daylight, reserving most rumination and rest activities for periods of darkness. Besides, there are other factors to determine this pattern as the difficulty of food selection in dark periods (Linnane et al., 2001), defense mechanisms (Rook and Huckle, 1997) and hormonal factors (Gregorini, 2012).

The extent of foraging taking place at daylight in summer and spring (higher temperatures) compared to autumn and winter (lower temperatures) were not highly variable, even though the peaks in this behaviour occur during different periods of the day. In summer and spring, foraging begins earlier in the day compared to the autumn and winter seasons. In the same way, foraging peak during the morning is more intense on warm seasons than cool seasons. This fact is probably due to the larger photoperiod encouraging the animals to start foraging earlier (Gregorini et al., 2006; 2008) and, in this way, it would reduce the need for foraging during the hottest period of the day (late-morning/early afternoon).

After animal´s first meal (morning grazing peak), animals decrease the time that they spend foraging, probably due to the rumen filling (Demment et al., 1995). Another very important fact supported by our data is the relation with the use of feeding supplements: in production systems, when the use of supplementary source of feeding is necessary, supplements should be offered to the animals between the peaks of foraging. Thus, with this management, it is possible to reduce substitution of herbage by supplement. Furthermore, when it is used energetic supplements, this management allows a better use of herbage nitrogen (Poppi and Mclennan, 1995).

Foraging peak during earlier afternoon, during the autumn and winter compared to summer and spring, may be a consequence of the interaction of photoperiod and environmental temperatures. The first are related to the light period, when animals can distribute better their grazing activity (Linnane et al., 2001), avoiding the high temperature periods of the day. Secondly, animals start foraging when temperatures are milder (afternoon end). In seasons with high environmental temperatures, foraging peak [mainly in summer (Gregorini et al., 2006; 2008)] is slightly longer than in other seasons.

The longer duration and later start of the afternoon foraging peak, probably, influence the latter onset of foraging over the night period, during the summer. Only during the summer, animals did not present a meal during night between 22:00 to 1:00h. Foraging events over the night are also necessary for the animals to maintain their metabolic heat production (by rumen fermentation), during cool seasons (Forbes, 2007). Furthermore, our data of nighttime behaviour observations contradict the assumption that heifers do not forage for significant periods at night (Phillips e Leaver, 1986; O'Connell et al., 1989; Krysl and Hess, 1993). Therefore, in this type of experiment, if one of the experimental goals is to measure the length of foraging events, it would be necessary to accurately evaluate periods of night time foraging, especially under subtropical and tropical climate conditions.

5. Conclusion

Visual observations starting at dawn until the mid-night hour were able to represent the total foraging time in a subtropical natural grassland. This period could be used to represent foraging activities performed during the entire day and, besides, it could be useful for calibration of automatic recording devices.

Diurnal evaluations of foraging behavior of beef heifers do not contemplate the necessary time to represent foraging activities in natural grasslands, in subtropical and tropical conditions.

Beef heifers managed in natural grassland have a diurnal pattern of foraging. However, there are significant foraging events in dark periods and there are also significant changes between seasons in the moments that animals perform these events.

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Figures list:

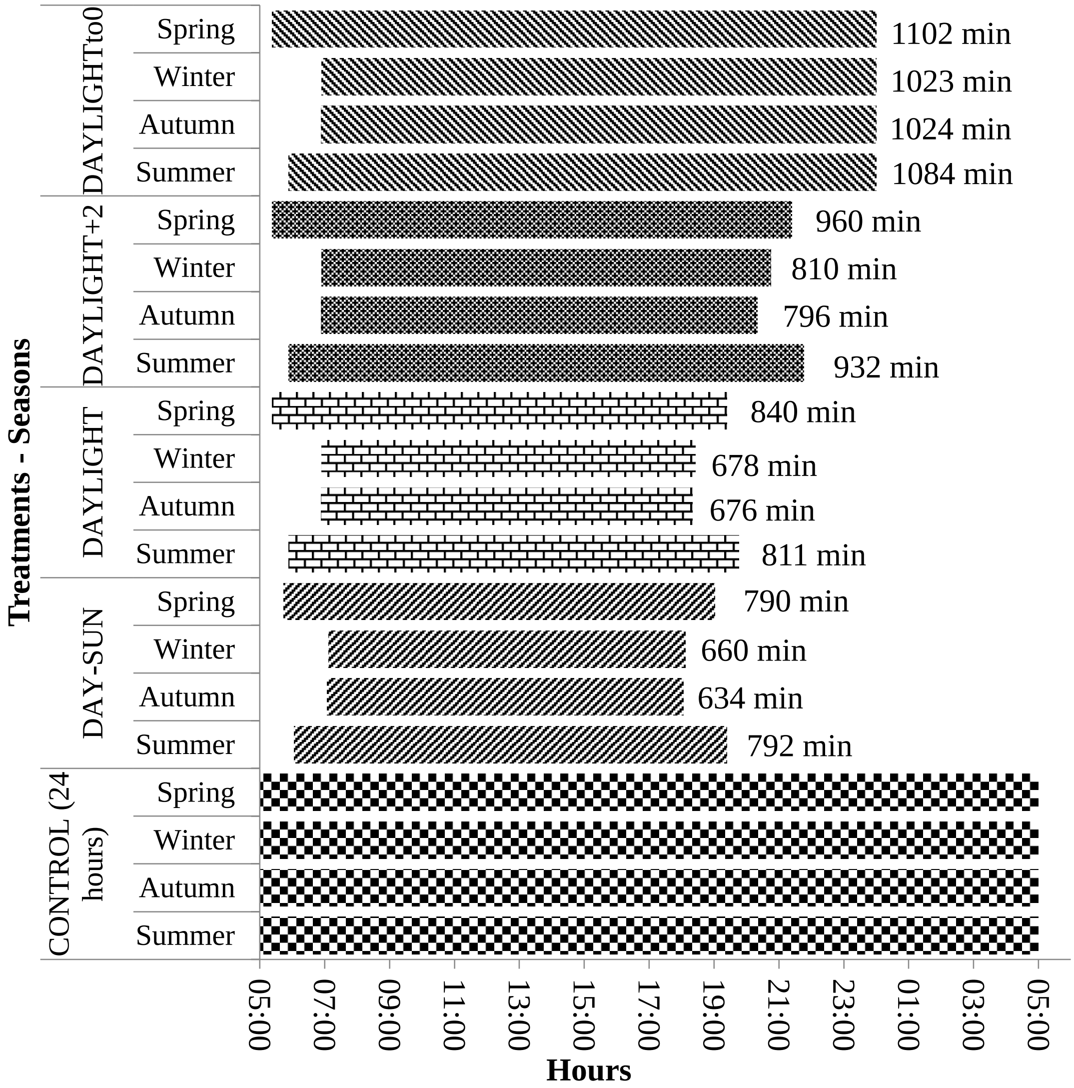

Figure 1 - Graphical timeline representation of the timing and duration of evaluations of grazing behaviour in 24 hours (Control; 1440 minutes assessment) and the tested periods of time (treatments): DAY-SUN (sunrise to sunset); DAYLIGHT (down to nightfall); DAYLIGHT+2 (down to nightfall plus two hours after dark) and MIDNIGHTto0 (down until midnight)

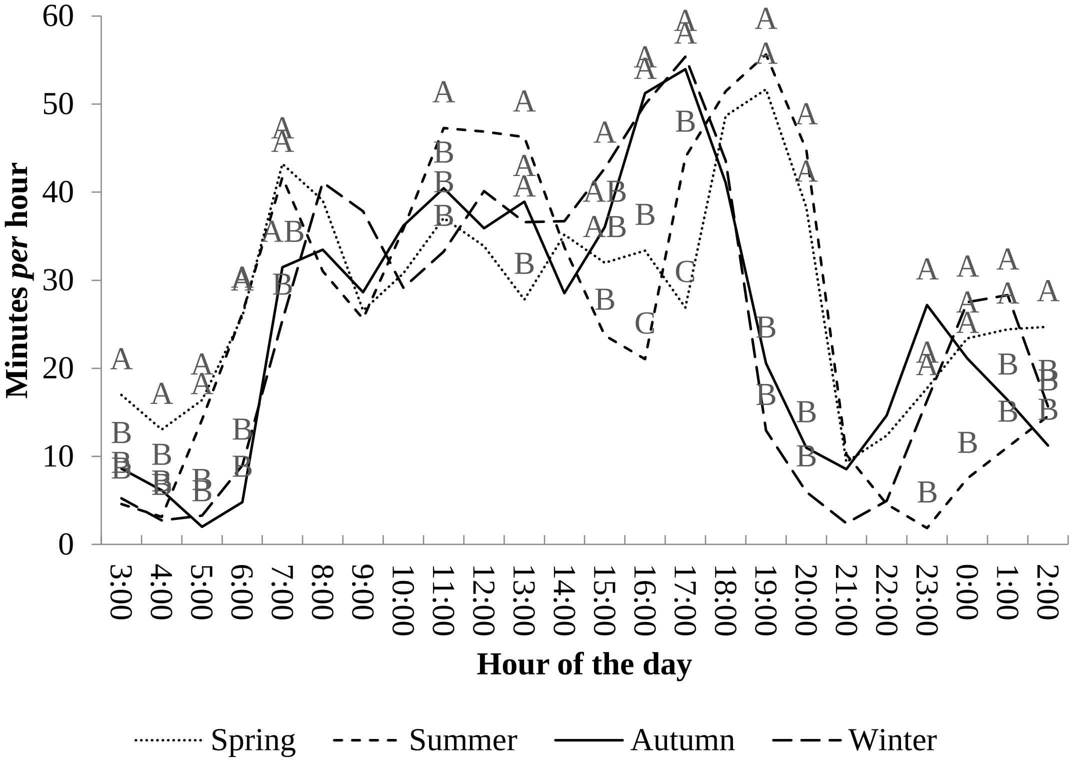

Figure 2 - Mean foraging time (minutes per hour) of beef heifers, over 24 hours, managed in natural grassland under rotational grazing method among the four climatic seasons over the years of 2010 to 2012 (*Different capital letters in column differs among them by Tukey test at 5%)

Tables list:

Table 1 - Mean initial body weight, age and number of beef heifers monitored during a study to quantify the daily foraging activities

Body weight is expressed as kg BW. Age is expressed as months. Monitored animals is the number of animals assessed in each evaluation year. Breed type represents the breed of animals assessed each year. Date of behavior evaluations represents the dates where the assessments were performed

	2010[1]	2011[2]	2012[2]
Body Weight	215	177	185
Age	18	12	12
Monitored animals	24	36	24
Breed type	Angus	Angus; Charolais×Nelore	Angus
Date of behaviour evaluations[3]	Jun, 11	Jan, 20	Jan, 16
	Aug, 15	Apr, 09	Mar, 24
	Sep, 30	Jun, 04	May, 26
	Dec, 17	Jul, 19	Jul, 07
		Sep, 03	Sep, 12
		Nov, 18	

[1]from Sep to Dec; [2]in 2011 and 2012, heifers started with 12 months remaining in paddocks until they reached 24 months; [3] June, July and August represent winter; September represents spring; December and January represent summer and March, April and May represent autumn.

Table 2 - Mean hour of dawn, sunrise, sunset and dusk among the four climatic seasons during a study to quantify the daily foraging activities of beef heifers

See the text for the definitions of dawn, sunrise, sunset and dusk. Mean hours of the events are an average of the last 30 years, provided by the National Institute of Meteorology (INMET).

Event	Climatic Seasons			
	Summer	Autumn	Winter	Spring
Dawn	05:53	06:53	06:55	05:23
Sunrise	06:04	07:05	07:07	05:44
Sunset	19:24	18:03	18:07	19:02
Dusk	19:46	18:20	18:25	19:24

Table 3 - Grazing, rumination and other activities times of beef heifers in a natural grassland managed under rotational grazing among the four climatic seasons

See text for definition of the different treatments (Control, SUN-DAY, DAYLIGHT, DAYLIGHT+2 and DAYLIGHTto0). Grazing, rumination and other activities (Other act.) are expressed in minutes. Different lowercase letters in line differ by Tukey test at 5% *Standard mean deviation

	Evaluation periods (Treatments)						
Min/day	CONTROL	SUN-DAY	DAYLIGHT	DAYLIGHT +2	DAYLIGHTto0	STD*	P-value
Summer							
Grazing	648[a]	536[c]	571[b]	597[b]	634[a]	11.2	0.001
Rumination	517[a]	191[d]	196[d]	267[c]	321[b]	13.8	0.001
Other act.	275[a]	93[c]	103[c]	126[bc]	155[b]	13.8	0.001
Spring							
Grazing	692[a]	549[c]	575[c]	609[b]	633[a]	14.7	0.001
Rumination	473[a]	164[d]	176[d]	230[c]	311[b]	10.2	0.001
Other act.	275[a]	97[c]	109[c]	141[bc]	156[b]	12.4	0.001
Autumn							
Grazing	637[a]	449[c]	475[c]	521[b]	602[a]	12.9	0.001
Rumination	469[a]	114[d]	122[d]	176[c]	270[b]	9.2	0.001
Other act.	334[a]	107[c]	113[c]	133[c]	178[b]	10.4	0.001
Winter							
Grazing	597[a]	447[d]	476[c]	502[b]	566[a]	7.7	0.001
Rumination	437[a]	91[d]	95[d]	167[c]	303[b]	8.1	0.001
Other act.	406[a]	142[d]	149[cd]	171[c]	191[b]	9.1	0.001

Table 4 - Hourly mean foraging distribution of beef heifers over 24 hours foraging behavior assessments in a natural grassland managed under rotational grazing (Supplementary file)

Timetable		Time Foraging (min/hour)				Standard error
		Autumn	Winter	Spring	Summer	
00:00	01:00	21.1 a	27.5 a	23.4 a	1.8 b	3.45
01:00	02:00	16.4 b	28.3 a	2.4 a	7.5 c	2.97
02:00	03:00	11.3 b	16.7 b	24.7 a	11.0 b	2.76
03:00	04:00	8.6 b	5.2 b	16.9 a	14.6 a	2.7
04:00	05:00	6.1 b	2.7 b	13.1 a	4.6 b	2.3
05:00	06:00	2.0 b	3.3 b	16.4 a	3.1 b	3.21
06:00	07:00	4.8 b	9.0 b	25.9 a	14.2 ab	4.13
07:00	08:00	31.5 b	25.4 b	43.1 a	26.3 b	4.4
08:00	09:00	33.5	41.1	39.1	41.6	3.47
09:00	10:00	28.6	37.8	26.6	31.1	3.64
10:00	11:00	36.2	29.1	30.7	25.6	4.11
11:00	12:00	40.4	33.3	37.1	35.8	3.38
12:00	13:00	35.9	40.1	33.9	47.4	3.61
13:00	14:00	38.9 a	36.6 a	27.8 b	46.8 a	2.48
14:00	15:00	28.5 b	36.7 ab	35.2 ab	46.3 a	2.41
15:00	16:00	36.0	42.7	31.9	33.7	2.84
16:00	17:00	51.2 a	49.9 a	33.4 b	23.7 b	3.33
17:00	18:00	53.9 a	55.4 a	26.9 b	21.1 b	4.47
18:00	19:00	41.1	43.6	48.6	43.9	3.02
19:00	20:00	20.6 b	12.9 b	51.7 a	51.4 a	4.95
20:00	21:00	10.9 c	5.9 c	38.3 b	55.6 ab	5.43
21:00	22:00	8.5 b	2.4 c	9.4 b	44.8 a	4.19
22:00	23:00	14.6	4.9	12.3	10.2	2.43
23:00	00:00	27.2 a	16.3 a	17.3 a	4.6 b	3.84

Time foraging is expressed in minutes for each daily hour. Different lowercase letters in line differ by Tukey test at 5%.

6. DISCUSSÃO

A elaboração da base de dados utilizada para confecção dos artigos aqui apresentados serviu como grande aprendizado em termos de compreender as dificuldades e importâncias do trabalho com banco de dados, da necessidade organizacional na elaboração e análise estatística bem como pela possibilidade de trabalhar com dados de vários anos. A utilização desse tipo de estratégia de pesquisa está sendo, e será cada vez mais, necessária aos pesquisadores por diversas razões, sejam de ordem orçamentária, ética e/ou estatística. Nesse sentido, estabelecemos a proposição de elaborar esse banco de dados e analisá-los conjuntamente.

A utilização de atributos funcionais de gramíneas para estabelecer critérios de rotação em pastagem natural é a grande originalidade proposta por esse dispositivo experimental. A partir de uma hipótese inicial que a utilização do pastoreio rotativo poderia melhorar a eficiência de utilização das áreas de pastagens naturais, historicamente caracterizadas pelos baixos índices de produtividade, utilizou-se dos dados de tipologia funcional e morfogênese das principais espécies de gramíneas da região para estabelecer os tratamentos (intervalos entre pastoreio). A partir do estabelecimento do dispositivo experimental, foram conduzidos os experimentos focados na compreensão das relações solo-planta-animal, sendo aqui descritas e analisadas as inter-relações planta-animal.

A utilização dos tratamentos propostos, aqui analisada ao longo dos anos, propiciou importantes resultados para o manejo das pastagens naturais e, por mais simples que pareça essa afirmação, é necessária ser realizada em vista da desconexão, que acontece algumas vezes, da pesquisa com as necessidades do manejador que transforma a informação em produção animal. Nesse sentido, as taxas de lotação obtidas com a metodologia utilizada, independente de tratamento ou estação climática, foram extremamente positivas em termos de maximizar a eficiência de uso da área, em relação às atuais possibilidades que a pesquisa apresenta aos produtores. Claro que, não menos importante, as taxas de lotação foram acompanhadas de ganhos individuais que possibilitam à categoria animal manejada, novilhas de corte, que atinjam o peso adequado para o acasalamento aos 24 meses. Se analisarmos a variabilidade dos ganhos individuais (entre -0,056 e 0,540 kg PV/dia), é notório que não há grandes ganhos individuais, porém, ao mesmo tempo, com as estratégias utilizadas (como a suplementação durante a estação fria), não houveram perdas de peso demasiadas nos animais. Esses fatores são muito importantes para o sistema de recria de fêmeas dentro de uma propriedade uma vez que, com um peso de desmame não muito elevado (160 kg PV), já seria possível o acasalamento desses animais aos 24 meses, sem grandes variações nos ganhos individuais dos animais. Obviamente, se cogitarmos a utilização de acasalamentos mais precoces (18 ou 14 meses), que indubitavelmente serão os próximos passos da pecuária de corte, as necessidades de peso ao desmame e/ou ganhos individuais, serão outras, e que deverão ser estudadas na sequência.

Além disso, a combinação de consideráveis taxas de lotação com os ganhos individuais gerou, por fim, elevados ganhos por área. Em suma, a mensuração dos ganhos por área é uma medida que permite analisar os ganhos dentro do sistema ao longo do ano (ou em uma base diária, como também exposto). A baixa produtividade da pecuária em pastagens naturais tem sido o principal argumento para conversão das mesmas em outras alternativas produtivas, principalmente cultivos agrícolas. Logo, a metodologia de pastoreio aqui apresentada, consolidada através da realização de vários experimentos ao longo dos anos, valida uma importante ferramenta para os produtores rurais assim como para pesquisadores avançarem em outras sub-áreas de pesquisa (diferentes intensidades de pastejo, utilização de adubação, introdução de espécies, etc).

Outra importante resposta obtida durante a avaliação dos experimentos foi sobre os padrões de comportamento ingestivo de novilhas de corte em pastagens naturais. Tanto em pastagens naturais, como principalmente em pastagens cultivadas, o comportamento ingestivo, juntamente às predições de consumo, tem sido objetivo de várias pesquisas. Essa linha de pesquisa baseia-se na premissa de que, em suma, ambas temáticas sejam as principais preditoras do desempenho animal. Entretanto, principalmente nos experimentos realizados em pastagens naturais, se utilizavam de algumas premissas como, por exemplo, o padrão de pastejo se concentrar, predominantemente, durante o período diurno ou, então, a premissa de que era necessário avaliar durante 24 horas para que não fosse negligenciado nenhum momento importante do pastejo. Assim, primordialmente, as avaliações de comportamento ingestivo foram realizadas por períodos de 24 horas ininterruptos no dispositivo experimental; posteriormente, após a realização de várias avaliações, colocamos a pergunta: afinal, por quanto tempo seria suficiente avaliar o comportamento ingestivo dos animais?

Nesse sentido, os resultados demonstraram que apenas a avaliação diurna do comportamento ingestivo dos animais é insuficiente para extrapolar ao período de 24 horas. Esse é um fator bastante importante pois, as estimativas de consumo utilizam-se de informações que são extrapoladas por essa avaliação de comportamento ingestivo; logo, subestimações do período avaliado irão, ao fim e ao cabo, não apenas determinar um resultado *per se* não fidedigno como irão gerar outros resultados incorretos. Assim, com os resultados possibilitados pela base de dados elaborada, houve a demonstração que a avaliação entre o alvorecer e a meia-noite foram capazes de representar a totalidade do período de 24 horas, possibilitando que tenhamos (assim como outros grupos de pesquisa) uma fonte fidedigna para basearmos as avaliações de comportamento ingestivo em pastagens naturais.

7. CONCLUSÃO

A utilização do pastoreio rotativo, com intervalos de descanso baseados nas características morfogênicas de gramíneas nativas, foi capaz de aumentar a eficiência de utilização das áreas de pastagens naturais, possibilitando ganhos individuais adequados para a recria de fêmeas de corte entre o desmame e o acasalamento aos 24 meses de idade.

Avaliações de comportamento ingestivo de novilhas de corte em pastagens naturais, apenas durante o período diurno, não contemplam o tempo necessário para representar a totalidade das atividades de pastejo. Para que seja contemplada a totalidade das atividades de pastejo, é necessário realizar as avaliações de comportamento ingestivo entre o período do alvorecer e a meia-noite.

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APÊNDICE A - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO I (PRIMAVERA)

Autor	Experimento	Tratamentos	Estação	Rep	Bloco	FA	FMe	FMs	FMm	CH	VD	FMg
Garagorry; F.C.	1	375	Primav.	1	Baixo	14.1	3774.0	2573.6	3173.8	16.0	235.9	1157.5
Garagorry; F.C.	1	375	Primav.	2	Encosta	14.5	3987.0	2557.4	3272.2	11.5	346.7	1229.0
Garagorry; F.C.	1	375	Primav.	3	Topo	15.1	3011.5	2181.1	2596.3	12.0	251.0	928.0
Garagorry; F.C.	1	750	Primav.	4	Baixo	9.2	3699.0	1725.8	2712.4	19.0	194.7	1110.0
Garagorry; F.C.	1	750	Primav.	5	Encosta	9.1	5397.0	2245.3	3821.1	20.0	269.9	1619.0
Garagorry; F.C.	1	750	Primav.	6	Topo	9.4	4929.0	2098.1	3513.5	14.0	352.1	1479.0
Barbieri, C. W.	3	375	Primav.	7	Baixo	4.5	1116.3	924.9	1020.6	8.9	124.9	659.1
Barbieri, C. W.	3	375	Primav.	8	Encosta	3.3	4267.7	3552.7	3910.2	14.6	293.0	2062.3
Barbieri, C. W.	3	375	Primav.	9	Topo	6.0	2392.1	2148.8	2270.5	10.6	225.1	1095.2
Barbieri, C. W.	3	750	Primav.	10	Baixo	5.1	2686.6	2299.9	2493.2	13.4	199.8	1402.3
Barbieri, C. W.	3	750	Primav.	11	Encosta	5.3	3905.2	3280.8	3593.0	15.1	258.2	1849.6
Barbieri, C. W.	3	750	Primav.	12	Topo	4.3	2625.3	2192.7	2409.0	12.6	207.6	1620.7
Kuinchtner, B.C.	5	375	Primav.	13	Baixo	18.1	3049.2	2567.6	1872.4	17.6	106.4	843.5
Kuinchtner, B.C.	5	375	Primav.	14	Encosta	29.8	6800.2	5093.6	3964.8	24.7	160.8	2295.3
Kuinchtner, B.C.	5	375	Primav.	15	Topo	24.1	5447.3	4238.3	3228.7	21.2	152.0	1369.4
Kuinchtner, B.C.	5	750	Primav.	16	Baixo	13.1	3895.3	3935.7	2610.5	18.3	142.9	1383.4
Kuinchtner, B.C.	5	750	Primav.	17	Encosta	11.6	4542.8	3774.4	2772.5	25.3	109.6	1602.1
Kuinchtner, B.C.	5	750	Primav.	18	Topo	16.2	4865.2	4782.8	3216.1	24.8	129.7	1796.7

APÊNDICE B - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO I (PRIMAVERA) - CONTINUAÇÃO

Autor	Experimento	Tratamentos	Estação	Rep	Bloco	SM	CP	NDF	SR	ADG	BWGs	BWGd
Garagorry; F.C.	1	375	Primav.	1	Baixo	2616.5	8.0	78.0	2240.0	0.110	124.4	1.37
Garagorry; F.C.	1	375	Primav.	2	Encosta	2758.0	10.0	76.7	2677.5	0.215	287.8	3.16
Garagorry; F.C.	1	375	Primav.	3	Topo	2083.5	8.1	76.6	1553.0	0.220	177.5	1.95
Garagorry; F.C.	1	750	Primav.	4	Baixo	2589.0	8.5	76.6	2030.0	0.050	52.2	0.57
Garagorry; F.C.	1	750	Primav.	5	Encosta	3778.0	8.4	77.6	3242.5	0.130	201.9	2.22
Garagorry; F.C.	1	750	Primav.	6	Topo	3450.0	9.4	76.6	2912.5	0.075	113.1	1.24
Barbieri, C. W.	3	375	Primav.	7	Baixo	457.2	9.7	76.9	419.7	0.429	85.7	0.94
Barbieri, C. W.	3	375	Primav.	8	Encosta	2205.4	10.2	77.5	1568.0	0.299	214.5	2.36
Barbieri, C. W.	3	375	Primav.	9	Topo	1296.9	7.8	77.5	533.8	0.449	113.1	1.24
Barbieri, C. W.	3	750	Primav.	10	Baixo	1284.3	8.1	75.5	479.9	0.252	57.8	0.64
Barbieri, C. W.	3	750	Primav.	11	Encosta	2055.6	9.1	75.4	779.2	0.377	138.9	1.53
Barbieri, C. W.	3	750	Primav.	12	Topo	1004.6	8.7	75.8	547.5	0.310	75.5	0.83
Kuinchtner, B.C.	5	375	Primav.	13	Baixo	933.1	7.9	73.2	467.9	0.345	90.0	0.99
Kuinchtner, B.C.	5	375	Primav.	14	Encosta	1526.7	.	.	627.5	0.296	97.7	1.07
Kuinchtner, B.C.	5	375	Primav.	15	Topo	1666.0	9.8	72.4	615.4	0.325	105.4	1.16
Kuinchtner, B.C.	5	750	Primav.	16	Baixo	1245.9	9.3	70.6	585.7	0.261	75.1	0.83
Kuinchtner, B.C.	5	750	Primav.	17	Encosta	1061.3	8.0	72.2	732.3	0.313	117.7	1.29
Kuinchtner, B.C.	5	750	Primav.	18	Topo	1373.7	7.3	76.9	576.3	0.223	69.3	0.76

APÊNDICE C - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO I (VERÃO)

Autor	Experimento	Tratamentos	Estação	Rep	Bloco	FA	FMe	FMs	FMm	CH	VD	FMg
Garagorry; F.C.	1	375	Verão	1	Baixo	17.5	3790.3	2823.4	3306.8	17.8	213.5	2141.0
Garagorry; F.C.	1	375	Verão	2	Encosta	17.9	2455.8	1803.1	2129.4	11.8	209.0	1389.0
Garagorry; F.C.	1	375	Verão	3	Topo	18.0	3031.3	2249.4	2640.3	14.3	212.7	1724.3
Garagorry; F.C.	1	750	Verão	4	Baixo	12.9	4352.5	2863.3	3607.9	18.0	241.8	2031.5
Garagorry; F.C.	1	750	Verão	5	Encosta	12.3	4826.8	3058.4	3942.6	19.5	247.5	2284.8
Garagorry; F.C.	1	750	Verão	6	Topo	12.9	3943.0	2595.6	3269.3	16.0	246.4	1863.8
Barbieri, C. W.	3	375	Verão	7	Baixo	6.4	2030.4	1756.7	1893.6	13.9	145.8	1454.0
Barbieri, C. W.	3	375	Verão	8	Encosta	5.4	2798.6	2443.6	2621.1	15.3	183.1	1525.5
Barbieri, C. W.	3	375	Verão	9	Topo	5.6	3422.2	2880.6	3151.4	13.5	254.4	1990.9
Barbieri, C. W.	3	750	Verão	10	Baixo	4.7	3216.1	2493.7	2854.9	19.5	165.1	1730.1
Barbieri, C. W.	3	750	Verão	11	Encosta	5.1	3542.2	2880.3	3211.3	17.8	199.1	1925.7
Barbieri, C. W.	3	750	Verão	12	Topo	4.0	4728.2	3599.7	4163.9	19.5	242.5	2642.2
Kuinchtner, B.C.	5	375	Verão	13	Baixo	20.6	3561.4	3274.0	2278.6	22.3	102.2	1442.5
Kuinchtner, B.C.	5	375	Verão	14	Encosta	28.2	4263.9	4836.7	3033.7	24.1	126.1	2085.8
Kuinchtner, B.C.	5	375	Verão	15	Topo	17.2	3912.4	2969.3	2294.0	18.9	121.3	1403.7
Kuinchtner, B.C.	5	750	Verão	16	Baixo	19.8	4848.9	4726.9	3192.1	20.3	157.1	1697.2
Kuinchtner, B.C.	5	750	Verão	17	Encosta	17.7	4334.3	5661.7	3332.1	29.7	112.1	2102.3
Kuinchtner, B.C.	5	750	Verão	18	Topo	21.1	5812.8	5131.5	3648.3	30.0	121.8	2274.2

APÊNDICE D - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO I (VERÃO) - CONTINUAÇÃO

Autor	Experimento	Tratamentos	Estação	Rep	Bloco	SM	CP	NDF	SR	ADG	BWGs	BWGd
Garagorry; F.C.	1	375	Verão	1	Baixo	1649.3	8.2	78.6	2073.0	0.312	291.4	3.20
Garagorry; F.C.	1	375	Verão	2	Encosta	1066.8	10.0	78.0	1401.7	0.255	160.6	1.77
Garagorry; F.C.	1	375	Verão	3	Topo	1307.0	8.6	79.4	1683.7	0.432	321.3	3.53
Garagorry; F.C.	1	750	Verão	4	Baixo	2321.0	8.5	77.3	1681.9	0.257	202.7	2.23
Garagorry; F.C.	1	750	Verão	5	Encosta	2542.0	9.0	78.6	1998.0	0.180	159.2	1.75
Garagorry; F.C.	1	750	Verão	6	Topo	2079.3	8.9	76.7	1520.1	0.262	188.5	2.07
Barbieri, C. W.	3	375	Verão	7	Baixo	576.4	8.7	74.3	612.9	0.361	92.1	1.01
Barbieri, C. W.	3	375	Verão	8	Encosta	1273.0	11.0	76.8	790.9	0.433	137.4	1.51
Barbieri, C. W.	3	375	Verão	9	Topo	1431.3	8.8	77.8	1210.4	0.471	229.8	2.52
Barbieri, C. W.	3	750	Verão	10	Baixo	1485.9	7.0	76.3	937.3	0.234	96.1	1.06
Barbieri, C. W.	3	750	Verão	11	Encosta	1616.5	8.1	76.2	857.6	0.379	134.4	1.48
Barbieri, C. W.	3	750	Verão	12	Topo	2086.1	8.1	77.3	1463.4	0.332	193.8	2.13
Kuinchtner, B.C.	5	375	Verão	13	Baixo	659.4	7.7	71.4	508.0	0.323	76.7	0.84
Kuinchtner, B.C.	5	375	Verão	14	Encosta	876.5	8.2	71.4	493.9	0.299	66.4	0.73
Kuinchtner, B.C.	5	375	Verão	15	Topo	788.7	7.3	68.6	608.0	0.348	93.4	1.03
Kuinchtner, B.C.	5	750	Verão	16	Baixo	1365.7	8.5	69.1	493.7	0.175	37.9	0.42
Kuinchtner, B.C.	5	750	Verão	17	Encosta	1145.9	8.7	68.2	576.3	0.314	78.9	0.87
Kuinchtner, B.C.	5	750	Verão	18	Topo	1239.3	8.5	72.4	528.7	0.267	66.3	0.73

APÊNDICE E - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO I (OUTONO)

Autor	Experimento	Tratamentos	Estação	Rep	Bloco	FA	FMe	FMs	FMm	CH	VD	FMg
Kuinchtner, B.C.	5	375	Outono	1	Baixo	18.6	3835.0	3133.6	2323.1	23.0	101.1	1081.0
Kuinchtner, B.C.	5	375	Outono	2	Encosta	21.7	3653.9	3730.3	2461.6	22.4	110.0	1228.4
Kuinchtner, B.C.	5	375	Outono	3	Topo	19.2	3999.8	4356.7	2785.7	19.5	142.9	1360.8
Kuinchtner, B.C.	5	750	Outono	4	Baixo	12.0	4285.8	3603.8	2630.1	22.3	117.8	1224.1
Kuinchtner, B.C.	5	750	Outono	5	Encosta	11.3	4504.6	3739.9	2748.3	27.3	100.5	1204.7
Kuinchtner, B.C.	5	750	Outono	6	Topo	14.3	5640.3	4396.6	3345.8	35.7	93.8	1639.5
Casanova, P. T.	7	375	Outono	7	Baixo	51.9	.	.	5600.1	26.9	208.1	2314.7
Casanova, P. T.	7	375	Outono	8	Encosta	52.4	.	.	7108.3	22.6	314.6	2586.9
Casanova, P. T.	7	375	Outono	9	Topo	51.8	.	.	6812.9	27.0	252.8	2682.4
Casanova, P. T.	7	750	Outono	10	Baixo	31.5	.	.	6650.6	42.5	156.4	2874.8
Casanova, P. T.	7	750	Outono	11	Encosta	31.4	.	.	5818.8	23.5	247.4	1947.5
Casanova, P. T.	7	750	Outono	12	Topo	31.1	.	.	5395.6	29.9	180.4	2582.5

APÊNDICE F - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO I (OUTONO) - CONTINUAÇÃO

Autor	Experimento	Tratamentos	Estação	Rep	Bloco	SM	CP	NDF	SR	ADG	BWGs	BWGd
Kuinchtner, B.C.	5	375	Outono	1	Baixo	1080.8	5.9	73.5	452.8	0.144	39.3	0.43
Kuinchtner, B.C.	5	375	Outono	2	Encosta	1109.2	8.4	75.1	409.6	0.043	10.4	0.11
Kuinchtner, B.C.	5	375	Outono	3	Topo	1241.5	7.9	72.1	507.1	0.218	63.1	0.69
Kuinchtner, B.C.	5	750	Outono	4	Baixo	1298.4	7.3	73.4	451.4	0.070	17.9	0.20
Kuinchtner, B.C.	5	750	Outono	5	Encosta	1464.8	7.3	76.4	496.9	0.106	32.4	0.36
Kuinchtner, B.C.	5	750	Outono	6	Topo	1586.7	8.7	71.6	468.1	0.037	10.8	0.12
Casanova, P. T.	7	375	Outono	7	Baixo	3224.5	5.9	74.5	397.6	0.097	15.1	0.17
Casanova, P. T.	7	375	Outono	8	Encosta	4427.8	7.8	80.8	393.3	0.014	2.2	0.02
Casanova, P. T.	7	375	Outono	9	Topo	4007.2	6.1	72.7	398.0	0.131	20.5	0.23
Casanova, P. T.	7	750	Outono	10	Baixo	3707.0	5.2	75.2	357.8	0.188	25.7	0.28
Casanova, P. T.	7	750	Outono	11	Encosta	3767.5	6.9	75.8	359.7	0.094	12.9	0.14
Casanova, P. T.	7	750	Outono	12	Topo	2668.6	6.6	72.4	362.8	0.159	21.8	0.24

APÊNDICE G - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO I (INVERNO)

Autor	Experimento	Tratamentos	Estação	Rep	Bloco	FA	FMe	FMs	FMm	CH	VD	FMg
Carvalho, T.H.N.	4	375	Inverno	1	Baixo	31.9	3406.5	2956.8	3181.7	.	.	.
Carvalho, T.H.N.	4	375	Inverno	2	Encosta	34.3	4676.0	4073.5	4374.7	.	.	.
Carvalho, T.H.N.	4	375	Inverno	3	Topo	31.0	3819.2	3281.2	3550.2	.	.	.
Carvalho, T.H.N.	4	750	Inverno	4	Baixo	23.2	5737.5	4798.6	5268.1	.	.	.
Carvalho, T.H.N.	4	750	Inverno	5	Encosta	21.9	6071.0	5016.7	5543.9	.	.	.
Carvalho, T.H.N.	4	750	Inverno	6	Topo	28.9	5163.1	4419.5	4791.3	.	.	.
Kuinchtner, B.C.	6	375	Inverno	7	Baixo	15.0	3580.0	2791.3	2124.0	14.2	149.8	668.8
Kuinchtner, B.C.	6	375	Inverno	8	Encosta	24.0	4861.8	4719.2	3193.9	12.9	248.1	987.0
Kuinchtner, B.C.	6	375	Inverno	9	Topo	22.5	5223.2	4601.4	3275.1	14.7	223.1	1073.1
Kuinchtner, B.C.	6	750	Inverno	10	Baixo	9.2	4570.4	3070.3	2547.1	19.6	130.0	725.9
Kuinchtner, B.C.	6	750	Inverno	11	Encosta	12.9	6010.4	5297.0	3769.3	16.7	226.0	1275.2
Kuinchtner, B.C.	6	750	Inverno	12	Topo	12.4	5820.0	4918.7	3579.8	20.9	171.2	1247.8
Casanova, P. T.	7	375	Inverno	13	Baixo	54.4	.	.	3004.6	14.2	211.6	913.0
Casanova, P. T.	7	375	Inverno	14	Encosta	54.4	.	.	4993.1	17.1	291.8	1726.3
Casanova, P. T.	7	375	Inverno	15	Topo	53.4	.	.	4948.8	16.6	297.6	1459.0
Casanova, P. T.	7	750	Inverno	16	Baixo	32.8	.	.	3811.2	13.8	277.1	1158.9
Casanova, P. T.	7	750	Inverno	17	Encosta	30.6	.	.	8698.6	17.2	505.9	2864.8
Casanova, P. T.	7	750	Inverno	18	Topo	30.5	.	.	5059.8	17.9	283.4	1624.9
Kuinchtner, B.C.	2	375	Inverno	19	Baixo	23.0	3222.7	1972.8	2597.7	14.9	174.3	1174.4
Kuinchtner, B.C.	2	375	Inverno	20	Encosta	36.1	4073.8	4069.2	4071.5	16.2	251.2	1150.3
Kuinchtner, B.C.	2	375	Inverno	21	Topo	30.8	3612.8	3158.3	3385.5	16.0	211.1	1096.1
Kuinchtner, B.C.	2	750	Inverno	22	Baixo	18.4	3129.1	3922.2	3525.7	15.9	221.1	1161.0
Kuinchtner, B.C.	2	750	Inverno	23	Encosta	22.1	4519.1	4356.6	4437.9	17.5	253.0	1306.8
Kuinchtner, B.C.	2	750	Inverno	24	Topo	21.5	3575.2	4558.6	4066.9	17.0	238.9	1269.6

APÊNDICE H - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO I (INVERNO) – CONTINUAÇÃO

Autor	Experimento	Tratamentos	Estação	Rep	Bloco	SM	CP	NDF	SR	ADG	BWGs	BWGd
Carvalho, T.H.N.	4	375	Inverno	1	Baixo	.	.	.	647.3	0.282	63.2	0.69
Carvalho, T.H.N.	4	375	Inverno	2	Encosta	.	.	.	879.0	0.456	135.3	1.49
Carvalho, T.H.N.	4	375	Inverno	3	Topo	.	.	.	788.8	0.444	118.5	1.30
Carvalho, T.H.N.	4	750	Inverno	4	Baixo	.	.	.	802.2	0.454	123.1	1.35
Carvalho, T.H.N.	4	750	Inverno	5	Encosta	.	.	.	897.4	0.397	125.5	1.38
Carvalho, T.H.N.	4	750	Inverno	6	Topo	.	.	.	605.0	0.479	102.4	1.12
Kuinchtner, B.C.	6	375	Inverno	7	Baixo	1346.0	7.1	73.7	438.7	-0.056	-14.8	-0.16
Kuinchtner, B.C.	6	375	Inverno	8	Encosta	2143.1	8.4	71.3	410.3	0.095	22.8	0.25
Kuinchtner, B.C.	6	375	Inverno	9	Topo	2036.4	7.2	77.3	443.8	-0.038	-9.5	-0.10
Kuinchtner, B.C.	6	750	Inverno	10	Baixo	1767.0	8.8	77.4	451.6	0.099	24.3	0.27
Kuinchtner, B.C.	6	750	Inverno	11	Encosta	2427.5	7.0	78.4	472.1	0.187	51.7	0.57
Kuinchtner, B.C.	6	750	Inverno	12	Topo	2249.4	6.8	72.9	457.7	0.120	32.7	0.36
Casanova, P. T.	7	375	Inverno	13	Baixo	2058.2	5.2	75.8	426.9	0.339	52.9	0.58
Casanova, P. T.	7	375	Inverno	14	Encosta	3178.4	7.2	74.0	426.9	0.468	73.0	0.80
Casanova, P. T.	7	375	Inverno	15	Topo	3436.5	6.1	64.6	435.0	0.536	83.7	0.92
Casanova, P. T.	7	750	Inverno	16	Baixo	2604.6	7.5	64.9	374.7	0.498	64.2	0.71
Casanova, P. T.	7	750	Inverno	17	Encosta	5731.1	8.4	70.5	402.3	0.540	73.7	0.81
Casanova, P. T.	7	750	Inverno	18	Topo	3397.0	5.8	74.8	402.9	0.519	70.9	0.78
Kuinchtner, B.C.	2	375	Inverno	19	Baixo	1855.7	9.8	74.7	945.5	0.264	95.1	1.05
Kuinchtner, B.C.	2	375	Inverno	20	Encosta	2783.7	8.9	60.2	935.6	0.260	92.0	1.01
Kuinchtner, B.C.	2	375	Inverno	21	Topo	2122.2	10.6	71.8	912.6	0.272	97.8	1.07
Kuinchtner, B.C.	2	750	Inverno	22	Baixo	1898.0	8.1	63.2	687.5	0.335	90.4	0.99
Kuinchtner, B.C.	2	750	Inverno	23	Encosta	3166.5	10.3	49.4	722.6	0.303	81.1	0.89
Kuinchtner, B.C.	2	750	Inverno	24	Topo	2250.7	9.1	69.7	677.9	0.211	56.9	0.63

APÊNDICE I - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO II (PRIMAVERA)

Experimento	Estação	Bloco	CONTROL				DAY-SUN				DAYLIGHT			
			Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total
Garagorry, F.C.	Primav.	1	720.0	362.9	357.1	1440	595.7	157.1	57.1	810	634.3	153.6	72.1	860
	Primav.	2	695.7	495.7	248.6	1440	542.9	155.7	111.4	810	582.9	157.9	119.3	860
	Primav.	3	731.4	448.6	260.0	1440	632.9	87.1	90.0	810	672.9	90.7	96.4	860
	Primav.	1	585.7	518.6	335.7	1440	385.7	204.3	220.0	810	425.7	207.9	226.4	860
	Primav.	2	648.3	505.0	286.7	1440	447.1	207.1	155.7	810	487.1	216.4	156.4	860
	Primav.	3	622.9	577.1	240.0	1440	498.6	181.4	130.0	810	538.6	185.0	136.4	860
Barbieri, C.W.	Primav.	1	685.0	380.0	375.0	1440	465.0	162.5	182.5	810	500	172.5	187.5	860
	Primav.	2	697.5	505.0	237.5	1440	515.0	230.0	65.0	810	542.5	237.5	80	860
	Primav.	3	760.0	457.5	222.5	1440	520.0	225.0	65.0	810	560	232.5	67.5	860
	Primav.	1	767.5	407.5	265.0	1440	600.0	155.0	55.0	810	640	162.5	57.5	860
	Primav.	2	697.5	467.5	275.0	1440	590.0	120.0	100.0	810	630	125	105	860
	Primav.	3	722.5	430.0	287.5	1440	497.5	205.0	107.5	810	532.5	205	122.5	860
Carvalho, T.H.N.	Primav.	1	710.0	543.3	186.7	1440	610.0	171.7	28.3	810	616.7	190.0	53.3	860
	Primav.	2	766.0	482.0	192.0	1440	633.3	121.7	55.0	810	653.3	150.0	56.7	860
	Primav.	3	691.7	500.0	248.3	1440	661.7	103.3	45.0	810	666.7	146.7	46.7	860
	Primav.	1	652.0	410.0	378.0	1440	534.0	138.0	138.0	810	498.3	150.0	211.7	860
	Primav.	2	640.0	531.7	268.3	1440	543.3	175.0	91.7	810	543.3	216.7	100.0	860
	Primav.	3	651.7	490.0	298.3	1440	598.3	163.3	48.3	810	620.0	178.3	61.7	860

APÊNDICE J - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO II (PRIMAVERA) - CONTINUAÇÃO

Experimento	Estação	Bloco	DAYLIGHT+2				DAYLIGHTto0			
			Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total
Garagorry, F.C.	Primav.	1	701.4	200.0	88.6	990	711.4	274.3	144.3	1130
	Primav.	2	682.9	182.9	124.3	990	689.3	302.1	138.6	1130
	Primav.	3	731.4	157.1	101.4	990	731.4	274.3	124.3	1130
	Primav.	1	498.6	251.4	240.0	990	547.1	304.3	278.6	1130
	Primav.	2	567.1	258.6	164.3	990	603.6	327.9	198.6	1130
	Primav.	3	617.1	227.1	145.7	990	618.6	354.3	157.1	1130
Barbieri, C.W.	Primav.	1	565.0	227.5	197.5	990	642.5	272.5	215.0	1130
	Primav.	2	617.5	270.0	102.5	990	660.0	345.0	125.0	1130
	Primav.	3	617.5	285	87.5	990	710.0	320.0	100.0	1130
	Primav.	1	677.5	220	92.5	990	715.0	280.0	135.0	1130
	Primav.	2	672.5	200	117.5	990	690.0	305.0	135.0	1130
	Primav.	3	592.5	255	142.5	990	687.5	297.5	145.0	1130
Carvalho, T.H.N.	Primav.	1	616.7	310.0	63.3	990	661.7	374.2	94.2	1130
	Primav.	2	653.3	248.3	88.3	990	708.3	308.3	113.3	1130
	Primav.	3	666.7	240.0	83.3	990	681.7	320.0	128.3	1130
	Primav.	1	501.7	231.7	256.7	990	614.2	240.4	275.4	1130
	Primav.	2	543.3	310.0	136.7	990	619.2	363.8	147.1	1130
	Primav.	3	628.3	258.3	103.3	990	645.0	334.2	150.8	1130

APÊNDICE K - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO II (VERÃO)

Experimento	Estação	Bloco	CONTROL				DAY-SUN				DAYLIGHT			
			Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total
Garagorry, F.C.	Verão	1	620.0	505.0	315.0	1440	555	187.5	77.5	820	582.5	197.5	90	870
	Verão	2	647.5	655.0	137.5	1440	562.5	230	27.5	820	592.5	222.5	55	870
	Verão	3	627.5	467.5	345.0	1440	512.5	187.5	120	820	542.5	190	137.5	870
	Verão	1	602.5	505.0	332.5	1440	447.5	220	152.5	820	477.5	232.5	160	870
	Verão	2	577.5	517.5	345.0	1440	510	182.5	127.5	820	540	192.5	137.5	870
	Verão	3	670.0	505.0	265.0	1440	500.0	187.5	132.5	820	530.0	205	135	870
Barbieri, C.W.	Verão	1	762.5	422.5	255.0	1440	610	132.5	77.5	820	660	132.5	77.5	870
	Verão	2	665.0	580.0	195.0	1440	570	202.5	47.5	820	610	210	50	870
	Verão	3	637.5	577.5	225.0	1440	537.5	247.5	35	820	577.5	252.5	40.0	870
	Verão	1	607.5	555.0	277.5	1440	507.5	200.0	112.5	820	557.5	200.0	112.5	870
	Verão	2	645.0	512.5	282.5	1440	580.0	157.5	80.0	818	612.5	157.5	100	870
	Verão	3	702.5	412.5	325.0	1440	540	162.5	117.5	820	565	167.5	137.5	870

APÊNDICE L - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO II (VERÃO) - CONTINUAÇÃO

Experimento	Estação	Bloco	DAYLIGHT+2				DAYLIGHTto0			
			Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total
Garagorry, F.C.	Verão	1	605.0	280.0	105.0	990.0	615	337.5	157.5	1110.0
	Verão	2	622.5	310.0	57.5	990.0	635	387.5	87.5	1110.0
	Verão	3	562.5	257.5	170	990.0	600	290	220	1110.0
	Verão	1	515	290	185	990.0	576	322.5	212.5	1111.0
	Verão	2	560	265	165	990.0	570	327.5	212.5	1110.0
	Verão	3	547.5	280	162.5	990.0	645	307.5	157.5	1110.0
Barbieri, C.W.	Verão	1	682.5	182.5	125.0	990.0	737.5	225	147.5	1110.0
	Verão	2	642.5	292.5	55	990.0	665	372.5	72.5	1110.0
	Verão	3	582.5	350	57.5	990.0	627.5	407.5	75	1110.0
	Verão	1	602.5	265	122.5	990.0	607.5	340	162.5	1110.0
	Verão	2	642.5	227.5	120	990.0	645	292.5	172.5	1110.0
	Verão	3	597.5	207.5	185	990.0	675	247.5	187.5	1110.0

APÊNDICE M - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO II (OUTONO)

Experimento	Estação	Bloco	CONTROL				DAY-SUN				DAYLIGHT			
			Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total
Garagorry, F.C.	Outono	1	650.0	470.0	320.0	1440	512.5	97.5	60	670	537.5	97.5	75	710
	Outono	2	717.5	505.0	217.5	1440	512.5	135	22.5	670	542.5	135	32.5	710
	Outono	3	712.5	497.5	230.0	1440	557.5	100	12.5	670	580	100	30	710
	Outono	1	657.5	520.0	262.5	1440	485	132.5	52.5	670	507.5	132.5	70	710
	Outono	2	742.5	412.5	285.0	1440	492.5	120	57.5	670	522.5	120	67.5	710
	Outono	3	717.5	445.0	277.5	1440	520	97.5	52.5	670	540	97.5	72.5	710
Kuinchtner, B.C.	Outono	1	480.0	572.5	387.5	1440	337.5	187.5	145	670	382.5	190	137.5	710
	Outono	2	532.5	580.0	327.5	1440	377.5	122.5	170	670	407.5	127.5	175	710
	Outono	3	585.0	555.0	300.0	1440	400	147.5	122.5	670	427.5	160	122.5	710
	Outono	1	552.5	640.0	247.5	1440	425	200	45	670	455	217.5	37.5	710
	Outono	2	667.5	475.0	297.5	1440	485	112.5	72.5	670	517.5	120	72.5	710
	Outono	3	630.0	495.0	315.0	1440	472.5	90	107.5	670	502.5	105	102.5	710
Carvalho, T.H.N. (1)	Outono	1	666.7	345.0	428.3	1440	440	104	126	670	470.0	108.3	131.7	710
	Outono	2	611.7	393.3	435.0	1440	348	94	228	670	380.0	108.3	221.7	710
	Outono	3	700.0	323.3	416.7	1440	458	86	126	670	475.0	88.3	146.7	710
	Outono	1	568.3	416.7	455.0	1440	324	98	248	670	338.3	130.0	241.7	710
	Outono	2	646.0	370.0	424.0	1440	382	78	210	670	406.7	93.3	210.0	710
	Outono	3	693.3	385.0	361.7	1440	546	58	66	670	548.3	76.7	85.0	710

APÊNDICE N - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO II (OUTONO) - CONTINUAÇÃO

Experimento	Estação	Bloco	DAYLIGHT+2				DAYLIGHTto0			
			Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total
Garagorry, F.C.	Outono	1	560	177.5	92.5	830	620.0	295.0	135.0	1050.0
	Outono	2	620	172.5	37.5	830	677.5	295.0	77.5	1050.0
	Outono	3	647.5	145	37.5	830	680.0	265.0	105.0	1050.0
	Outono	1	542.5	202.5	85	830	657.5	285.0	107.5	1050.0
	Outono	2	577.5	172.5	80	830	690.0	232.5	127.5	1050.0
	Outono	3	582.5	150	97.5	830	697.5	210.0	142.5	1050.0
Kuinchtner, B.C.	Outono	1	397.5	260.0	172.5	830	477.5	352.5	220	1050.0
	Outono	2	430.0	222.5	177.5	830	532.5	317.5	200	1050.0
	Outono	3	487.5	217.5	125.0	830	547.5	347.5	155	1050.0
	Outono	1	490.0	267.5	72.5	830	517.5	425	107.5	1050.0
	Outono	2	557.5	170.0	102.5	830	630	302.5	117.5	1050.0
	Outono	3	547.5	160.0	122.5	830	587.5	307.5	155	1050.0
Carvalho, T.H.N. (1)	Outono	1	551.7	128.3	150.0	830	648.3	186.7	215.0	1050.0
	Outono	2	430.0	146.7	253.3	830	545.0	215.0	290.0	1050.0
	Outono	3	501.7	140.0	188.3	830	631.7	203.3	215.0	1050.0
	Outono	1	423.3	143.3	263.3	830	495.0	228.3	326.7	1050.0
	Outono	2	440.0	153.3	236.7	830	553.3	190.0	306.7	1050.0
	Outono	3	580.0	148.3	101.7	830	643.3	208.3	198.3	1050.0

APÊNDICE O - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO II (INVERNO)

Experimento	Estação	Bloco	CONTROL				DAY-SUN				DAYLIGHT			
			Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total
Kuinchtner, B.C.	Inverno	1	390.3	430.7	1440.0	1440	505.0	61.9	113.1	680	529.4	67.2	123.3	720
	Inverno	2	406.7	409.3	1440.0	1440	476.6	90.0	113.4	680	496.1	100.0	123.9	720
	Inverno	3	425.0	349.4	1440.0	1440	493.3	111.1	75.6	680	521.7	127.8	70.6	720
	Inverno	1	390.0	437.2	1440.0	1440	401.1	78.3	200.6	680	427.2	80.6	212.2	720
	Inverno	2	468.3	402.2	1440.0	1440	463.9	107.2	108.9	680	488.9	118.9	112.2	720
	Inverno	3	391.9	394.9	1440.0	1440	451.7	93.6	134.8	680	472.2	98.3	149.4	720
Carvalho, T.H.N. (1)	Inverno	1	693.3	405.0	341.7	1440	570.0	56.7	53.3	680	606.7	53.3	60.0	720
	Inverno	2	626.7	441.7	371.7	1440	475.0	106.7	98.3	680	513.3	113.3	93.3	720
	Inverno	3	636.7	316.7	486.7	1440	521.7	68.3	90.0	680	551.7	68.3	100.0	720
	Inverno	1	613.3	458.3	368.3	1440	406.7	110.0	163.3	680	445.0	111.7	163.3	720
	Inverno	2	725.0	466.7	248.3	1440	563.3	73.3	43.3	680	585.0	78.3	56.7	720
	Inverno	3	673.3	440.0	326.7	1440	465.0	88.3	126.7	680	505.0	88.3	126.7	720
Carvalho, T.H.N. (2)	Inverno	1	563.3	431.7	445.0	1440	400.0	65.0	215.0	680	440.0	68.3	211.7	720
	Inverno	2	566.7	439.2	434.2	1440	407.5	94.6	177.9	680	444.2	93.8	182.1	720
	Inverno	3	556.7	471.7	411.7	1440	403.3	80.0	196.7	680	445.0	75.0	200.0	720
	Inverno	1	525.8	515.8	398.3	1440	375.8	98.3	205.8	680	405.8	102.1	212.1	720
	Inverno	2	492.9	493.5	453.3	1440	383.3	101.7	195.0	680	402.9	102.1	215.0	720
	Inverno	3	542.1	491.7	406.3	1440	401.3	110.0	168.8	680	421.3	114.6	184.2	720

APÊNDICE P - VARIÁVEIS UTILIZADAS PARA ELABORAÇÃO DA BASE DE DADOS ARTIGO II (INVERNO) - CONTINUAÇÃO

Experimento	Estação	Bloco	DAYLIGHT+2				DAYLIGHTto0			
			Pastejo	Rumin.	Ócio	Total	Pastejo	Rumin.	Ócio	Total
Kuinchtner, B.C.	Inverno	1	542.2	137.2	180.6	860	592.8	204.4	252.8	1050
	Inverno	2	512.2	160.6	187.2	860	580.6	233.9	235.6	1050
	Inverno	3	531.7	212.2	116.1	860	619.4	236.1	194.4	1050
	Inverno	1	485.0	123.9	251.1	860	596.1	201.7	252.2	1050
	Inverno	2	490.6	208.9	160.6	860	531.7	286.1	238.9	1050
	Inverno	3	507.8	165.6	186.7	860	604.4	230.0	215.6	1050
Carvalho, T.H.N. (1)	Inverno	1	618.3	106.7	135.0	860	658.3	181.7	210.0	1050.0
	Inverno	2	568.3	165.0	126.7	860	578.3	273.3	198.3	1050.0
	Inverno	3	553.3	121.7	185.0	860	591.7	153.3	305.0	1050.0
	Inverno	1	493.3	175.0	191.7	860	588.3	238.3	223.3	1050.0
	Inverno	2	588.3	173.3	98.3	860	666.7	228.3	155.0	1050.0
	Inverno	3	550.0	165.0	145.0	860	641.7	218.3	190.0	1050.0
Carvalho, T.H.N. (2)	Inverno	1	506.1	171.5	182.4	860	541.3	238.3	270.4	1050
	Inverno	2	489.4	212.4	158.2	860	510.4	270.7	268.9	1050
	Inverno	3	479.4	173.6	206.9	860	510.8	274.2	265.0	1050
	Inverno	1	446.7	217.9	195.4	860	494.6	295.0	260.4	1050
	Inverno	2	468.3	227.9	163.8	860	481.3	295.8	272.9	1050
	Inverno	3	456.4	234.3	169.3	860	510.0	273.7	266.3	1050

ANEXO A – NORMAS PARA PUBLICAÇÃO (RANGELAND ECOLOGY & MANAGEMENT)

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ANEXO B – NORMAS PARA PUBLICAÇÃO (ANIMAL PRODUCTION SCIENCE)

Author Instructions

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