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

Estratégias de forrageamento de bovinos em campo nativo: identificando categorias funcionais de bocados e suas relações com atributos de ingestão de nutrientes

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Tese apresentada como um dos requisitos à obtenção do grau de Doutor em Zootecnia
Área de Concentração Produção Animal

Porto Alegre (RS), Brasil
Março, 2019

CIP - Catalogação na Publicação

Rebés de Azambuja Filho, Júlio Cezar
Estratégias de forrageamento de bovinos em campo nativo: identificando categorias funcionais de bocados e suas relações com atributos de ingestão de nutrientes / Júlio Cezar Rebés de Azambuja Filho. -- 2019.
104 f.
Orientador: Paulo Cesar de Faccio Carvalho.

Coorientadores: Olivier Jean François Bonnet, Magali Jouven.

Tese (Doutorado) -- Universidade Federal do Rio Grande do Sul, Faculdade de Agronomia, Programa de Pós-Graduação em Zootecnia, Porto Alegre, BR-RS, 2019.

1. Classificação de potenciais bocados por bovinos. 2. Seleção da dieta por bovinos em campo nativo. 3. Qualidade da dieta e oferta de forragem. I. de Faccio Carvalho, Paulo Cesar, orient. II. François Bonnet, Olivier Jean, coorient. III. Jouven, Magali, coorient. IV. Título.

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

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Mestre em Zootecnia

TESE

Submetida como parte dos requisitos
para obtenção do Grau de

DOUTOR EM ZOOTECNIA

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

Aprovada em: 19.03.2019
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“Dedico ao Professor Carlos Nabinger”

AGRADECIMENTOS

Em primeiro lugar agradeço a Deus por ter nascido, pela luz e pela saúde que me moveu durante o doutorado, também ao Gauchito Gil. Muito obrigado a todos meus familiares pelo incentivo ao estudo que me deram desde sempre; a Lara, minha namorada, que esteve presente nessa jornada de estudo e pesquisa. Agradeço a sorte de ter a oportunidade de conviver com as pessoas que tive a oportunidade de conhecer durantes estes anos de UFRGS mais precisamente o departamento de plantas forrageiras. Agradeço o Professor Nabinger pelas conversas aleatórias de precisão. Deixo meu muito obrigado a todo grupo de pesquisa em ecologia de pastejo GPEP destacando o professor Paulo Carvalho. A ele agradeço não apenas por ser meu orientador, mas também por ser proporcionador de oportundades. Agradeço ao amigo Olivier Bonnet que também me orientou. Sempre me ajudou, desde o mestrado, nos ensinamentos em ecologia e na técnica de observação direta do pastejo que faz parte desse trabalho. Agradeço aos colegas que trabalharam na observção dos animais durante a coleta de dados de comportamento ingestivo o Ian Cezimbra, o Marcelo Tischler e o Fabio Neves. Além desses, todos os que colaboraram a cada ajuste de carga no famoso experimento de longa duração, o “Nativão”. Agradeço a CAPES pelo apoio financeiro e a UFRGS pela estrutura de trabalho. Agradeço à equiple da estação experimental EEA/UFRGS que sempre está na ativa para manter os protocolos experimentais em andamento assim como os bolsistas não medem esforços pra pegar um Lozada em POA e ir pra ESTAÇÃO ajustar carga e fazer qualquer serviço em prol de pesquisa. Agradeço à EMBRAPA de Pelotas pelo apoio com equipamentos para análises das amostras de bocados. Agradeço Professora Magali Jouven a qual conheci durante minha estadia no SUPAGRO/INRA de Montpellier – França, por ter bem me orientado, pela peciência e perícia na orientação deste aluno brasileiro aprendendo francês falado e inglês escrito. Meu muito obrigado também aos colegas da professora Magali que também colaboraram no meu trabalho. Agradeço a todos os incentivadores ao Petiço, Gentil, Wallau e todos os demais combustíveis de minha perceverança, que foram “olvidados” nesse momento.

Estratégias de forrageamento de bovinos em campo nativo: identificando categorias funcionais de bocados e suas relações com atributos de ingestão de nutrientes[1]

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Resumo: O bioma Pampa, situado no sul do Brasil, é contemplado por paisagens campestres que por sua vez contribuem como superfície pastoril para herbívoros domésticos. Tal superfície pastoril se caracteriza por ampla diversidade de pasto que confere largas possibilidades de escolha por parte do animal. Essas escolhas, bocado a bocado, resultam na dieta total dos animais que dependem dessa superfície pastoril. A pesquisa tem buscado entender quais mecanismos regem a escolha de alimento por parte do animal. Entretanto, a vasta diversidade de bocados potencialmente colhíveis pelos animais em pastejo torna complexa a análise e o estudo das estratégias de seleção da forragem. Há a necessidade de agrupar itens alimentares (bocados) com características comuns para verificar a contribuição de cada classe de bocado na dieta do animal. Nesse contexto, foram testadas duas hipóteses: 1) os componentes alimentares podem ser classificados em categorias funcionais, de acordo com a função desempenhada na maximização da ingestão de um ou outro nutriente; 2) o índice de seleção dessas classes e sua contribuição na dieta de novilhas pastejando campo nativo na escala diária mudam em função dos itens ofertados, entre níveis de oferta de forragem. O presente trabalho classificou uma vasta lista de tipos de bocados realizados por bovinos em cinco níveis de oferta de forragem, coletados em quatro estações do ano. Foi utilizada a técnica de observação direta do pastejo para coletar as amostras e contabilizar cada tipo de bocado realizado pelo animal. As amostras foram secas em estufa, moídas e escaneadas em espectrômetro de infravermelho próximo NIRS. O agrupamento dos bocados foi realizado através de análises de componentes principais e classificação hierárquica. Tal procedimento resultou em cinco classes de bocados que se distribuíram em um gradiente de qualidade com itens alimentares (bocados) contendo desde 30,9 % até 56,7 % de digestibilidade da matéria orgânica. Com o uso da observação direta do pastejo foi verificado a proporção de tais itens na dieta como forma de validar a classificação. O trabalho resultou na produção de classes funcionais de bocados baseado em espectro NIRS com relevância no estudo da seleção e composição da dieta de novilhas em pastejo, confirmando a primeira hipótese. Distintos níveis de ofertas de forragem resultam em diferentes proporções de classes de bocados ofertados que influenciam a seleção de forragem. Tal influência é mais nítida quando se compara as ofertas de forragem extremas. O FDN da dieta influencia a seleção de forragem pelo animal. Ofertas de forragem moderada permitem melhor expressão da seleção e maior possibilidades no processo seletivo da forragem por bovinos.

Palavras chaves: Campo nativo, NIRS, bocado funcional, comportamento ingestivo, seleção da forragem, bocado.

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[1] Tese em Zootecnia – Faculdade de Agronomia – Departamento de Plantas Forrageiras, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil. (103 p.), Mar, 2019.

Cattle foraging strategies on Pampa natural grasslands: a functional meaning of the different bite type their relationships with nutrient intake attributes [2]

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Abstract: The Pampa biome located in south Brazil is contemplated by country landscapes that contributes like pastoral surface for domestic herbivores. Such pastoral surface is characterized by a wide pasture diversity that confers wide possibilities of choice on the part of the grazing animal. These choices, bite to bite, result in the total diet of the animals that depend on this pastoral surface. The research has sought to understand which mechanisms govern the feed choice by the animal. However, the vast diversity of potentially bites selectable by grazing animals makes complex the analysis and study of forage selection strategies by the animal. There is a need to group feed items (bites) with common characteristics to verify the contribution of each feed class in the animal's diet. In this context, two hypotheses were tested: 1) the complex information contained in the infra-red spectra is good support for establishing functional bites categories that can be used to understand and manage grazing in natural pastures; 2) The index of selection of these classes and their contribution in the diet of heifers grazing a native field in the daily scale change according to the offered items, among levels of forage supply. The objective of this study was to classify a wide list of bites types made by cattle in five levels of forage allowance collected in four seasons of the year. The direct biting observation technique was used to collect the samples and to account for each bite type obtained by the animal. The samples were oven dried, ground and scanned in a NIRS near-infrared spectrometer. The bite grouping was performed through principal components analysis and hierarchical classification analysis. This procedure resulted in five feed classes that were distributed in a quality gradient with feed classes containing from 30.9% to 56.7% of organic matter digestibility. Using the direct observation of grazing, the proportion of such items in the diet was verified as a way of validating the classification. The work resulted in the production of NIRS spectrum functional classes with relevance in the study of the selection and composition of the diet of grazing heifers, confirming the first hypothesis. The forage allowance results in different proportions of feed items offered that influence the selection of pasture. Such influence is sharper when comparing extreme forage allowance. The NDF of the diet influences the selection of forage by the animal. Moderate forage allowance allows better expression of forage selection by the animal.

Key words: native grasslands, nir, functional feed, grazing behaviour

[2] Ph.D. thesis in Animal Science – Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil. (110 p.), Mar, 2019.

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Lista de abreviaturas

NIRS – infravermelho próximo
OF – oferta de forragem
MS – matéria seca
FDN – fibra em detergente neutro
PV – peso vivo
MF – Massa de forragem
CBM – continuous bite monitoring
DM – dry matter
FA – forage allowance
NDF – neutral detergent fiber
ADF – acid detergent fiber
ADL – acid detergent lignin
CP – crud protein
ADG – average daily gain
BW – body weight
DAF – forage accumulation rate
FM – forage mass

CAPÍTULO I - INTRODUÇÃO

1. INTRODUÇÃO

A interação dos herbívoros com os pastos nativos, através do pastejo, impacta tanto a composição da comunidade vegetal como a produção primária e secundária (Maraschin et al, 1997; Bergman, Fryxell, & Gates, 2000; Soares et al., 2005). Em ambiente pastoril heterogêneo o pastejo moderado proporciona equilíbrio entre produção primaria e secundária (Maraschin et al, 1997). Além disso, pesquisas recentes demonstraram que a variação estratégica da oferta de forragem em diferentes estações do ano potencializa o ganho por área sem comprometer o ganho individual (Soares et al., 2005). Entretanto, para entender os processos envolvidos nesses resultados, pesquisas em escalas espaço-temporal reduzidas, com perspectiva mecanística de entendimento do pastejo, demonstraram que a estrutura do pasto influencia o consumo de matéria seca por ruminantes em pastejo. Estas sugerem que determinadas estruturas de dossel podem maximizar a taxa de ingestão de matéria seca em pastejo (Bremm et al., 2012; Júlio K Da Trindade et al., 2012; Gonçalves et al., 2009).

No mesmo sentido, interpretações do ato do pastejo em ambientes complexos têm utilizado a identificação de diferentes tipos funcionais de bocado (exemplos, bocados com baixa massa e alta qualidade com função de nutrição ruminal e ou bocados pesados com função de preenchimento ruminal) para melhor entendimento do processo de forrageamento por ungulados. Resultados de avaliações em pastagens nativas no sul da França verificaram que tais tipos funcionais permitem que o animal em pastejo, guiado por pastor, estabeleça combinação de tipos de bocado que podem aumentar a ingestão de matéria seca (MS) e de energia (Agreil et al, 2006; Meuret et al, 2015). Meuret & Agreil (2005) verificaram que a ingestão diária de MS de ovinos e caprinos permanece constante mesmo quando o bocado preferido se rarefaz, desde que o ambiente pastejado permita combinar distintos componentes alimentares. E isto ocorre mesmo que a oferta de forragem se reduza, até certo ponto, mas mantendo a possibilidade de realizar diversos tipos de bocados durante o pastejo.

Uma forma de entender os fundamentos das estratégias de forrageamento dos herbívoros em pastos heterogêneos é comparar os comportamentos observados com regras teóricas mais ou menos simples, por exemplo, a otimização dos custos-benefícios na aquisição de energia (Fortin, et al 2003; Fortin, et al 2002) ou comparando a dieta selecionada pelo animal com a disponível na área (Manousidis et al., 2016). As estratégias de forrageamento podem ocorrer quando há diversidade de componentes do pasto, que também pode interferir na motivação ao pastejo (Gregorini, 2012; Meuret & Agreil, 2005; Provenza, et al 2015). Feng et al. (2016) verificaram, em condições controladas (estábulo), que a diversidade da diet ofertada proporciona aumento na motivação no final da refeição. Segundo os autores, nessa fase os fatores endógenos (a fome) que motivam o consumo se reduzem e a diversidade entra como fator exógeno mantendo a motivação à ingestão de forragem. Tal aumento da motivação ao consumo talvez ocorra pela complementariedade dos fatores endógenos e exógenos. Contudo, para conseguir executar tais estudos em ambientes pastoris complexos é necessária a aquisição de informações quantitativas e qualitativas detalhadas sobre o comportamento ingestivo na escala do bocado. Neste sentido, o uso da técnica de monitoramento do pastejo descrita por Bonnet et al. (2015) permite identificar o consumo dos distintos componentes do pasto, amostrar a massa, a composição e a taxa dos bocados, gerando inferências relativas ao processo de pastejo por ruminantes. Entretanto, se considerado todos os tipos de bocado, embora haja riqueza de informações, seu processamento e interpretação pode apresentar dificuldade pelo volume e sobreposição de informações. Quando vários tipos de bocados da grade de bocados apresentam a mesma ou similar composição nutricional há sobreposição de informações. O uso da espectroscopia no infravermelho próximo (NIR), juntamente com análise de classificação hierárquica usando espectro NIR como variável de entrada, tem sido utilizado para classificar componentes de pastagens por características comuns (Silué et al., 2016). Neste sentido, o presente trabalho testou tal técnica para agrupar itens alimentares presentes no campo nativo do bioma Pampa. Após o agrupamento, verificou-se a proporção de tais itens na dieta de novilhas em ambientes pastoris com várias estruturas resultantes de distintas intensidades de pastejo.

Os produtos desta Tese poderão ajudar a responder perguntas como: quais estratégias de forrageamento adotam os bovinos em campo nativo? Quais os principais fatores que regem tais estratégias? A seleção do pasto ocorre para maximizar a ingestão instantânea de MS ou equilibrar fibra? A seleção da dieta muda em função da oferta de forragem e diversidade do pasto?

CAPÍTULO II – REVISÃO BIBLIOGRÁFICA

REVISÃO BIBLIOGRÁFICA

1.1. Evolução do conhecimento em uso de pastagens nativas

Esta seção pretende discorrer o que foi iniciado na introdução a partir de um breve histórico dos resultados obtidos na EEA/UFRGS. Tais resultados, em grande parte, foram obtidos em um protocolo experimental de longa duração que vem testando o comportamento e desempenho animal em distintos níveis de oferta de forragerm. A partir disso, apontar algumas evidências que serão estudadas nesta Tese e outras que poderão ser estudadas no futuro. Este ramo da ciência vem aprofundando o conhecimento nos últimos anos. Os primeiros experimentos foram de cunho produtivo, que testaram raças e carga animal (kg/ha), estudando a oferta de forragem ideal para melhor e maior produtividade primária e secundária. Maraschin (2009) e Maraschin et al. (1997) verificaram no bioma Pampa que a oferta de forragem moderada proporciona equilíbrio entre a produção por área (146 kg de PV/ano) e por animal (0,517 kg de PV/dia). Posteriormente, sob a perspectiva de produção sustentável foi avaliada a produção animal com variações na oferta de forragem, com vistas a manipular a estrutura do pasto. Neste sentido, na busca do manejo ideal que proporcione o teto de produção animal em campo nativo sem adição de insumos, Soares et al. (2005) verificaram que aumento na produção animal quando ofertas de forragem variáveis no tempo eram comparadas a ofertas fixas (havendo uma melhor combinação dependendo da magnitude e sentido de variação das ofertas (vide Soares et al., 2005). Os autores registraram produção de 230 kg de PV/ha/ano e atribuíram esse resultado à melhor estrutura de pasto proporcionada pela variação da oferta de forragem. Este resultado de ganho por área representava quase o dobro do observado por Maraschin et al. (1997) no mesmo protocolo experimental e na oferta de forragem fixa de 12% (12 kg de MS/100 kg de PV por dia).

A busca pelo entendimento dos processos envolvidos na manipulação da estrutura do pasto e que decorriam indiretamente das ofertas de forragem levou a redução da escala de observação em estudos subsequentes. Experimentos com escala reduzida, em nível de bocado, demonstraram a importância da massa de bocado na taxa de ingestão de MS. Entretanto, a massa de bocado por si só não explica e/ou mantém a taxa de ingestão. Para isso, também é necessário estudar a taxa de bocados, que é regulada pela estrutura do pasto e pela capacidade de processamento dos bocados por parte do animal (Laca, 1992). Bergman et al. (2001) demonstram que os bisões buscam maximizar a taxa de ingestão instantânea e minimizam o tempo de pastejo nos ambientes selvagens. Isto porque os animais necessitam de tempo para desempenhar outras atividades (Bergman, et al. 2001) como o período reprodutivo, dispêndio de tempo com vigilância e resguardo do calor e do frio. Um bom exemplo é o tempo de pastejo em bisões, que se reduz durante a temporada reprodutiva tanto nos machos quanto nas fêmeas (Melton et al. 1989). Entretanto, os animais podem optar por maximizar a aquisição de energia por unidade de risco ao invés de fazê-la por unidade de tempo em ambientes perigosos com a presença de predadores ou caçadores (Fortin et al., 2015). Em sistemas de produção, a importância de maximizar a taxa de ingestão vem no sentido de otimizar o tempo. Sobretudo em propriedades leiteiras, onde as vacas lactantes têm seu acesso ao pasto restrito por passarem pelo processo de ordenha. Esta categoria, por exemplo, pode gastar mais de 5 horas por dia entre horários de ordenha e deslocamento. Dessa forma, há necessidade de ingestão rápida de forragem durante o pastejo para suprir a demanda diária de nutriente. Vários trabalhos têm verificado que há compensação, por parte do animal, no sentido de consumir a mesma quantidade de pasto, uma vez que seu tempo de acesso ao pasto se reduz (Pérez-Ramírez, et al., 2008; Gregorini et al., 2009; Kennedy et al., 2011; Liz et al., 2014). Tal compensação do consumo de MS, ocorre pelo aumento na taxa de ingestão de forragem, aumento no tempo dedicado ao pastejo, aumento da taxa de deslocamento e diminuição da mastigação. Entretanto, isso ocorre se a estrutura do pasto permite, pois ela exerce importante impacto na ingestão de forragem (Carvalho et al., 2007; Gonçalves et al., 2009).

Com esta perspectiva, foi realizada uma série de experimentos com o intuito de verificar qual a estrutura de pasto que proporcionaria uma maior taxa de ingestão visando o consumo de MS diária. Isto porque segundo Mertens (1994), o desempenho animal depende em grande parte do consumo de matéria seca diária. Segundo o autor, entre 60 e 90% do desempenho animal é explicado pelo consumo de MS, e entre 10 e 40% é explicado pela digestibilidade da forragem. Sob essa fundamentação, pesquisadores da área buscam estratégias de manejo, estruturas de pasto e entendimento dos processos intrínsecos ao pastejo que proporcionem maximizar o consumo diário de MS. Neste sentido, Gonçalves et al. (2009) avaliaram o efeito da estrutura do campo nativo, representada por diferentes alturas, na taxa de ingestão instantânea de MS. Os autores verificaram que a altura e a massa de forragem (MF) do estrato inferior do pasto ideal pra maximizar a taxa de ingestão de MS por bovinos é de 12 cm e 2500 kg de MS/ha, respectivamente. Entretanto, embora a estrutura do pasto no estrato entre touceiras seja uma variável de grande importância para garantir adequada taxa de ingestão, somente esta variável não é suficiente para explicar o desempenho animal. Para isto há necessidade de incorporação de outros componentes do pasto e do animal (Carvalho et al., 2015).

Dada a importância do entendimento dos processos, tanto para ambientes pastoris naturais como em ambientes pastoris produtivistas, a pesquisa continuou a busca por entender como a estrutura do pasto influencia a taxa de ingestão de MS em distintos ecossistemas. Bremm et al. (2012) incorporaram mais um componente estrutural no pasto (a touceira), criando uma estrutura de estrato inferior conforme preconizado por Gonçalves et al. (2009), de 12 cm, porém, com proporções crescentes de touceiras no dossel. Bremm et al. (2012) verificaram uma resposta quadrática, onde o potencial da taxa de ingestão de MS foi alcançado quando o percentual de touceiras cobriu 34% da área. Da mesma forma, mas em escala de potreiro, Da Trindade et al. (2015) verificaram que o consumo diário de MS em pastagem nativa é maximizado em estruturas de pasto similares às observadas por Bremm et al. (2012). Tal estudo demonstrou que as variáveis de estrutura do pasto, MF no estrato inferior, frequência de touceiras e altura do estrato inferior do pasto determinam o consumo diário de MS e, consequentemente, o desempenho por bovinos em pastejo. Neste trabalho, o consumo diário de MS foi maximizado com estrutura de pasto com MF entre 1800 e 2300 kg/ha, altura do estrato inferior entre 11,5 e 13,4 cm e uma frequência de touceiras não maior que 30% (Trindade et al., 2015), o que legitima os resultados em escala reduzida encontrados por Bremm et al. (2012) e Gonçalves et al. (2009).

Assumindo que o conhecimento gerado esteja disponível aos produtores, nota-se que, em certas ocasiões, ele pode não ser utilizado ou implementado. Muitas vezes manter uma estrutura de pasto a qual maximize a taxa de ingestão, o consumo diário e que garanta bom desempenho animal em um ambiente produtivo, não se alcança com facilidade na prática. Isto por uma série de motivos: falta de maquinário, declividade do terreno, presença de afloramento rochoso no terreno (que não permite o uso de roçadoras), o mercado do gado que retarda as vendas resultando no excesso de lotação (SEBRAE/SENAR/FARSUL, 2005). Enfim, situações que não permitem a formação de estruturas de pasto ideal para altas taxas de consumo de forragem. Este fato, no presente estudo, é encarado como oportunidade de aprofundamento no entendimento dos processos na busca de alternativas. A Zootecnia, que tem atuado com foco na utilização dos ambientes pastoris naturais, vem buscando interagir com distintas áreas do conhecimento tentando entender a fundo os processos envolvidos no pastejo com perspectiva interdisciplinar e de aplicabilidade desse conhecimento integrado (Karl et al., 2012). Embora em escala reduzida, este trabalho buscou este foco.

1.2. Interface planta animal em pastagens complexas

Em ambiente heterogêneo com alta oferta de forragem, a digestibilidade não se mantém constante no tempo e no espaço, e o consumo de MS muitas vezes acaba sendo reduzindo quando a participação de material com alto valor nutritivo diminui (Fryxell, 1991). Nesse sentido, alguns modelos de predição apontam que a estratégia de seleção por parte do animal pode se modificar em função da qualidade e da quantidade do material ofertado (Hirakawa, 1997). A forma com que o pasto se apresentam ao animal também exerce influência na ingestão de forragem (Carvalho et al., 2009). Dessa forma, para cada tipo de vegetação há uma altura do dossel que potencializa a ingestão de forragem. Vários resultados destacam evidências de que a combinação de distintos componentes alimentares disponíveis, por parte do animal em ambientes heterogêneos, permite manter um consumo de

MS maior que o esperado, se considerado a qualidade média do pasto possibilitando, assim, desenvolver sistemas pastoris mais sustentáveis (Villalba e Provenza, 2009; Feng et al. 2016).

Algumas referências na literatura demonstram que os herbívoros em pastejo têm estratégias de forrageamento para obterem mais eficiência na aquisição de energia por unidade de tempo (Stephens and Krebs, 1986), de forma instintiva em ambiente natural (Bergman et al., 2001), ou guiados por pastores (Agreil et al., 2006; Meuret & Provenza, 2015), como nos Alpes. Várias interações fisiológicas e neurais determinam a tomada de decisão durante a alimentação (Provenza and Launchbaugh, 2004). Ao iniciar a ingestão, também é dado início à secreção de sinais de saciedade que, ao atingirem certo acúmulo, determinam o final da refeição (Smith and Gibbs, 1998). Tais sinais podem sofrer distúrbios. Por exemplo, em humanos uma sobremesa pode anular o sinal de saciedade após uma longa refeição, permitindo uma refeição ainda mais longa e consequentemente com maior consumo (Stephens et al., 2007). Em consequência disso que provavelmente (Feng et al., 2016) verificou maior motivação à ingestão de forragem por pequenos ruminantes quando foi ofertado dietas com alta deversidade de plantas. Tais fatores do comportamento ingestivo e a diversidade da dieta ofertada podem explicar o maior consumo de nutrientes observado por Meuret & Provenza (2015) em ovinos e cabras conduzidas por pastores comparado ao consumo potêncial desse animais em pastagens monoespecíficas. Neste sentido, a forma com que o pasto se apresenta, ou seja, a altura do dossel, proporciona a possibilidade física da ingestão de forragem e a diversidade do pasto atua na motivação ao invertir mais tempo em consumo de forragem.

1.3. Justificativa do trabalho

Frente a complexidade da ingestão de nutrientes em ambientes heterogêneos, apenas a diversidade ou a quantidade do pasto não irão garantir satisfatória ingestão de nutrientes pelo animal. O fator estrutura, representado pela altura do pasto, exerce importante influência na ingestão de forragem (Carvalho et al., 2009). Por isso, a possibilidade física de acesso ao bocado deve ser considerada quando se objetiva suficiente ingestão de forragem em pastejo. Em pastagens complexas, os herbívoros interagem com a variabilidade no material ingerido e existe certa sequência lógica na ingestão dos itens alimentares guiados por sinais hipotalâmicos (Stephens et al., 2007), de forma a buscar a manutenção da homeostase (Provenza et al., 2007). Pesquisas vêm sugerindo que os sinais intracelulares reguladores da saciedade, que determinam o andamento da refeição e, por sua vez, a homeostase energética, são os mesmos para mamíferos, insetos, nematoides e leveduras (Porte et al., 2005), com diferenças apenas na fonte de energia e no método de forrageamento utilizado (Stephens et al., 2007).

Os modelos de otimização da ingestão podem ser utilizados para compreender o comportamento seletivo dos herbívoros (Fortin et al., 2015). Segundo esses modelos, o animal busca bocados em função do retorno em alguma “moeda” de interesse. Tais modelos contemplam o tempo de manipulação, o tempo de busca e a disponibilidade relativa do bocado, buscando predizer a energia ingerida por unidade de tempo (Bergman et al., 2000; Hirakawa, 1997; Sih e Christensen, 2001).

Este trabalho pretende aprofundar o entendimento das estratégias de forrageamento utilizadas por herbívoros em pastejo, hierarquizando os itens alimentares por valor de importância relativa. Também pretende compreender o processo de aquisição, composição e organização da dieta selecionada. Isto para buscar entender os fatores limitantes para o consumo, e verificar se há viabilidade do animal em manter determinado nível de consumo de alimentos que não penalize seu desempenho, selecionando forragem em estruturas de pasto heterogêneas caracterizada por alta riqueza de bocados. Na literatura temos evidências de que isto possa ocorrer. Meuret & Agreil (2005) avaliaram o comportamento ingestivo de ovelhas e cabras em pastagem heterogênea por 15 dias. Durante este período foi realizado um pastejo severo, uma vez que entre 75-95% das espécies herbáceas do piquete foram consumidas. Foi verificado que a ingestão de nutrientes destes animais permaneceu constante em escala diária enquanto a oferta de forragem diminuía. A seleção de dietas, a taxa e a massa de bocados são manipuladas pelos animais. Esse ajuste foi interpretado pelos autores como uma resposta funcional do comportamento em situações de uso de recursos heterogêneos. Pela literatura disponível, somam-se evidências de que os herbívoros exercem certa organização no material ingerido quando pastejando em ambiente heterogêneo. Porém, como ocorre tal organização? O caso acima relatado foi descrito com pequenos ruminantes, que tendem a ser “browsers” (Hofmann, 1989). Os bovinos, “grazers”, teriam a mesma capacidade?

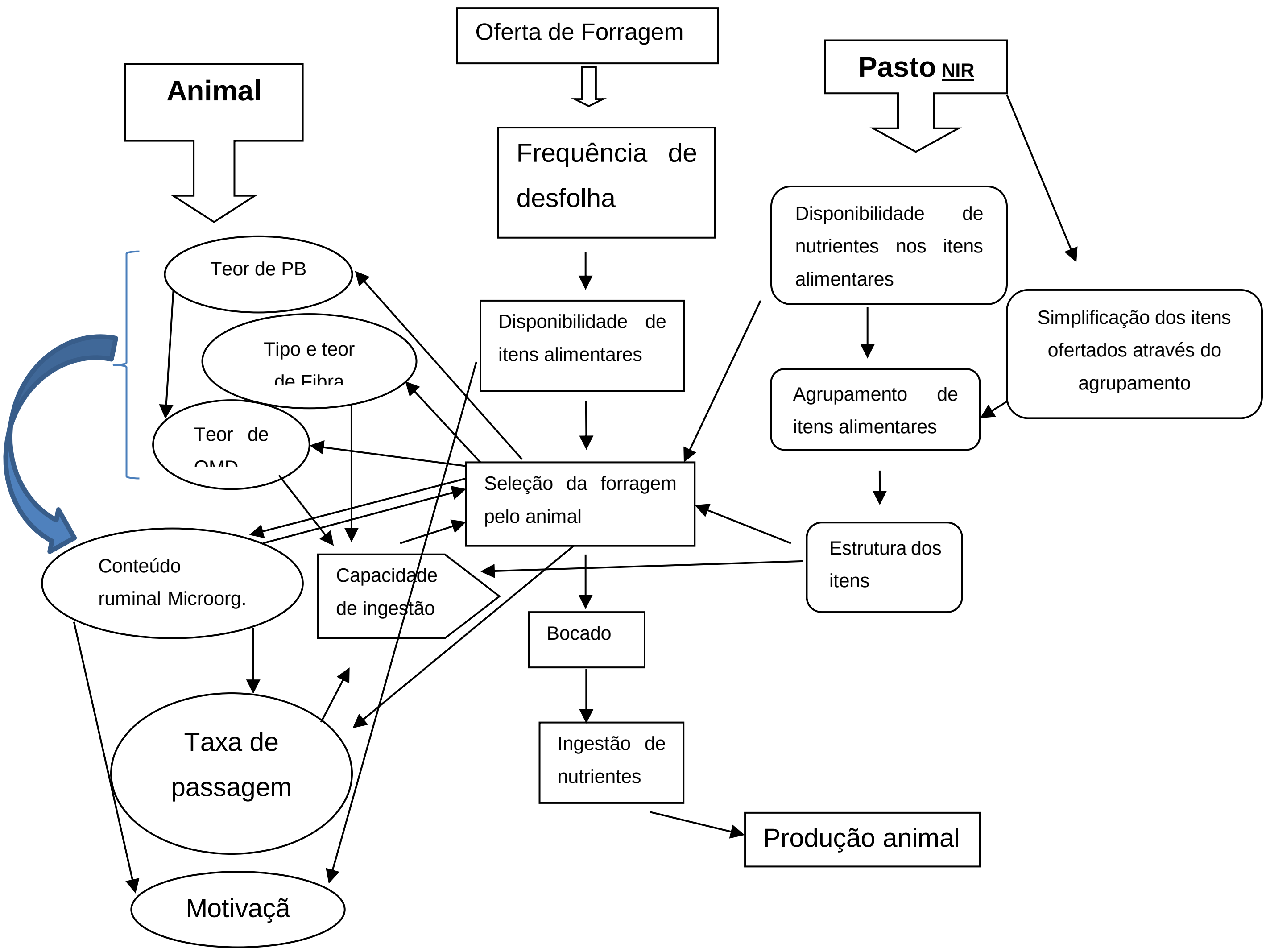
A metodologia de observação direta dos animais em pastejo descrita por (Bonnet, et al. 2011; Bonnet et al., 2015) se faz pertinente para identificar os padrões de ingestão dos itens alimentares e, a partir desse banco de dados, pretende-se verificar quais são as estratégias adotadas por bovinos em cinco ambientes pastoris moldados por diferentes intensidades de desfolha. A composição de itens alimentares em ambientes com alta diversidade é bastante vasta. Neste sentido, surge a necessidade de seu agrupamento com base em características comuns. Por exemplo, no Garrigue – Mediterraneo - França foi realizada a classificação de itens selecionados por ovelhas utilizando análises de componentes principais (APC) e classificação hierárquica com espectros do NIR (Silué et al., 2016). Tal procedimento poderia ser interessante para classificar itens alimentares selecionados por bovinos em campo nativo do bioma Pampa. Isto possibilitaria a formação de um banco de dados para estudar o comportamento ingestivo por bovinos e talvez responder àquelas questões apresentadas no item 1.

O uso da espectroscopia no infravermelho próximo, com sigla oriunda do inglês NIRS “near-infrared spectrum” (*a região do espectro eletromagnético mais próximo da região visível pelo olho humano*), é uma técnica utilizada para avaliar o objeto de estudo neste trabalho, ou seja, se utilizou para classificar itens alimentares (tipos de bocado) em campo nativo. Tal ferramenta tem sido utilizada em vários ramos da ciência. Na medicina é utilizada para monitorar a oxigenação dos tecidos (Lima and Bakker, 2011), avaliar as propriedades da gasolina no ramo dos combustíveis (Balabin et al., 2007), assim como precisar a composição de nutrientes na área de alimentos (Pasquini, 2003). O uso do NIR para estimar a composição de forragens se baseia na relação do espectro produzido da luz que passa pela amostra e constituintes químicos dentro da amostra, os quais estão associados a certas regiões de comprimento de onda de absorção de luz. É uma técnica que não requer reagentes químicos, não produz poluentes e oferece uma avaliação de alimentos barata, não destrutiva, rápida e relativamente precisa (Adesogan et al., 2000). Além disso, é adequada para analisar volume grande de amostras, característica necessária para caracterizar a larga variabilidade de bocados existentes em ambientes pastoris heterogêneos.

1.4. Modelo conceitual da seleção e ingestão de forragem em campo nativo

A questão de pesquisa dessa tese reside na possibilidade formação de classes de bocados com características comuns para ser utilizada em estudos de estratégias de seleção da forragem e assim avançar no entendimento do processo de pastejo em campo nativo. Além disso, pretende-se criar um índice de seleção de tais bocados a partir da proporção deles na dieta de novilhas sob distintas ofertas de forragem e de diversos itens alimentares. A questão de fundo seria: Quais estratégias de seleção são tomadas pelos animais e o que poderia dirigir tais decisões?

O modelo conceitual abaixo busca representar as variáveis envolvidas nesta questão de pesquisa. O NIRS foi utilizado para formação dos grupos de bocado, conforme mencionado anteriormente. Os possíveis fatores que influenciariam a seleção do bocado estão ilustrados no modelo.


Oferta de Forragem
Animal
Pasto NIR
Frequência de desfolha
Disponibilidade de nutrientes nos itens alimentares
Teor de PB
Tipo e teor de Fibra
Disponibilidade de itens alimentares
Simplificação dos itens ofertados através do agrupamento
Agrupamento de itens alimentares
Teor de OMD
Seleção da forragem pelo animal
Estrutura dos itens
Conteúdo ruminal Microorg.
Capacidade de ingestão
Bocado
Taxa de passagem
Ingestão de nutrientes
Produção animal
Motivaçã

1.5. Hipóteses

a) Os bocados podem ser classificados em várias categorias funcionais, de acordo com a função desempenhada na maximização de um ou outro nutriente por meio de espectros NIRS. Os bocados podem ter função de maximizar a ingestão ou de nutrientes ou de volume de pasto e exercer uma função intermediaria entre os duas anteriores.

b) O índice de seleção de classes de bocado e sua contribuição na dieta de novilhas forrageando em diferentes estruturas de campo nativo na escala diária muda em função das condições da forragem, entre níveis de oferta e a composição da dieta.

1.6. Objetivos

a) Classificar os bocados selecionados por novilhas em campo nativo em vários grupos funcionais de bocados baseado em análise de componentes principais e classificação hierárquica valendo-se de espectros NIRS de amostras de simulação de bocados.

b) Testar como as variações na estrutura da vegetação disponível pela variação na oferta de foragem (representada por oferta de classes de bocado) pode afetar o índice de seleção desses itens e sua proporção na dieta de novilhas.

CAPÍTULO III – THE FEED CLASSIFICATION

2. FUNCTIONAL CLASSIFICATION OF FEED ITEMS IN PAMPA GRASSLAND BASED ON THEIR NIR SPECTRUM

Júlio Azambuja, Paulo Carvalho, Olivier Bonnet, Denis Bastianelli and Magali Jouven

Abstract

Native pastures usually display high botanical richness. It results in large variation of bite types by the grazing animal. Diet selection is set up bite by bite, resulting in his total diet. The grazing science pursuits understanding of what are the mechanisms that determine animal selection in order to propose best management practices in pastoral ecosystems, and examining its capacity to feed a herd. We hypothesized that the complex information contained in the infra-red spectra of sampled bites would be useful for establishing functional bite categories that can be used to understand and manage pastoral ecosystems. We proceed the analysis of the NIR spectrum of 1515 bite samples gathered using the continuous bite monitoring method. Treatments were five grazing intensities distributed in a randomized block design with two replicates. Heifers were grazing native pastures in continuous stocking. Grazing intensities had been applied since 1987 and bite samples were collected over 2012. In order to evaluate the functional value of the classification, we tested its ability to take into account seasonal changes in plant composition, and to describe the variations in animal intake and performance depending on varying grazing conditions. We conclude that the complex information contained in the NIR spectrum is a good support for establishing functional categories of feed items that can be used to understand the foraging behaviour and diet composition. The proposed classification allows describing a large range of feed items in a smaller number of classes.

Key words: NIRS, tussocks, Campos grasslands, functional groups, bite, diet selection

2.1. Introduction

Native pastures usually display high botanical richness (Fraser et al., 2015). For example, Pampa grasslands host about 450 Poaceae, 200 Fabaceae, 600 Asteraceae, and 200 Cyperaceae species, of variable interest as a forage resource for grazing animals (Modernel et al., 2016; Boldrini et al., 2009). Within a pasture, botanical diversity is combined with the diversity of pant parts, which abundance and nutritive value vary with season and grazing intensity. This results in a wide range of potential feed items for large herbivores (Carvalho, 2013; Milne, 1991).

The diversity of feed items (that is, potential bites) enables grazing animals to select a diet as close as possible to their nutritional requirements. Previous works have provided evidence that the composition of herbivores' diet depends: on the abundance and spatial distribution of preferred feed items (Dumont et al., 2001), on previous grazing experience (Villalba et al., 2015), on the grazing context in terms of plant association or watering time (Gobindram et al., 2018) and on the type of animal in terms of species (Celaya et al., 2011) or physiological stage (Farruggia et al., 2006). Such selective behaviour is made possible by the ability of herbivores to use their senses (sight, smell, taste) and memory to choose the right combination of feed items (Dumont, 1997; Provenza, 1995). In continuously-grazed native pastures, the diversity of feed items in terms of characteristics and distribution varies in time (seasons) and space (feeding sites). Such changes are known to affect herbivore diet in terms of bite composition (items), but also nutritional composition (proportion of items). Previous research showed that the availability of bites with large nutritive content, although small, impacts mainly diet quality (Garcia et al., 2003), while the availability large bites at the paddock impacts mainly the amount of forage ingested daily (Agreil et al., 2005).

In complex grazing environments, finding a simple way to describe the diversity of feed items is crucial in order to understand animal behaviour, predict intake and performance depending on the grazing conditions, or anticipate the ability of a given pasture to provide adequate forage for a given type of animal. The difficulty of producing a simple classification of feed items able to respond to all three objectives has oriented research towards simple, controlled grazing environments where vegetation diversity could be easily accounted for by sward height or phenological stage (Ginane et al., 2003) or by plant botanical species (Prache and Damasceno, 2006). Diet taxonomy may reveal little about differences in animal nutrition (Hobbs et al., 1983) because the same taxon may offer different forage quality if the phenological stage is different. The few studies carried out in natural grazing environments used categories of feed items based either on bite size (Agreil et al., 2006) or – for shrubby vegetation – on botanical species or orders (Manousidis et al., 2016). Most models predicting animal selection at pasture use information about the abundance and composition (green/dead material) or digestibility of a limited number of vegetation components (Jouven et al., 2008). Finally, the pastoral value of a natural grassland is usually evaluated either by estimating the available biomass (Trindade et al., 2015) or by measuring the botanical composition and applying expert-based coefficients (Daget and Poissonet, 1971) or a functional classification of plants based on their morphology and physiology (Cruz et al., 2010; Duru et al., 2005). But the problem is that, when the classification is largely detailed using both the botanical classification and the morphological aspect of the bites, it ends up in a huge variety of classes, thus making it extremely difficult to analyze data and interpret animal behavior. Though, recent works in *Garrigue* – France rangelands (Silué et al., 2016) shown that the information contained in the full NIRS spectrum could be used to classify bites unsupervisionedly in a "functional" way, that is in classes which can be interpreted in terms of contribution to animal feeding and nutrition and thus can explain animal selective behavior. The foraging strategy over the course of a meal, for example, the cattle can choose only big bites with low quality for rumenal filling. The daily and sesonal grazing strategy may be differents proporções of differents bite types.

The objective of our work was to produce a simplified and unsupervised classification of feed items for cattle grazing at Pampa grasslands based on analysis of the information contained in the NIR spectrum of a large number of bite samples collected using the detailed classification of the continuous bite monitoring method (CBM). Thus, we hypothesized that the complex information contained in the infra-red spectra is a good support for establishing functional bite categories that can be used to understand and manage grazing in natural pastures. In order to evaluate the functional value of the classification, we tested its ability to take into account seasonal changes in plant composition and to describe the variations in animal intake and performance depending on grazing conditions.

2.2. Materials and methods

2.2.1. Experimental site and conditions

The work was carried out in 2012 on the Agronomic Experimental Station of the Federal University of Rio Grande do Sul (lat 30°05′S, long 51°40′W, 46m a.s.l.), Brazil. The station is located in a depression of Pampa biome with typical Pampa native grasslands; the local climate is subtropical humid with a mean annual rainfall of 1440 mm well distributed throughout the year.

The paddocks and cattle (250 kg of BW average) we used part of a long-term experiment initiated in 1987 (Trindade et al., 2016) comparing various forage allowances (FA) on Pampa grasslands continuously stocked by cattle. The FA are 4, 8, 12, 16 and 8-12% kg dry matter (DM)/100 kg live weight. Each treatment is applied to 2 paddocks of about 4.5 ha; FA is adjusted by changing the number of grazing animals (usually two-year-old heifers) according to herbage growth following the “put-and-take” method (Mott & Lucas, 1952). These five treatments represent a variety of grazing intensities, representing a range that can be found in real farms. Their continuity on the long-term has produced distinct pasture vegetation structures, which we used as models of constrating grazing environments.

2.2.2. Data collection

Two types of data were needed to fulfil our objectives: (1) animal selective behaviour was recorded in order to identify possible feed items and test the classification by evaluating diet composition; (2) based on the observed grazing behaviour, a large number of samples of feed items were collected and analyzed in order to provide the data for the statistical classification. Practically, we needed to apply ex-ante the most accurate description of the diversity of feed items; in this perspective, we used the bite coding grid presented in Figure 1, which takes into account vegetation stratum, plant morphology, plant parts taken and plant height or bite depth. The training of observers and animals occurred within a period of one month. Before each evaluation in each season we made the bite grid, this during a week. After all evaluation we find with total of 43 bite type that may be made by cattle combining four season and 51 plant species. We also recorded the time of year (day and season), and whenever possible, the botanical species or family.

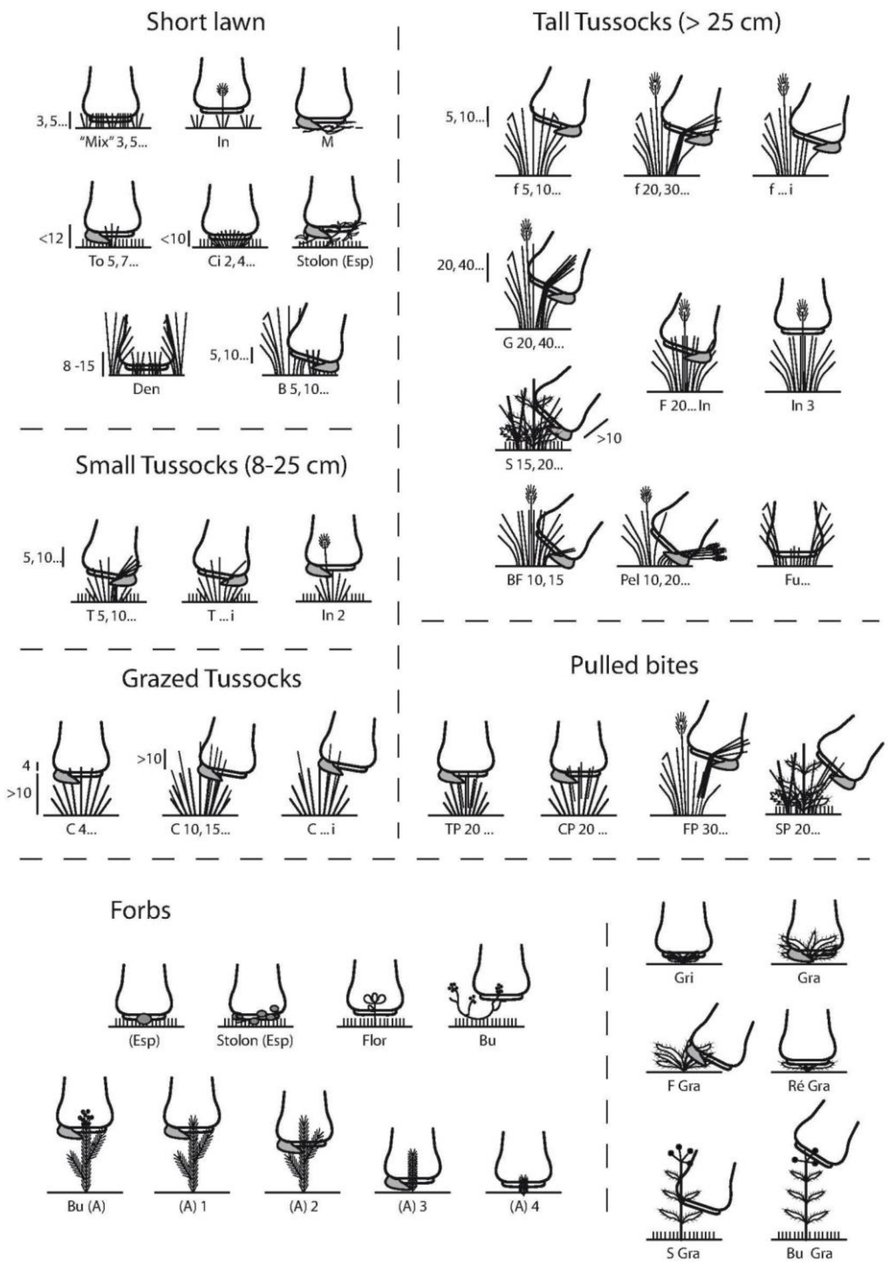


Figure 1. **Bite coding grid for feed items grazed by heifers in Pampa grassland**. The coding procedure associates: letters or short words standing for the morphological part (see a drawing

of the plants) and for the position of the animal mouth and tongue (also drawed) + plant height or (for tussocks) bite depth + species when mentioned (esp.).

2.2.2.1. Recording of animal foraging behaviour

Five observers (one person/heifer/day) carried out behaviour observations in autumn (10 to 23 May 2012) and spring (15 to 25 October 2012), two estreme conditions. Twenty-nine, two-year-old heifers were observed individually. Continuous bite monitoring was performed using the coding grid presented in Figure 1 and a Sony ICD-PX312 (Sony Corp., Japan) digital voice recorder accounting the bites (feed items) made by animal each observed. Bite monitoring started in the morning with the onset of grazing, paused in the middle of the day while the animals rested, and started again in the afternoon. No observations were carried out at night, but given the conditions in autumn (plant growth season end) and spring (plant growth season), we assume that night grazing was not significant. The information recorded was subsequently transcribed using the JWatcher® software (www.jwatcher.ucla.edu) according to the continuous bite monitoring method described by Bonnet et al., (2015). We calculated the intake rate in DM/min of feed items (bites) using temporal windows of 30 seconds with auxiliary data four help to understand the functionality of feed classes (NIRS). Practically, we added the masses of each bite and divide by the time spent to realize these bites.

2.2.2.2. Sampling of feed items and evaluation of bite mass

The sampling was performed by hand plucking, trying to closely mimic the animal behaviour. Bite simulations were carried out in summer (11 to 19 February), autumn (4 to 14 May 2012), winter (30 August to 11 September 2012) and spring (17 October to 8 November 2012). The sampling seasons differed from the observations on the animals, it is because two work was made by same observers and both works used all day. The sampling periods in spring and autumn are close to the periods where foraging behaviour was recorded. The same twenty-nine heifers were re-observed in the same paddocks, during the same periods of the day. Simulations were performed for all the bite categories described in Figure 1. In total, we collected 3034 samples of which 439 in summer, 852 in autumn, 916 in winter and 827 in spring. In both seasons was made the number maximum possible sample in a day.

Bite mass was obtained separately, by simulating 8 to 30 bites (20 bites on average) of a given bite category. The biomass collected was dried at 60ºC and weighted. The dry weight was then divided by the number of bites to obtain the average bite mass. Bite mass was used to estimate the proportion of each class of feed item in the diet.

2.2.2.3. Estimation of diet composition

The classification of feed items produced was applied to simplify the description of the observed animal behaviour. The classes are the group of potential bites classified by PCA and hierarchical analysis usin sprectruns NIR. Diet composition was estimated in terms of each class proportion in observed DM intake. We used the average bite mass of each class for this. Practically, depending on the season and on the sample, a given bite category based on the coding grid could appear in different classes. Thus, to ensure the best attribution of each class to each animal bite type, we considered the two seasons (spring and autumn) separately and attributed to each bite category (or feed items) the proportion of classes obtained in the sample analysis.

2.2.2.4. Analysis of plant samples

The smallest samples were grouped by two or three (of same nature) in order to obtain sufficient weight for subsequent analyses (at least 2g DM); thus, only 1515 samples of feed items were analyzed. Each sample was ground to 0.5 mm and scanned in a NIR spectrophotometer (NIRFlex 500, Buchi Labortechnik, Flawil, Switzerland) in reflectance mode between 1100 to 2500 nm with 2 nm step. The nutritional characteristics (*in vitro* digestibility, crude protein, fibre and ash content) of each sample were predicted based on its NIR equations developed by the CRA-W laboratory (Walloon Agricultural Research Center, Gembloux, Belgium). The calibration equations used for prediction of nutritional value are based on the following reference methods: De Boever et al. (1986) for in vitro organic matter digestibility, Dumas combustion method for crude protein content, Van Soest (1963) adapted to the Fibertec System for fiber fractions (NDF, ADF, ADL) and gravimetric method based on the incineration of sample at 550°C during 3 hours for ash content.

2.3. Statistical analysis

2.3.1. Classification of feed items

NIR spectra were used to classify feed items into five categories functional of feed items. The spectra were mathematically pretreated by applying an SNV (standard normal variate) correction and a second derivative (Rinnan et al., 2009), in order to minimize information not related to chemical composition. The wavelengths associated with water bands were removed (1380 – 1520 and 1860 – 2020 nm) because the residual water content after drying is not informative. Then, a principal component analysis was performed, and the first thirty principal components were used for hierarchical classification of samples, using the Ward criterion. At various clustering levels, was cut to five classes, as a compromise between inter-classes dissimilarity (that is, that is, considering the sharpness of the graphical difference between groups in the points cloud) and precision in the description of the forage resource (that is, possibility of re-identifying bite types in the Pampa grassland). This statistical analysis was performed with the FactoMineR package of the R Core Team (2017).

2.3.2. Statistical analysis between classes

We used the Pairwise Wilcoxon Rank Sum Tests (non-parametric analysis) to evaluate the difference between characteristics of feed classes (bite mass, digestibility, protein, fibre and ash) established by NIRS spectrum because no-showed of the presuppositions for parametric analysis. The distribution of the five classes in animal diet and diet quality for each treatment were compared using analysis of variance (ANOVA, model 1) followed by Tukey tests. Differences were considered significant for P-values < 0.05.

(1) $Y = \mu + T + \varepsilon$

where Y is the variable tested, μ is the average value, T is the effect of the Treatment and ε is the random error.

This statistical analysis was performed with the base package of the R software (R Core Team, 2017).

2.4. Results

2.4.1. Classification of feed items into five classes

The dendrogram representing the classification and the statistical differences between classes. The five classes were then characterized by their dominant plant type, species and bite mass (Table 1), and by their nutritional characteristics (Table 2).

2.4.1.1. General characterization of the five classes

Each of the five feed classes represented between 9% (class 2) and 28% (class 4) of the the analyzed samples. Thus, we can fairly assume that each class should represent a substantial contribution to the daily intake at pasture, although such contribution might vary with season and grazing conditions. Bite mass was always statistically different between classes (Table 1) while plant type or botanical species represent auxiliary information; though, it is possible to identify "typical characteristics" of the feed items in a given class.

Three classes (classes 1, 2, 3) are characterized by small feed items (= small bite mass – often associated with small plant size), from prostrated grasses and non-grass species. Class 1 includes feed items from small, tender grass species mainly from wet areas. Class 2 is composed mainly of feed items from the grass *Paspalum notatum* and from a diversity of non-grass species associated with a variety of habitats. Class 3 includes feed items composed of mixed species, mainly short *Poaceae* characterizing the lower stratum of the pasture. The two remaining classes

(classes 4, 5) include feed items with moderate to high bite mass, from large non-grass species or from cespitose grasses. Class 4 is composed by feed items from the characteristic Pampa tussocks which display high phenotypic plasticity. Class 5 associates feed items from the spiny plant “Caraguatá” (*Eryngium horridum*) and from stiff tussock species, both providing extra-large bites to grazing cattle.

Table 1. General characteristics of the five classes from the NIR spectrum. The samples cover the variety of morphological feed items of Figure 1 and the four seasons of the year, with repetitions.

Class (nº of samples)	Bite mass (g)		The dominant type of plant (Frequency of main species in the samples of each class, in %)
	mean	s.d.	
1 (321)	0.09[e]	0.1	**Wetland grass and short grass:** *Luziola peruviana (17%)*, *Panicum aquaticum (3%)*, *Mnesithea selloana (2%)*, *Cynodon dactylon*, *Paspalum pumilum (9%)* and *Paspalum notatum (45%).*
2 (135)	0.16[c]	0.1	**Not grass and short grass:** *Vernonia nudiflora (27%)*, *Baccharis trimera (2%)*, *Desmodium incanum (2%)*, *Eleocharis viridans (7%)*, *Paspalum pumilum (14%)* and *Axonopus affinis (11%).*
3 (369)	0.11[d]	0.09	**Short *Poaceae* and mixed species:** *Paspalum notatum (40%)*, *Paspalum pumilum (17%)*, *Piptochaetium montevidese (3%)*, *Rhynchospora globosa (3%)* and *Paspalum paucifolium (3%).*
4 (422)	0.27[b]	0.2	**Tussocks *Poaceae*:** *Andropogon lateralis (70%)* and *Andropogon virgatus (16%).*
5 (268)	0.69[a]	2	**Stiff tussock *Poaceae* and *Apiaceae*:** *Eryngium horridum (9%), Aristida leavis (18%)*, *Aristida flaccida (53%)*, *Aristida jubata (8%)* and *Sorghastrum sp (9%)*.

Letters refer to the statistical difference (P<0.05) between classes for the non-parametric Wilcoxon test.

2.4.1.2. Nutritional characteristics of the five classes

There was a gradient of nutritional characteristics (Table 2) from class 1 (highly nutritive) to class 5 (bulky). The high protein (CP) content was associated with high digestibility (OMD), lower fibre content (NDF) and a higher proportion of minerals (Ash).

The interesting in this classification method is that classes 1 and 2 are quite similar chemically and the difference is made precisely on other criteria to be discovered in future. The same is verified with classes 4 and 5 that had low protein (approx. 6% DM) and mineral (approx. 7% DM) contents, with a low organic matter digestibility (<34%) and a high fibre content (78-81% DM). But class 5 displayed more variability with twice standard deviation. Suggestively, this finding makes precisely the interest of the unsupervised classification.

Class 1 has a 20.24% contribution of C3 photosynthetic pathways plants; *Luziola peruviana*, *Briza subaristata* and *Piptochaetium montevidense* while the others classes have less contribution of C3 plants; 7.4, 3.25, 0.47 and 6% for classes 2, 3, 4 and 5, respectively. Species associated with class 2 were mainly *Asteraceae* and no-grass plants, thus probably they might display specific nutritional characteristics associated with secondary compounds. Feed items in class 3 are relatively intermediate in terms of nutritional characteristics.

Table 2. Nutritional characteristics of the feed items in the five classes, estimated from the NIR spectrum. The nutritional parameters: *in vitro* Organic Matter Digestibility (OMD) organic matter, Crude protein (CP), Neutral Detergent Fiber (NDF) and Ash in % of dry matter.

Class (nº of samples)	OMD		CP		NDF		Ash	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
1 (321)	53.7[a]	5.8	14.7[a]	3.3	68.7[d]	3.5	10.2[a]	1.6
2 (135)	56.7[a]	9.7	12.5[b]	3.1	66.1[d]	9.3	9.7[a]	1.1
3 (369)	44.7[b]	4.6	9.2[c]	1.4	74.0[c]	2.6	8.8[b]	0.9
4 (422)	30.9[d]	4.0	5.8[d]	1.3	78.3[b]	2.2	6.8[c]	0.8
5 (268)	33.8[c]	7.1	5.9[d]	2.3	81.2[a]	4.7	7.2[c]	1.3

Letters refer to the statistical difference (P<0.05) between classes for the non-parametric Wilcoxon test.

2.4.2. Testing the value of such classification

Classifying feed items based on their NIR spectrum, whatever the season and grazing conditions, can be considered as an interesting approach for understand herbivores feed strategies. Our five classes make sense because they can clearly be differentiated as a combination of nutritional characteristics, botanical origin and bite masses. Thus, it should be possible to associate each class with a function in terms of herbivore nutrition. The usefulness of such “functional groups”, for research (as a tool to describe intake at pasture) or for extension (as a tool to improve grazing management) depends on the ability of such classes to describe contrasted situations of grazing conditions, the composition of intake or animal performance.

2.4.2.1. The grazing environment and the composition of feed intake

Based on the data collected during continuous bite monitoring, we estimated the proportion of each class in the diet of heifers, for two contrasted seasons and grazing intensities (in terms of forage allowances; Figure 2). Diet composition is significantly different between environments. Especially, the proportion of class 1 in the diet is high in spring and decreases in autumn in favour of class 3 at low forage allowance, or in favour of classes 4 and 5 at high forage allowance. The proportion of classes 4 and 5 is always low at low forage allowance. Low forage allowances provoke smaller tussocks availability and less grazing of erect grass (species that are more present in the classes 4 and 5) because of the higher stocking rates by a long period of time. Generally, the quality of the diet (in terms of digestibility and protein content) decreases in autumn compared to spring and is lower at high compared to low forage allowance. We observed a lower proportion of class 2 in autumn at high forage allowance.

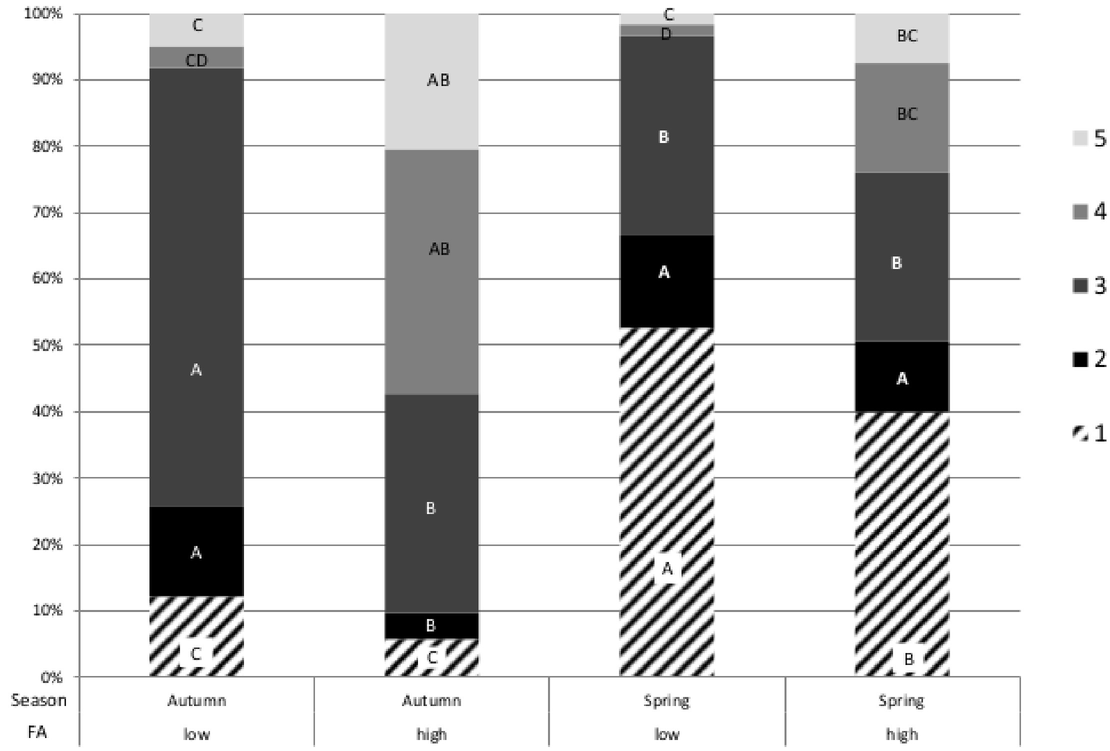


Figure 2. Diet composition of grazing heifers, depending on the season (spring or autumn) and (low and high) forage allowance. The forage allowances (FA) are 4% (low FA) and 12% (high FA) kg DM /100 kg live weight of grazing animals. The y axis gives the proportion of the five groups of feed items in the daily intake. Letters refer to the statistical difference ($P<0.05$) between Season: FA (x axis) in terms of the proportion of each group in the diet.

Class 3 is the only one to be resilient enough in all conditions (> 25%), which makes it a "pivot" class to feed animal.

2.4.2.2. Potential to predict intake composition of grazing heifers

The average dry matter intake rate (IR, g/min) of feed items varied between classes (Table 3). IR is the product of bite mass and bite rate, the latter depending on the ease of prehension. Intake rate is usually considered as a major driver of diet selection (the second being nutritional characteristics), as it influences greatly the amount of forage ingested daily. IR was lowest at all seasons for class 2, and highest at all seasons in class 5. Thus, we may hypothesize that although highly nutritious, class 2 is less interesting than class 1 for grazing animals because it requires more grazing time. Conversely, the high intake rate of class 5 might make it more attractive than class 3 if the IR of class 5 compensates its low digestibility. The observations reported in Figure 2 are consistent with our interpretation. This auxiliary information collaborates in understand the functionality of feed classes.

Table 3. Intake rate IR (g/min) and standard deviation (sd) of five feed classes made from components principal analysis and hierarchical classification with spectrum NIR. The presence of feed items (bite type) of each feed class used to calculate intake rate was greater than 76%.

IR	Feed Classes				
	1	2	3	4	5
Mean	5.57^{abc}	4.5^{c}	5.21^{bc}	5.97^{ab}	6.59^{a}
Sd	1.30	1.20	1.68	1.66	1.61

The letters refer to the statistical difference between feed classes Tukey test (P<0.05) level.

Based on the proportion of classes in the diet and on the average nutritional characteristics of each class, we estimated diet composition (Table 4) and digestible energy content. Unsurprisingly and consistently with Figure 2, the quality and digestible energy content of the diet decreased from spring to autumn and was lower at high forage allowance. We compared the values to the nutritional requirements and especially to the limiting factor that is energy, in spring and autumn (table 4). Diet quality depends on pasture structure. The inter-tussock sward height verified in high FA (6 cm) was double compared with low FA (3 cm). The intake rate was low at 4% FA but no statistical difference was verified.

Table 4. **Nutritional characteristics of heifers' diet and animal performance in contrasting grazing environments.** Nutritional parameters are estimated from continuous bite monitoring and bite class proportion in the diet. Two seasons (spring and autumn) are compared, and within each season we consider two forage allowances (FA): 4% (low FA) or 12% (high FA) kg DM /100 kg live weight of grazing animals. The nutritional parameters are: in vitro organic matter digestibility (OMD, in % organic matter); crude protein (CP), neutral detergent fiber (NDF) and mineral content (Ash) in % DM; digestible energy (DE) in Mcal/kg dry matter. The indicator for animal performance is the average daily gain (ADG) in kg live weight.

FA	Season	OMD%	CP%	NDF%	Ash%	DE	ADG
Low FA	Autumn	46^{aA}	10^{aB}	72^{aA}	8^{aA}	2.04^{aA}	-0.24^{aA}
High FA	Autunm	38^{aB}	07^{aB}	76^{aB}	7^{aB}	1.69^{aB}	-0.07^{aA}
Low FA	Spring	51^{bA}	12^{bA}	69^{bA}	9^{bA}	2.25^{bA}	0.16^{bB}
High FA	Spring	46^{bB}	10^{bB}	71^{bB}	8^{bB}	2.04^{bB}	0.51^{bA}

The lowercase letters refer to the statistical difference between Season and uppercase letters refer to the statistical difference between FA in each Season (P<0.05) level.

2.5. Discussion

We were able to produce, based on the NIR spectrum of feed items collected on Pampa grasslands, five classes of “bites” corresponding to a nutritional gradient, with distinct properties in terms of bite mass and intake rate. The proportion of each class in animal diet allows rebuilding the diet quality in terms of digestibility, protein, fiber, ash and energy. In this section, we will discuss subsequently: (1) the functional interpretation of our five classes in terms of contribution to the daily intake; (2) the contribution of this work, compared to previous studies; (3) the scientific perspectives and practical uses of this classification to assist grazing management in Pampa ecosystems.

2.5.1. Functional interpretation of our classification

The characteristics of each class of feed items and its seasonal contribution to the diet of [non-supplemented] grazing heifers suggest specific functions:

- Class 1, with the highest nutrient concentration (especially proteins) but the smallest bite mass (although not the lowest intake rate), could typically represent a “concentrate grazed feed”, probably preferred by the animals but ingested in moderate amounts due to the small bite mass and the season-dependent availability. Like concentrate feed, class 1 would be important as a provider of nutrients to increase animal performance and/or to support the ruminal microflora activity in case of high fiber diets.
- Class 2 also displays high nutrient concentration, but its consumption seems to remain moderate – probably due to the lowest intake rate and the presence of secondary compounds responsible for toxic effects. In fact, this class contains mainly *Asteraceae* and especially *Vernonia nudiflora* with 1.33% of bites observed, which is known to induce hepatotoxicity when ingested in large amounts (Dutra et al., 2016; Miolo, 1996), but the possible benefits are unknown. The rather constant contribution of this class to intake (approx. 8% of DM) suggests that it could assume the function of a “medicinal feed”, contributing to both nutrient intake and the regulation of rumen and possibly animal health. The

low intake of class 2 in autumn at high forage allowance could be due to the lower energy of the diet which could decrease the ability to metabolize secondary compounds (Forbes & Provenza, 2000).

- Class 3 corresponds to mixed bites and is "intermediate", both in terms of nutrient content, bite mass and intake rate. Depending on the context, it might serve as a source of fiber (in spring) to complement class 1 or as a source of nutrients to complement classes 4 and 5 (autumn). Another interest of this feed item is that it is consumed constantly suggesting that it is reasonably available at all seasons. Thus, the function of this class could match that of the "permanent small bites" described by Agreil et al. (2004).
- Class 4 contains feed items from "tussocks", characterized by low nutrient and high fibre content, thus naturally complementing class 1. The large bite mass (on average three times greater than class 1) and the high intake rate make this class very useful to maintain the quantitative intake of forage fulfilling to feed safety.
- Class 5 is similar to class 4, with higher bite mass and fibre content. Such feed items may serve as "roughage" to the animals. However, they are more difficult to collect for the animals because has spiky and hard plant and thus result in a lower intake rate than class 3. That is, these classes appear to be chemically similar but when the plant-animal interface is added in the system they appear to have different feed function.

Our classification can be connected with the work of Cruz et al. (2010), who classified the plant species of the Pampa as a function of their ecological strategy towards the locally available resources: species with conservative strategy (ability to recycle nutrients, associated with characteristics such as high dry matter content and leaf lifespan, low specific leaf area) *vs* species with capture strategy (ability to take advantage of the soil resources, associated with characteristics such as high specific leaf area, low dry matter content and leaf lifespan), or classification of other grassland environments (Duru et al., 2005). Conservative species (*Andropogon lateralis*, *Aristida laevis* and *Aristida spp*.) provide feed items mainly in classes 4 and 5, while classes 1, grasses of 2 and 3 (*Axonopus affinis*, *Mnesithea selloana*, *Paspalum paucifolium* and *Paspalum notatum*) are capture species. Such interpretation suggests that feed nutritional functionallity to the animal has connection with plant functional traits that cope with environmental function in the same grassland environment. Ryser and Urbas (2000) propose that the plants with “conservative resource” strategy are an advantage in nutrient-rich environments when the plants are not subjected to frequent defoliation. Our data show feed assurance importance to herbivorous at FA 12% linked to grassland resource maintenance too. Trindade et al. (2016) observed the greater DM intake by beef heifers when the coverage of conservative plants was around 35%. In a biodiversity perspective, the tussocks are important (Dias et al., 2014) to keep the “keystone structures” that are crucial for maintaining species diversity (Tews et al., 2004) vital to Pampa biome. Presumably, the management goal that keeps around 34% of tall grass (Bremm et al., 2012) reasonable from both production and environmental perspective.

2.5.2. The contribution of this work to pasture science

In previous scientific studies, classifications of feed items in heterogeneous pastures were used either to study short-term animal preferences or to predict daily intake. In the first case, feed items would be classified in terms of botanical species or genus (Mancilla-Leytón et al., 2012; Manousidis et al., 2016; Pfister & Malechek, 1986) or by morphological characteristics such as sward height (Fleurance et al., 2010) or bite mass (Shipley, 2007), green/dead/reproductive material (Farruggia et al., 2006) and phenological stage (Ginane et al., 2003). In the second case, average sward height (Jouven et al., 2008) or availability of “large bites” (Agreil et al., 2005) would serve as indicators for quantitative intake.

Our classification based on the NIR spectrum of feed items is more precise for animal feeding than the botanical classification because it takes into account the distinct nutritive value of the various plant parts ingested and the effect of the phenological stage on such characteristics. Figure 3 shows the distribution of the five main botanical species into our classification based on the NIR spectrum. Apart for *Vernonia nudiflora* in autumn and *Eryngium horridum* in spring, all species have samples in more than one class, which shows that botanical description alone is not sufficient to account for bite nutritional value characteristics. We suggest that the change in proportion of feed classes in diet are resulting from phenological stage and pasture structure.

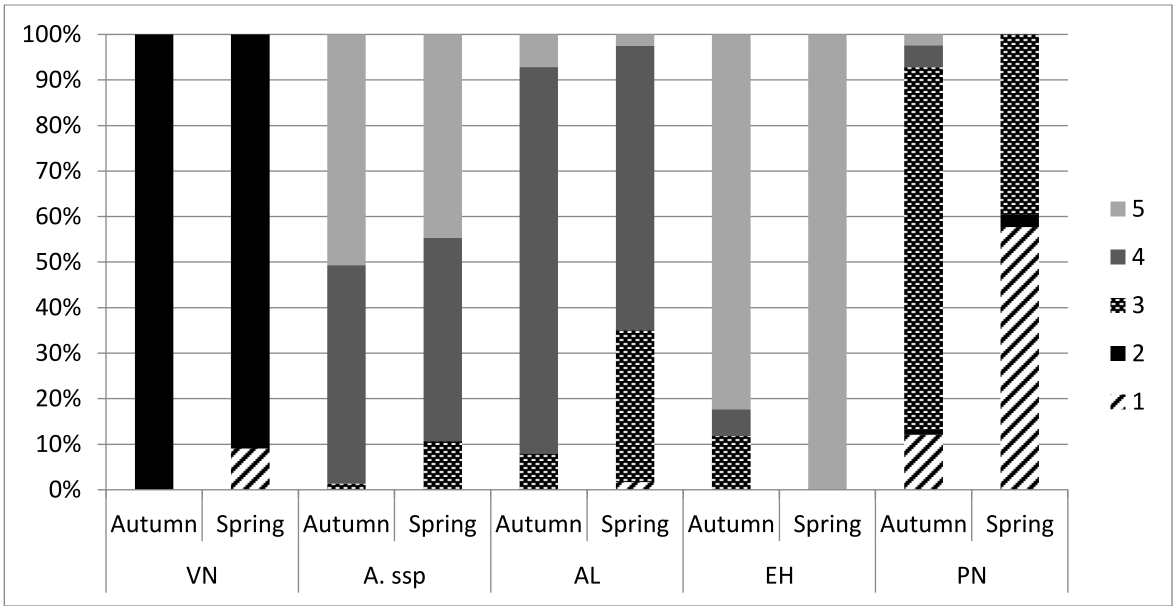


Figure 3. The five main species in each feed classes depending on the season. The species are *Vernonia nudiflora* (VN), *Aristida* ssp. (A. ssp), *Andropogon lateralis* (AL), *Eryngium horridum* (EH) and *Paspalum notatum* (PN) which make up 63% of the samples of Autumn and Spring.

The relevance of our method is the possibility of the description of all feed items or “bite type” available at the field in five classes with commun traits. Also, it separates the sample with different nutritional characteristics due to plant physiology, as a response to seasonal conditions, grazing intensity or both (Figure 4). For example, for five bite types from our detailad coding grid, the proportion of the 5 classes of feed items changes with season. Bite “c” includes feed items from class 2 in spring, but not in autumn; the proportion of classes 1 and 2 for the bite type “mono” is reversed in spring compared to autumn. The proportion of class 3 is reduced by more than half from spring to autumn for “Mix”, “Mono”, “t & tp” and “f” bite types. The class 1 (highly nutritious) in the bite type “mix” (which is the most frequent) drops from 48% in spring to 14% in autumn.

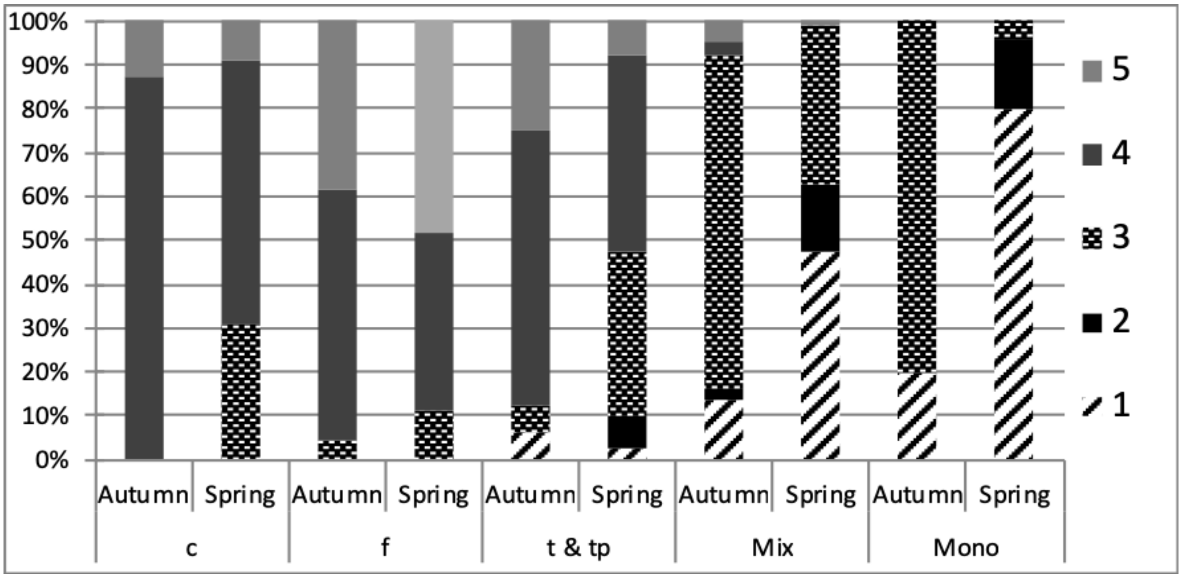


Figure 4. Correspondence between morphological bite types (feed items) of our coding grid and classes of feed items from NIR classification, for two grazing seasons. Five frequent morphological classes are considered: c, f, t & tp, Mix and Mono. The numbers refer to the five classes from NIR classification. The correspondence is expressed in % of bite samples analyzed.

Since NIR classes are distinct both in terms of nutrient content (with the highest precision given the full NIR spectrum is taken into account) and bite mass, they have the potential to predict both animal preferences at pasture and animal intake, from a quantitative and qualitative point of view. Until now, to our knowledge, no other classification enabled to do this for complex grazing environments.

Clearly, the classification obtained for Pampa grasslands is specific to such environments. In fact, it differs widely from the classification of feed items in *garrigue* rangeland obtained by similar methods by Silue et al. (2016). The high diversity of ligneous species in *garrigue* (browsed by sheep) produced a classification enhancing the diversity between browse types and reducing the diversity of grass species to only one class (gathering all bite types from 5 species). Also, in *garrigue* rangeland the high plant diversity made it easier to identify bites according to protein content or energy content than in Pampa grasslands. Though, based on the function of each class in herbivore diet, it is possible to draw connections between the two classifications. Thus, even though the exact nutrient, botanical and morphological characteristics of each class might be different depending on the grazing environment, it should be possible to draw a generic model of herbivore intake at pasture, based on the functions of each class. The calibrations of such model in terms of precise nutrient content and bite mass of each class would be context-specific. The animal species are also presumably important at clustering by selection behaviour. Silué et al. (2016) considered the potential feed items for ewes; thus, feed items included more fruit and plants or plant parts which cattle would not have been able to select, due to their larger mouth.

2.5.3. Perspectives and practical applications

Our work opens interesting perspectives. To research, it offers a new framework which can be applied to understand further the foraging behaviour at pasture. Before using for such purposes, though, the classification should be associated with a coding grid enabling a good match between classes and observations, and avoiding our *a priori* morphological approach (Figure 1). The analysis of animal intake composition for each season and treatment in the long-term experiment should enable us to propose soon a model of selective intake in Pampa grasslands. From a modelling perspective, it would also be interesting to apply the same classification method in a variety of grazing environments, in order to support the generic value of the model.

The feed classes allow rebuilding the animal diet in terms of parameters used in conventional animal nutrition (protein, energy, fibre and ash). This result evidences the possibility of using feed class to predict animal feeding choices. Nevertheless, there is room for improvement. For example, we did not assess volatile compounds by measuring the NIR spectra on dried samples, which might have been involved in self-medication, antinutritional or natural self-additive driven animal behavior (Villalba et al., 2014). Figure 5 conceptually address to this issue proposing a schematic representation of bites in a nutrient concentration gradient that is intervened by plant secondary compounds.

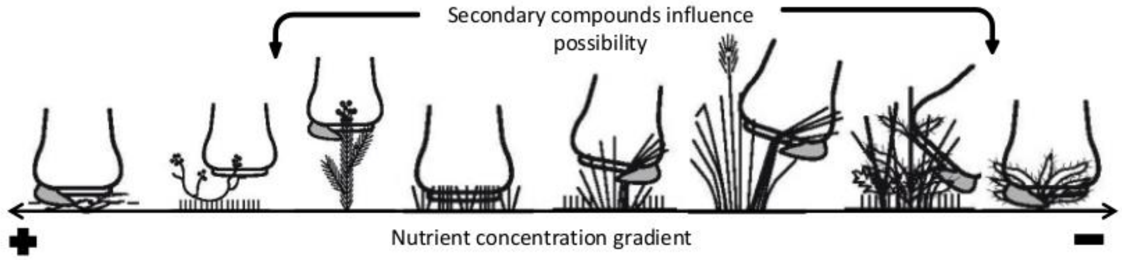


Figure 5. Simplified schematic representation of the conceptual model made after grazing observation of heifers at Pampa grassland showing a nutrient concentration gradient (class 1 to 5) and some possible interference caused by secondary compounds.

Another practical application of our work is to support the design of better animal diets aiming for higher animal performances. The requirement for a daily gain of 0.51 kg (Table 4) is 6.5% CP. However, our data showed a minimum of 7% CP in the diet, suggesting that heifers on such grasslands don't have seasonal CP deficit. This implies that energy supplementation and/or higher daily DM intake management interventions (e.g., higher FA or sward heights) would be taken into account for better animal performance goals.

The bite functinal classes allow rebuild the animal diet in terms of protein, energy, fiber and ash. In this way, if considerate daily intake verified by (Trindade et al., 2016) which is 1.97% of BW to FA 4% and 2.67% of BW to 12% at some experiment on spring-summer season, we verify that account intake is considerably coherent with animal performance at spring. So, the digestible energy requirement for gain obtained (0.51 kg/day) on FA 12% is 14.6 Mcal/heifer/day (BR-CORTE, 2016) if considerate DM intake of 2.67% of BW the daily energy intake is 14.97 Mca/heifer/day. Yet, the digestible energy requirement for gain obtained (0.195 kg/day) on FA 4% is 9.7 Mcal/heifer/day using DM intake of 1.97% of BW the digestible energy intake is 9.5 Mcal/heifer/day validating the bite classes use to prediction of diet consumed.

For extension purposes, this classification could facilitate the acquisition of references in terms of feed choices of animals depending on the characteristics of the grazing environment. Such references are lacking for Pampa grasslands. The issue at stake is the optimization of supplementation at pasture and/or pasture clearing, and thus the reduction of costs and more generally the sustainability of extensive livestock systems in southern Brazil. For such purposes, practical indicators linked to favorable/unfavorable grazing contexts need to be assessed. In order to produce such indicators, further research is needed in order to connect each class, or number of typical combinations of classes, to simple visual cues (typical sward aspect, colour, a mosaic of tussocks and short grass and montoring of feeding/nutritive value over the course of a meal).

2.6. Conclusion

In a Pampa grazing environment, we try and produced a “functional and simple” classification of feed items based on their NIR spectrum, tested its relevance for studying animal intake at pasture and discussed its functional interpretation. Based on our results, we conclude that the complex information contained in the NIR spectrum is a good support for establishing functional categories of feed items that can be used to understand the foraging behaviour of grazing cattle, and to predict intake [quantitative and qualitative]. The proposed classification allows describing a large range of feed items in a smaller number of classes than 30 bite types or 70 plant species. Provided a suitable coding grid be determined, the utilization of this classification method in research should help to improve the understanding and modelling of animal grazing behaviour. The functional classes of feed items could also serve extension purposes, by providing information to farmers about the ability of a given grazing environment to provide the quantitative and qualitative requirements of their herd. Before such applications, though, simple indicators related to the functional composition of the pasture need to be assessed.

Acknowledgement

We thank EMBRAPA of Pelotas-RS-Brazil and Walloon Agricultural Research Center, Gembloux, Belgium (CRA-W laboratory) for the prediction of the chemical composition of the samples and CAPES by the PhD scholarship and the Brazilian-French collaboration Project CAPES/COFECUB Valorizar o Pampa.

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CAPÍTULO IV – BEHAVIOUR SELECTIVITY

3. CATTLE FORAGE STRATEGIES IN COMPLEX GRASSLANDS OF THE PAMPA BIOME: EFFECT OF GRAZING MANAGEMENT

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Abstract

The Pampa grasslands display a large diversity of feed items (that is, potential bites) for domestic herbivores. The diversity of potential bites that can be taken changes according to grazing intensity. The objective of this experiment was to investigate the differences in feeding choices of cattle grazing Pampa native grasslands, depending on pasture structure (produced by long-term grazing management practices). We hypothesized those changes in cattle selective behaviour depend on the availability of different classes of potential bites and the limiting factor in animal diet. Treatments were five forage allowances distributed in a randomized complete block design with two replicates. Heifers were grazing native pastures in continuous stocking. Five grazing intensities has been applied since 1987 and bite samples were collected over 2012 in all treatments using the continuous bite monitoring. We investigated how forage allowance influences the selectivity index (IVELV, 1961) of heifers. A functional classification of feed items based on their NIR spectrum was used to account for the proportion of each feed class in heifers' diet in each treatment. Forage allowances influenced IVELV. We verified that selectivity index of potential bites depends of bite class availability and the limiting factor in the diet. Fiber was the constituent that most influenced selectivity of the forage.

3.1. Introduction

The Pampa biome is covered by a highly heterogeneous mosaic of herbaceous plants species. Such natural grasslands represent 70% of the nutritional basis for 18.4 million domestic herbivores in the Rio Grande do Sul state, Brazil (IBGE, 2015). They also contribute to a variety of ecosystem services, such as gas regulation, water regulation, erosion control, pollination and food production (Costanza et al., 1997). Nevertheless, the conservation of these natural pastures has been largely neglected by local authorities. Its preservation is in the hands of farmers who need to produce efficiently to compete against the expansion of monocultures (e.g. soybean) that have been pressing the conversion of natural vegetation to crops (Overbeck et al., 2007).

Efficiency of grassland-based meat production depends mainly on the ability of farmers to implement grazing practices which reconcile good animal performance, natural vegetation as the main (or sole) feed resource for livestock and conservation of the long-term availability of the pastoral resource. Such practices are based on a good knowledge of animal and plant behavior and their response to management practices (Gobindram et al., 2018).

A number of research studies already addressed the question of the interaction between system productivity and grazing management in the Pampa biome. Maraschin et al. (1997) verified that a moderate grazing intensity provides a balance between productivity per area (146 kg of LW / year) and production per animal (0.517 kg of LW / day). Soares et al. (2005) showed that animal production could be increased from 146 kg to 230 kg of LW / ha / year, by increasing grazing intensity in spring which modulated the canopy of pasture. When it comes to animal behavior, local farmers display a certain amount of ecological knowledge, but no scientific data is available to document forage selection by cattle and identify its drivers. Filling this knowledge gap could help to improve further grazing management (Dumont, 1997) and to explain/predict animal performance (Carvalho et al., 2015) while enabling environment-friendly grazing practices.

Forage selection by ruminants is mainly determined by their evolutionary history and their ability to store forage for fermentation in the rumen

(Janis, 1976), which has enabled them to base their diet on plant parts with high cellulose content. Forage selection can be assessed with a selectivity index, which is the ratio of the proportion of a given plant [part] in the diet on its proportion in the sward. Among ruminants, Hofmann (1989) classified cattle as a “grass/roughage eaters”, because they tend to favor quantity over nutritive value of forage, and adapt to seasonal shortages in forage availability by increasing grazing time and storage of body reserves of energy (fat). Conversely, “concentrate selectors” such as goats tend to be more selective for high-nutrient feeds, and adapt to seasonal variations in forage supply by changing, sometimes drastically, the composition of their diet (Gordon and Print, 2008).

Within a given ruminant type, forage selection at pasture is widely influenced by habitat conditions, season and even the individual history of each herbivore (Villalba and Provenza, 2009). That is, optimal diet selection rules can change in time and space when there are resources depletion (Mitchell, 1990). These adaptations have been found both in wild, free-ranging grass eaters such as bisons and domestic cattle. Fortin et al. (2002) working with bisons observed a shift in diet composition between winter and growing season (spring and summer) and associated it with a strategy of short-term intake maximization. In similar conditions, Bergman et al. (2000) showed that the proportion of leaf and stem in the sward affects their selectivity. Bergman et al. (2001) observed patch selection by bison and found that the strategy was of grazing time minimization rather than energy intake maximization. Some experiments verified adjustment of intake composition depending on available feeds (Dumont et al., 2002; Ginane et al., 2002) with the short-term intake maximization (Fortin et al., 2002) or with optimization/minimization of grazing time (Bergman et al., 2001). In domestic cattle, the physiological condition would also affect feeding choices, with cows being more selective towards green forage when lactating and tending to slightly increase their daily grazing time compared with dry cows (Farruggia et al., 2006). At larger spatio-temporal scales, different grazing practices will result in different vegetation structures (Carvalho et al., 2007; Nunes et al., 2019; Soares et al., 2011), and thus potentially in different selective behavior of cattle, different amount and composition of nutrients intake, and different performance (Prache et al., 1998; Soares et al., 2005). This selective behaviour in turn drives vegetation shifts which will in a feedback loop impact grazing opportunity for grazers.

Hence, we hypothesized that the changes in cattle selective behaviour under different forage allowances of native grasslands depend on the availability of different feed classes and the limiting factor in animal diet. Our objective was to investigate the changes in feeding choices of cattle grazing in Pampa biome, depending on vegetation structure (produced by long-term grazing practices). We tried to connect behavioral and nutritional variables, as suggested by Soder et al. (2009). We capitalized on a recent work where feed items in Pampa grasslands were classified according to the diverse information contained in their NIRS spectrum (Azambuja et al. 2018, in press).

The applications of our study are both scientific and technical: on the one hand, to test different hypothesis of foraging strategies; on the other hand, to provide information useful to improve grazing management and eventually increase animal performance or reduce supplementation at pasture, thus maximizing the efficiency of traditional livestock farming.

3.2. Methods

3.2.1. Experimental site and conditions

The experiment was carried out at Agronomic Experimental Station of the Federal University of Rio Grande do Sul (lat 30°05′S, long 51°40′W, and 46m above sea level [a.s.l.]), Brazil. The physiographic region is a central depression of Pampa biome characterized by a subtropical humid climate with a mean annual rainfall of 1440 mm well distributed throughout the year. The experimental design was a randomized complete block with two replicates. The observations were made on a long-term experiment initiated in 1986 testing various levels of forage allowance (FA) in natural grasslands continuously stocked by beef crossbreed heifers. The experiment compares five FA: 4, 8, 12, 16 and 8-12% expressed as kg dry matter

(DM)/100 kg of body weight (BW). Each treatment is applied to 2 paddocks (2 replicates) of about 4.5 ha.

Stocking rate is adjusted according to pasture growth to maintain FA. Monthly measurements were carried out to document grazing conditions such as: sward height (50 points per paddock using a sward stick), forage mass (FM, kg $DM.ha^{-1}$), daily forage accumulation rate (DAR, kg DM $ha^{-1}\cdot day^{-1}.d^{-1}$), weigh of heifers, and stock adjustments to keep the desired FA. The FM was estimated visually with 50 observations/paddock, using the double sampling technique and a calibration of visual estimates with clipped and weighted samples (Wilm et al., 1944). To obtain DAR we used four exclusion cages per paddock according to Klingman et al. (1943). In each cage, two frames (0.5 x 0.5 m) were positioned in two analogous vegetation structures (that is, the cage was positioned in similar pasture conditions to proceed DAR). In one, vegetation was clipped to soil level and oven-dried at 55ºC for 72 h. In the other, vegetation was protected from grazing with cage until the next month. To verify if the stocking rate was in agreement with the FA of the treatment, we calculated:

$$FA = \left(\frac{\left[\frac{FM}{n}\right] + DAR}{SR} \right) x100$$

where FM is the forage mass in kg $DM.ha^{-1}$, n is the number of days between the two measurements, DAR is the daily DM accumulation rate in kg $DM.ha^{-1}\cdot d^{-1}$ and SR is the stocking rate in kg $BW^{-1}\cdot ha^{-1}$. If FA was different from that of the treatment, the number of grazing heifers was adjusted. This adjustment of the stocking rate was performed according to “put-and-take” technique described by (Mott & Lucas 1952). The five grazing intensities of the long-term experiment represent a range of possible management options of Pampa grasslands. At the time of our observations in 2012, the different defoliation regimes applied for 25 years had resulted in distinct pasture structures.

3.2.2. Data collection

In order to analyze the foraging behavior of heifers in the five FA of Pampa grassland, we performed direct observations using the continuous bite monitoring method described by Bonnet et al. (2015). In addition, we described the vegetation in order to assess the availability of each feed item (or "type of bite") in each paddock. Using both data, we calculated, for each treatment, the selectivity index for the feed item groups described in Azambuja et al. (in preparation).

3.2.2.1. Bite account of foraging behavior

Twenty-nine two-year-old heifers were observed individually, from 15 to 25 October 2012 (spring), by five trained observers. Every day, an observer was associated with an animal, where behavior was monitored continuously during the two main grazing periods (around 2-3 hours in the morning and in the evening), thus excluding night grazing. Foraging behavior was recorded using typified bites (e.g. of codes; "c, f, t, tp, Mix and Mono"). The sequence of bites was recorded for each animal registering the chronological diet evolution on Sony ICD-PX312 (Sony Corp., Japan) digital voice recorders, and subsequently transcribed using the Jwatcher® software (www.jwatcher.ucla.edu). Then, we made a correspondence between bite types and the functional groups of feed items obtained for the same period and in the same experiment by Azambuja et al. (in preparation). Then, feed selection and intake composition were expressed in terms of proportions of each group of feed items.

3.2.2.2. Availability of bite type estimates at paddocks

The availability of feed items (bite types) was estimated in October and November 2012, by using semicircular stations systematically distributed in 10 experimental paddocks and simulating feeding stations. Stations were regularly located on a 20x30 m² grid within each paddock and characterized as described in Figure 1. An average of 24 points per station, and 1746 points per paddock were assessed. The procedure consisted in placing a vertical graduated stick in 12 points within each station. For each point, all plant [part] touched by the sward stick tongue, from top to down. Each contact was associated with a bite type, using the same coding grid as for animal behavior.

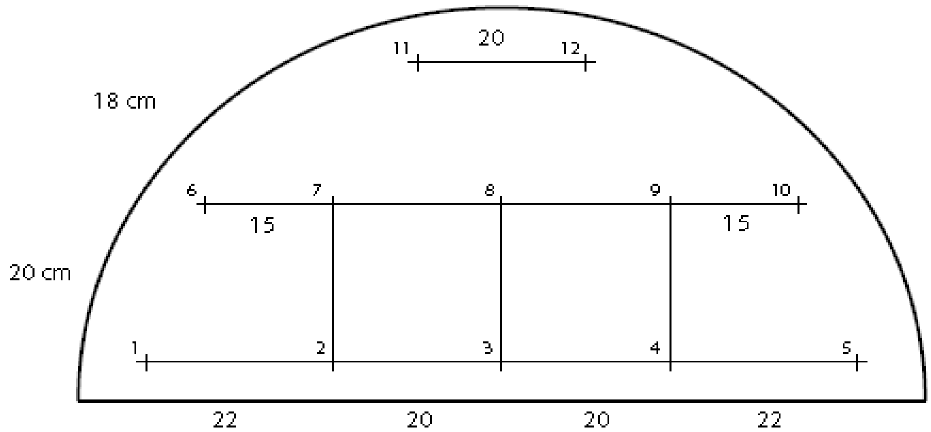

Figure 1. Schematic representation of the feeding station (distances in cm). The small numbers 1 to 12 are the localizations of 12 points, where the estimate of each bite type on offer per station was assessed.

The sum of all bites in the feeding stations was used to calculate the total of bites available per paddock in each bite type. The relative allowance of each bite type was calculated as $\mathrm{RA} = \left(\frac{TBi}{TB}\right) x\ 100$, where RA= relative allowance of bite I, tBi= total number of bite i on the paddock and TB=total number of bites on the paddock.

3.2.3. Analysis

3.2.3.1. Selectivity of bite type groups

We used Ivlev's selectivity index (Ivlev, 1961) to calculate the selection of groups of feed items described in Azambuja et al. (2019, in press). The nutritional composition of each group of feed items, obtained from predictions based on the NIR spectra, is available in Table 1.

Table 1. Characteristics of the five functional groups of feed items from Azambuja et al. (2019, in press): *in vitro* Organic Matter Digestibility (OMD), Crude protein (CP), Neutral Detergent Fiber (NDF) and Ash in %; Bite mass (BM) in g DM; NE Mcal/kg and Dominance (most frequent botanic type in each class).

Class[1]	OMD %	CP %	NDF %	Ash %	BM g	NE Mcal/kg	Dominant type of plant
Nutr	53.7(5)	14.7(3)	68.7(3)	10.2(1)	0.09(0.1)	1.09(0.3)	Soft wetland grass and short grass (86%)
Nutr+SC	56.7(9)	12.5(3)	66.1(9)	9.7(1)	0.16(0.1)	1.12(0.3)	Non grass species and short grass (76%)
Interm	44.7(4)	9.2(1)	74(2)	8.8(0.9)	0.11(0.09)	0.69(0.2)	Short *Poaceae* mix (76%)
Fiber+	30.9(4)	5.8(1)	78.3(2)	6.8(0.8)	0.27(0.2)	0.03(0.2)	*Andropogon* sp. tussocks (88%)
Fiber+MD	33.8(7)	5.9(2)	81.2(4)	7.2(1)	0.69(2)	0.17(0.3)	*Poaceae* or *Apiaceae* stiff tussock (68%)

[1]Feed classes: (Nutr) Highly nutritious small bites; (Nutr+SC) Bites high in digestible energy and secondary compounds; (Interm) Moderately nutritious bites; (Fiber+) Large, fiber-rich bites; (Fiber+MD) Large, fiber-rich bites with mechanical defenses. The standard desviation is in parentheses.

Based on the estimated chemical composition, we calculated the energy concentration of each group of feed items using the following NRC equations (NRC, 2016):

Digestible Energy **DE (Mcal/kg) = (OMD (g/kg)** × **4.409)/1000**

Metabolizable Energy **ME (Mcal/kg) = DE** × **0.82**

Net Energy **NE (Mcal/kg) = ME × 0.644**

The selection index (comprised between -1 and +1) was calculated for each group of feed items and for each experimental treatment, using the equation:

$$\text{Selection index} = \left(\frac{\%\ \text{diet} - \%\ \text{available in the paddock}}{\%\ \text{diet} + \%\ \text{available in the paddock}}\right)$$

3.2.3.2. Statistical analysis

Statistical analyses were performed by the base package of the R software (R Core Team, 2017). We considered the paddock as the experimental unit (N=2), and the animal (3 per paddock; n=3) as the sampling unit. We performed the Bartlett and Shapiro-Wilk test to check the homogeneity and normality of residuals of data, respectively. We compared the results obtained for the various treatments using analysis of variance (1) followed by Tukey tests, applied to selection index (-1 to 1) and availability of feed class in the paddocks (%), pasture height (cm) and intake rate (g/min) calculated in windows of 30 seconds. Differences were considered significant for P-values < 0.05.

(1) $Y = \mu + T + \varepsilon$

where Y is the variable tested, μ is the average value, T is the effect of the Treatment and ε is the random error.

We also performed a regression analysis (2) to test the influence of diet NDF content in the selection of Interm and Fiber+MD classes.

(2) $Y = b_0 + b_1x + \varepsilon$

where Y is the variable tested, b_0 and b_1 are the parameters, x are the explanatory variables and ε is the random error.

For the Nutr class, we used a polynomial model (3).

(3) $Y = b_0 + b_1x + b_2x^2 + \varepsilon$

where Y is the variable tested, b_0 and b_1 are the parameters, x are the explanatory variables and ε is the random error.

3.3. Results

3.3.1. The availability of each feed item at the paddocks

Pasture height was higher with increasing FA, being 3.4, 5.2, 5.8, 6.7 and 7.5 cm with standard deviation 0.4, 0.7, 0.5, 1 and 0.6 respectively for the FA of 4, 8, 8-12, 12 and 16 kg DM/100 kg BW ($P<0.05$).

The availability of bites high in digestible energy and secondary compounds (Nutr+SC), which is originated mostly by bites on *Asteraceae*, were not affected by forage allowance (Table 2). Highly nutritious small bites (Nutr) and moderately nutritious bites (Interm) were less available on higher FA, that was characterized by the availability of fiber-rich bites (Fiber+ and Fiber+MD). Extremes FA of 4 and 16 kg DM/100 kg BW had more contrasting bite types availability than intermediate FA.

Table 2. Availability of five functional groups of feed items from Azambuja et al. (2019, in press) according to five forage allowances (FA): 4, 8, 12, 8-12 and 16 kg DM/100 kg BW.

FA (kg DM/100 kg BW)	Nutr (%)	*sd*	Nutr+SC (%)	*sd*	Interm (%)	*sd*	Fiber+ (%)	*sd*	Fiber+ MD (%	*sd*
4	54[a]	*0.2*	16	*0.05*	24[a]	*0.2*	0.1[c]	*0.2*	02[b]	*1*
8	31[ab]	*5*	16	*0.3*	24[ab]	*0.4*	0.7[bc]	*0.2*	20[a]	*5*
8-12	24[ab]	*0.9*	14	*0.2*	20[ab]	*3*	16[ab]	*1*	24[a]	*0.01*
12	22[ab]	*2*	13	*2*	18[ab]	*2*	19[ab]	*2*	26[a]	*1*
16	16[b]	*1*	10	*1*	12[b]	*0.1*	26[a]	*4*	35[a]	*4*

Letters refer to statistical difference (P<0.05) class availability of each feed class between treatments. Feed classes: (Nutr) Highly nutritious small bites; (Nutr+SC) Bites high in digestible energy and secondary compounds; (Interm) Moderately nutritious bites; (Fiber+) Large, fiber-rich bites; (Fiber+MD) Large, fiber-rich bites with mechanical defenses.

The availability of Nutr class which is characterized by greater digestibility and protein content composed mostly by soft grasses was more present in low FA (4%) and less present in the higher FA (16%). The Interm class is intermediate relative to nutritional quality scale and of easy access for animals. The Fiber+ class was composed mostly by tussocks (*Andropogon* sp.) and availability was very low in 4% and 8% FA. The Fiber+MD class was composed mostly per tussocks (*Aristida* sp.) and a prickly type of *Asteraceae* which presence was insignificant in low FA 4% and different from other treatments that registered a minimum 20% of frequency.

3.3.2. The diet composition at the treatments

Figure 2 presents the composition of the diet of heifers grazing over the range of forage allowances. The proportion of Nutr class (1) in the heifers' diet decreases as the FA increases. The 16% FA was different from others FA diet. The contribution in heifers' diet from Nutr class between intermediate (8, 8.12 and 12%) FA had no significance. The 16% FA was different from 4% and 8.12% for Nutr+SC class; 8 and 12% FA did not differ from the others. The Intem class has a similar contribution in the diet to Nutr class. The participation of this class was similar among 8-12%, 12 and 16% FA following the same gradient concentration in the diet even though the

Nutr class. The Fiber+ and Fiber+MD class increase as the FA increased showing flexibility and/or opportunity for diversity in such pastoral environment.

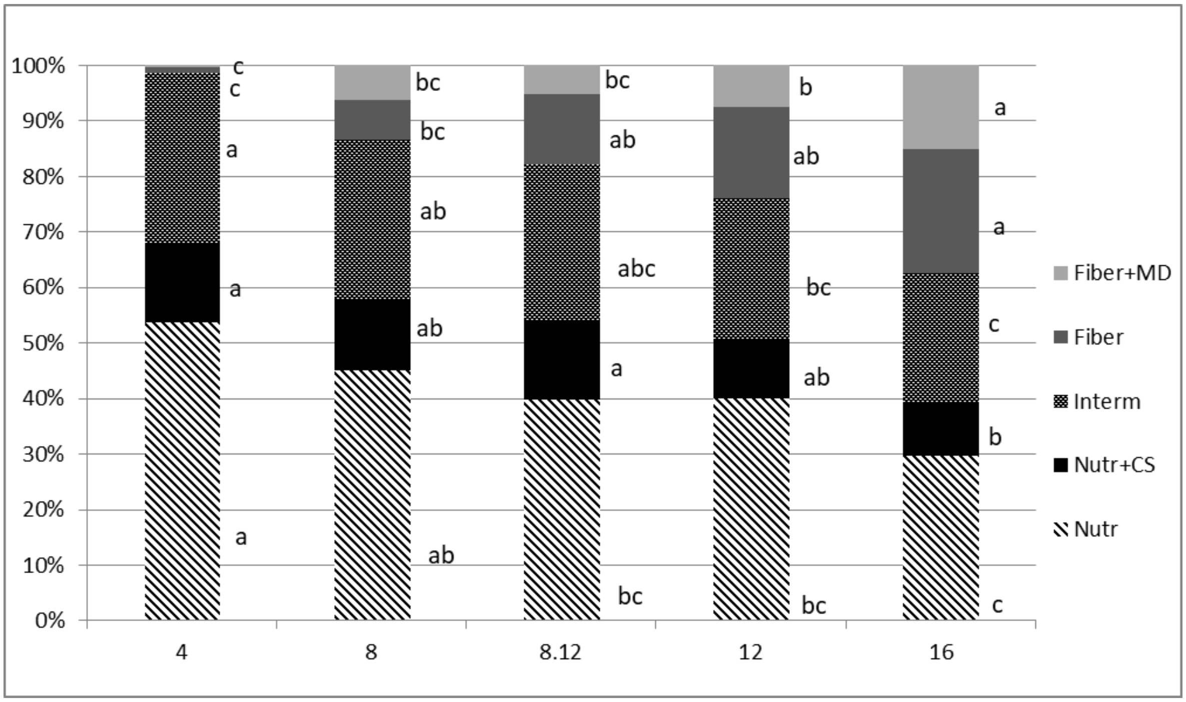

Figure 2. Diet composition of grazing heifers in spring at five FA. The diets compositions are expressed by the proportion of each feed class in the heifer diet; and the FA are 4, 8, 8-12, 12 and 16% expressed in kg DM /100 kg of BW. The statistical difference between treatments P<0.05 level.

Table 3 shows the nutritional composition on the average consumed diet that the different combinations of feed classes provides for each treatment. We present the average daily gain as an auxiliary data for a better understanding of the results. The average daily gain (ADG) during the month that was behavior evaluation. was 0.16, 0.44, 0.44, 0.51 and 0.45 kg of BW/day for 4, 8, 8-12, 12 and 16% of FA; the statistical difference (P<0.05) was observed between 4% and 12, and 16%.

Table 3. **Nutritional characteristics of heifers' diet in five contrasting grazing intensities.** Nutritional parameters are estimated from continuous bite monitoring and proportion of classes in the diet in Spring 2012. Forage allowances (FA) are: 4, 8, 8-12, 12 and 16% kg DM /100 kg body weight of grazing animals. The parameters are: *in vitro* organic matter digestibility (OMD), crude protein (CP), neutral detergent fibre (NDF) and mineral content (Ash) in % DM; and digestible energy (DE) in Mcal/kg DM.

FA (kg DM /100 kg BW)	OMD (%)	CP (%)	NDF (%)	Ash (%)	DE (Mcal/kg DM)
4	51^{a}	15.5^{a}	69^{c}	9.6^{a}	2.250^{a}
8	48^{ab}	11.6^{ab}	70^{cb}	9.3^{b}	2.143^{ab}
8.12	47^{b}	11.2^{b}	71^{b}	9.1^{b}	2.101^{b}
12	46^{bc}	10.9^{b}	71^{ab}	9.0^{bc}	2.049^{bc}
16	43^{c}	9.8^{c}	73^{a}	8.5^{c}	1.923^{c}

The letters refer to the statistical difference between treatments (P<0.05).

For all nutritional parameters, the 4% FA was different from the treatments with moderate FA (8-12 and 12), which were different of high FA 16% as CP. So, we identified that from 4% FA to 16% FA has the composition of feed classes was gradually losing nutritional value. The treatment with less Fiber+ and Fiber+MD class intake provide the best diet composition considering the classic nutritional parameters. The best diet did not result in better performance due to the lower total dry matter intake. The intake rate in each treatment was 5.0, 5.9, 5.7, 6.8 and 6.7 g of DM / min on FA 4, 8, 8-12, 12 and 16% respectively.

3.3.3. The selectivity index of feed itens

We calculated the Ivlev's selectivity index for each class of feed for the range of FA (Table 4). Then, we verified the positive or negative selectivity in the five treatments. The Nutr class selectivity was inversely proportional to its availability in the paddocks (Table 2). This phenomenon presented statistical significance when comparing the extreme levels of FA (4% and 16%). Among the intermediary (8%, 8.12% and 12%) FA there was no statistical difference signaling the search for less fibrous feeds in such heterogeneous pastures. The Nutr+SC class, that is composed majorly by non grass *Asteraceae*, did not presented statistical significance for the selectivity between treatments (P>0.05). The selectivity of Interm class was inversely proportional to its own availability in the paddocks. Table 2 and 4 show similar standard selective behavior on Interm class than on Nutr class. Therefore, the statistical difference in selectivity index of Interm class remains between the FA of 4% and 16%, and between FA of 8% and 16%. That is, comparing the selectivity index of classes Nutr and Interm, we found an approximation in the selectivity standard with exception of Interm selectivity in the 8% FA, that was different from 16% and equal to 4% FA. The other results from Table 4 are that Fiber+ and Fiber+MD class have negative selectivity index in all treatments with no statistical difference among treatments.

Table 4. Ivlev's selectivity index of five clusters made via PCA, hierarchical classification with spectrum's NIR from Azambuja et al. (2019, in press) in five forage allowances (FA): 4, 8, 12, 8.12 and 16 kg DM/100 kg BW.

FA (kg DM /100 kg BW)	Nutr	Nutr+SC	Interm	Fiber	Fiber+MD
4	-0.005[b]	-0.06	0.13[b]	-0.1	-0.7
8	0.18[ab]	-0.13	0.09[b]	-0.06	-0.56
8.12	0.24[ab]	0.004	0.17[ab]	-0.19	-0.65
12	0.27[ab]	-0.1	0.16[ab]	-0.09	-0.58
16	0.28[a]	-0.02	0.32[a]	-0.07	-0.4

Letters refer to statistical difference ($P<0.05$) of each feed class between treatments.

The FA of 4% has showed that the selectivity index is more nearly to zero for its main diet components. The selectivity index was positive just for Interm class, which is the second more important feed class in the heifers' diet (Figure 2). We identified that higher expressions of selectivity index occurred in the highest FA, 16%, with 0.28 for the Nutr and 0.32 for Interm class (Table 4). Regarding classes of feed with low digestibility (Fiber+ classes), the availability did not show influence in selectivity because all selectivity index was negative and was not different among FA. The FA only influenced the selectivity signal (+ or -) in the Nutr and Nutr+SC that expresses search for, or rejection to, this feed class. The others feed classes did not influence the selectivity signal, but in terms of magnitude it showed an effect. For example, the search for Nutr and Interm classes increases as the paddock heterogeneity also increased. This occurs because it has important nutritional value and probably there is a good return in nutritional per unit of time invested to search these bite classes.

3.3.4. The composition of the diet and forage selectivity

Our hypotheses state that diet composition has influence in forage selectivity of heifers. The selectivity index was affected by the fiber contents in animal diet, in addition to the availability of feed items mentioned above. The relationship between selectivity index and NDF in the diet is shown on Figures 3, 4 and 5, only for classes that were significant. The higher the NDF in diet, the more the selectivity index for Nutr class (Figure 3) which has lower NDF contents and is more digestible (Table 1).

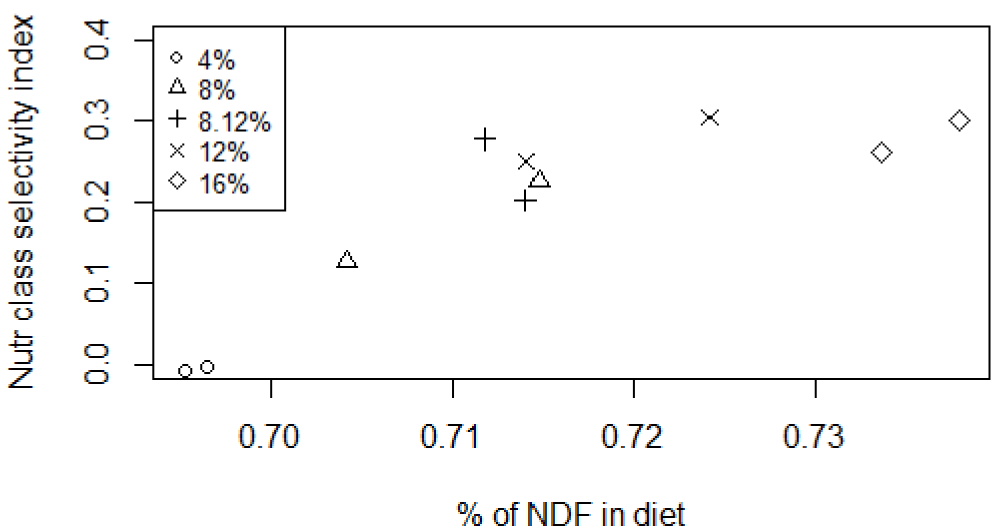

Figure 3. The relationship of selectivity index (IVLEV) of Nutr class feed according to the NDF concentration in diet by heifers at Pampa grassland. Equations are for **Nutr class**: $y = -279.4x^2 + 407.2x - 148.0$ / $R^2=0.92$ / $P<0.01$;

Around 71% of NDF in heifers' diet there is a change in Nutr class feed selectivity which turns from near zero to 0.25 of the selectivity index. This occurred in the moderate FA from nearly 8% FA.

A similar phenomenon of Nutr class was verified on Interm class, which also had abruptly changes of selectivity on nearly 71% of NDF in the heifers' diet (Figure 4).

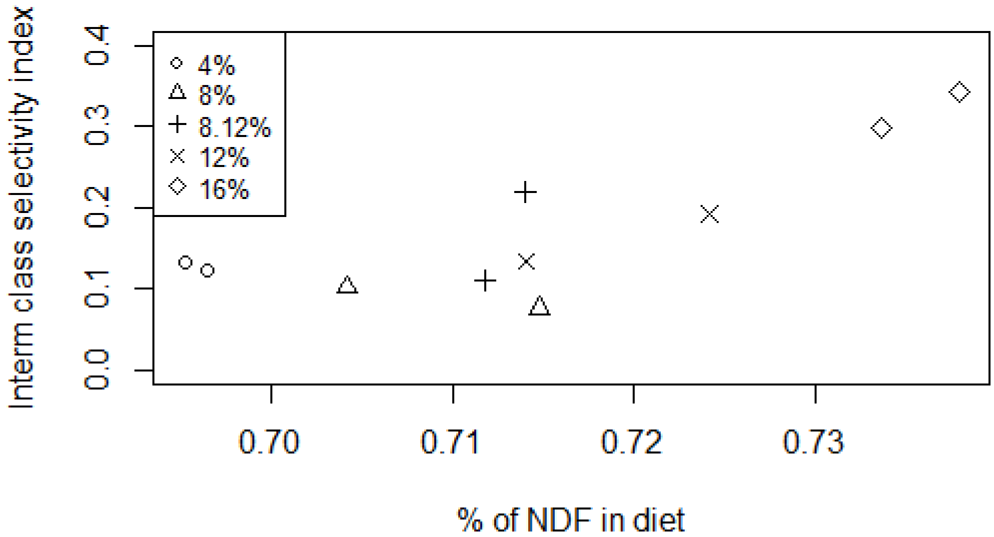

Figure 4. The relationship of selectivity index (IVLEV) of **Interm class** feed according NDF concentration in diet by heifers at Pampa grassland. Equation: y=4.996x-3.396 / R^2=0.59 / P=0.005.

The selectivity index response for Interm feed class was more pronounced than that of Nutr class. Moderate FA (8, 8.12 and 12%) compared to the highest FA (16%) registered a change from 0.2 to 0.3 selectivity index.

The Fiber+ class showed a linear relationship of the NDF in heifers' diet and their selectivity index (Figura 5). The NDF of the diet did not influence in selectivity index of Nutr+sc and Fiber classes (P>0.05).

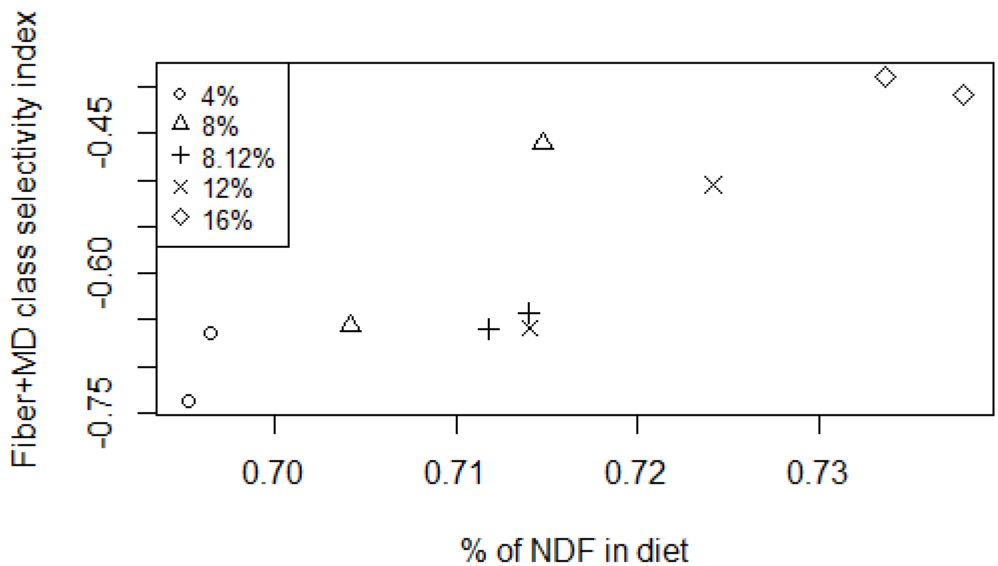

Figure 5. The relationship of selectivity index (IVLEV) of **Fiber+MD class** feed according NDF concentration in diet in foraging behavior by heifers at Pampa grassland. Equation: y=7.735x-6.106 / R^2=0.74 / P<0.001.

3.4. Discussion

The patterns of feed items selection in cattle grazing different Pampa grassland structures were studied. We hypothetized that changes in cattle selective behaviour depends on the tradeoff between the availability of different feed classes and the limiting factor (NDF, in this case) in animal diet. If no selection occurs, each class of feed item would be consumed as an uneven proportion between treatments, and proportional to its availability in grassland.

4.4.1. The pastoral environment and the selection of the diet

The availability of each class of feed in the treatments influenced forage selectivity and the diet of [non-supplemented] grazing heifers suggesting the following interpretations.

- The range of forage allowances produced different feeding environments with a gradient of heterogeneity that display different availability of feed itens from high-quality to low-quality. The 4% FA produced the grazing environment with the highest homogeneity as a result of overgrazing. Thus, there was a low possibility of diet selection in such low FA. The lack of feed options in this treatment may "homogenize" diet choices to indifference among feed classes. In moderate FA (8, 8-12 and 12%) the heterogeneity is fostered by moderate to low grazing intensities which consequences are the diversity of feed classes and diverse diets. The greater opportunity of feeding choices results in tradeoffs in heifers' diet, so heifers eat Fiber and Fiber+MD classes in lower proportions when compared to that available in the paddock. Lenient grazing, represented by the highest FA (16%), resulted in greater diversity of food items, but the predominance of the Fiber+ and Fiber+MD classes penalize the quality of the forage offered in this treatment; the heifer's intake of Fiber+ and Fiber+MD classes is equal to the available in the paddock and around 40%.

- Throughout the grazing process, cattle select a feeding site, and then a patch within that site (Baumont et al., 2000) and then a bite within the patch (Laca and Ortega, 1995). According to Prache et al. (1998), the animal selects a diet of higher nutrient quality than that available on pasture. In our study, the diet composition was related to feed class availability in the paddock. We detected differences between the diet actually collected by the animal and the diet available at the paddocks. For example, on the 12% of FA the diet consumed (OMD 46%) is better than that available (OMD 41%). Comparing data of forage quality at paddock level from the same experiment (Trindade et al., 2015) verified 34.3% of OMD. Furthermore, grazing environments built by moderate to lenient grazing result in lower availability of Nutr and Interm feed classes, as a consequence of lower grazing intensity. Similarly, studies also verified forage selection determined according to pasture condition, meaning better diets (higher protein, digestibility and less fiber) in the period of higher pasture growth, the opposite occurring at less favorable growing conditions (Miller and Thompson, 2007; Redjadj et al., 2014).

- The selectivity index it’s a different parameter compared to diet composition because it refers to the intent of the animal and not to what is ingested; the heifers could have an intention (preference) that could not be accomplished (selection). The selectivity indexes in the various feeding environments showed that animal made “various” strategies or intention to adapt to different constraints. The availability of each feed class and the NDF of the heifers' diet seems to be the main drivers of forage selection at the Pampa grassland. Such drivers can be found in other pastoral environments for cattle with a similar diversity of feed options. This biological expression by heifers on Pampa grasslands is strongly tagged for the tradeoff between two principal feed classes at the pasture. This classes are the Nutr class which is a concentrate items, and Fiber+MD class one roughage feed. We suggest that at this environment, with the exception of 4% FA, the heifers grazing "avoiding" fiber, but the heifers need this to fill the rumen. The selectivity consequences that are not understood with our data set may have been motivated by other aspects of fitness (Laca and Demment, 1996). So, our data confirms the trade-off between quality and quantity, and the changes for the less preferred items when a greater benefit is obtained from it, as reported by (Laca and Demment, 1996; Prache et al., 1998).

Why have changes in proportion of feed class at heifer diet? There is every factor that determines the forage selection. Forage selectivity is influenced by palatability (Baumont, 1996). The Fiber class even with low availability at the paddocks has been large proportion in diet and better selectivity index than Fiber+MD class. Perhaps the Fiber+MD class is considered less palatable by animals, comparing with other classes, because of their higher fiber content and the thorns of some plants. The Nutr+cs class predominately asteraceae with low diet contribution can help future model as input, that is considering the toxicity of the plants as a secondary factor of models. Also, will be help understand the learning porcess in heifers. For example, in moderate and low FA the Fiber+SC represent 14% of the DM intake and in high FA it is 10% in the proportion similar to offered during spring season. Notably, the classes Nutr and Nutr+SC are the most desired by animals. But, heifers have a motive for this. We can link this behavior with the optimal foraging theory; where the costs of obtaining feed also determine the feed selection (Pyke, 1984; Stephens and Krebs, 1986). These costs modify feed intake rates and according to the optimal foraging theory (OFT) will affect dietary choices (Pyke, 1984). This may to justify the intake rate and selection of each feed class.

4.4.2. Comments on the originality and limitation of this work

The curve inflection after the 71% NDF in the diet is an important result of this work. That point is the same in all figures 3, 4 and 5 and seems to be a sign of something. For example, the Nutr Class increasing the selectivity index up to around 71% of the NDF then stabilize, if the environment have low relative availability of Nutr class in 16% FA than others treatment (table 2), making it difficult for the heifers to express their interest for that feed class in this FA. This trend is according the OFT (Stephens et al., 2007). The Interm class of the feed showed the some trend, that is, the same selective change point but increasing selectivity index for Interm class from 71% of NDF. The less variability of Interm class we suppose that have more warranties of nutrient acquisition by bite in this class than the Nutr class which would take to greater investment by the animal in Interm class. The linear trend in feed selectivity of Fiber+MD class as far as increase the NDF in diet is, probably, by greater relative availability of this class and low relative availability of the Nutr and Interm class at the paddock. Thus, become difficult the selectivity of the animal by classes more nutritive with Nutr and Interm classes.

The feed classes from grass erect and the sward height that provides fast ingestion impacts on the rate of intake of each treatment, which end up repercussions on animal performance. The DM intake rate is influenced by sward structure, (Gonçalves et al., 2009) verified that maximum DM instantaneous intake rate by heifers occurs at a sward grassland surface height of 12 cm and that sward surface below 5 cm penalize the instantaneous intake cannot even maintenance supply. Let's see a change in sward height from 3.4, 5.2, 5.8, 6.7 and 7.5 cm for 4, 8, 8-12, 12 and 16% FA doing as that the intake rate 5.0, 5.9, 5.7, 6.8 and 6.7 g / min for FA 4, 8, 8-12, 12 and 16% respectively, is the evidence that is less profitable to bite in low FA. Fortin et al. (2002) suggests that in some cases bison simply kept foraging on the item (*C. atherodes*) even when all food types were of good quality to avoid the need for adjustments of digestive processes considering that changes in diet impose adjustments in the microbial species of the rumen. In our study, we suggest that such strategy change by heifers was necessary to save rumen filler. But in practice, the environment need make possible this. The generalizable result of this work is that the maintenance of environment pastoral with availability moderate of Fiber and Fiber+MD feed items, that is, large bites, results in good quantity and quality of diet.

Despite of the low level of selectivity index the Fiber+MD class, they is a roughage component important when Nutr and Interm items are in levels low at the paddock. Same with selectivity index negative, the Fiber+ and Fiber+MD classes are present in the diet on treatments with of greater FA (figure 2), showing this case and highlight your feed importance with roughage forage. Probably the large Fiber classes in diet and your negative selectivity index occurs because the nutritious reward of these classes is significantly lower than Nutr class and Interm class, and also had greater fiber content. In large FA the chance of meeting with Nutr is low and they search supposedly would don't is compensatory for heifers feeding. For example, we database show that if the heifers invest all time “710 min” only (Trindade et al., 2012) in eat Nutr class they intake around 60% of your dry matter intake requirement (2.5% of BW). With this it is understandable that when Fiber+MD class availability is upper than 20% at the grassland has minor rejection strength. The structures that offers this feed items (Fiber class) we consider as “keystones structures”, an important component for Pampa grassland ecosystems services (Dias et al., 2014; Tews et al., 2004).

The net energy gain from each feed class may help undemand your selectivity index. Net energy of feed classes in Mcal/kg of DM: 1= 1.24, 2=1.31, 3=1.03, 4=0.71 and 5=0.78 considering the bite type from continuous bite monitoring. The Nutr+CS class has the greater contribution of Asteraceae and Fabaceae for your net energy content. If account only Asteraceae family, the net energy would increase for 1.54 Mcal/kg of DM consumed. Other, the Fiber+MD class has greater contribution of

Apiaceae for net energy. The same way, if account only the *Eryngium horridum* of the Fiber+MD class, the net energy change from 0.72 Mcal/kg to 0.82 Mcal/kg of DM consumed. What shows that even being a spiny species is somewhat interesting from a point of view energetically when compared to Aristida sp..

Merging the information of table 2 and figure 2 is possible see that while increase the Nutr class availability at the paddock his proportion on diet increase too, but the selectively index decrease. This is due to the greater Fiber+MD class and low Nutr class (figure 2) presence while occurring an attempt to regulate the diet on the part of the animal; marking the tradeoff between this two pasture components. The NDF, together with energy and protein, contribute to metabolic discomfort in ruminants (Forbes and Provenza, 2000), so it is expected that this factor display forage selection influence by NDF and opportunity in this case. Thereby, it can be seen how animals can use "nutritional wisdom" by learning (Forbes and Provenza, 2000) to prefer or avoid particular feeds according to their comfort and metabolic effects when previously sampled (Forbes, 1999)**.**

The point limiting of our study is the fact overlap of bites in more than one feed class. Although there were strong tendencies for certain types of bites to be in the same food group. The overlap make limiting in precision of calculation of intake rate, because it is possible only with part of data. Despite the identification of when the animal changes its grazing behavior to maintain a similar performance. It would be interesting to carry out an experiment with different seasons of the year to identify the point at which food strategies of the heifers are not sufficient nor for maintenance. And with that, we would have a grant to take action at the farm level before that happens.

4.4.3. Implications for other grassland systems

At this paper, we showed the importance of the bite diversity in animals' diet at the Pampa grassland (table 3). For example, even with a higher concentration of nutrients per unit of feed consumed, the heifers that were managed in 4% of FA did not perform well. The 4% FA resulting in mostly of diet made per Nutr and Nutr+SC feed class. This confirms that only the pasture quality is not sufficient for feed management of cattle in natural pasture. Moreover, the structure of pasture that permits a daily intake mostly should be considered. That is the large bite is “more important” than good bite in Pampa grassland. In this environment the best animal performance was made with proportion in diet of: 40, 11, 25, 17 and 8% for the classes Nutr, Nutr+SC, Interm, Fiber+ and Fiber+MD respectively. This occurred in a heterogeneous mosaic pastoral environment.

Besides that, the balance between quantity and quality offers to animal should be considered. Experiment using showed that when the energy was the limiting factor of consumption, DM intake was positively correlated with the concentration of NDF. On the other hand, DM intake was negatively correlated with NDF concentration when it was the distention of the restriction rumen restrictor (Mertens, 1992). The intake increases until it is no longer limited by the capacity maximum of distention of the rumen-reticulum and decreases when the excess of metabolic products are limiting (Fisher, 2002). In our case, the capacity may be limitation in 16% FA by large NDF consumed and in 4% by small bites. Environments with ingestion limitation and homogeneous we expect a selective behavior as 4%, heterogeneous with grazing moderate we expect a behavior similar to 8, 12 and 8.12%, already in heterogeneous with large matter senescent expect a behavior similar 16%.

4.5 Conclusion

We assessed the foraging behavior of cattle grazing a typical native pasture of the Pampa biome. The forage allowances influence the diet selectivity index. Foraging behavior depends on the vegetation offered, that is, the availability of different feed classes. The NDF of the diet is influential in selectivity index.

Grassland managed with intermediate forage allowances (i.e., moderate grazing) permits best expression of animal behavior selectivity. Only the NDF in the diet does not allow for predictions of diet selection, which can be improved by the proportion of feed classes available in the paddocks. Future studies may investigate in the dynamics of intake and energetic cost to refine the understanding of foraging behavior.

Acknowledgement

We thank Walloon Agricultural Research Center, Gembloux, Belgium (CRA-W laboratory) for the prediction of the chemical composition of the samples and CAPES by the PhD scholarship and the Brazilian-French collaboration Project CAPES/COFECUB Valorizar o Pampa.

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CAPÍTULO V – CONSIDERAÇÕES FINAIS

4. CONSIDERAÇÕES FINAIS

O uso do NIRS para estimar a composição de forragens pode auxiliar tanto as pesquisar futuras quanto o uso aplicado pelos manejadores. No presente trabalho o objetivo de classificar os bocados das novilhas em diferentes classes funcionais de bocado foi alcançado. O uso espectro NIR como variável de entrada nas análises de classificação dos bocados possibilitou distinguir os indivíduos (tipos de bocados) por meio da análise de componentes principais. A análise de agrupamento hierárquico foi utilizada para classificar ou agrupar os indivíduos mais semelhantes. Felizmente os grupos de bocados coincidiram com a classificação previamente realizada no momento de observação do pastejo. Tal coincidência foi em média 80% dentro da mesma estação. Isso significa, por exemplo, que os códigos de bocados Mono, T, F e C permaneceram quase que em totalidade nas mesmas classes formadas pelo espectro NIR. Tal prática demonstrou que a transformação dos dados do NIR para identificar os indivíduos visualizando suas diferenças pela luz infravermelha que eles absorveram, foi de sucesso. Entretanto, se necessário mais precisão podemos utilizar mais alguns fatores na simulação dos bocados. Um desse fatores poderia ser o “índice verde” do bocado (poderíamos dar um escore de cinco níveis de verde objetivando determinar o quanto verde e de alto valor nutricional é cada bocado) porque o mesmo tipo de bocado que considera o órgão da planta apreendido e a espécie ou grupo de espécie apreendida, pode encontrar-se em estágio fenológico um pouco distinto embora na mesma estação do ano. Isso denota composição diferente e consequentemente absorção da luz diferente aumentando a chance de serem de grupos diferentes. No mesmo sentido, poderia ser utilizado o teor de material morto do bocado para aumentar a precisão da classificação.

O conjunto de dados permitiu verificar a composição da dieta em termos de nutrientes e foi sensível às suas variações sazonais e de composição do pasto. Para estimar a composição da dieta em termos de classes de bocados consideramos além do tipo de bocado utilizado na observação do pastejo a frequência com que ele apareceu na simulação dos bocados. Tal prática considerou a sobreposição dos tipos bocados (Grid) nas classes originadas do espectro NIRS e com isso conferiu maior precisão na estimativa da proporções das classes de bocado na dieta das novilha.

Os dados de composição da dieta sejam em termos de classes de bocados (NIRS) ou em termos de nutrientes (Proteína, energia e fibra) juntamente com o índice de seleção de cada classe permitiu algumas conclusões a respeito da seleção dos pastos. Algumas dessas conclusões são óbvias, mas, colaboram no sentido de sedimentação do conhecimento em pastejo para balizar as propostas de manejo. Foi nítido que em ambientes com baixa oferta de forragem proporciona menos material senescente pela maior taxa de desfolha e renovação do dossel. Isso confere ao animal uma dieta mais rica em nutrientes por unidade de material ingerido. Entretanto, não há possibilidade física do animal consumir quantidade suficiente deste alimento o que acarreta em menor desempenho mesmo com uma dieta de melhor qualidade. As ofertas intermediárias (8, 8.12 e 12% OF) de maneira geral são as que conferem maior possibilidade do animal exercer a seleção da dieta. As mesmas mantém um equilíbrio entre qualidade e quantidade do material ingerido. Já em alta oferta de forragem 16% há maior presença de touceiras pela baixa frequência de desfolha, assim mais classes Fiber+ e Fiber+MD são encontradas pelo animal que acaba realizando uma ingestão maior desses tipos de bocado.

Foi possível detectar que os animais fazem melhor com o que tem disponível no ambiente em que pastejam em prol da ingestão de nutrientes, o que corrobora grande parte da literatura existente. Os bovinos exercem o equilíbrio entre quantidade e qualidade do material ingerido e isso é relativo às oportunidades que o potreiro ou ambiente lhes proporciona. Ao realizar o tradeoff entre quantidade e qualidade do material ingerido os bovinos conseguiram realizar uma dieta no ponto de equilíbrio entre estes dois fatores. Isso pode ser checado comparando a figura 2 e a tabela 3 do segundo artigo, onde distintas proporções das classes de bocado são consumidas resultando em dietas e performasses similares, quando em ofertas de forragem de moderada a alta (8 a 16 %). Os dados sugerem que quando há diferença no ganho de peso em campo nativo, isto se dá mais pela quantidade (que resulta em maior ingestão de nutrientes) do material ingerido do que pela qualidade do mesmo. O presente resultado junto aos dados de consumo já verificados no mesmo experimento, certifica essa afirmação.

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VITA

Nascido no dia 18 de junho de 1982 teve sua infância nos arredores da praça da Lagoa em São Borja. Em 1988 iniciou os estudos (pré-escolar) no Colégio Getulio Vargas onde conclui o primeiro grau em 1997. Durante o final da década de 80 e início da década de 90 influenciado pelos seus tios, avos, familiares e anônimos campeiros que conheceu durante sua infância e adolescência pega gosto pela "lida de campo". Dessa forma, passou dividir o tempo do estudo formal com doma, laço, camperadas e artesanato em couro cru.

1997- Estuda violão com o violonista Sergio Sousa, funda um piquete em seu colégio Getúlio Vargas e começa a escrever versos e ginetear.

2001- conclui o segundo grau no Colégio Getúlio Vargas.

2002- ingressa no exército brasileiro como soldado recruta passa a soldado cavalarista e ordenança do comandante da Coudelaria do Rincão em São Borja.

2003- Presta vestibular para Zootecnia na UFSM, não teve sucesso. Inicia faculdade de veterinária em Virasoro-Corrientes-Argentina e desiste no primeiro mês. Em 2004 presta novamente vestibular, tendo êxito, ingressa na faculdade de Zootecnia na UFSM no primeiro semestre de 2004. E nos próximos anos se divide entre a Zootecnia, música, poesia, ginetiada e a guasquearia que lhe ajuda a se manter em Santa Maria. Em 2005 classifica a música ”Domero livre na Pampa" no festival Ronda de São Pedro. Em 2006 sua composição "Na crina" é eleita música mais popular no festival Ronda de São Pedro. Em 2007 entra pela fase local no festival Ronda de São Pedro colocando-se em 2° lugar do festival com a obra - Uma arte de campo. Em 2008 Grava "Pra enfeitar a madrugada" em parceria com Poeta itaquiense João Sampaio publicado no álbum "Querência João Sampaio e Amigos". A música esteve bastante presente durante a graduação em zootecnia. O que não impediu de realizar estagiário voluntário nos setores de: ovinocultura, bovinoviltura, forragem e tambpem ser moitor disciplina de melhoramento animal.

2009- Estágio curricular obrigatório em sistemas de produção bovinos e ovinos na Estância Santo Izidro em Quaraí-RS e produção de leite a pasto em uma fazenda na Nova Zelândia. Concluindo a graduação de Zootecnia na UFSM.

2010- Recem formado, trabalha em duas estâncias no município de Itaqui-RS. Passa no processo seletivo na UFRGS e ingressa no curso de mestrado em Zootecnia com bosista CNPq. Nesse mesmo ano tem parceria musical no álbum "Temporona São Miguel" de Gustavo Gozales com as composições "Domero livre na pampa" e "Pra enfeitar a madrugada". Em abril de 2011 em 31 começa o curso de mestrado voltando toda atenção para ciência agropecuária e inicia as primeiras publicações científicas. Em 2012 apresenta oral seu primeiro trabalho científico na RBZ, conclui o mestrado em zootecnia na UFRGS. Em 2013 trabalha como bosista DTI no PELD projeto de pesquisa de longa duração no laboratório de ecologia quantitativa ECOQUA no departamento de ecologia da UFRGS. Em 2014 publica o album sonográfico 100% autoral “potros e milongas”. Em 2015 ingressa no curso de doutorado em zootecnia pela UFRGS. Em 2017 tem a oportunidade de realizar uma segunda experiência além-mar pelo CAPES/COFECUB e passa um ano em doutorado sanduiche no INRA/SUPAGRO de Montpellier – França. Em março de 2019 o candidato a doutor em zootecnia apresenta a tese.