UNIVERSIDADE FEDERAL DE PELOTAS

Programa de Pós-Graduação em Zootecnia

Tese

A nutrição como estratégia para períodos metabolicamente críticos em bovinos de corte

Claudia Faccio Demarco

Pelotas, 2020

Claudia Faccio Demarco

A nutrição como estratégia para períodos metabolicamente críticos em bovinos de corte

Tese apresentada ao Programa de Pós-Graduação em Zootecnia da Faculdade de Agronomia Eliseu Maciel da Universidade Federal de Pelotas, como requisito parcial à obtenção do título de Doutor em Ciência Animal.

Orientador: Dr. Cássio Cassal Brauner

Orientador no Exterior: Dr. Scott Lake

Coorientadora: Dra. Lisandre de Oliveira

Pelotas, 2020

Universidade Federal de Pelotas / Sistema de Bibliotecas
Catalogação na Publicação

D372 Demarco, Claudia Faccio

A nutrição como estratégia para períodos metabolicamente críticos em bovinos de corte / Claudia Faccio Demarco ; Cássio Cassal Brauner, orientador. — Pelotas, 2020.

111 f.

Tese (Doutorado) — Programa de Pós-Graduação em Zootecnia, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas, 2020.

1. Tanino. 2. DFM bacteriano. 3. *Ipomoea batatas*. 4. Pós-parto recente. I. Brauner, Cássio Cassal, orient. II. Título.

CDD : 636.2

Elaborada por Gabriela Machado Lopes CRB: 10/1842

Claudia Faccio Demarco

A nutrição como estratégia para períodos metabolicamente críticos em bovinos de corte

Tese aprovada, como requisito parcial para obtenção do grau de Doutor em Ciência Animal, Programa de Pós-Graduação em Zootecnia, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas.

Data da defesa: 11 de Fevereiro de 2020.

Banca Examinadora:

Prof. Cássio Cassal Brauner (Presidente) – Dr. (UFPel)

Joao Alveiro Alvarado Rincón – Dr. (UFPel)

Prof. José Acélio Silveira da Fontoura Júnior – Dr. (Unipampa)

Prof. Júlio Otávio Jardim Barcellos – Dr. (UFRGS)

Prof. Philipe Moriel - PhD (University of Florida)

Agradecimentos

À Deus.

A Universidade Federal de Pelotas e Universidade do Wyoming, por dar suporte, estrutura física e corpo docente para a realização do doutorado.

À CAPES pelo financiamento da bolsa de estudo tanto no Brasil como nos Estados Unidos.

Ao professor e orientador Cássio Brauner pela amizade, ensinamentos e confiança.

Ao professor e também orientador Marcio Nunes Corrêa pelos ensinamentos transmitidos e encorajamento.

Aos professores da Universidade do Wyoming, Scott Lake e Hannah Cunningham por toda ajuda, hospitalidade e paciência nos Estados Unidos.

Ao NUPEEC pela ajuda em todas as etapas da minha formação e auxílio na execução dos projetos.

Aos meus amigos pelo companheirismo nas horas difíceis e incondicional apoio em todos os momentos.

Ao Rafael, pelo apoio e companheirismo de sempre

A minha família, por todo suporte e amor.

Resumo

DEMARCO, Claudia Faccio. **A nutrição como estratégia para períodos metabolicamente críticos em bovinos de corte.** Orientador: Cássio Cassal Brauner. 2020. 111 f. Tese (Doutorado em Zootecnia) – Departamento de Zootecnia, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas, Pelotas, 2019.

A manipulação ruminal através da utilização de novos aditivos alimentares está baseada no propósito de otimizar a fermentação e, consequentemente, o desempenho dos animais. Além disso, alguns países eliminaram o uso de tecnologias defasadas, como antibióticos como promotores de crescimento, renovando a demanda por uma novos produtos e alimentos para a produção animal. Nesse contexto, com objetivos distintos, foram avaliadas diferentes estratégias nutricionais sobre o desempenho, saúde, fermentação ruminal e desempenho reprodutivo de bovinos. No Experimento 1, 142 vacas de corte primíparas e multíparas Hereford foram mantidas em campo nativo e divididas em 2 grupos baseados na diferença de peso corporal entre o parto e o pico de lactação, sendo um grupo os animais que perderam peso e o outro as vacas que ganharam peso nesse período. Com objetivo de avaliar o efeito dessa variação de peso no pós-parto sobre o desempenho dos bezerros e das vacas, foram avaliadas medidas de desempenho dos bezerros, produção de leite e desempenho reprodutivos das vacas. Houve diferença significativa na produção de leite (P=0,01) durante os 189 dias de lactação, em que o grupo que perdeu peso entre o parto e o pico de lactação, produziu mais leite que o grupo que ganhou peso. Não houve diferença estatística no peso ao desmame dos bezerros entre os dois grupos, no entanto, as vacas que ganharam peso apresentaram tendência de maior taxa de prenhez. A variação de peso após o parto até o pico de lactação compromete o desempenho reprodutivo da vaca, mas não interfere no peso ao desmame dos bezerros. No experimento 2, foram avaliados os efeitos de dois aditivos alimentares, Direct fed microbial (DFM bacteriano) e tanino, sobre o desempenho e imunidade em bezerros desmamados e confinados. Foram avaliados 287 bezerros confinados durante 42 dias recebendo ou não uma dieta acrescida de $2x10^8$ UFC/animal/dia de *Propionibacterium acidipropionici*; $5x10^7$ UFC/animal/dia de *Lactobacillus animalis*; $5x10^7$ UFC/animal/dia de *Bifidobacterium animalis* e tanino na quantidade de 15 g/animal/dia. Não houve diferença para o peso corporal final (P= 0,43) e ingestão de matéria seca (P= 0,31) entre os tratamentos. Entretanto, os animais que receberam os aditivos alimentares tiveram maior ganho médio diário total (P=0,06). Bezerros desmamados confinados recebendo DFM bacteriano e tanino tiveram uma melhor eficiência alimentar durante os primeiros 42 dias após o desmame e uma redução nas concentrações de haptoglobina nos dias 0 e 4 após um evento de estresse. O experimento 3 teve como objetivo avaliar a produção de gás *in vitro* da farinha de batata-doce em substituição ao milho moído em uma dieta com silagem de milho e farelo de soja. Foram realizados 4 tratamentos, com substituição do milho pela farinha de batata-doce em 0, 33%, 66% e 100% em matéria seca. A produção de gás acumulada foi maior na substituição do milho pela farinha de batata-doce em 100% comparado com a dieta com 0% de farinha de batata-doce (P = 0,001). A taxa de degradação foi 7,10 7,59, 8,08 e 8,59 ± 0,06% por hora nas substituições 0, 33, 66 e 100%, respectivamente (P < 0,0001).

Palavras-chave: Tanino. DFM bacteriano. *Ipomoea batatas*. Pós-parto recente.

Abstract

DEMARCO, Claudia Faccio. **The nutrition as a strategy for metabolically critical periods in beef cattle**. Advisor: Cássio Cassal Brauner. 2020. 111 p. Thesis (PhD) – Department of Animal Science, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas, Pelotas, Brazil, 2019.

Ruminal manipulation through the use of new feed additives is based on the purpose of optimizing fermentation and subsequently animal performance. In addition, some countries have eliminated the use of old technologies, renewing the demand for a new generation of livestock products and feed. In this context, with different objectives, different nutritional strategies on performance, health, rumen fermentation and reproductive performance in beef cattle were evaluated. In Experiment 1, 142 primiparous and multiparous Hereford cows were kept in the native field and divided into 2 groups based on the difference in body weight between calving and peak lactation, one group were the animals that lost weight and the other the cows that gained weight during this period. In order to evaluate the effect of this postpartum weight variation on calf and cow performance, measures of calf performance, milk yield and reproductive performance of cows were evaluated. There was a significant difference in milk production (P = 0.01) during the 189 days of lactation, in which the group that lost weight between calving and peak lactation produced more milk than the group that gained weight. There was no statistical difference in calf weaning weight between groups, although the cows that gained weight had a increase in the pregnancy rate. The change in weight after calving to the peak lactation compromises the reproductive performance of the cow but does not interfere with calf weaning weight. In experiment 2, the effects of two feed additives, Direct fed microbial (bacterial DFM) and tannin, on performance and immunity in confined weaned calves were evaluated. A total of 287 calves kept in feedlot for 42 days were evaluated receiving or not a diet added $2x10^8$ CFU / head / day *Propionibacterium acidipropionici*; $5x10^7$ CFU / head / day of *Lactobacillus animalis*; $5x10^7$ CFU / head / day of *Bifidobacterium animalis* and the tannin in the amount of 15 g / head / day. There was no difference detected for final body weight (P=0.43) and dry matter intake (P=0.31) between treatments. However, the animals that received the feed additives tended to a higher total average daily gain (P = 0.06). The calves receiving bacterial DFM and tannin improved feed efficiency (5.5 vs 5.0 for Control and treatment groups) during the first 42 days after weaning and a reduction in haptoglobin concentrations on days 0 and 4 after a stress event. Experiment 3 aimed to evaluate the *in vitro* gas production of sweet potato flour as a substitute for ground corn in a diet with corn silage and soybean meal. Four treatments were performed, with replacement of corn by sweet potato flour in 0, 33%, 66% and 100%. Accumulated gas production was higher in replacing maize with sweet potato flour by 100% compared with 0% (P = 0.001). The degradation rate was 7.10, 7.59, 8.08 and 8.59 ± 0.06% per hour at 0, 33, 66 and 100% substitutions, respectively (P <0.0001).

Keywords: Tannin. Bacterial DFM. *Ipomoea batatas*. Early postpartum.

Lista de Figuras

Lista de Tabelas

ARTIGO I

ARTIGO II

ARTIGO III

Sumário

1 Introdução

A produção de carne bovina no Brasil no ano de 2017 aumentou para 9,6 milhões de toneladas, sustentada por vários fatores, incluindo menor custo de produção, impulsionado pela disponibilidade de alimentos para animais a preços competitivos e melhores pastagens devido ao clima, além do aumento da demanda de exportação (FAO, 2018). No Brasil e em outros países como os Estados Unidos, as expansões das exportações foram apoiadas por abundantes suprimentos domésticos e alta demanda de importação dos mercados asiáticos. Entre eles, a China se destaca sendo um mercado importante para a carne bovina para os dois países (FAO, 2018). Em 2018, o Brasil exportou US$1,35 bilhão em carne bovina para a China, se tornando em 2019 o principal mercado das exportações brasileiras. Em 2019, houve um aumento de 39,6% nas exportações para esse país, atingindo US$2,17 bilhões comercializados (ABRAFRIGO, 2020).

A crescente demanda de carne bovina e o contínuo desenvolvimento da pecuária abrangem aspectos tecnológicos, econômicos e também ambientais. De um lado, a necessidade de produzir carne para atender o aumento do consumo da população mundial e por outro, como produzir de forma sustentável. Os sistemas de pecuária são os principais emissores de nitrogênio reativo (N). As formas reativas de N incluem formas inorgânicas, como amoníaco (NH_3), óxido nitroso, óxidos de nitrogênio, nitrato e formas orgânicas, como ureia e aminas (HRISTOV et al., 2011). A agricultura contribui com mais de 80% das emissões de NH_3 na América do Norte e a pecuária é responsável por mais de 65% das emissões agrícolas (ECCC, 2016). Produzir carne, laticínios e outros produtos proteicos de uma maneira que reduza seus impactos ambientais é um ponto chave na evolução desse sistema produtivo.

Uma das maneiras de produzir carne de forma mais sustentável é melhorar a conversão alimentar de bovinos. Para isso, em sistemas de produção de bezerros, o objetivo do sistema é produzir um bezerro por vaca por ano (PITTROFF et al., 2002), e para tanto, surgirão desafios metabólicos no pós-parto, entre eles o de suprir a exigência energética para a produção de leite e mantença e quando para vacas primíparas, também para o crescimento (SHORT et al., 1990). Sabe-se também que esse período crítico afetará o desempenho reprodutivo desse animal, comprometendo a eficiência da produção.

Outra alternativa para tornar esse sistema sustentável e eficiente é a manipulação da dieta. Os custos com alimentação de bovinos confinados podem chegar até 63% das despesas anuais de uma propriedade (MILLER et al., 2001) e dentre os ingredientes a proteína é considerada como nutriente limitante (DELCURTO et al., 2000). Já em ruminantes mantidos em pastagens de alta qualidade, a maior parte da proteína é rapidamente solubilizada, liberando de 56 a 65% da concentração de N no rúmen durante a fermentação e consequentemente, ocorre perda de N (entre 25 e 35%) na forma de NH_3 pela urina (DSCHAAK, 2011; MIN et al, 2000). Diante disso, aditivos alimentares como o tanino surgem como alternativa para melhorar a utilização da proteína da dieta (HERNANDEZ et al., 2014; SALEM et al., 2013).

A manipulação do ambiente ruminal surge como outra forma para aumentar a eficiência dos animais. As motivações para a manipulação ruminal são justificadas no objetivo de fazer mudanças positivas e incrementais para otimizar a fermentação e, posteriormente, o desempenho sem a ocorrência de distúrbios digestivos. A utilização de antibióticos como promotores do crescimento tem sido empregada por muitas décadas e se mostrou efetiva ao melhorar o desempenho dos animais (HUANG et al., 2018). No entanto, acredita-se que o uso de antibióticos como promotores de crescimento em animais de produção promova a evolução e a seleção de microrganismos resistentes a antibióticos (CHATTOPADHYAY, 2014). Assim sendo, alternativas naturais aos antibióticos na alimentação animal têm sido estudadas e entre os microrganismos utilizados, as bactérias têm recebido considerável atenção, especialmente para ruminantes.

Além de pesquisas com aditivos alimentares, busca-se hoje novos alimentos ou co-produtos, que sejam estratégicos e sustentáveis. Entre as fontes energéticas, a busca por novos alimentos é importante uma vez que o milho, sendo o principal alimento utilizado para alimentação animal, também serve para a produção de etanol e consumo humano, fazendo com que haja variações nos preços desse insumo (LIU et al., 2016). A batata-doce é amplamente produzida em regiões tropicais e subtropicais por ser uma raiz rica em amido poderia ser um substituto ao milho na alimentação animal (WHEATLEY et al., 1995). Porém, pesquisas preliminares devem ser realizadas para avaliar a utilização desse produto para alimentação em ruminantes.

Para tanto o presente trabalho engloba a avaliação da produção de leite de vacas de corte e a sua influência no desempenho dos bezerros e na eficiência

reprodutivas das vacas (apresentados no artigo 1) além de estratégias suplementares (aditivos naturais) à alimentação de bezerros desmamados (apresentadas no artigo 2). Também terá espaço nessa tese, a avaliação de um alimento alternativo energético (batata-doce) em substituição às já existentes (apresentado no artigo 3).

2 Objetivo geral

Avaliar como a nutrição pode ser utilizada como ferramenta estratégica para fases metabolicamente críticas na produção de bovinos de corte, sejam elas em vacas de corte no pós-parto recente ou em bezerros desmamados e encontrar na batata-doce uma alternativa de alimento energético para ruminantes.

2.1 Objetivos específicos

1- Avaliar a influência das mudanças de peso entre o parto e o pico de lactação de vacas de corte sobre a produção de leite e desempenho reprodutivo da vaca e crescimento pré-desmame do bezerro;
2- Avaliar a utilização de Direct Fed Microbials (DFM) bacteriano e tanino simultaneamente em bezerros recém desmamados e confinados e seus efeitos no ganho de peso e resposta imune;
3- Avaliar os parâmetros da fermentação *in vitro* da inclusão de farinha de batata-doce em diferentes níveis em uma dieta de ruminantes.

3 Revisão Bibliográfica

3.1 Manejo nutricional da vaca de corte no pós-parto

Estratégias nutricionais e de manejo, que sejam flexíveis e oportunas, são essenciais para minimizar os desafios que o gado enfrenta e para demonstrar sua capacidade inata de se adaptar a essas adversidades (LAUNCHBAUGH; HUNT, 2000). Mudanças no manejo nutricional e situações estressantes criam desafios à homeostase do organismo, e a falha em se adaptar a essas mudanças pode resultar em queda na eficiência da produção. Mesmo quando a quantidade e a qualidade da forragem são abundantes, o ciclo produtivo em bovinos de corte é energeticamente exigente devido aos custos energéticos da lactação e da gestação (MULLINIKS et al., 2019).

As exigências energéticas para mantença são 20% superiores durante a lactação quando comparados com vacas de corte não lactantes (FERRELL; JENKINS, 1985; MOE et al., 1970; PATLE; MUDGAL, 1975). Os custos energéticos da lactação são ainda maiores se o potencial genético exceder a capacidade nutricional do sistema em que o animal se encontra (EDWARDS et al., 2017). Em sistema de pastejo os animais passam por múltiplos períodos em que a oferta de nutrientes fica abaixo dos requerimentos, e então as reservas corporais necessitam ser metabolizadas (MULLINIKS et al., 2019). Entre esses períodos e talvez um dos mais importantes dentro do sistema é o pós-parto recente.

Na região sul do Brasil, em que a produção de bovinos de corte é majoritariamente a base de pastagens nativas (TANURE et al., 2011), a flutuação na produção e qualidade de forragem pode indicar a incapacidade das vacas sob pastejo atingirem um escore ideal de condição corporal (ECC) em fases metabólicas específicas com altos requisitos de energia (DO CARMO et al., 2016). Desse modo, as vacas são submetidas a baixos níveis nutricionais durante a segunda metade da gestação no inverno e a amamentação dos bezerros coincidirá com a época de reprodução (BRAUNER et al., 2009). O maior transtorno no pós-parto é justificadp pelo fato do pico da produção de leite ser anterior ao pico de ingestão (SARTORI; GUARDIEIRO, 2010).

O peso ao desmame dos bezerros é resultado do potencial genético dos bezerros para o crescimento e do ambiente pré-desmame disponível para esses animais, incluindo a produção e qualidade do leite das matrizes. A produção de leite é responsável por cerca de 40% do peso ao desmame (ROBISON et al., 1978). Entretanto, o aumento da ingestão energética no pós-parto pode não ser economicamente vantajoso, pois nesse período a energia adicional ofertada será particionada para a produção de leite e tecidos maternos (JENKINS; FERRELL, 1992; REYNOLDS; TYRRELL, 2000).

Exemplos de estratégias para períodos críticos em bovinos de corte incluem o ajuste das demandas de energia dos animais e da disponibilidade de alimentos e o ajuste do ciclo de produção da vaca em aleitamento com o crescimento das pastagens (BARCELLOS et al., 2011).

3.2 Bezerros desmamados e estresse

O início do sistema de recria é uma das fases mais críticas do ciclo de produção de carne bovina, quando o animal é exposto a inúmeros desafios que afetam diretamente seu bem-estar e produtividade (DUFF; GALYEAN, 2007). Como exemplo, bezerros recentemente desmamados passam por longos períodos de transporte, são misturados com outros animais, mudando de ambiente e alimentação. Estas práticas são conhecidas por impactar negativamente o sistema imune e o desempenho (COOKE et al., 2013). Como consequência, a incidência de doenças nesse período é elevada, mesmo utilizando programas de vacinação e outros manejos para minimizar os eventos acima mencionados (KIRKPATRICK et al., 2008). O transporte é um dos fatores estressantes mais comuns, especialmente com o crescente aumento nas movimentações de gado em nível nacional e internacional e de acordo com Marti et al., (2017) é considerado um fator contribuinte para o aumento da suscetibilidade à ocorrência de doenças.

O estresse provocado por essas situações que o bezerro passa a partir do desmame e é sinalizado por duas diferentes vias, pelas quais os mamíferos montam uma resposta fisiológica integrada ao perigo percebido. A resposta ao perigo é iniciada no nível do hipotálamo, que libera hormônio liberador de corticotrofina e vasopressina (MINTON, 1994; MORMEDE et al., 2007). Esses hormônios transmitem um sinal para

a glândula pituitária para iniciar a liberação do hormônio adrenocorticotrópico, que atinge o córtex adrenal. Esse eixo hipotálamo-hipófise-adrenal inicia uma das respostas endócrinas ao estresse, mediado pela liberação de glicocorticoides do córtex adrenal. A segunda resposta é rápida e envolve o eixo simpático-adrenal-medular (SAM), que culmina na liberação de catecolaminas da medula adrenal. O eixo SAM inicia a resposta de "luta ou fuga" que inclui uma resposta comportamental integrada ao perigo percebido ou estresse agudo, bem como respostas metabólicas e imunológicas (AICH et al., 2007; HUANG et al., 2013).

A reação de fase aguda é um componente do mecanismo de defesa inata do organismo e resulta na produção de um vasto e variado grupo de proteínas hepáticas (SUFFREDINI et al., 1999). Essas proteínas, chamadas de proteínas de fases aguda (PFA), são sintetizadas pelas células do parênquima hepático e liberadas na corrente circulatória em resposta a diversos fatores estressantes, incluindo inflamação, infecção bacteriana e injúrias físicas (BAUMANN; GAULDIE, 1994; SUFFREDINI et al., 1999). A resposta imunológica ao estresse pode ser mensurada pelas alterações nas concentrações das PFAs. Essas variações têm sido descritas por diversos autores, que demonstram o perfil, principalmente, da haptoglobina em bezerros (MURRAY et al., 2014), em situações como o transporte (ARTHINGTON et al., 2013), desmame (O'LOUGHLIN et al., 2014), mudanças alimentares (BERRY et al., 2004) e ressocialização e agrupamentos (ARTHINGTON et al., 2003).

3.3 Aditivos alimentares

3.3.1 *Direct Fed Microbial* (DFM) Bacteriano

Nos últimos 30 anos pesquisadores e produtores têm procurado melhorar a eficiência alimentar, saúde e desempenho de animais de produção (MCALLISTER et al., 2011). Há um aumento no interesse em utilizar aditivos alternativos como *Direct-Fed Microbials* (DFM) com objetivo de diminuir a utilização já bastante criticada de antibióticos como aditivos alimentares. Entre os principais efeitos, os DFM podem melhorar a fermentação e limitar a ocorrência de acidose ruminal, resultando em incrementos no ganho de peso em bovinos de corte confinados, por exemplo (SEO et al., 2010).

Os DFM, por muitos autores, são definidos como probióticos, porém o FDA (2015) conceitua os DFM como produtos alimentares que contém somente fonte de microrganismos vivos ou que ocorrem naturalmente (KREHBIEL et al., 2003; YANG et al., 2004). Portanto, nem todo probiótico é DFM, uma vez que o probiótico pode conter além dos microrganismos, enzimas e extratos (YOON; STERN, 1995). Entre as espécies utilizadas estão incluídas bactérias como *Lactobacillus, Bifidobacterium*, *Enterococcus*, *Streptococcus*, *Bacillus* e *Propionibacterium,* e leveduras como a *Saccharomyces* e entre os fungos, o *Aspergillus* (SEO et al., 2010).

O conceito original de suplementar ruminantes com DFM bacteriano era baseado primeiramente no máximo efeito pós rúmen. No entanto, alguns autores demonstraram que há efeito benéfico no rúmen, principalmente com relação à manutenção do pH ruminal e isso se enquadra na habilidade do ecossistema do rúmen em gerenciar a produção e utilização de ácido láctico (YANG, 2004).

Bezerros de corte passam por frequentes situações de estresse em curtos espaços de tempo, como no desmame (KREHBIEL et al., 2003), por isso, esta categoria animal e a suplementação com DFM bacteriano foi um dos objetos de estudo dessa tese. Além do estresse da separação da materna, outros manejos estressantes estão associados e ao incluir DFM na dieta inicial desses animais, garante a colonização de microrganismos benéficos dentro do trato gastrointestinal nesses períodos de estresse e gera efeitos positivos no desempenho em termos de ganho de peso diário (SEO et al., 2010).

Outros efeitos encontrados em diferentes categorias animais estão relacionados com aumento na produção de leite (DAWSON, 1990; LEHLOENYA et al., 2008), melhora na eficiência alimentar (DAWSON, 1990; ISIK et al., 2004; JOUANY, 2006; OETZEL et al., 2007; LEHLOENYA et al., 2008, KREHBIEL et al., 2003; GUILLEN, 2009), aumento no ganho médio diário (GMD) e no desempenho de bezerros (KREHBIEL et al., 2003; GUILLEN, 2009; NOVAK et al., 2012) e melhora na imunidade e saúde (KREHBIEL et al., 2003; GUILLEN, 2009).

3.3.1.1 Modo de ação

3.3.1.1.1 Rúmen

Bactérias originárias do rúmen têm potencial de alterar a fermentação dentro do rúmen (MCALLISTER et al., 2011) e no trato gastrointestinal pós-ruminal (SEO et al., 2010). As cepas de DFM bacteriano podem ser classificadas tanto como espécies acido lático produtoras (do inglês Lactic Acid Bacteria) como ácido lático utilizadoras (do inglês Lactic acid Utilizing Bacteria).

As LAB, incluem espécies como *Lactobacillus*, *Bifidobacterium*, *Streptococcus*, e *Enterococcus* (SEO et al., 2010), facilitam o crescimento de microrganismos ruminais adaptados à presença de ácido lático no rúmen (GHORBANI et al., 2002; KREHBIEL et al., 2003; SEO et al., 2010). Frequentemente essas espécies são suplementadas juntamente com leveduras ou com bactérias LUB para alcançar resultados positivos (MCALLISTER et al., 2011). Outrossim, as LAB estimulam as LUB e com isso permitem a estabilização do pH ruminal (SEO et al., 2010). Esse efeito é importante quando há mudanças de dieta, por exemplo, no desmame de bezerros em sistemas de recria ou confinamento ou quando a proporção de concentrado na dieta aumenta. As LUB limitam a queda de pH e permitem com isso menor tempo necessário para adaptação à nova dieta (KUNG; HESSION, 1995).

Exemplos de LUB incluem a *Megasphaera* e *Propionibacterium* (RUSSELL; BALDWIN, 1978; KREHBIEL et al., 2003; SEO et al., 2010). Somado aos mecanismos de ação das LAB, as LUB metabolizam lactose, glicose e maltose para gerar propionato através do ciclo de Krebs (RUSSELL; BALDWIN, 1978). Esse ácido graxo de cadeia curta (AGCC) é crucial para a mantença do status energético em ruminantes, pois supre 67% do total de glicose (REYNOLDS et al., 1994) e economiza aminoácidos da gliconeogênese (VAN SOEST, 1994). Ademais, as LUB têm o potencial de diminuir a produção de metano (CH_4) (SEO et al., 2010). Essa diminuição na produção de metano é justificada pelo desvio de hidrogênio disponível para a produção de propionato, ao invés de produzir metano. Menos metano emitido via eructação se traduz em máxima energia retida, tornando os animais suplementados com DFM bacteriano mais eficientes (LUAN, 2014; WOLIN, 1960;).

3.3.1.1.2 Intestino

De acordo com Isolauri (2001), utilizando outros modelos animais, a utilização de DFM bacteriano é capaz de modular a imunidade inata e adquirida a nível local e

sistêmico. O mecanismo proposto para ambos grupos (LAB e LUB) após a passagem no rúmen é similar. Primeiramente, os microrganismos se aderem e colonizam dentro da superfície do epitélio intestinal; segundo, o DFM bacteriano exibe uma ação inibitória dos organismos patogênicos dentro do intestino, e por último, o DFM bacteriano estimula a função imune (KREHBIEL et al., 2003). O estudo de Lee et al. (2003), ao utilizar *Lactobacillus rhamonsus* verificou que a mesma se aderiu às células epiteliais intestinais através de interações hidrofóbicas e com isso limitou a aderência de outros patógenos aos receptores enterocíticos. Outro estudo, como de Frizzo et al., (2010), também comprova o mecanismo de ação de competição de receptores. Ao utilizar LAB as mesmas se aderiram ao trato intestinal de ratos, impedindo a adesão de microrganismos patogênicos, como a *Salmonella*.

Com isso, o DFM altera a microbiota intestinal, incrementando a sua eficiência e também modulando a resposta imune inata do animal. A modulação da função imune é outro modo de ação proposto. No trato gastrointestinal, existem células do sistema imune como dendríticas, natural killers, macrófagos, neutrófilos, e linfócitos B e T que estão agregados nas placas de Peyer, lamina própria e regiões intraepiteliais (KREHBIEL et al., 2003). Após a suplementação com DFM, as bactérias são diretamente absorvidas pelas células epiteliais do intestino via transcitose. Com isso, as células do sistema imune citadas anteriormente iniciam a estimulação da resposta imune (DICKS; BOTES, 2010).

Várias cepas de LAB ativam macrófagos para produzir citocinas que irão estimular o sistema imune. No estudo de Matsuguchi et al, (2003) sugere-se que *L. casei e L. rhamnosus* estimulem a secreção de TNF-α e promova o desenvolvimento de células dendriticas. Miettinen et al. (1996) também demonstrou que as LAB poderiam induzir a produção de citocinas pró inflamatórias, TNF-α e IL-6, estimulando assim uma resposta imune inespecífica. Vale lembrar que a resposta imune inata é a imunidade presente em todos animais ao nascimento. Consiste em uma resposta química rápida e um mecanismo de defesa celular (por exemplo, macrófagos, células dendríticas, citocinas, e células natural killers) que não precisam ser induzidas por exposição prévia a um agente infeccioso (TIZARD, 2009).

3.3.2 Tanino

A utilização de taninos pode ser benéfica ou prejudicial aos ruminantes, dependendo de quanto e como será inserido na dieta, a estrutura e peso molecular, e a fonte do mesmo (HAGERMAN; BUTLER, 1991). Tais compostos, de elevado peso molecular, são resultado de mecanismos desenvolvidos ao longo da escala do processo evolutivo das plantas, como forma de defesa contra os pastejo dos animais (MUIR et al., 2017).

Os taninos apresentam-se como múltiplos grupos heterogêneos de alto peso molecular com capacidade de formar complexos reversíveis e irreversíveis com proteínas (principalmente), íons metais, aminoácidos e polissacarídeos (FRUTOS et al., 2004; MAKKAR, 2003). Tradicionalmente, os taninos são classificados em 2 grupos: condensados e hidrolisáveis. Os taninos condensados (TC), também conhecidos como proantocianidinas, são polímeros não ramificados de flavonoides (flavan-3-ol, flavan-3,4-diol) e geralmente têm maior peso molecular que os taninos hidrolisáveis (TH; 1000 a 20000 Da comparados de 500 a 3000 Da do TC; MAKKAR, 2003) (MAKKAR, 2003).

Os complexos tanino-proteína podem surgir através de quatro tipos de ligação: 1) ligações de hidrogênio (reversíveis e pH dependentes) entre os radicais hidroxila dos grupos fenólicos e o oxigênio dos grupos amida nas ligações peptídicas das proteínas, 2) por interações hidrofóbicas (reversíveis e pH dependentes) entre o anel aromático dos compostos fenólicos e as regiões hidrofóbicas da proteína, 3) por ligações iônicas (reversíveis) entre o íon fenolato e o sítio catiônico da proteína (exclusiva para HT) e 4) por ligação covalente (irreversível) através da oxidação de polifenóis em quinonas e sua subsequente condensação com grupos nucleofílicos da proteína (FRUTOS et al., 2004).

A formação de tais complexos é estável no rúmen (com o pH variando entre 5 e 7) e também resistente à degradação dos microrganismos ruminais, mas se dissocia no pH mais baixo encontrado no abomaso (MAKKAR, 2003). Com isso, os taninos podem reduzir a proteína que é digerida no rúmen e aumentar o fluxo de proteína para o intestino. Tal formação é específica, tanto em termos do tanino quanto da proteína envolvida, o grau de afinidade entre as moléculas participantes, que está relacionado com as características químicas de cada um (FRUTOS et al., 2004). Com relação aos taninos, os fatores que irão alterar a formação do complexo estão vinculados com o peso molecular e flexibilidade estrutural (MUELLER-HARVEY; MCALLAN, 1992). As proteínas com maior afinidade com os taninos são geralmente grandes e hidrofóbicas,

apresentam uma estrutura flexível e são ricas em prolina (MUELLER-HARVEY; MCALLAN, 1992).

3.3.2.1 Modo de ação

Uma vez que esse complexo tanino-proteína é formado no rúmen, há uma mudança no local de degradação da proteína. Há menor degradação proteica no rúmen, levando a um maior fluxo de aminoácidos para o intestino delgado (BARRY; MCNABB, 1999; MIN et al., 2003). Esse efeito pode explicar os incrementos observados em bovinos recém desmamado iniciando em sistema intensivo, ou seja, na fase de crescimento em que a proteína metabolizável é limitante (BARAJAS et al., 2010; ZINN et al., 2007).

Tradicionalmente os taninos têm sido comumente associados com redução na ingestão em ruminantes principalmente por sua palatabilidade e adstringência (LANDAU et al., 2000; COOPER; OWEN-SMITH, 1985). Esse efeito negativo na ingestão geralmente está vinculado com altas concentrações utilizadas (acima de 5% na dieta em matéria seca de tanino) (MCNABB et al., 1996). Entretanto, foram observadas diminuições na ingestão mesmo utilizando doses menores que a citada anteriormente (1,85% no estudo de Aguerre et al., 2016, e 3% no estudo Dschaak et al., 2011). Convergindo com isso, os taninos podem reduzir a digestibilidade por inibir enzimas digestivas e a atividade microbiana ruminal (MAKKAR, 2003). O estudo de Min et al., 2002 confirma o efeito da diminuição da degradação ruminal da proteína ao demonstrar que com a inclusão de taninos condensados na dieta de ovinos diminuiu a população de bactérias proteolíticas.

Além do complexo tanino-proteína produzido no rúmen, a redução na degradação da proteína também ocorre como resultado da diminuição da população de bactérias proteolíticas, como *Clostridium proteoclasticum*, *Butyrivibrio fibrisolvens*, *Eubacterium* sp., e *Streptococcus bovis* (MIN et al., 2002; PATRA; SAXENA, 2011). Outro efeito positivo da suplementação com tanino é a redução da produção de metano pela diminuição no crescimento de bactérias metanogênicas e alguns protozoários (SAMINATHAN et al., 2016; YANG et al., 2017) com isso reduzindo as perdas de energia e permitindo mais energia disponível para o animal. O efeito na redução de metano foi apenas observado em animais alimentados com uma dieta de

maior nível de fibra (PUCHALA et al. 2005; WOODWARD et al. 2004) e não em animais confinados.

Os efeitos dos taninos na nutrição de ruminantes, saúde e produtividade têm sido extensivamente estudados e revisados (FRUTOS et al., 2004; MUELLER-HARVEY, 2006; WAGHORN, 2008; PATRA; SAXENA, 2011; WANG et al., 2015). Barajas et al. (2010, 2011) também encontraram efeitos benéficos da suplementação com taninos no ganho médio diário e eficiência de bovinos de corte confinados. Pesquisas, porém, apontaram que a inclusão de tanino na dieta pode diminuir a ingestão (AL-DOBAIB, 2009; AMMAR et al., 2011; SALEM et al., 2013). Mezzomo et al. (2011) ao suplementarem com tanino animais recebendo uma dieta altamente concentrada e tendo como fonte proteica o farelo de soja encontrou efeitos positivos na utilização da proteína bruta (PB), diminuição da taxa de degradação e digestibilidade da PB, e consequente aumento no fluxo de proteína metabolizável no duodeno, sem outras alterações nos parâmetros ruminais. Dessa maneira, os resultados benéficos no crescimento e desempenho têm sido atribuídos às melhorias no suprimento proteico metabolizável intestinal (WAGHORN, 1996).

3.4 Alimentos energéticos alternativos para ruminantes

Suplementar ruminantes com carboidratos não fibrosos (CNF) é frequentemente uma estratégia utilizada para alcançar os requerimentos para mantença e também aumentar a produtividade do sistema (CATON; DHUYVETTER, 1997). Entre os CNF, o mais utilizado para nutrição de ruminantes é o amido, que é um polissacarídeo encontrado em diferentes tipos de plantas e é composto por 2 tipos de moléculas: amilopectina e amilose (SANTANA; MEIRELES, 2014). O milho, juntamente com a cevada e o trigo, são os grãos com maior proporção de amido utilizados na alimentação de bovinos (DECKARDT et al., 2013).

Devido à grande competição pela utilização de milho e outros grãos fontes de amido entre os diferentes sistemas de produção animal como em suínos e aves, tal qual a alimentação humana e até mesmo produção de biocombustíveis (LIU et al., 2016), existe uma necessidade crescente pela busca de potenciais fontes alternativas de amido que sejam economicamente e ambientalmente sustentáveis (GALINDO et al., 2009).

Entre os alimentos que podem ser utilizados para a alimentação de ruminantes tem-se a batata-doce, uma raiz tuberosa rica em amido (*Ipomoea batatas*) (ROSTAGNO, 2005). A batata-doce encontra-se entre os principais alimentos de subsistência plantados em todo o mundo e que normalmente são cultivados apenas para produzir o suficiente para alimentar as famílias dos agricultores. Seus usos e seu potencial de produzir grandes quantidades de alimento a baixo custo e com baixo uso de insumos, de maneira sustentável, tornam esta espécie particularmente interessante como opção para a agricultura familiar em todas as regiões do país (MONTEIRO et al., 2007). Segundo dados do IBGE (2018) foram plantados no Brasil 53.024 hectares de Batata-doce, com produção de 741.203 toneladas, com rendimento de 13.998kg/ha, sendo o Estado do Rio Grande do Sul responsável por cerca de 29,7% da área plantada (aproximadamente 13.000 hectares) e é responsável por 31% da produção (175.060 toneladas).

A cultura da batata-doce pode ser considerada uma excelente alternativa socioeconômica para pequenos e médios produtores, especialmente para a agricultura familiar. No entanto, grande parte das ramas de batatas-doces produzidas não possui padrão comercial e acaba nem sendo colhida, ou então, descartada antes de chegar ao mercado. Prover um destino a estas ramas otimiza o sistema produtivo, diminui o descarte e a contaminação ambiental, além de melhorar a rentabilidade ao produtor.

A batata-doce, ao ser colhida, apresenta cerca de 30% de matéria seca, que contém em média 85% de carboidratos, cujo componente principal é o amido. Tanto as ramas, quanto as raízes, podem ser fornecidas frescas, para ruminantes. A raspa, constituída de raízes picadas e secas, é um excelente complemento alimentar energético que pode ser adicionado à ração de animais. A grande limitação para este tipo de utilização é o alto teor de umidade contido nas batatas frescas (70%) (SILVA et al., 2008), problema este que seria eliminado através de secagem e transformação do produto em farinha.

O milho e batata-doce apresentam concentração de amido similar, 70 e 75%, respectivamente. O amido do milho é formado por 30% de amilose e 70% de amilopectina, enquanto a batata-doce é formada por 28% de amilose e 72% de amilopectina (GÓMEZ et al., 2016). Apesar dos valores serem similares, diferenças na fermentação ruminal podem ocorrer e, adicionalmente, afetar o metabolismo, digestibilidade total e o desempenho dos animais (GÓMEZ et al., 2016).

As semelhanças bromatológicas entre os dois substratos ricos em carboidratos, milho e batata-doce, não são suficientes para considerar a batata-doce um substituto do milho nas dietas de ruminantes. Por exemplo, a degradabilidade do amido no rúmen é maior para batata e milho do que para cevada e ervilha (CHAI et al., 2004). Técnicas que caracterizam o metabolismo ruminal e a degradabilidade desses ingredientes, como a produção de gás *in vitro*, são indispensáveis para descrever a cinética da atividade dos microrganismos em resposta a um potencial novo substrato (SILVA et al., 2015).

Poucos estudos foram realizados buscando a utilização da farinha de batata-doce na dieta animal. Frye et al. (1948) substituíram 100% o milho moído pela farinha de batata-doce na dieta de vacas leiteiras, sem efeito negativo na produção de leite ou gordura. Outro estudo observou queda de 2,6% e 8,6% na produção de leite quando o milho foi substituído pela farinha de batata-doce em 50% ou 100%, em comparação ao concentrado com milho como fonte energética (MATHER et al., 1948). No entanto, há uma grande variabilidade na composição das diferentes variedades de batata-doce, podendo não se repetir este efeito, principalmente pela razão de que os trabalhos publicados com ruminantes não foram desenvolvidos em condições brasileiras.

4 Artigo I

Artigo formatado e submetido de acordo com as normas da revista “Animal of Production Science”

Influence of recent postpartum weight variation on milk production, calf performance and reproductive efficiency of beef cows

Short title: Postpartum weight variation affects milk yield

Claudia Faccio Demarco[a,b], Jordani Cardoso[a,b], Marcelo Alves Pimentel[b], Scott Lake[c], Cassio Cassal Brauner[a,b*]

[a] Núcleo de Pesquisa, Ensino e Extensão em Pecuária (NUPEEC), Federal University of Pelotas, Pelotas, RS, Brazil.

[b] Department of Animal Science, Federal University of Pelotas, Pelotas, RS, Brazil.

[c] Department of Animal Science, University of Wyoming, Laramie, WY, United States.

*Corresponding author: cassiocb@gmail.com

Abstract

Context. Cows lose body condition to offset an energy-deficient diet at early lactation, when the energy requirement can exceed de energy intake. There is a prioritization of nutrients utilization for lactation to the detriment of metabolic activities that favor reproductive activity.

Aims. The objective of this study was to evaluate the influence of the weight changes in beef cows between calving and peak lactation on the performance of calves, cow milk production and reproductive efficiency of beef cows in pasture system.

Methods. Data were collected from 142 primiparous and multiparous Hereford cows. Cows were kept in a native pasture and were divided into two groups based on their weight difference between calving and peak lactation, the cows that gained weight in this period formed the G group, and the cows that lost weight were the L group. Cows and calves weights and milk production (weigh-suck-weigh technique) were taken every 21 days from calving until weaning.

Key Results. There was a significant difference in total milk production (P = 0.01) during the 189 days of lactation, in which L group cows produced more milk (1065.37 ± 20.88 kg) than cows in the G group (974.74 ± 27.92 kg). Between 21 and 42 days postpartum, calves from the L group cows had greater ADG (0.66 ± 0.02 kg/d vs. 0.56 ± 0.03 kg/d, for L and G groups, respectively, P = 0.03). However, from peak lactation until weaning, the G group calves had a greater ADG (0.70 ± 0.02 kg/d) compared with the L group calves (0.65 ± 0.02 kg/d) (P = 0.05) despite there was no difference in weaning weight. Cows that gained weight between calving and the peak lactation had a 15% increase in pregnancy rate compare to cows that lost weight in the same period (P = 0.08).

Conclusions. The weight variation after calving until peak lactation does compromise the reproductive performance but does not compromise the weight at weaning of the calves.

Implications. Beef cattle producers should select cattle that do not require as much nutritional support to such restrictive nutritional environments. Furthermore, ensure that their nutritional requirements are met.

Key words: lactation, nutrition, weaning weight, native pasture.

Introduction

The main objective of a cow-calf production system is to produce one calf per cow annually and, in addition to this, weaning percentage dramatically affects producer income and success in the beef industry (Pittroff et al., 2002). Weaning weights are the results of the genetic potential of the calves for growth and the preweaning environment available to calves, including the yield and quality of milk of their dam. Milk yield may account for 40% of the variance in 205-d calf weight (Robison et al., 1978). However, selection of animals with high milk production and consequently greater nutritional requirements in a grazing system with low nutritional quality can challenge these cows during the lactation period. Furthermore, the partitioning of nutrients used by the cow is prioritized sequentially for basal metabolism, physical activity, growth, basic body reserves, lactation, accumulation of body reserves, estrous cycle and for gestation (Short et al., 1990). There is a prioritization of nutrients utilization for activities such as lactation to the detriment of metabolic activities that favor reproductive activity. This will likely result in lower reproductive performance and ultimately may decrease profitability (Edwards et al., 2017).

In Southern Brazil, the majority of beef cattle production utilizes native pasture. Additionally, these pastures grazed by cattle have variations in annual vegetative growth. In spring and summer, they are low and dense, forming a good quality natural cover for grazing. In the winter period (June to August), they do not grow up and become dry due to the occurrence of rime (Tanure et al., 2011). Herbage production within the productive cycle, and the relatively high and fixed stocking rate used, may points out the inability of grazing beef cows to achieve

an ideal body condition score (BCS) in specific metabolic phases with high energy requirements (Do Carmo et al., 2016). Thereby, most cows are submitted to low nutritional levels during the latter half of gestation in winter, and they are nursing their calves at the time when the breeding season begins (Brauner et al., 2009).

The objective of this study was to evaluate the influence of the weight changes between calving to peak lactation of range beef cows on the cow and calf performance, milk production and pregnancy rate. The hypothesis is that the body weight variation in this period along the milk production is one of determinant factors for the cow's future reproductive performance and for the performance of the calf.

Materials and Methods

Data were collected from 142 primiparous and multiparous Hereford cows, 3 to 5 years of age, over a 5-year period. Cattle were from a private ranch located in Aceguá (31°49'50"S 54°41'58"W), Rio Grande do Sul, Brazil. Animal procedures were approved by the Animal Experimentation Committee of Universidade Federal de Pelotas, Brazil (under n. 3255).

Cows calved during the spring (September, October, and November) and were kept in a native field of Pampa biome with a stocking rate of 380kg of body weight (BW)/ha. The predominant vegetation were warm season grasses, mainly bahiagrass (*Paspalum notatum*) and louisiana grass (*Axonopus affinis*). The most common cool season grasses were sprouts (*Stipa* spp) and ryegrass (*Lolium multiflorum* spp). The population of winter legume forages were composed of some clover species (*Tripholium* spp).

Cows were divided into two groups based on their weight difference between calving and peak lactation, as 42 days postpartum was considered peak lactation, as described by Neville et al., (1974) and Boggs et al. (1980). Thus, the cows that gained weight (n = 59, 336.90 ± 5.40 kg of BW at calving and gain of 16.67 ± 11.03 kg) in this period formed the G group,

and the cows that lost weight (n = 83, 328.34 ± 4.06 kg of BW at calving and loss of 25.56 ± 15.68 kg) in the same period were the L group. Cows and calves weights were measured from calving until weaning that was 189 days postpartum, every 21 days. The weight was measured, using an electronic scale with a capacity of 1,500 kg and sensitivity of 100 g.

Milk production data were measured every 21 days, from calving to weaning (189 days postpartum) by the consumption of milk from the calf obtained from the difference in weight before and after the milk feeding (Bartle et al., 1984). Calves were separated from their dams the day before weighing. At the end of the afternoon (6:00 pm) calves were returned to their dams and allowed to nurse to exhaustion of the udder and separated again for 12h. The next morning (6:00 am) calves were weighed and allowed to suck for 30 min, weighed again, and the difference between the weights considered the milk production of 12h, which was multiplied by two and used as the estimate for 24h (Brown et al., 1996). These indirect method (weight-suckle-weight) despite underestimate the milk yield (Jenkins and Ferrell, 1992), measures exactly milk consumed by calves (Freetly et al., 2006).

The lactation persistency (PERS) was defined as the linear average daily change in milk production (g/d) between peak lactation (MPP: milk production on peak lactation) and weaning (MPW: milk production at the end of lactation) (JENKINS et al., 2000):

$$\text{PERS} = \frac{(MPP - MPW)}{D} * 1000$$

Where D = number of the days between the peak and the end of lactation.

This variable is expressed in grams per day and explains how much the average milk production per day is reduced from the peak lactation (Jenkins et al., 2000) until the last day.

Primiparous cows were mated at the months of December, January and February, in natural mating, with a bull: cow ratio of 1:25. Multiparous cow's estrus was synchronized between 30 and 100 days postpartum. The method described by Moraes et al., (2007), using pessaries (intravaginal sponges impregnated with 250 mg of medroxyprogesterone acetate) for

seven days and injection of 1 mg of estradiol benzoate at the time of insertion was used. After the pessaries were removed, calves were separated from cows for four days and bred via artificial insemination (AI) after estrus detection. After AI, cows were intermingled with bulls for 50 days. Cows pregnancy diagnosed via rectal palpation 60 days after the breeding season.

Year, parity and the result of the diagnosis of gestation were considered independent variables. Total milk production, daily milk production, lactation persistency, calf weight at birth, weight at 21 days and weaning were considered dependent variables. The variable pregnancy (yes or no) were quantified as percentages, considering parturition dates and compared using chi-square analysis. Data were submitted to analysis of variance (ANOVA - GLM), using software NCSS (NCSS 7.0, Statistical system for Windows, Kaysville, Utah, USA). For all variables analyzed, a P value < 0.05 was considered significant, whereas values of $0.05 \geq P < 0.10$ were identified as a tendency approaching significance.

Results

The results of calves ADG and BW are present on Table 1. The ADG between 21 and peak lactation ($P = 0.03$) was greater for calves from L cows. However, in the period after the peak lactation until weaning it was observed that the calves from the G group had greater ADG ($P = 0.05$). Although differences were detected between calves of each group for ADG, there were no difference in weaning weight.

[Table 1 here]

In table 2 are presented the results of cow's performance in both groups. As expected, there was a difference in total milk yield during the 189 days of lactation, in which L group cows produced more (1065.37 ± 20.88 kg) than the cows in G group (974.74 ± 27.92 kg; $P = 0.01$). Another difference observed was in lactation persistency ($P < 0.001$), the L group cows presented a minor persistent lactation curve, i.e., decreasing more grams per day of milk after

the peak lactation. As observed in Table 2, there was a trend (P = 0.08) of greater pregnancy rate on cows that had weight gain between calving and peak lactation.

[Table 2 here]

Discussion

Beef cows face dynamic and highly variable nutritional environments that periodically are inadequate in meeting nutrient and energy requirements. Nutritional management during high metabolically stressed are the key to successfully achieved the objective of a cow-calf system. One of these periods is the recent postpartum wherein the cow must first meet the requirement for maintenance, then to raise the calf with milk and finally to reproductive efficiency. The prioritization of milk production will come at the expense of body condition of the cow, which is consistent with the current study, wherein greater milk production was reported by the group of cows that lost weight between calving and peak lactation. At the onset of lactation, nutrients are partitioned to mammary tissue for synthesis of milk at the expense of body condition (Lake et al., 2005). Therefore, energy expended for milk production imposes significant demands on metabolism to support milk production in the beef cow and results in mobilization of body energy stores to support the increased energetic demands (Short et al., 1990).

In agreement, Hess et al. (2005) also reported that much of the variation in reproductive performance of beef cows may be accounted for by changes in energy intake and body condition throughout the yearly production cycle. Therefore, cows losing weight and resulting in a negative energy balance in the first weeks after calving, or in thin condition prior to calving, can result in an extended postpartum anestrus period (Short et al., 1990). Even in environments where energy intake levels are high and met or exceed requirements, increased milk production may decrease reproductive performance in beef cattle (Edwards et al., 2017). This inverse relationship between milk yield and fertility in dairy cows already has been reported by Butler

(2000) and is due to increased demand of energy competing with nutrient demands for reproduction. Edwards et al., (2017) categorizing beef cows in low, medium and high milk production reported differences in pregnancy rate due to change in body condition in favor of increased milk production requirements. The low and medium production animals had greater pregnancy rates compared to the high milk production. The author proposes that reproduction decreased in mature beef cows when peak milk production was greater than 9 kg/d. Therefore, managements aiming to select those animals in each environment can increase productivity and profitability in the different systems, once cows can be able to produce more and be pregnant again by the end of the reproduction season.

This result is similar to Johnson et al. (2003), wherein cows that produce more milk had a higher rapid decline in milk production after reaching the peak lactation. High persistency is characterized by a slow rate of decline after peak yield, while low persistency is characterized by a high rate of decline after peak yield (Dekkers et al., 1998). In dairy farmers, highly persistent cows or cows with a flat lactation curve are reported to be more profitable because of fewer health and reproductive problems with less energy imbalance. The links between health disorders, fertility and persistency have been investigated with varied results (Appuhamy et al., 2007; Harder et al., 2006). This lower decline in G group milk production may points out the greater ADG after peak lactation until weaning, there was a significant difference in ADG in this period ($P = 0.05$), and the G group calves had higher ADG because the dams had a minor reduction on daily milk yield. Under these conditions, it becomes interesting future research relating milk yield and lactation curve and the performance of calves after weaning.This ADG difference is support by the greater milk production of the L cows.

The amount of milk that the calves ingests represents their ability to consume and not the dam production (Brauner et al., 2011). Clutter and Nielsen (1987) suggested that calves suckling dams with low milk production potential better utilized milk that was available while

cows with higher levels of milk production produced more than what calves could utilize. These authors confirm the results of this study, wherein the calves of cows with a lower milk production needed less liters of milk to convert in 1 kg of BW. In agreement, milk with higher fat and protein has been associated with greater pre-weaning weight gain (Brown et al., 2001) but in contrast, Rutledge et al. (1971) reported that milk quantity was more important that milk quality on weaning weight. Forster et al., (2010) and Boggs et al., (1980) demonstrated that calves of G group presented an increase in their initial ADG; however, this difference was diluted in the remainder of the lactation period resulting in no difference in weaning weights between the two groups.

The results of this study suggest that lower milk production dams that maintain or gain body condition are able to wean a calf similar in weight as cows that produce more milk and lose body condition. Additionally, cows that are maintaining or gaining weight also have greater reproductive performance. Thereby considering cow variation weight postpartum and reproductive performance, as well as calf performance, beef cattle producers should select cattle that fit their environment to ensure that their nutritional requirements are met, which may ultimately contribute to an increase in conception rates during the following breeding season.

Conclusion

The weight variation of cow between calving and peak lactation can be an evidence for the cow's future reproductive and calf performance. One of the alternatives to improve beef production in range systems is identify and select adapted animals that do not require as much nutritional support to such restrictive nutritional environments.

Conflict of Interest

Declarations of interest: none

Funding Sources

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

References

Appuhamy JA, Cassell BG, Cole JB (2007) Phenotypic and genetic relationships of common health disorders with milk and fat yield persistency from producer-recorded health data and test-day yields. *Journal of Dairy Science* **92**, 1785–1795.

Brauner CC, Pimentel MA, Lemes JS, Pimentel CA, Moraes JCF (2009) Desempenho reprodutivo pós-parto de vacas de corte submetidas a indução/sincronização de cio. *Revista Brasileira de Zootecnia* **38,** 99-103.

Brauner CC, Pimentel MA, Menezes LM, Machado JPM, Moraes JCF (2011) Effect of short period feed supplementation during early lactation on performance of cows and calves raised in extensive system. *Revista Brasileira de Zootecnia* **40**, 1381-1387.

Brown MA, Brown AH, Jackson WG, Miesner JR (1996) Milk production in Angus, Brahman, and reciprocal-cross cows grazing common bermuda grass or endophyte-infected tall fescue. *Journal of Animal Science* **74**, 2058-66.

Brown MA, Brown AH, Jackson WG, Miesner JR (2001) Genotype × environment interactions in milk yield and quality in Angus, Brahman, and reciprocal-cross cows on different forage systems. *Journal of Animal Science* **79**:1643–1649.

Boggs DL, Smith EF, Schalles RR, Brent BE, Corah LR, Pruitt RJ (1980) Effects of milk and forage intake on calf performance. *Journal of Animal Science* **51**, 550-553.

Bartle SJ, Males JR, Preston RL (1984) Effect of energy intake on the postpartum interval in beef cows and the adequacy of the cow's milk production for calf growth. *Journal of Animal Science* **58**, 1068-1074.

Butler WR (2000) Nutritional interactions with reproductive performance in dairy cattle. *Animal Reproduction Science* **60**, 449–457.

Clutter AC, Nielsen MK (1987) Effect of level of beef cow milk production on pre- and post-weaning calf growth. *Journal of Animal Science* **64**, 1313–1322.

Dekkers JCM, Ten Hag JH, Weersink A (1998) Economic aspects of persistency of lactation in dairy cattle. *Livestock Science* **53**, 237-252.

Do Carmo M, Claramunt M, Carriquiry M, Soca P (2016) Animal energetics in extensive grazing systems: Rationality and results of research models to improve energy efficiency of beef cow-calf grazing Campos systems. *Journal of Animal Science* **94**, 84–92.

Edwards SR, Hobbs JD, Mulliniks JT (2017) High milk production decreases cow-calf productivity within a highly available feed resource environment. *Translational Animal Science* **1**, 54–59.

Forster KM, Pimentel MA, Moraes JCF (2010) Disponibilidade de energia líquida no leite e desempenho ponderal de bezerros Hereford e Aberdeen Angus do nascimento à desmama. *Revista Brasileira de Zootecnia* **39**, 2545-2552.

Freetly HC, Nienaber JA, Brown-Brandl T (2006) Partitioning of energy during lactation of primiparous beef cows. *Journal of Animal Science* **84**, 2157–2162.

Harder B, Bennewitz J, Hinrichs D, Kalm E (2006) Genetic parameters for health traits and their relationship to different persistency traits in German Holstein dairy cattle. *Journal of Dairy Science* **89**, 3202–3212.

Hess BW, Lake SL, Scholljegerdes EJ, Weston TR, Nayigihugu V, Molle JDC, Moss GE (2005) Nutritional controls of beef cow reproduction. *Journal of Animal Science* **83**, 90–106.

Jenkins TG, Ferrell CL (1992) Lactation characteristics of nine breeds of cattle fed various quantities of dietary energy. *Journal of Animal Science* **70**, 1652–1660.

Jenkins TG, Ferrell CL, Roberts AJ (2000) Lactation and calf weight traits of mature crossbred cows fed varying daily levels of metabolizable energy. *Journal of Animal Science* **78**, 7-14.

Johnson CR, Lalman DL, Brown MA, Appeddu LA, Buchanan DS, Wettemann RP (2003) Influence of milk production potential on forage dry matter intake by multiparous and primiparous Brangus females. *Journal of Animal Science* **81**, 1837–1846.

Lake SL, Scholljegerdes EJ, Atkinson RL, Nayigihugu V, Paisley SI, Rule DC, Moss GE, Robinson TJ, Hess BW (2005) Body condition score at parturition and postpartum supplementation fat effects on cow and calf performance. *Journal of Animal Science* **83**, 2908–2917.

NCSS, NCSS: statistical system for Windows: user guide V. Kaysville, 2007. 565p.

Neville WE, Warren EP, Griffey WA (1974) Estimates of age effects on milk production in Hereford cows. *Journal of Animal Science* **38**, 1-10.

Pittroff W, Cartwright TC, Kothmann MM (2002) Perspectives for livestock on grazinglands. *Archivos Latinoamericanos de Produccíon Animal*. **10**, 133–143.

Robison OW, Youseff MKM, Dillard EU (1978) Milk production in Hereford cows I. Means and correlations. *Journal of Animal Science* **47**, 131–136.

Rutledge, JJ, Robison, OW, Ahlschwede WT, Legates, JE (1971) Milk yield and its influence on 205-day weight of beef calves. *Journal of Animal Science* **33**:563–567.

Short RE, Bellows RA, Staigmiller RB, Berardinelli JG, Custer EE (1990) Physiological mechanisms controlling anestrus and infertility in postpartum beef cattle. *Journal of Animal Science* **68**, 799–816.

Tanure S, Pötter BAA, Lobato JFP (2011) Natural and improved natural pastures on the reproductive performance of first-calf beef cows. *Revista Brasileira de Zootecnia* 40, 690-699.

Tables

Table 1. ADG and BW (adjusted means ± standard error mean) of calves born from cows that gained weight between calving and peak lactation (G group) and cows that lost weight during the same period (L group)

Calf	G	L	*P* - Value
ADG[1] (kg/day)			
First 21d postpartum	0.58 ± 0.07	0.65 ± 0.06	0.40
Peak Lactation	0.56 ± 0.05	0.61 ± 0.04	0.46
Calving – weaning	0.66 ± 0.02	0.63 ± 0.01	0.29
21d - peak Lactation	0.56 ± 0.03	0.66 ± 0.02	0.03
Peak Lactation - weaning	0.70 ± 0.02	0.65 ± 0.01	0.05
BW[2] (kg)			
Calving	32.65 ± 1.04	34.64 ± 0.83	0.13
First 21d postpartum	44.79 ± 1.73	48.34 ± 1.37	0.10
Peak Lactation	57.50 ± 2.17	61.68 ± 1.72	0.13
Weaning	158.07 ± 4.15	155.06 ± 3.28	0.57

[1]ADG average daily gain; [2]BW body weight.

Table 2. Milk yield, BW variables (adjusted means ± standard errors means), and pregnancy rate of cows that gained weight between birth and peak lactation (G group) and lost weight in the same period (L group)

Cow	G	L	*P* - Value
Milk yield			
21d postpartum (kg/day)	5.40 ± 0.31	5.73 ± 0.25	0.40
Peak Lactation (L/day)	5.85 ± 0.36	6.42 ± 0.29	0.21
Total Milk Yield (L)	974.74 ± 27.92	1065.37 ± 20.88	0.01
Persistency Lactation (g/d)	39.12 ± 2.54	49.31 ± 1.79	<0.001
BW[1] (kg)			
Calving	336.90 ± 5.40	328.34 ± 4.06	0.32
Peak Lactation	353.57 ± 4.63	302.56 ± 5.58	0.01
Difference	16.67 ± 11.03	-25.56 ± 15.68	<0.001
Weaning	369.81 ± 5.13	359.60 ± 6.65	0.23
Reproductive variable			
Pregnancy rate (%)	37.28 (22/59)	24.09 (20/83)	0.08

[1] BW body weight.

5 Artigo II

Artigo formatado de acordo com as normas da revista “Animal of Production Science”

Effects of bacterial DFM and tannin on immunity and performance of weaned beef calves

Claudia Faccio Demarco[a,b], Steve Paisley[c], Cassio Cassal Brauner[a,b*], Scott Lake[c]

[a] Núcleo de Pesquisa, Ensino e Extensão em Pecuária (NUPEEC), Federal University of Pelotas, Pelotas, RS, Brazil.

[b] Department of Animal Science, Federal University of Pelotas, Pelotas, RS, Brazil.

[c] Department of Animal Science, University of Wyoming, Laramie, WY, United States.

*Corresponding author: cassiocb@gmail.com

Abstract

Context. Weaning of beef calves has been previously shown to be a stressful event. A number of feed additives have been developed to attenuate the periods of stress in calves, such as the direct-fed microbials (DFM) and the tannins.

Aims. A two-year study was conducted to determine the effect of DFM plus tannins on newly weaned calf performance and indicators of immune response.

Methods. Calves (n = 142 year 1; 143 year 2) were weaned at approximately 6 mo of age, entered the feedlot and were fed one of two diets for 42 days: a receiving ration with added DFM + Tannins (DFM; direct fed microbials were added at the following rate: $2x10^8$ CFU/hd/d *Propionibacterium acidipropionici*; $5x10^7$ CFU/hd/d *Lactobacillus animalis*; $5x10^7$ CFU/hd/d *Bifidobacterium animalis*. Tannins were added at the rate of 15 g/hd/d, or a receiving ration with no added DFM + Tannins (CON). Weights were taken on consecutive days and averaged at the beginning and ending of the study, while single day weights were taken on d 28. In year 2 of the study, blood samples were collected on d 0, 14, and 28 to measure Bovine Viral Diarrhea (BVDV) titers against vaccination. Upon completion of the 42-day feeding study (year 2 only), calves (n=72) were transported to Laramie, WY and additional blood samples were taken on d 0, 2, 4, 7, and 9 after transportation to measure haptoglobin concentrations.

Key results. There were no differences detected for year (P = 0.18), initial (P = 0.42) and final BW (P = 0.43) or DMI (P = 0.31) due to dietary treatment. However, DFM + tannin treated calves had lower (P = 0.001) feed:gain (F:G) ratio overall and greater overall ADG (P = 0.06) when compared with CON calves. DFM + tannin calves tended to have lower F:G during the first 28 days (P = 0.12), and greater (P = 0.11) total gain overall. There were no differences (P = 0.22) in performance of calves after transportation back to Laramie.

However, there was a tendency for a treatment x day interaction for DFM calves to have lower blood haptoglobin concentration after transportation (P = 0.09).

Conclusions. Weaned calves fed DFM + Tannins tended to have greater performance during the first 42 d post weaning and had a reduction in blood haptoglobin concentrations.

Implications. This study demonstrates the potential beneficial impacts that DFM plus tannin can have on weaned calf performance and immunity.

Key words: stress, vaccine response, feed additives.

Introduction

Weaning may be considered an extremely stressful phase of livestock production system affecting physiological, metabolic, endocrinological, and behavioral processes (Weary et al., 2008). The stressors are derived from the abrupt separation of the calf from its dam, nutritional adjustments, and vaccinations (Lynch et al., 2010). Road transportation, one of the stressors factors for weaned calves, can cause an activation of the acute-phase inflammatory process due to the stimulation of body reserves (Earley and O'Riordan, 2006; Cooke et al., 2013) as well as impaired ruminal function (Marques et al., 2012). Additionally, stress associated with weaning has been linked to immunosuppression and mortality in newly weaned cattle entering feedlots (Marti et al., 2017).

A number of feed additives have been developed to attenuate the periods of stress in animals. Among the additives currently used are the direct-fed microbials (DFM) describe as feed products that contain a source of live, naturally occurring microorganisms (FDA, 2015). Another class of natural additives are the tannins, which are a complex group of polyphenolic plant secondary compounds.

Tannins have been reported to have an effect on the ruminal microbiota, directly affecting specific populations of microorganisms in the rumen, specifically on methanogenic bacteria (Focant et al., 2019), which has led to improvements on feed efficiency. McSweeney et al. (2001) reported that although the tannins had reduced the population of fiber digesting bacteria, the effect on the metabolism of ruminal microorganisms was not enough to alter the efficiency of microbial protein synthesis. In fact, the tannins protected dietary protein from ruminal degradation, allowing an increase in the absorption of amino acids in the intestine (Focant et al., 2019).

Conversely, bacterial DFM support ruminal microorganisms to develop and adapt to the presence of lactic acid. These bacterial DFM strains are classified as lactic acid producing and lactic acid utilizing and despite having different modes of action, both groups act together in rumen. The lactic acid producing bacteria stimulate lactic acid utilizing bacteria and allow a stabilization of ruminal pH. Bacterial DFM promote ruminal fermentation, favoring the feed efficiency improved energy status via propionate. Additionally, feeding bacterial DFM have beneficial intestinal effects, including the establishment of a desirable gut microflora and prevention of pathogenic organisms (Krehbiel et al., 2003; Seo et al., 2010).

The aim of this study was to evaluate the utilization of bacterial DFM and tannin fed in combination to weaned beef calves in feedlot and its effects on weight gain and immune response.

Materials and Methods

The 42-d feeding portion of the study was conducted from October 2017 until December 2017 and October 2018 until December 2018 on James C. Hageman Sustainable Agriculture Research and Extension Center (SAREC) in Lingle (WY). Two hundred and

eighty-eight Angus newly weaned calves (2017: 64 heifers, body weight (BW): 241.282 ± 25.54kg and, 80 steers, 249.085 ± 31.72kg; 2018: 80 heifers, 262.94 ± 19.91kg and, 64 steers, 254.27 ± 24.89kg) were used in a trial to evaluate the effects of supplemental tannin (ByPRO, MicroBios, Amarillo, Texas) plus DFM (Direct PBL, MicroBios, Amarillo, Texas) on feedlot growth performance and immunity. Calves were randomly allocated to one of two diets: DFM + Tannins (DFM), or a control (CON) without DFM or Tannins. The animals were grouped by nine (2017: 4 steers and 5 heifers per pen and 2018: 5 steers and 4 heifers per pen) into 16 pens weight blocked. Pens were 120 m^2, equipped with automatic drinkers, and 06 m fence-line feed bunks. Each group consisted of 8 pens/year, 9 animals/pen, totaling 144 animals per group in both years.

The DFM was composed of three bacterial strains ($5x10^8$ colony forming units – CFU of *Propionibacterium acidipropionici*, $2x10^8$ CFU of *Lactobacillus acidophilus,* and $2x10^7$ CFU of *Bifidobacterium animalis* per head/day). The daily amount was 0.69 g per head. Treatments were applied as a top dress to each feed bunk daily. DFM treatments were stored in a freezer in individually marked packets. Each day one packet (50g) was reconstituted with 15.4 L (1.9 L for each treatment pen) of water in an individual sprinkler that corresponded to the specific treatment. After the feed was delivered to each feed bunk, the DFM mixture or water were sprayed onto the top surface of the bunk fed, once daily. For the tannin, condensed and hydrolyzed derived from Chestnut and Quebracho, 135 grams per pen (15 g/head/day) were also top-dressed after the feed delivery. Only water served as placebo for the Control group.

Calves were fed with a basal diet to meet or exceed the nutrients requirement of growing beef calves to gain 1.10 kg with an estimated 6.5 kg/day/DM intake (NRC, 2001). The composition of the basal diet during the first 5 days of the feedlot was 50% of cracked

corn and 50% of alfalfa hay. After that was 50% of cracked corn, 20% of alfalfa hay and 30% of corn silage for 21 days (TMR 1). After, the diet was composed of 50% of cracked corn, 10% of alfalfa hay and 40% of corn silage (TMR 2). Feed samples for TMR 1 and 2 were collected and analyzed (Table 1).

Feed bunks were managed to allow little or no accumulation of unconsumed feed (visual scores). When a pen had an empty bunk at the time of evaluation, the feed allotment for that pen was increased (10%). This process was continued until a maximum level of intake was attained and was reinitiated when a pen of steers consumed all the feed from the previous day. The offer and intake were measured in the beginning (d 0), half (d 28) and, final days (d 42) of trial. According the visual score, the orts were taken into account to calculate the consumption per pen.

Samples of offered feed were analyzed for dry matter (DM), crude protein (CP) and acid detergent fiber (ADF). DM was determined by drying at 105ºC for 24 hours, based on AOAC Method No. 935.29, (Gales and Peter, 1990). ADF content was determined based on the procedures described by Mertens (2002). CP was determined according AOAC Methods No. 990.03 and 968.06 (Padmore and Joel, 1990). Total Nutrient Digestible (TDN), Net Energy for maintenance and for gain were calculated based on NRC (2001).

(Insert Table 1 here)

The animals were vaccinated on 14th day of the trial with PYRAMID 5 + Presponse® SQ (Bovine Rhinotracheitis-Virus Diarrhea-Parainfluenza 3-Respiratory Syncytial Virus Vaccine; Boehringer Ingelheim, St. Joseph, MO, USA) and One Shot Ultra® 7 (Clostridium Chauvoei-Septicum-Novyi-Sordellii-Perfringens Types C e D- Mannheimia Haemolytica Bacterin-Toxoid; Zoetis, Kalamazoo, MI, USA).

To evaluate the performance and ADG, all calves were weight on consecutive days and averaged at the beginning (0) and ending of the study (42), while single day weights were taken on days 14 and, 28. In the 2018 trial, blood samples were collected on 14th (prior to vaccination), 28th and, 42th days of the feedlot study for Bovine Viral Diarrhea Virus (BVDV) neutralization assay. Blood samples were taken from 50% of the calves (n=72) through the coccygeal vascular complex puncture into vacuolated tubes without anticoagulant. The samples were centrifuged at 1800 x g, for 15 minutes, and the serum were separated, packed into 1.5 mL microtubes, and frozen for later analysis.

Upon completion of the 42-day feeding study in 2018 (year 2 only), 72 calves were used for the short distance transport study. The animals were transported from SAREC to Laramie (approximately 228 km) and remained for 10 days receiving the same treatments with DFM and tannin but with a different diet consisting of alfalfa hay ad libitum and cracked corn (3.62 kg of DM/head/day). In this second phase, blood samples were collected on days 0 (day of transport), 2, 4, 7 and, 9 relatives to the shipping and were used to determine haptoglobin levels.

Serum were tested for neutralizing antibodies against BVDV 1a at multiple time points during the study. The geometric mean of antibody titers was calculated from the endpoint log2 titers of the animals in each group. Serum haptoglobin concentrations were determined using a commercially available enzyme immune assay kit according to the manufacturer's directions (Immunology Consultants Laboratory, Inc., Portland, OR). Intra- and inter-assay coefficients of variation were 10.12% and 7.56%, respectively.

The trial was analyzed as a randomized complete block using pens as experimental units. Two animals from 2017 trial and one from 2018 trial were removed from the study.

All statistical analyses were performed using commercially available statistical software SAS (SAS 9.3; SAS Inst. Inc. Cary, NC).

For the BVDV titers, neutralizing antibody titers were expressed as the reciprocal of the highest serum dilution capable of preventing viral replication. The average values of the titers were transformed into geometric mean titers (GMT; Thrusfield, 1986) by the reaction: GMT = 2*a*, as *a* the mean log of the antibody titer. The geometric mean of the antibody was calculated from the endpoint log2 titers of the animals in each group and then converting the mean to a real number.

Data including year, ADG, initial, final weight and haptoglobin levels were compared among groups using a categorical response mixed model. The model included the fixed effect of treatment group. The data were measured repeatedly, the calves as experimental units with the following model: response = treatment + time + treatment*time. The comparison of means by the Tukey Test and were considered significant when $P \leq 0.05$ and a trend when $0.05 < P$ to <0.10.

Results

There were no differences ($P \geq 0.18$) detected for year, initial and final BW, DMI, or ADG from d 1-28, or F:G d 29-42 due to dietary treatment. However, DFM + tannin treated calves tended to have greater overall ADG ($P = 0.06$) although was not observed a difference on overall gain ($P = 0.11$). DFM + Tannin calves had lower ($P = 0.001$) F:G ratio compared with CON calves. The results of 42 days feedlot performance are show in Table 2. After shipping, we did not expect any difference in performance measures between groups due to

the short duration (only 10 days) of the trial. Calves did not have any differences in initial weight (P = 0.43), final weight (P = 0.40), ADG (P = 0.22) or overall gain (P = 0.22).

(Insert Table 2 here)

As expected, a day effect to vaccination (P < 0.001) was observed with an increase in antibody titers to the vaccination at each collection day. The back transformed means were similar between the groups in the 3-day virus neutralization evaluation for the BVDV, as shown in Table 3.

(Insert Table 3 here)

A day effect (P = 0.05) on haptoglobin means post-transportation was observed (9.83, 4.67, 26.58, 5.09 and, 6.31 ± 1.68μg/mL for 0, 2, 4, 7 and, 9 days after shipping). The DFM + Tannins calves had lower (P < 0.001) haptoglobin concentrations at d 0 and d 4 compared with the Control group (treatment x day effect P = 0.09). The values of haptoglobin measured on the days after shipping are shown in the table below.

(Insert Table 4 here)

Discussion

The influence of Direct-fed Microbial and tannin during the feedlot period on performance and indicators of immune response were investigated. Apart from that, it was observed a trend to greater ADG from the supplemented calves, although the immune response for vaccination was not affected by DFM and tannic acid and a small effect of these treatments to the haptoglobin levels was observed.

Although the metabolizable protein (MP) did not exceed the nutrient requirements for the animals used in the study, it is worth suggesting that moderated levels of tannins supplementation have shown positive effects on lamb growth performance even in a short

period (less than 42 days) when metabolizable protein supply of the basal diet is expected to exceed requirements (NRC, 2001; Barajas et al., 2011). However, Buntyn et al. (2016), suggested a connection between DFM supplementation and increasing concentrations of degradable intake protein (DIP). As DIP increased from 80% to 120% of recommended (10% increments), a cubic increase in ADG was observed when animals received DFM. Tannins have been known to decrease ruminal degraded protein (Frutos et al., 2004), however, little is known about the interaction between tannins and DFM on ruminal degradable protein. Additionally, the reactions between tannins and bacterial cells are less understood than the reactions between tannins and diet intake protein (Mim et al., 2003). Although tannins bind to both bacterial cells and protein, the interaction between tannins and substrate (protein or bacterial cells) seems to be different. Molan et al., (2001) reported that the tannin-bacterial interactions are much stronger than tannin-protein interaction or may cause a different type of interaction.

Another factor that may be important is the daily amount of tannin dosage. The daily intake of tannin on Rivera-Méndez (2017) study did not exceed 0.14 g/kg live weight and comparing with the daily amount of tannins used in this study, wherein animals received 0.06 g/day/BW of acid tannins (15g/day/animal), based on initial body weight of the treatment group. Barajas et al., (2011) observed similar enhancements in ADG (11–13%) and dietary energy (4–5%) in growing-finishing bulls supplemented with 6 - 29g tannin/head/day. Krueger et al. (2010) and Mezzomo et al. (2011) did not observe effects of supplemental condensed tannins (0.38 g and 0.4g / kg of BW, respectively) on DMI of finishing feedlot steers. The study of Yang (2017) which evaluated the effects of tannic acid, had its doses between 35.1 and 140.4 g per day per animal, which was close to the maximum dose recommended (<0.4g/kg of live weight daily) by Murdiat et al. (1990), had not adverse effect

on the liver and the protein metabolism status of cattle. High levels of dietary tannin have markedly depressed feed intake in ruminants and is likely due to palatability (Frutos et al., 2004). This study corroborates with other reported data suggest that tannins have a beneficial effect on growth performance when fed in smaller doses.

The presence of moderate levels of condensed tannins in the rumen is related to the protection of dietary protein against degradation by ruminal microorganisms, increasing the flow of protein for absorption in the intestine (Min et al., 2003). Because of these effect on protein degradation, Ben-Salem et al. (1999) and Min et al. (2003) attributed increased growth performance due to supplemental tannins on increased intestinal metabolizable protein supply (Waghorn, 1996). This mechanism can explain improved ADG from the DFM + tannin calves in the current study.

In a review, Krehbiel et al. (2003) proposes that feeding DFM generally results in a 2.5 to 5% improvement in ADG and 2% increase in feed efficiency in feedlot animals. Elam et al., (2003) also reported an increased in 7.5% on ADG with supplemented animals without other effects on performance. Cattle tend to have greater responses in ADG and F:G ratio due to DFM supplementation during the early stages of growth. DFM may alter the efficiency of production and proportional concentrations of volatile fatty acids (VFA) in the rumen (Kmet et al., 1993) to promote greater propionate production, thereby, increasing the energy available to the animal.

Krehbiel et al. (2003) offered several mechanisms by which bacterial DFM might benefit the immune system in supplemented animals. Mechanisms included competitive inhibition of pathogenic microorganisms for attachment in the gastrointestinal tract; antibacterial effects, such as hydrogen peroxide production; immunomodulation via

enhanced phagocytosis and natural killer cell activity; and beneficial manipulation of ruminal fermentation.

Newly weaned beef calves entering in feedlot undergo a variety of stresses, such as recent separation from the dam, transport and, feed changes. Such stresses can alter microorganisms in the rumen and lower gut (Willians and Mahoney, 1984). The supplementation of bacterial DFM can repopulate the gut and reduce the changes in the microbial population (Krehbiel et al., 2003).

The mode of action of bacterial DFM in the rumen is closely related to the maintenance of ruminal pH, either through lactic acid utilizing bacteria (LUB) or lactic acid producing bacteria (LAB). The presence of LAB allows the ruminal microorganisms to adapt to the presence of lactic acid in the rumen (Yoon and Stern, 1995) avoiding sudden drops in pH when changing the diet or adding highly fermentable carbohydrates. Kung and Hession (1995) inoculating *in vitro* with lactate-utilizing bacteria and using a highly fermentable substrate demonstrates a prevention of lactate accumulation. According to Huffman (1992), *Lactobacillus acidophilus* might modify subacute ruminal acidosis and these may be explained due to reduce the amount of time that ruminal pH was below 6.0 compared with control when animals were feeding with this *Lactobacillus acidophilus.*

Some supplemented species are also involved in the use of the ruminal acid lactic produced, however its main action is the production of propionate, such as one of the bacteria used in this study, *Propionibacterium acidipropionici*. Propionate is the largest precursor of glucose among short chain fatty acids (SCFA) and plays a role in hormonal release and nutrient distribution in tissues. Propionate is responsible for 61 to 67% of glucose release and as propionate increases, the acetate:propionate ratio decreases, and is accompanied by decreased in CH_4 production, leading to greater energy retention by the animal. Propionate

production increases as the dosage of *Propionibacterium* used are increase. Whilst the ruminal pH maintain and there is an increase in energy retention, these factors collectively may help explain greater F:G conversion and ADG of calves during the trial.

Bacterial DFM have been reported to modify the balance of intestinal microorganisms, adhere to intestinal mucosa and prevent pathogen adherence or activation, influence the gut permeability, and modulate immune function (Salimen et al., 1996; Holzapfel et al., 1998). As discussed earlier, these mechanisms could benefit ruminants by increasing nutrient uptake via decreased thickening of the intestinal wall as a result of inflammation. Furthermore, bacterial DFM could directly and indirectly enhance energy production and efficiency of utilization by altering ruminal fermentation and decreasing the amount of energy used for tissue turnover in the gastrointestinal tract.

Inactivated vaccines primarily elicit a humoral immune response. Viruses included in modified live vaccines, as used in the current study, replicate in the animal and induce T and B cell-based immunity (Moenning et al., 2005). The modified live vaccine response is greater (Newcomer, 2015) when compared to inactivated vaccines and thus making it difficult for the DFM and tannin supplementation to provide any increased responses to live vaccine-induced response.

One of the most widely recognized stressors in beef cattle production is transportation (Broom, 2003; Knowles, 1999). Transportation issues related to livestock and feeding production area of beef industry are especially important because management practices for production of cattle at this age are generally novel and inherently stressful for the animal (Fike and Spire, 2006). It is worth noting that the duration of the road transport in this study was approximately 3 hours which is considered a short distance. Makimura and Suzuki (1982) indicated that haptoglobin concentrations are often undetectable in unstressed cattle

and, additionally, Marti et al. (2017) reported greater haptoglobin concentrations in calves during a long-distance transport. Nonetheless, it is important to highlight the significant difference on day 0 (at arrival). Although this was a short distance, the supplemented calves had lower haptoglobin levels. This lower value suggests that supplemented animals were less stressed immediately after transportation. On fourth day post shipping, both groups had increased in haptoglobin levels, and the supplemented animals, despite the increase in values, were still lower than the Control group animals.

The reason for the increase on day 4th remains unclear, but Chibisa et al., 2018 also suggested that haptoglobin concentration increases and peaks approximately 96 h after transport (Cooke et al., 2013), suggesting the presence of inflammation. This is consistent with our peak concentrations occurring around day 4 (96 hours) post-transportation, followed by a decrease in haptoglobin concentration. Haptoglobin is produced by hepatocytes after stimulation with proinflammatory cytokines, such as interleukin-1 and tumor necrosis factor-α, as a part of the acute-phase response (Bauman, 1994; Wassel, 2000). The increase in serum haptoglobin concentration in calves could have reflected transport stress, a clinical or subclinical inflammation, or an acute-phase response associated with adaptation to a higher-concentrate diet (Ametaj et al, 2009).

Circulating concentrations of haptoglobin in transported feeder cattle have been negatively associated with feedlot performance (Berry et al., 2004; Qiu et al., 2007; Araujo et al., 2010), and such outcome can be attributed to altered basal metabolism, increased tissue catabolism, and reduced feed efficiency during an acute-phase response (Johnson, 1997). The bovine acute-phase response may be triggered by road transport via neuroendocrine stress reactions that stimulate breakdown of body reserves and activate acute-phase and

inflammatory processes (Cooke and Bohnert, 2011; Cooke et al., 2012). Marques et al. (2012) also reported that feed and water deprivation during road transport elicit acute-phase reactions, likely due to the death of rumen microbes and subsequent release of endotoxins into the circulation (Carroll et al., 2009).

To our knowledge, there are no reported studies evaluating the effects of tannins directly on immunity status, like haptoglobin and the virus neutralization assay. In view of the tannin has no direct relation to immunity, a possible effect on the immunity of the animals in this study could be credited due to mode of action of the bacterial DFM or an indirect effect by improvement on feed efficiency for both treatments, DFM and tannins, leading to a better immune response. A more powerful study would be necessary to clearly identify the effects of tannins associate or not with bacterial DFM on immunity.

Notwithstanding this study demonstrates the potential beneficial impacts that DFM plus tannin can have on weaned calf performance and immunity, with improvement in ADG during the first 28 days along with decrease in haptoglobin concentrations indicate that DFM and/or tannin may play a role in reducing stress of weaned calves, the effect of these two compounds needs to be separated. It is the first study evaluating the simultaneously supplementation of these two additives and that the effects of tannin on the bacterial DFM used are not yet elucidated and may have not allowed to demonstrate the full effect on animal performance. The improvement in feed conversion along with the improved performance could result in heavier calves sold or heavier healthier calves entering the feedlot.

Conclusion

Weaned calves fed with DFM and tannin fed in combination tended to have greater performance during the first 42 days post weaning and had a reduction in haptoglobin concentrations suggesting a reduction in stress.

References

Ametaj BN, Koenig KM, Dunn SM, Yang WZ, Zebeli Q, Beauchemin KA (2009) Backgrounding and finishing diets are associated with inflammatory responses in feedlot steers. *Journal of Animal Science* **87**, 1314–1320.

AOAC (2006) Official Methods of Analysis. 18th ed. AOAC Int., Arlington, VA.

Araujo DB., Cooke RF, Hansen GR, Staples CR, Arthington JD (2010) Effects of rumen-protected polyunsaturated fatty acid supplementation on performance and physiological responses of growing cattle following transportation and feedlot entry. *Journal of Animal Science* **87,** 4125–4132.

Barajas R., Cervantes BJ, Camacho A, Verdugo M, Espino MA, Flores LR, Romo JA, Velaquez EA, Lomeli JJ (2011) Influence of addition of tannins-extract in low concentration of dietary dry matter on feedlot-performance of bulls. *Journal of Animal Science* **89**, 615.

Barajas R., Cervantes BJ, Espino MA, Camacho A, Verdugo M, Flores LR, Loneli JJ, Romo JA (2012b) Effect of tannins extract supplementation on feedlot performance and plasma urea nitrogen of yearling bulls fed dry-ground corn-based diets containing corn-DDG and cane molasses. *Journal of Animal Science* **90**, 600.

Barajas R, Cervantes BJ, Arechiga SC, Espino MA, Barajas LR, Cervantes BJ, Espino MA, Camacho A, Verdugo M, Flores LR, Arechiga SC, Lomeli JJ, Romo JÁ (2012a.) Influence

of tannins extract addition on feedlot-performance of bulls fed sorghum-based diets. *Journal of Animal Science* **90**, 372– 373.

Baumann H, Gauldie J (1994) The acute phase response. *Immunology Today* **15**, 74–80.

Ben-Salem H, Nefzaoui A, Ben-Salem L, Tisserand JL (1999) Different means of administering polyethylene glycol to sheep: effect on the nutritive value of Acacia cyanophylla Lindl. *Foliage Animal Science* **68**:809–818.

Berry BA, Confer AW, Krehbiel CR, Gill DR, Smith RA, Montelongo M (2004) Effects of dietary energy and starch concentrations for newly received feedlot calves: II. Acute- phase protein response. *Journal of Animal Science* **82**, 845–850.

Broom, DM (2003) Transport stress in cattle and sheep with details of physiological, ethological, and other indicators. *Deutsche tierarztliche Wochenschrift* **110**, 83-89.

Buntyn JO, Schmidt TB, Nisbet DJ, Callaway TR (2016) The Role of Direct-Fed Microbials in Conventional Livestock Production. *Annual Review of Animal Biosciences* **4:1**,335-355.

Carroll JA, Reuter RR, Chase CCJr.,Coleman SW, Riley DG, Spiers DE, Arthington JD, Galyean ML (2009) Profile of the bovine acute-phase response following an intra- venous lipopolysaccharide challenge. *Innate Immunity* **15**, 81–89.

Chibisa GE, Vinyard JR, Laarman AH (2018) Short communication: Effects of meloxicam administration on protein metabolism and growth performance in transported Jersey calves. *Journal of Dairy Science* **12**, 11435-11440. doi: 10.3168/jds.2018-14493.

Cooke RF, and Bohnert DW (2011) Bovine acute-phase response following corticotrophin-release hormone challenge. *Journal of Animal Science* **89**, 252–257.

Cooke RF and Arthington JD (2012) Concentrations of haptoglobin in bovine plasma determined by ELISA or a colorimetric method based on peroxidase activity. *Journal of Animal Physiology and Animal Nutrition*. doi:10.1111/j.1439-0396.2012.01298.x

Cooke RF, Guarnieri Filho TA, Cappellozza BI, Bohnert DW (2013) Rest stops during road transport: Impact on per- formance and acute-phase protein responses of feeder cattle. *Journal of Animal Science* **91**, 5448–5454. doi:10.2527/jas.2013-6357

Earley B and O'Riordan EG (2006) Effects on transporting bulls at different space allowances on physiological, haematological and immunological responses to a 12-h journey by road. *Irish Journal of Agricultural and Food Research* **45**, 39–50.

Elam NA, Gleghorn JF, Rivera JD, Galyean ML, Defoor PJ, Brashears MM, Younts-Dahl SM (2003) Effects of live cultures of *Lactobacillus acidophilus* (strains NP45 and NP51) and *Propionibacterium freudenreichii* on performance, carcass and intestinal characteristics, and *Escherichia coli* strain O157:H7 shedding of finishing beef steers. *Journal of Animal Science* **81**, 2686–2698.

FDA. Direct-Fed Microbial Products in Compliance Policy Guides. Washington, D.C, 2015. Available from: <http://www.fda.gov/ICECI/ComplianceManuals/CompliancePolicyGuidanceManual/ucm074707.html.>

Fike K., Spire MF (2006) Transportation of cattle. *Veterinary Clinics of North America: Food Animal Practice* **22**, 305-320.

Focant M, Froidmont E, Archambeau Q, Dang Van QC, Larondelle Y (2019) The effect of oak tannin (Quercus robur) and hops (Humulus lupulus) on dietary nitrogen efficiency, methane emission, and milk fatty acid composition of dairy cows fed a low-protein diet

including linseed. *Journal of Dairy Science* **102**, 1144-1159. ISSN 0022-0302, https://doi.org/10.3168/jds.2018-15479.

Frutos P, Hervás G, Giráldez FJ, Mantecón AR (2004) Review. Tannins and ruminant nutrition. Span. *Journal of agricultural research* **2**, 191–202.

Gales PW (1990) Moisture in Malt – Gravimetric Method, Method 935.29. (In Kenneth Herlich, Ed.) Official Methods of Analysis of the Association of Official Analytical Chemists, 15th Ed. AOAC (Inc: Arlington, VA).

Harland RJ, Jim GK, Guichon PT, Townsend HG, Janzen ED (1991) Efficacy of parenteral antibiotics for disease prophylaxis in feedlot calves. *The Canadian Veterinary Journal* **32**, 163.

Holzapfel WH, Haberer P, Snel J, Schillinger U, Huis in't Veld JHJ (1998) Overview of gut flora and probiotics. *International Journal of Food Microbiology* **41**, 85–101.

Huffman RP, Karges KK, Klopfenstein TJ, Stock RA, Britton RA, Roth LD (1992) The effect of Lactobacillus acidophilus on subacute ruminal acidosis. Journal of Animal Science **70**, 87.

Johnson RW (1997) Inhibition of growth by pro-inflammatory cytokines: An integrated view. *Journal of Animal Science* **75**, 1244–1255.

Kmet V, Flint HJ, Wallace RJ (1993) Probiotics and manipulation of rumen development and function. *Archives of Animal Nutrition* **44**, 1–10.

Knowles TG (1999) A review of the road transport of cattle. *Veterinary Record* **144**, 197-124.

Krehbiel CR, Rust SR, Zhang G, Gilliland SE (2003) Bacterial direct-fed microbials in ruminant diets: Performance response and mode of action. *Journal of Animal Science* **81**, E120–E132.

Krueger WK, Gutierrez-Banuelos H, Carstens GE, Min BR,.Pinchak WE, Gomez RR, Anderson RC, Krueger NA, Forbes TDA. (2010) Effects of dietary tannin source on performance, feed efficiency, ruminal fermentation, and carcass and non-carcass traits in steers fed a high-grain diet. *Animal Feed Science Technology* **159**, 1–9. doi:10.1016/j.anifeedsci.2010.05.003

Kung LM, Hession AO (1995) Preventing *in vitro* lactate accumulation in ruminal fermentations by inoculation with *Megasphaera elsdenii*. *Journal of Animal Science* **73**, 250–256.

Lynch EM, Earley B, McGee M, Doyle S (2010) Effect of abrupt weaning at housing on leukocyte distribution, functional activity of neutrophils, and acute phase protein response of beef calves. *BMC Veterinary Research* **6**, 39.

Makimura S, Suzuki N (1982) Quantitative determination of bovine serum haptoglobin and its elevation in some inflammatory disease. *Japanese Journal of Veterinary Science* **44**, 15–21.

Marques RS, Cooke RF, Francisco CL, Bohnert DW (2012) Effects of twenty-four-hour transport or twenty-four-hour feed and water deprivation on physiologic and performance responses of feeder cattle. *Journal of Animal Science* **90**, 5040–5046. doi:10.2527/jas.2012-5425

Marti S, Wilde RE, Moya D, Heuston CE, Brown F, Schwartzkopf-Genswein KS (2017) Effect of rest stop duration during long-distance transport on welfare indicators in recently weaned beef calves. *Journal of Animal Science* **95**, 636-644. doi: 10.2527/jas.2016.0739.

McSweeney CS, Palmer B, McNeill DM, Krause DO (2001) Microbial interactions with tannins: nutritional consequences for ruminants. *Animal Feed Science and Technology* **91**, 83–93.

Mertens DR (2002) Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. *Journal of AOAC International* **85**, 1217–1240.

Mezzomo R, Paulino PVR, Detmann E, Valadares SC, Paulino MF, Monnerat JPIS, Duarte MS, Silva LHP, Moura LS (2011) Influence of condensed tannin on intake, digestibility, and efficiency of protein utilization in beef steers fed high concentrate diet. *Livestock Science* **141**,1–11.

Min BR, Barry TN, Attwood GT, McNabb WC (2003) The effect of condensed tannins on the nutrition and health of ruminants fed fresh temperate forages: A review. *Animal Feed Science and Technology* **106**, 3–19.

Moennig V, Eicken K, Flebbe U, Frey HR, Grummer B, Haas L, Greiser-Wilke I, Molan AL, Attwood GT, Min BR, McNabb WC (2001) The effect of condensed tannins from *Lotus pedunculatus* and *Lotus corniculatus* on the growth of proteolytic rumen bacteria *in vitro* and their possible mode of action. *Canadian Journal of Microbiology* **47**, 626–633.

Murdiati, TB, McSweeney CS, Lowry, JB (1991) Complexing of toxic hydrolysable tannins of yellow-wood (Terminalia oblongata) and harendong (Clidemia hirta) with reactive susbtances: An approach to preventing toxicity. *Journal of Applied Toxicology*, **11**, 333-338.

Newcomer BW, Walz PH, Givens MD, Wilson AE (2015) Efficacy of bovine viral diarrhea virus vaccination to prevent reproductive disease: a meta-analysis. *Theriogenology* **83**, 360-365.e1. doi:10.1016/j.theriogenology.2014.09.028.

Padmore, JM (1990) Protein (Crude) in Animal Feed – Dumas Method, Method No. 968.06. In Kenneth Herlrich (ed), Official Methods of Analysis of the Association of Official Analytical Chemists, 15th Edition. AOAC. Pp. 71-72 (Arlington, Virginia 22201).

Qiu X, Arthington JD, Riley DG, Chase Jr CC, Phillips WA, Coleman SW, Olson TA (2007) Genetic effects on acute phase protein response to the stresses of weaning and transportation in beef calves. *Journal of Animal Science* **85**, 2367–2374.

Rivera-Méndez C, Plascencia A, Torrentera N, Zinn RA (2017) Effect of level and source of supplemental tannin on growth performance of steers during the late finishing phase. *Journal of Applied Animal Research* **45**, 199–203. doi:10.1080/09712119.2016. 1141776

Salminen S, Isolauri E, Salimen E (1996) Clinical uses of probiotics for stabilizing the gut mucosal barrier: successful strains and future challenges. Antonie Leeuwenhoek **70**, 347–358.

SAS (2004) SAS/STAT user's guide: Version 9.1. Cary (NC): *SAS Institute*.

Seo JK, Kim SW, Kim MH, Upadhaya SD, Kam DK, Ha J K (2010) Direct-fed microbials for ruminant animals. *Asian- Australasian Journal of Animal Sciences* **23**, 1657–1667.

Thrusfield M (1986) Veterinary epidemiology. London: Butterworths, 280p. (University of Edinburgh)

Van Soest PJ (1994) Nutritional ecology of the ruminant. 2nd ed. (Cornell Univ. Press, Ithaca, NY).

Waghorn G (1996) Condensed tannins and nutrient absorption from the small intestine. In: Rode LM, editor. Proceedings Canadian Society of Animal Science Annual Meeting. p. 175– 194 (Canada: Lethbridge)

Wassell J (2000) Haptoglobin: function and polymorphisms. *Clinical laboratory* **46**,547–552.

Weary DM, Jasper J, Hötzel MJ (2008) Understanding weaning distress. *Applied Animal Behaviour Science* **110,** 24-41.

Williams DL, Mahoney JH (1984) Pre-weaning and post- weaning nutrition. In Proc. 17th *Annual Conference of the American Association of Bovine Practitioners* pp. 98.

Yang K, Wei C, Zhao GY, Xu ZW, Lin SX (2017) Effects of dietary supplementing tannic acid in the ration of beef cattle on rumen fermentation, methane emission, microbial flora and nutrient digestibility. *Journal of Animal Physiology and Animal Nutrition (Berl)* **101**, 302–10.

Yoon IK, Stern MD (1995) Influence of direct-fed microbials on ruminal microbial fermentation and performance of ruminants: a review. *Asian Australasian Journal Animal Science* **8**, 533–555.

Tables and Figures

Table 1. TMR analysis (kg of dry matter (DM)) offered to the animals during the trial period.

Item	TMR 1	TMR 2
Ingredients (g/kg DM)		
Cracked corn	500	500
Alfalfa Hay	200	100
Corn silage	300	400
Chemical composition (dry basis)		
Dry matter, %	66.76	72.25
Crude protein, %	11.00	11.41
ADF[a], %	23.6	21.89
TDN[b], %	69.2	70.91
Net Energy Maint, MCal /cwt	45.63	
Net Energy Gain, MCal /cwt	73.01	

[a]*ADF- Acid detergent fiber;*

[b]*TDN- Total Digestible Nutrients*

Table 2. Performance parameters (means ± standard error of means) from animals of Control (n = 143) and DFM + Tannin group (n = 142; 2017 and 2018 trial).

	Control	DFM[1] + Tannin	S.E.M[2]	P - Value
Weight (kg)				
Initial	248.3	248.9	4.6	0.42
Final	298.2	301.8	5.07	0.43
Overall gain	49.9	52.9	0.77	0.11
ADG[3] (kg/day)				
1 - 28 days	1.33	1.42	0.05	0.15
29 - 42 days	1.06	1.09	0.05	0.65
Total	1.19	1.26	0.02	0.06
DMI[4] (kg/day)				
1 - 28 days	5.83	5.67	0.23	0.29
29 - 42 days	7.12	6.94	0.28	0.27
Total	6.48	6.30	0.25	0.31
F:G[5]				
1 - 28 days	6.64	5.46	0.58	0.12
29 - 42 days	6.21	5.92	0.15	0.18
Total	5.50	5.00	0.09	0.001

[1]: Direct Fed Microbial; [2]: standard error of means; [3]: average daily gain; [4]: dry matter intake (calculated from each pen (n = 8/treatment per year), but divided by the number of cattle within each pen (n = 9 head/pen) and expressed as kg per animal/day); [5]: feed:gain ratio (calculated using total DMI and BW gain of each pen and expressed as kg per animal/day).

Table 3. Back transformed geometric mean antibody titers (mean ± standard error of mean) of study calves in each treatment group to BVDV (BVDV type 1a); study days 14 (vaccination day), 28, and 42 (P-value for treatment: 0.41; for days: <.0001 and for treatment x day interaction: 0.60).

Group	Days		
	14	28	42
DFM[1] + Tannin	2.44 ± 1.19[A]	14.94 ± 1.17 [B]	156.80 ± 1.16 [C]
Control	2.33 ± 1.18 [A]	31.35 ± 1.17 [B]	170.51 ± 1.16 [C]

[A, B, C:] Same letters in the column and line do not differ statistically (P > 0.05). [1]: Direct-Fed Microbial.

Table 4. Haptoglobin levels of calves receiving DFM + Tannin and the Control group after shipping (n = 36 per group, treatment vs day interaction; P value = 0.09).

Haptoglobin	Days post-shipping					S.E.M[2]
(mg/dl)	0	2	4	7	9	
DFM[1] + Tannin	5.5 ^{D}	4.7 ^{D}	22.8 ^{B}	5.8 ^{D}	6.1 ^{D}	1.49
Control	14.1 ^{C}	4.7 ^{D}	30.4 ^{A}	4.4 ^{D}	6.5 ^{D}	1.68

$^{A, B, C:}$ Same letters in the column and line do not differ statistically (P > 0.05).

[1]: Direct-Fed Microbial; [2]: standard error of the mean.

6 Artigo III

Artigo formatado e submetido de acordo com as normas do periódico “Ciência Rural”

In vitro fermentation of diets containing sweet potato flour as a substitute for corn in diets for ruminants

Fermentação _in vitro_ de dietas contendo farinha de batata-doce como substituto do milho em dietas para ruminantes

Claudia Faccio Demarco[I], Fabian Manuel Guerrero Paredes[I], Claudio Antonio Pozo[II], Marilisa Mibach[I], Gilberto Vilmar Kozloski[II], Lisandre de Oliveira[III], Eduardo Schmitt[I], Viviane Rohrig Rabassa[I], Francisco Augusto Burkert Del Pino[I], Marcio Nunes Corrêa[I], Cassio Cassal Brauner[I*]

[1]- NOTA -

RESUMO

Com a intensificação dos sistemas de produção e o aumento das exigências alimentares das vacas leiteiras criou-se a necessidade de diversificação nas opções de alimentos, focando em alternativas mais eficientes, modernas e sustentáveis. Poucas pesquisas foram realizadas avaliando a inclusão da farinha de batata-doce como fonte de energia em substituição ao milho para ruminantes. O objetivo deste trabalho foi avaliar a produção de gás *in vitro* da farinha de batata-doce (SPF) em substituição ao milho moído em diferentes níveis. Para a produção de gás *in vitro*, foram realizados quatro tratamentos, com substituição de milho por farinha de batata-doce a 0, 33, 66 e 100%, em uma dieta com silagem de milho, farelo de soja e milho moído. As incubações foram conduzidas em frascos selados contendo 50 ml do inóculo preparado

[1I] Núcleo de Pesquisa, Ensino e Extensão em Pecuária, Universidade Federal de Pelotas (UFPel), Pelotas, Brasil, 96160-000. E-mail: cassiocb@gmail.com. *Corresponding author.
[II]Departamento de Zootecnia, Universidade Federal de Santa Maria (UFSM), Santa Maria, RS, Brasil.
[III]Departamento de Zootecnia, Instituto Federal Sul Rio Grandense (IFSul), Campus Pelotas, RS, Brasil.

utilizando o fluido ruminal, solução tampão e 0,5 g de cada tratamento. A produção de gás acumulada foi maior na substituição do milho pela SPF em 100% (224 ± 7.5 e 231,9 ±7.5 ml/g de MS incubada para as substituições 0 e 100%, P = 0.001). A taxa de degradação foi 7,10, 7,59, 8,08 e 8,59 ± 0,06% por hora nas substituições 0, 33, 66 e 100%, respectivamente (P < 0.0001). Houve também diferença (P = 0.013) no lag time, em que as dietas com maior inclusão de SPF tiveram tempo de colonização bacteriana menor. Em conclusão, a farinha de batata-doce produziu mais gás e é degradada mais rapidamente que o milho.

Palavras-chave: Fermentação, amido, nutrição de ruminantes, tubérculos.

ABSTRACT

With the intensification of production systems, dairy cow feeding has undergone changes creating the need to increase substitute feed options, focusing on more efficient, modern, and sustainable alternatives. Few researches were carried out evaluating the inclusion of sweet potato flour as an energy source in substitution of maize for ruminants. The aim of this study was to evaluate the *in vitro* gas production of ground corn replacement by sweet potato flour at different levels. For *in vitro* gas production, four treatments were performed, consisting of corn replacement by sweet potato flour at the levels of 0, 33, 66, and 100%, in a diet consisting of corn silage, soybean meal, and ground corn. *In vitro* incubations were conducted in sealed bottles containing 50 ml of the inoculum prepared using ruminal fluid and 0.5 g of each treatment. Gas production was determined in 96 consecutive hours. The cumulative gas production was greater when the corn was replaced 100% by SPF (224 ± 7.5 and 231.9 ± 7.5 ml/g DMi for 0 and 100% of replacement, P = 0.001). Degradation rates were 7.10, 7.59, 8.08, and 8.59 ± 0.06% per hour for the 0, 33, 66, and 100% replacement rates respectively (P < 0.0001). There was also a difference (P = 0.013) in the lag time, in which the diets with the

highest SPF inclusion had a lower colonization time. In conclusion, sweet potato flour produced more gas and is more rapidly degraded than corn.

Key words: Fermentation, starch, ruminant nutrition, tubers.

In high-producing ruminants, meeting the energy requirements is important in order to maintain the health status of the animal and to support high milk yields and rapid weight gains. Cereals represent the primary source of energy in ruminant diets (GOZHO & MUTSVANGWA, 2008). Starch is a major energy source for both ruminant animals and ruminal microorganisms (MOHARRERY et al., 2014), and cereal grains contain high concentrations of this component. Among the cereals used are corn, sorghum, barley, wheat, and oats and differences exist for ruminal starch degradability among these grains.

In addition to these differences in degradability that will result in different ruminant performance, other factors such as availability and price determine which cereal to use. The high cost of some feeds encourages the use of alternative local sources of energetic feed, notably the starchy tubers in temperate and tropical countries (WHEATLEY et al., 1995). Among the starch-rich tuber feeds studied in substitution of cereals for ruminants are cassava (*Manihot esculenta Crantz*) (WANAPAT & KANG, 2015), beet and by-products (EVANS & MESSERSCHMIDT, 2017), potato (*Solanum Tuberosum*) (BABAEINASAB et al., 2015) and sweet potato (*Ipomoea batatas)* (MATHER et al., 1948).

Sweet potato is an annual crop grown widely in the tropical and subtropical countries. Sweet potato roots have high levels of energy (85% of soluble carbohydrate) and low levels of crude protein (3.87%) (ROSTAGNO, 2005). Using sweet potato flour as animal feed to supply energy is not a new concept. MATHER et al. (1948) tested dehydrated sweet potatoes in comparison to corn and did not find an impact on milk production, but an increase in vitamin A.

Bromatological similarities between the two carbohydrate rich substrates, corn and sweet potato, is not sufficient to consider the sweet potato eligible for replacing corn in ruminant diets. Differences in the ruminal starch disappearance rates among cereal grains and tubers makes the results of previous studies inconsistent. For instance, starch degradability in the rumen is greater for potato and maize than for barley and pea (CHAI et al., 2004). Techniques that characterize the ruminal metabolism and degradability of these ingredients, such as technical *in vitro* gas production, are indispensable for describing the kinetics of the activity of microorganisms in response to a potential new substrate (SILVA et al., 2015). Thus, the aim of this study was to evaluate the *in vitro* gas fermentation parameters of sweet potato flour at different levels of substitution for ground corn. The hypothesis of this study is that the substitution of corn by sweet potato alters the *in vitro* fermentation parameters.

The *in vitro* gas production assays and laboratory analyzes were carried out in the facilities of the Laboratory of Bromatology and Nutrition of Ruminants of the Department of Animal Science, Federal University of Santa Maria, from March to July of 2017. Sweet potato roots were obtained from family farms of Mariana Pimentel, geographic location 30 ° 21 '10 "S, 51 ° 34' 58" W, in the South-Central region of the State of Rio Grande do Sul, Brazil.

The samples of sweet potato flour (SPF) were from four varieties: Beauregard, Cabeluda, Catarina and Rubisol. The SPF was obtained from the artisanal processing of the root. After harvesting, the tubers were washed and crushed in a knife grinder, resulting in pieces of 2 to 3 cm, which were then dried in a static grain dryer. Forced hot air was used, not exceeding the temperature of 40ºC, avoiding loss of nutrients and altering the chemical composition of sweet potato (ARAÚJO et al., 2015). After 6 hours, the dried sweet potato passed through a hammer crusher with medium sieve and was stored hermetically. After this process, the SPF samples were dried in an oven at 55ºC, ground to 1 mm and stored for later bromatological analysis and *in vitro* gas incubation.

A preliminary *in vitro* gas production test with one run was performed to describe the *in vitro* gas parameters of SPF varieties (Beauregard, Cabeluda, Catarina, and Rubisol) and corn grain. A second *in vitro* gas production test with three runs was conducted to evaluate the effects of the substitution of ground corn by SPF at levels of 0, 33, 66, and 100% in a diet. The diet (Table 1) was formulated to meet the requirements of a dairy cow (650 kg of body weight (BW), 75 days in milk) producing 24 kg/d of milk composed of 3.4% fat and 3.2% protein (NRC, 2001).

[Table 1 here]

Samples were weighed (0.5g) into 125 ml glass bottles. Subsequently, 40 mL of buffer solution (MOULD et al., 2005) was added and then kept refrigerated at 4°C for 12 hours to allow hydration of the substrate. After that, the bottles were put in a water bath with agitation at 39ºC and 10 mL of ruminal inoculum was added. The inoculum was collected from the rumen of a fistulated bovine kept on pasture and supplemented with 2 kg/day of a concentrate with 18% of CP, composed of 75% of ground corn and 25% of soybean meal. All procedures were performed under continuous CO_2 injection. Bottles without substrate were included as blanks. In each run, the samples were weighed in triplicates.

Gas production was manually recorded after 3, 6, 9, 12, 18, 24, 36, 48, 72, and 96 hours of incubation using a three-outlet valve. The first outlet was connected to a needle (0.6 mm), which was inserted in the rubber cap. The second outlet was connected to the pressure gauge, which has a graduate column filled with distilled water and the third remained free being used to remove gases from inside the bottles at each reading, down to zero pressure. The volume of gas generated by each bottle at each measurement was recorded and the volume of gas produced by blanks was subtracted in order to estimate the evolution of the fermentation. The volume of produced gas was expressed in ml of gas produced per gram of incubated dry matter (DMi).

The unicompartmental model proposed by SCHOFIELD et al. (1994) was used to describe the kinetics of the fermentation process through the cumulative production of gases as follows:

$$V = Vf * (1 + \exp(2 - 4 * S * (t - L)))^{-1},$$

where: Vf = final volume of gas (ml) at time t; S = rate of degradation (/ h); L = colonization time of the bacteria on the substrate (in hours).

Total DM content was determined by drying at 105°C until a constant weight was reached. Ash was determined by combustion at 600°C for 3 h and OM by mass difference. Total N was determined by the Kjeldahl method (Method 984.13; AOAC, 1997). The neutral (NDF) and acid (ADF) detergent fiber analyses included ash and were based on the procedures described by MERTENS (2002) and AOAC (1997), respectively, except that samples were weighed in polyester filter bags (porosity of 16 μm) and treated with neutral or acid detergent in an autoclave at 110°C for 40 min. For the NDF analysis also was added α-amylase (SENGER et al., 2008). Ether extract (EE) was determined using a fat extractor (Ankom XT15; Ankom Technology, Macedon, NY) and petroleum ether as solvent. The total digestible nutrients (TDN) was calculated according NRC (2001) and starch was analyzed using acid hydrolysis followed by glucose determination using the spectrophotometric method of Glucose-Oxidase (TRINDER, 1969), with changes in the hydrolysis time and the temperature of the digestion based on the study of KOZLOSKI et al. (1999). Amylose was analyzed according to MCGRANCE et al. (1998). The values of the bromatological analysis of the diet and sweet potato varieties are presented in Table 2.

[Table 2 here]

In vitro gas parameters of SPF and ground corn of the preliminary test were analyzed through descriptive statistics. Fermentation parameters of diets on the second *in vitro* gas production test were analyzed with NCSS 7.0 software (Statistical System, Utah, USA, 2005)

after verifying normality of residuals and homogeneity of variance. With normally distributed values a One-Way ANOVA was executed. Data was analyzed using GLM procedure, at a 0.05 significance level, according to the following model:

$$Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij},$$

where: y is the value observed in the plot treatment; μ: overall mean; α_i: effect of level of substitution; β_j: effect of the run, and e_{ij}: experimental error. The calculation was done on the supposition that the terms μ, α_i, and β_j are fixed effects, and e_{ij} uncorrelated random effects.

Tukey Kramer multiple range test was used to compare averages. Orthogonal polynomial contrasts were used to test statistical significance of the linear, quadratic, or cubic components of treatments.

The results from the preliminary *in vitro* gas production test are demonstrated in Table 3 and Figure 1. The fermentation parameters obtained for the four varieties of sweet potato and ground corn are presented in the table below (Table 3). Although there is no statistical analysis, it is observed that sweet potatoes ferment faster and produce more gas than corn. Furthermore, bacterial colonization of sweet potato varieties begins earlier than corn.

These results can be verified by the gas production curve during the incubation period (Figure 1). It is noticeable that the maize degradation curve separates from the set of SPF and SPF varieties show higher gas production in the first hours of incubation.

[Table 3 here]

[Figure 1 here]

The fermentation parameters obtained for the four levels of substitution on the second *in vitro gas* production test are presented in the table below (Table 4). There was a significant difference between substitutions 0 and 100% for the PG ($P = 0.049$), Kd ($P < 0.0001$) and lag time ($P = 0.013$) parameters. Including SPF in the mixtures lead to an increase in the volume

of gas produced in the flasks and therefore during the fermentation, the production of gas was linearly higher as the level of substitution increased (P = 0.005). In addition, the inclusion of SPF at higher levels caused a linear increase in the fermentation rate (P < 0.001) and the fermentation began earlier (P = 0.001). The greater the level of replacement of ground corn by SPF, the faster the substrate was degraded with larger gas production.

[Table 4 here]

In vitro gas production has been developed as a predictive tool of nutrient content (BLÜMMEL & BECKER, 1997). One of the advantages of the gas production technique makes it possible to conduct frequent simultaneous measurements on a large number of samples of small size. It has been widely used (CHAI et al., 2004; HATEW et al., 2015; LUTAKOME et al., 2017) to assess the nutritional quality of feeds due to its high correlation with *in vivo* digestibility, which results from its ability to simulate the process of digestion in ruminant animals (HATEW et al., 2015).

The increased in total gas production (mL/g DMi) may be related to the level and source of starch in each diet. This linear increase of the gas production observed with the increase of sweet potato inclusion probably occurs due to the increase in ruminal fermentation as shown in Table 5. In this study, the value of starch was found to be 75.7% for sweet potato, while ROSTAGNO (2005) found 62.9%. However, these values are higher than the levels found by Brazilian researchers, who determined the starch values of sweet potato to range from 13.4% to 29.2% (OLIVEIRA et al., 2005). The wide range of sweet potatoes produced in Brazil could explain this difference. In addition, phosphorus present in the soil may influence the accumulation of starch in sweet potatoes. Another influential factor is the source of organic fertilization (OLIVEIRA et al., 2013).

The higher and more rapid gas production explained by the content of starch found in sweet potato as well as others tubers like cassava (LUNSIN et al., 2010) is due to the readily

available non-fiber carbohydrates (NFC). These provide energy for microbial growth and for the host (STEVNEBØ et al., 2009) through the production of organic acids, CH_4 and CO_2.

The extent of starch degradation is dependent on its nature and structure. These include the chemical composition of the feed, starch granule size and shape, amylose and amylopectin ratio, presence of a protein matrix, and adaptation of rumen bacteria to different starch sources (GIUBERTI et al., 2014). These factors should be considered as sources of variation for fermentable parameters. In agreement, MCALLISTER et al. (1993) suggested that differences in ruminal starch digestibility between cereals are related to the structural components within the endosperm rather than structural components within the starch granules. As there have been few *in vitro* studies evaluating tubers, we will discuss both the components within the starch granules and the structural components.

Understanding of the relationships between amylose and amylopectin ratio and starch digestion in the rumen is still limited and inconsistent (STEVNEBØ et al., 2009). *In vitro* studies revealed a negative relationship between amylose content and starch digestion rate in cereals (LI et al., 2001). The decreased starch digestion potential of high amylose starch structures is hypothesized to occur because hydrogen bonding in the glucose chains of amylose is more extensive and therefore making high amylose starch less accessible for enzymatic hydrolysis as compared to amylopectin, which has many branched chains of glucose and a larger surface area per molecule (BREWER et al., 2012).

Data from literature shows amylose contents varying between 19.1 to 28% for sweet potatoes (HOOVER, 2001); in this study, the value was 21.06%, whereas for ground corn these values have been found to be quite varied (2.7 to 70%), depending on the botanical variety and differences in the geographical origin (ALCÁZAR-ALAY & MEIRELES, 2015). CONE & WOLTERS (1990) point out that the rapid ruminal *in vitro* digestion obtained with cassava and rice starch was due to the lower amylose content in this starch sources. Contrastingly, in others

starch rich cereals with cultivars of varying amylose content (e.g. barley) it was observed that the starch amylose proportion and granule particle size had only a minor influence on the *in vitro* ruminal rate of starch digestion (STEVNEBØ et al., 2009).

According to CALDAS NETO et al. (2000), cassava starch has a higher concentration of amylopectin than corn (83.0 and 76.0%, respectively). These values of amylopectin in cassava and the non-association of starch grains with the protein matrix that surrounds these granules interfere with the grains digestibility, favoring greater use by the ruminal microorganisms, decreasing the lag time. Replacing corn for sweet potato, the time of bacterial colonization decreases from 2.56h on 0% to 2.20h on 100% of sweet potato flour replacement ($P = 0.013$). Under these conditions, the starch found in energy sources other than cereals, such as cassava and sweet potato, do not present a protein matrix and this may explain the shorter colonization time (RICACHESKI et al., 2017).

Degradation rate ranged from 11.57 to 13.30% per hour among sweet potato varieties and was 8.34% per hour for corn. The corn degradation rate found here was not similar to the values reported by PATTON et al. (2012), who estimated the *in vitro* kd of various ruminant feeds and others starch rich sources such as corn co-products (kd = 7.0%/h) and wheat germ meal (kd = 6.8%/h). This difference in the rate of corn degradation reported by several studies can be explained by the corn hybrid used and the maturity of the plant, as the degradability of corn starch is strongly influenced by these factors (PEREIRA et al., 2004). Tubers such as cassava and sweet potato have a higher degradability than cereals due to their lack of pericarp, protein matrix and, peripheral endosperm (GOMÉZ et al., 2016).

The adaptation of the rumen inoculum to different sources and amounts of starch can affect the *in vitro* gas parameters and was discussed by HATEW et al. (2015). In these studies, when comparing *in vitro* and *in vivo* starch degradation from different sources, a discrepancy was found between the *in vivo* starch degradation and the degradation rate estimated based on

an *in vitro* gas production experiment, in which the donor animals were not adapted to the diets containing the used starch source. Taking this into account, it can be considered a weakness of this study that the rumen inoculum was not adapted to the different starch sources.

It is important to understand the structural characteristics of starch, its ruminal and post-ruminal digestion and the factors affecting its digestibility, in order to improve the performance and profit of livestock systems. The use of sweet potato as a source of starch provides faster fermentation of the starch when compared to corn, allowing better synchronization with rapidly degraded nitrogen sources, such as urea.

The replacement of ground corn with sweet potato flour resulted in a difference between the fermentation parameters of diets with 0 and 100% sweet potato flour content, with an increasing linear response to the substitution level of sweet potato flour. The sweet potato may be a viable source of starch in diets for ruminants. Nevertheless, a larger scale study would be required to clarify the effects of sweet potato on ruminant performance and metabolism.

DECLARATION OF CONFLICTING INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript and in the decision to publish the results.

SOURCES OF ACQUISITION

This study was funded in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001 and Cooperativa Sicredi.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the design and writing of the manuscript. All authors critically reviewed the manuscript and approved the final version.

REFERENCES

ALCÁZAR-ALAY, S.C.; MEIRELES, M.A.A. Physicochemical properties, modifications and applications of starches from different botanical sources. **Food Science and Technology,** v.35, n.2, p.215-236, 2015. Available from: <http://dx.doi.org/10.1590/1678-457X.6749>. Accessed: Dec, 12, 2018. DOI: 10.1590/1678-457X.6749.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. **Official Methods of Analysis**. 16. ed. Washington: AOAC, 1997. p.1141.

ARAÚJO, C.S.P. et al. Desidratação de batata-doce para fabricação de farinha. **Agropecuária Científica no Semiárido,** v.11, n.4, p.33-41. 2015. Available from: <http://revistas.ufcg.edu.br/acsa/index.php/ACSA/article/view/687>. DOI: 10.30969/acsa.v11i4.687. Accessed: Dec, 12, 2018.

BABAEINASAB, Y. et al. Chemical composition, silage fermentation characteristics, and *in vitro* ruminal fermentation parameters of potato-wheat straw silage treated with molasses and lactic acid bacteria and corn silage. ***Journal of Animal Science***, v.93, n.9, p.4377–4386, 2015. Available from:<https://academic.oup.com/jas/article-abstract/93/9/4377/4700245?redirectedFrom=fulltext>. Accessed: Mar, 27, 2019. DOI: 10.2527/jas.2015-9082.

BLÜMMEL, M.; BECKER, K. The degradability characteristics of fifty-four roughages and roughage neutral detergent fibers as described by *in vitro* gas production and the relationship to voluntary feed intake. **British Journal of Nutrition**, v.77, p.757–768, 1997. Available

from: <https://www.ncbi.nlm.nih.gov/pubmed/9175995>. Accessed: Mar, 26, 2019. DOI: 10.1079/BJN19970073.

BREWER, L.R. et al. Mechanism and enzymatic contribution to *in vitro* test method of digestion for maize starches differing in amylose content. **Journal of Agricultural Food and Chemical**, v.60, p.4379–4387. 2012. Available from: <https://pubs.acs.org/doi/pdf/10.1021/jf300393m>. Accessed: Apr, 11, 2019. DOI: 10.1021/jf300393m.

CALDAS NETO, S.F. et al. Mandioca e resíduos das farinheiras na alimentação de ruminantes: digestibilidade total e parcial. **Revista Brasileira de Zootecnia**, v.29, n.6, p.2099-2108, 2000. Available from: < http://www.sbz.org.br/revista/artigos/2873.pdf >. Accessed: Apr, 09, 2019.

CHAI, W.Z. et al. Relationship between gas production and starch degradation in feed samples, **Animal Feed Science and Technology**, v.114, p.195-204, 2004. Available from: < https://www.sciencedirect.com/science/article/pii/S0377840104000306>. Accessed: Apr, 09, 2019. DOI: j.anifeedsci.2003.11.014.

CONE, J.W.; WOLTERS, M.G.E. Some properties and degradability of isolated starch granules. **Starch**, v.42, p.298–301. 1990. Available from: < https://onlinelibrary.wiley.com/doi/abs/10.1002/star.19900420804 >. Accessed: Apr, 14, 2019. DOI: 10.1002/star.19900420804.

EVANS, E.; MESSERSCHMIDT, U. Review: Sugar beets as a substitute for grain for lactating dairy cattle, **Journal of Animal Science and Biotechnology**, v.8, n.25, 2017. Available from: < https://jasbsci.biomedcentral.com/articles/10.1186/s40104-017-0154-8> Accessed: Apr, 02, 2019. DOI: 10.1186/s40104-017-0154-8.

GIUBERTI, G. et al. Factors affecting starch utilization in large animal food production system: A review. **Starch - Stärke,** v.66, n.1-2, p.72-90, 2014. Available from: <https://onlinelibrary.wiley.com/doi/abs/10.1002/star.201300177>. Accessed: Dec, 13, 2018. DOI: 10.1002/star.201300177.

GÓMEZ, L.M. et al. Starch in ruminant diets: a review. **Revista Colombiana de Ciencias Pecuarias**, v.29, p.77-90, 2016. Available from: < http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0120-06902016000200077>. Accessed: Apr, 11, 2019. DOI: 10.17533/udea.rccp.v29n2a01.

GOZHO, G.N.; MUTSVANGWA, T. Influence of carbohydrate source on ruminal fermentation characteristics, performance, and microbial protein synthesis in dairy cows. **Journal of Dairy Science,** v.91, n.7, p.2726-35, 2008. Available from: < https://www.journalofdairyscience.org/article/S0022-0302(08)71147-0/fulltext>. Accessed: Nov, 23, 2018. DOI: 10.3168/jds.2007-0809.

HATEW, B. et al. Effects of dietary starch content and rate of fermentation on methane production in lactating dairy cows. **Journal of Dairy Science**, v.98, n.1, p.486-499, 2015. Available from: < https://www.journalofdairyscience.org/article/S0022-0302(14)00743-7/fulltext >. Accessed: Nov, 23, 2018. Epub 2014 Nov 7. DOI: 10.3168/jds.2014-8427.

HOOVER, R. Composition, molecular structure, and physicochemical properties of tuber and root starches: a review, **Carbohydrate Polymers**, v.45, n.3, p.253-267, 2001. Available from: < https://www.sciencedirect.com/science/article/pii/S0144861700002605 >. Accessed: Apr, 12, 2019. DOI: 10.1016/S0144-8617(00)00260-5.

KOZLOSKI, G.V. et al. Comparison of acid and amyloglucosidase hydrolysis for estimation of non-structural polysaccharides in feed samples. **Journal of the Science of Food and Agriculture,** v.79, n.8, p.1112-1116, 1999. Available from:

<https://onlinelibrary.wiley.com/doi/abs/10.1002/%28SICI%291097-0010%28199906%2979%3A8%3C1112%3A%3AAID-JSFA318%3E3.0.CO%3B2-D>. Accessed: Nov, 17, 2018. DOI: 10.1002/(SICI)1097-0010(199906)79:8<1112::AID-JSFA318>3.0.CO;2-D.

LI, J.H. et al. Starch from hul-less barley. II. Thermal, rheological and acid hydrolysis characteristics. **Food Chemistry**, v.74, n.4, p.407–415. 2001. Available from: < https://www.infona.pl/resource/bwmeta1.element.elsevier-3e73ca41-3988-3e6d-a14b-78bd979fbdd9>. Accessed: Apr, 13, 2019. DOI: 10.1016/S0308-8146(01)00247-3.

LUNSIN, R. et al. Effects of pelleted cassava chip and raw banana (Cass-Bann) on rumen fermentation and utilization in lactating dairy cows. **Journal of Animal and Veterinary Advances**, v.9, n.17, p.2239-45, 2010. Available from: < https://www.researchgate.net/publication/287315006_Effects_of_Pelleted_Cassava_Chip_and_Raw_Banana_Cass-Bann_on_Rumen_Fermentation_and_Utilization_in_Lactating_Dairy_Cows>. Accessed: Apr, 03, 2019. DOI: 10.3923/javaa.2010.2239.2245.

LUTAKOME, P. et al. Rumen liquor from slaughtered cattle as inoculum for feed evaluation. **Animal Nutrition**, v.3, n.3, p.300-308, 2017. Available from: < https://www.sciencedirect.com/science/article/pii/S2405654517300732>. Accessed: Apr, 10, 2019. DOI: 10.1016/j.aninu.2017.06.010.

MATHER, R.E. et al. Dehydrated Sweet Potatoes as a Concentrate Feed for Dairy Cattle. **Journal of Dairy Science,** v.31, n.7, p.569-576, 1948. Available from: < https://www.journalofdairyscience.org/article/S0022-0302(48)92244-9/pdf >. Accessed: Nov, 02, 2018. DOI: 10.3168/jds.S0022-0302(48)92244-9.

MCALLISTER, T.A. et al. Effect of the protein matrix on the digestion of cereal grains by ruminal microorganisms. **Journal of Animal Science**. v.71, p.205–212, 1993. Available from: <https://academic.oup.com/jas/article-abstract/71/1/205/4632093?redirectedFrom=PDF>. Accessed: Apr, 02, 2019. DOI: 10.2527/1993.711205x.

MCGRANCE, S.J. et al. A Simple and Rapid Colorimetric Method for the Determination of Amylose in Starch Products. **Starch - Stärke**, v.50, n.4, p.158-163, 1998. Available from: < https://onlinelibrary.wiley.com/doi/abs/10.1002/%28SICI%291521-379X%28199804%2950%3A4%3C158%3A%3AAID-STAR158%3E3.0.CO%3B2-7>. Accessed: Nov, 11, 2018. DOI: 10.1002/(SICI)1521-379X(199804)50:4<158::AID-STAR158>3.0.CO;2-7.

MERTENS, D. R. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing beakers or crucibles: a collaborative study. **Journal of AOAC International**, v.85, n.6, p.1217–1240. 2002. Available from: < https://www.ncbi.nlm.nih.gov/pubmed/12477183>. Accessed: Dec, 10, 2018.

MOHARRERY, A. et al. Starch digestion in the rumen, small intestine, and hind gut of dairy cows - A meta-analysis. **Animal Feed Science and Technology**, v.192, p.1–14, 2014. Available from: <https://www.sciencedirect.com/science/article/pii/S0377840114000893?via%3Dihub>. Accessed: Dec, 10, 2018. DOI: 10.1016/j.anifeedsci.2014.03.001

MOULD, F.L. et al. A review and simplification of the *in vitro* incubation medium. **Animal Feed Science and Technology**, v.123–124, p.155-172, 2005. Available from: <http://centaur.reading.ac.uk/8950/>. Accessed: Dec, 10, 2018. DOI: 10.1016/j.anifeedsci.2005.05.002

NRC. **Nutrient requeriments of dairy cattle**. 7ª ed. Washinton: DC. National Academy of Sciences, 2001. 381p.

OLIVEIRA, A.P. et al. Produção de batata-doce e teor de amido nas raízes em função de doses de P_2O_5. **Acta Scientiarum Agronomy**, v.27, p.747-745, 2005. Available from: < https://www.researchgate.net/publication/237027589_Producao_de_batata-doce_e_teor_de_amido_nas_raizes_em_funcao_de_doses_de_P2O5>. Accessed: Apr, 13, 2019.

OLIVEIRA, A.P. et al. Produção e teor de amido da batata-doce em cultivo sob adubação com matéria orgânica. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.17, n.8, p.830-834, 2013. Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-43662013000800005&lng=pt&nrm=iso>. Accessed: Apr, 13, 2019. DOI: 10.1590/S1415-43662013000800005.

PATTON, R.A. et al. Defining ruminal and total-tract starch degradation for adult dairy cattle using in vivo data. **Journal of Dairy Science,** v.95, n.2, p.765-82, 2012. Available from: <https://www.ncbi.nlm.nih.gov/pubmed/22281342>. Accessed: Dec, 19, 2018. DOI: 10.3168/jds.2011-4183.

PEREIRA, M.N. et al. Ruminal degradability of hard or soft texture corn grain at three maturity stages. **Scientia Agricola**, v.61, n.4, p.358-363, 2004. Available from: < http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-90162004000400002>. Accessed: Dec, 19, 2018. DOI: 10.1590/S0103-90162004000400002.

RICACHESKI, S.T. et al. Chemical composition and ruminal degradation kinetics of white oat (Avena sativa L.) IPR 126. **Revista Brasileira de Saúde e Produção Animal,** v.18, p.50-

61, 2017. Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1519-99402017000100050&nrm=iso>. Accessed: Nov, 23, 2018. DOI: 10.1590/s1519-99402017000100006.

ROSTAGNO, H.S. **Tabelas Brasileiras para Aves e Suínos – Composição de Alimentos e Exigências Nutricionais.** 3ª ed. Viçosa: UFV, Departamento de Zootecnia, 2005.

SCHOFIELD, P. et al. Kinetics of fiber digestion from *in vitro* gas production. **Journal of Dairy Science**, v.72, n.11, p.2980-299, 1994. Available from: < https://academic.oup.com/jas/article-abstract/72/11/2980/4632581?redirectedFrom=fulltext >. Accessed: March, 28, 2019. DOI: 10.2527/1994.72112980x.

SENGER, C.C.D. et al. Evaluation of autoclave procedures for fiber analysis in forage and concentrate feedstuffs. **Animal Feed Science and Technology**, v.146, p.169-174, 2008. Available from: <https://www.researchgate.net/publication/248333292_Evaluation_of_autoclave_procedures_for_fibre_analysis_in_forage_and_concentrate_feedstuffs >. Accessed: Dec, 04, 2018. DOI: 10.1016/j.anifeedsci.2007.12.008.

SILVA, A.M.A. et al. Potential *in vitro* degradability and gas production of the byproducts of the biodiesel chain. **Ciencia e Investigación Agraria**, v.42, n.2, p.285-293, 2015. Available from: <https://scielo.conicyt.cl/scielo.php?script=sci_arttext&pid=S0718-16202015000200014&lng=pt&nrm=iso>. Accessed: Apr, 12, 2019. DOI: 10.4067/S0718-16202015000200014.

STEVNEBØ, A. et al. Ruminal starch digestion characteristics *in vitro* of barley cultivars with varying amylose content. **Animal Feed Science and Technology,** v.148, n.2, p.167-182, 2009. Available from:<

http://www.sciencedirect.com/science/article/pii/S0377840108000898 >. Accessed: Nov, 29, 2018. DOI: 10.1016/j.anifeedsci.2008.03.011.

TRINDER, P. Determination of Glucose in Blood Using Glucose Oxidase with an Alternative Oxygen Acceptor. **Annals of Clinical Biochemistry,** v.6, n.1, p.24-27, 1969. Available from: < http://journals.sagepub.com/doi/abs/10.1177/000456326900600108 >. Accessed: Dec, 18, 2018. DOI: 10.1177/000456326900600108.

WANAPAT, M.; KANG, S. Cassava chip (Manihot esculenta Crantz) as an energy source for ruminant feeding, **Animal Nutrition**, v.1, n.4, p.266-270, 2015. Available from: < https://www.sciencedirect.com/science/article/pii/S2405654515300615 >. Accessed: Dec, 18, 2018. DOI: 10.1016/j.aninu.2015.12.001.

WHEATLEY, C.C. et al. **Adding value to root and tuber crops: a manual on product development.** International center for tropical agriculture, v.247, 264 p, 1995, ISBN: 958-9439-14-4.

Tables and Figure

Table 1. Ingredients (mg/500mg of DMi) for each of the treatment diets replacing ground corn by SPF in 0, 33, 66, and 100%

	Replacement of ground corn by SPF (%)			
Item, mg/500mg of DMi[1]	0	33	66	100
Corn Silage	208	208	208	208
Soybean Meal	92	92	92	92
Ground Corn	200	134	66	0
Sweet Potato	0	66	134	200

[1]: Dry Matter incubated;

Table 2. Chemical Composition of ingredients including 4 varieties of SPF and diet replacing ground corn by SPF in 0, 33, 66, and 100%.

	as % of DM									
Item	DM[1]	Ash	OM[2]	CP[3]	NDF[4]	ADF[5]	EE[6]	TDN[7]	Amylose	Starch
Corn Silage	25.56	5.61	94.39	8.75	46.47	-	-	-	-	-
Soybean Meal	88.45	7.54	92.46	47.05	20.23	11.11	3.87	-	-	-
Ground Corn	85.69	1.75	98.25	8.51	11.12	4.33	3.83	-	-	-
Sweet Potato										
Beauregard	90.57	2.73	97.27	5.89	6.83	1.61	2.2	96.19	-	-
Catarina	88.43	2.2	97.80	3.64	5.49	1.39	2.19	95.76	-	-
Rubisol	86.79	2.39	97.61	5.65	4.54	2.53	1.74	95.72	-	-
Cabeluda	85.01	2.93	97.07	3.26	13.41	5.92	2.11	93.77	21.06	75.7
Total mixed diet										
0	61.18	4.42	95.58	15.70	27.50	3.78	2.24	-	-	-
33	61.45	4.53	95.47	15.19	27.03	3.58	2.01	-	-	-
66	61.72	4.64	95.36	14.66	26.55	3.38	1.77	-	-	-
100	61.99	4.75	95.25	14.14	26.08	3.19	1.54	-	-	-

1: Dry Matter; 2: Organic Matter; 3: Crude Protein; 4: Neutral Detergent Fiber; 5: Acid Detergent Fiber; 6: Ethereal Extract; 7: Total Digestible Nutrients

Table 3. Means of gas production parameters estimates during the preliminary *in vitro* incubation test, total gas production (total GP), Kd (degradation rate) and lag time of the 4 varieties of sweet potato flour and ground corn (n = 3 flasks per substrate).

Parameters	Corn	Beauregard	Catarina	Rubisol	Cabeluda
Total GP (mL/g de DMi)	257.1	271.7	277.5	286.0	286.5
Kd (%/h)	8.34	13.30	11.66	11.57	11.62
Lag time (h)	3.22	2.75	3.00	2.90	3.09

Table 4. Means ± standard error of means (S.E.M) of fermentation parameters, total gas production (Total GP, mL/g of DMi), degradation rate (Kd, %/h), and lag time (lag, hours) obtained for the four levels of substitution of ground corn by SPF (n = 36 flasks per treatment) on the second *in vitro* gas production test.

	0%	33%	66%	100%	S.E.M	P – Value			
						Treatment	L^1	Q^2	C^3
Total GP	224 ^{B}	226.64 ^{AB}	230.5 ^{A}	231.9 ^{A}	7.51	0.049	0.005	0.70	0.75
Kd	7.10 ^{A}	7.59 ^{B}	8.08 ^{C}	8.59 ^{D}	0.06	<0.0001	<0.001	0.98	0.96
Lag time	2.56 ^{B}	2.37 ^{AB}	2.27 ^{A}	2.20 ^{A}	0.04	0.013	0.001	0.88	0.43

$^{A.B}$ Values followed by the same capital letter on the same line do not differ significantly.
$^{1.2.3}$ Linear, quadratic and cubic effects, respectively.

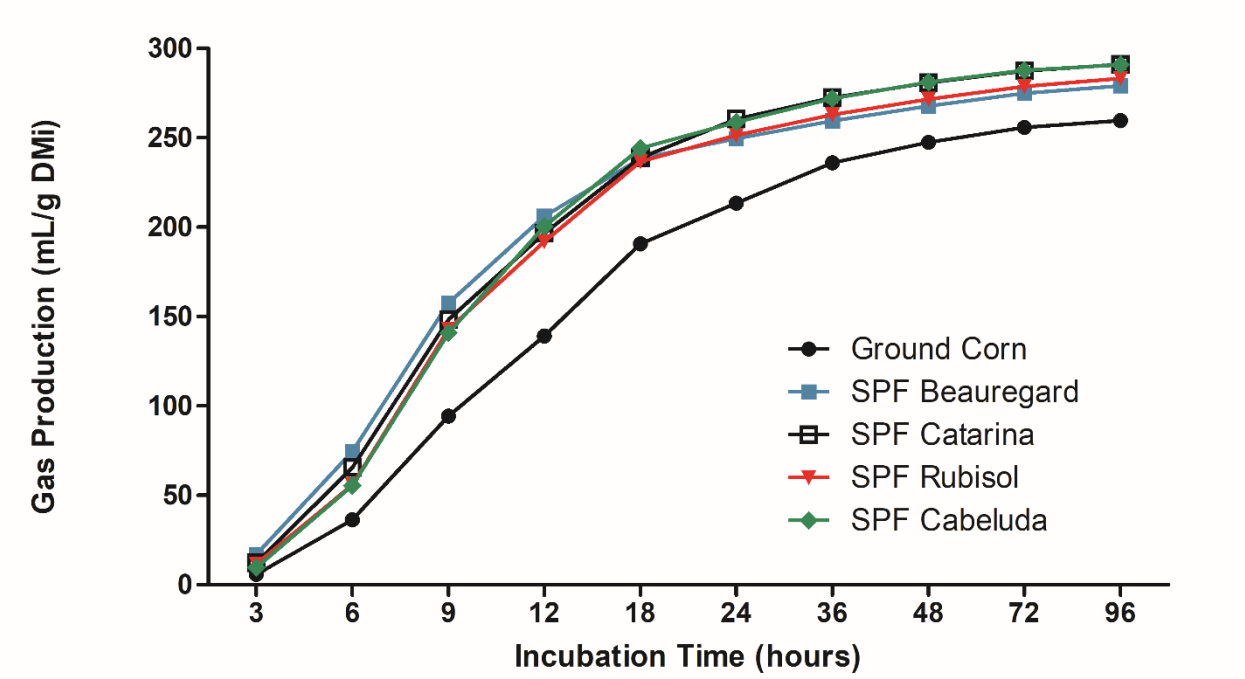

Figure 1. Gas production (mL/g DMi) for the 4 varieties sweet potato flour (SPF) and ground corn (n = 3 flasks per substrate) during the preliminary *in vitro* gas production test.

7 Considerações Finais

De uma forma geral, tanto a utilização de aditivos alimentares e novos alimentos, como também estratégias nutricionais em fases metabolicamente críticas para a produção de bovinos podem atender de forma eficaz as necessidades das diferentes categorias desse sistema.

Vacas com menor produção de leite que mantêm ou melhoram no pós-parto o peso corporal são capazes de desmamar um bezerro de peso semelhante ao das vacas que produzem mais leite e perdem condição corporal. Além disso, as vacas que estão mantendo ou ganhando peso também têm melhor desempenho reprodutivo. Assim, considerando as condições corporais da vaca e o desempenho reprodutivo, bem como o desempenho dos bezerros, os produtores devem selecionar animais que se encaixem em seu ambiente para garantir que seus requisitos nutricionais sejam atendidos, o que pode contribuir para um aumento nas taxas de concepção durante a estação reprodutiva seguinte.

Impactos benéficos do DFM bacteriano e do tanino foram observados no desempenho e na imunidade de bezerros desmamados, indicando que suplementação com os mesmos podem desempenhar um papel na redução dos efeitos causados pelo estresse nesses animais. A melhoria na conversão alimentar juntamente com o melhor desempenho pode resultar em bezerros mais pesados à venda e mais saudáveis para a fase de recria.

É importante entender as características estruturais do amido, sua digestão ruminal e pós ruminal e os fatores que afetam sua digestibilidade, a fim de melhorar o desempenho e o lucro dos sistemas pecuários. O uso da batata-doce como fonte de amido proporciona uma fermentação mais rápida do amido quando comparado ao milho, permitindo uma melhor sincronização com fontes de nitrogênio rapidamente

degradáveis, como a ureia. A batata-doce pode ser uma fonte viável de amido nas dietas para ruminantes.

Assim sendo, a nutrição dentro de um sistema produtivo pode ser empregada como uma ferramenta eficaz e a pesquisa de novos aditivos alimentares e alimentos economicamente viáveis e sustentáveis assumem importância fundamental na busca de alternativas nutricionais para a bovinocultura.

Referências

ABOAGYE, I. A.; OBA, M.; CASTILLO, A. R.; KOENIG, K. M.; IWAASA, A. D.; BEAUCHEMIN, K. A. Effects of hydrolyzable tannin with or without condensed tannin on methane emissions, nitrogen use, and performance of beef cattle fed a high-forage diet. **Journal of Animal Science**, v.96, n.12, p.5276-5286, 2018.

ABRAFRIGO. Exportação de Carnes Bovina e Derivados, janeiro a dezembro de 2019. Disponível em: <http://abrafrigo.com.br/wp-content/uploads/2019/11/ABRAFRIGO-Exportação-Carne-Bovina-Jan_2018-a-Nov_2019.pdf> Acesso em: 05 janeiro de 2020.

AGUERRE, M. J.; CAPOZZOLO, M. C.; LENCIONI, P.; CABRAL, C.; WATTIAUX, M. A. Effect of quebracho-chestnut tannin extracts at 2 dietary crude protein levels on performance, rumen fermentation, and nitrogen partitioning in dairy cows. **Journal of Dairy Science**, v.99, n.6, p.4476-4486, 2016.

AICH, P.; JALAL, S.; CZUBA, C.; SCHATTE, G.; HERZOG, K.; OLSON, D.J.; ROSS, A.R.; POTTER, A.A.; BABIUK, L.A.; GRIEBEL, P. Comparative approaches to the investigation of responses to stress and viral infection in cattle. **OMICS**, v.11, p.413–434, 2007.

ALCÁZAR-ALAY, S.C.; MEIRELES, M.A.A. Physicochemical properties, modifications and applications of starches from different botanical sources. **Food Science and Technology**, v.35, n.2, p.215-236, 2015.

AL-DOBAIB, S.N. Effect of different levels of Quebracho tannin on nitrogen utilization and growth performance of Najdi sheep fed alfalfa (*Medicago sativa*) hay as a sole diet. **Animal Science Journal**, v.80, p.532–541, 2009.

AMETAJ, B.N.; KOENIG, K.M.; DUNN, S.M.; YANG, W.Z.; ZEBELI, Q.; BEAUCHEMIN, K.A. Backgrounding and finishing diets are associated with inflammatory responses in feedlot steers. **Journal of Animal Science***, v.*87, p.1314–1320, 2009.

AMMAR, H.; LÓPEZ, S.; SALEM, A.Z.M.; BODAS, R.; GONZÁLEZ, J.S. Effect of saliva fromsheep that have ingested quebracho tannins on the *in vitro* rumenfermentation activity to digest tannin-containing shrubs. **Animal Feed Science and Technology**, v.163, p.77–83, 2011.

AOAC. Official Methods of Analysis. 18th ed. **AOAC** Int., Arlington, VA. 2006.

APPUHAMY, J.A.; CASSELL, B.G.; COLE, J.B. Phenotypic and genetic relationships of common health disorders with milk and fat yield persistency from producer-recorded health data and test-day yields. **Journal of Dairy Science,** v.92, p.1785–1795, 2007.

ARAUJO, D.B.; COOKE, R.F.; HANSEN, G.R.; STAPLES, C.R.; ARTHINGTON, J.D. Effects of rumen-protected polyunsaturated fatty acid supplementation on

performance and physiological responses of growing cattle following transportation and feedlot entry. **Journal of Animal Science**, v.87, p.4125–4132, 2010.

ARAÚJO, C.S.P; ANDRADE, F.H.A.; GALDINO, P.O; PINTO, M.S.C. Desidratação de batata-doce para fabricação de farinha. **Agropecuária Científica no Semiárido**, v.11, n.4, p.33-41. 2015.

ARTHINGTON, J.; EICHER, S.; KUNKLE, W.; MARTIN, F. Effect of transportation and commingling on the acute-phase protein response, growth, and feed intake of newly weaned beef calves. **Journal of Animal Science**, v.81, n.5, p.1120-1125, 2003.

ARTHINGTON, J.; COOKE, R.; MADDOCK, T.; ARAUJO, D.; MORIEL, P.; DILORENZO, N.; LAMB, G. Effects of vaccination on the acute-phase protein response and measures of performance in growing beef calves. **Journal of Animal Science**, v.91, n.4, p.1831-1837, 2013.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. Official Methods of Analysis. 16. ed. Washington: AOAC, p.1141, 1997.

BABAEINASAB, Y.; ROUZBEHAN, Y.; FAZAELI, H.; REZAEI, J. Chemical composition, silage fermentation characteristics, and *in vitro* ruminal fermentation parameters of potato-wheat straw silage treated with molasses and lactic acid bacteria and corn silage. **Journal of Animal Science,** v.93, n.9, p.4377–4386, 2015.

BARAJAS, R.; CERVANTES, B.J.; CAMACHO, A.; VELÁZQUEZ, E.A.; ESPINO, M.A.; JUÁREZ, F.; FLORES, L.R.; VERDUGO, M. Condensed tannins supplementation on feedlot performance of growing bulls. **Journal of Animal Science,** v.88 (Suppl 2), p.7-11, 2010.

BARAJAS, R.; CERVANTES, B.J.; CAMACHO, A.; VERDUGO, M.; ESPINO, M.A.; FLORES, L.R.; ROMO, J.A.; VELAQUEZ, E.A.; LOMELI, J.J. Influence of addition of tannins-extract in low concentration of dietary dry matter on feedlot-performance of bulls. **Journal of Animal Science,** v.89, 2011.

BARAJAS, R.; CERVANTES, B.J.; ARECHIGA, S.C.; ESPINO, M.A.; BARAJAS, L.R.; CERVANTES, B.J.; ESPINO, M.A.; CAMACHO, A.; VERDUGO, M.; FLORES, L.R.; ARECHIGA, S.C.; LOMELI, J.J.; ROMO, J.Á. Influence of tannins extract addition on feedlot-performance of bulls fed sorghum-based diets. **Journal of Animal Science,** v.90, p.372– 373, 2012a.

BARAJAS, R.; CERVANTES, B.J.; ESPINO, M.A.; CAMACHO, A.; VERDUGO, M.; FLORES, L.R.; LONELI, J.J.; ROMO, J.A. Effect of tannins extract supplementation on feedlot performance and plasma urea nitrogen of yearling bulls fed dry-ground corn-based diets containing corn-DDG and cane molasses. **Journal of Animal Science,** v.90, p.600, 2012b.

BARCELLOS, J. O. J.; QUEIROZ FILHO, L. A.; CEOLIN, A. C.; GIANEZINI, M.; MCMANUS, C.; MALAFAIA, G. C.; OAIGEN, R. P. Technological innovation and

entrepreneurship in animal production. **Revista Brasileira de Zootecnia**, v.40, p.189-200, 2011.

BARRY, T. N.; MCNABB, W. C. The implications of condensed tannins on the nutritive value of temperate forages fed to ruminants. **British Journal of Nutrition**, v.81, n.4, p.263-272, 1999.

BARTLE, S.J.; MALES, J.R.; PRESTON, R.L. Effect of energy intake on the postpartum interval in beef cows and the adequacy of the cow's milk production for calf growth. **Journal of Animal Science**, v.58, p.1068-1074, 1984.

BAUMANN, H.; GAULDIE, J. The acute phase response. **Immunology Today**, v.15, p.74–80, 1994.

BEAUCHEMIN, K.A.; YANG, W.Z.; MORGAVI, D.P.; GHORBANI, G.R.; KAUTZ, W.; LEEDLE, J.A.Z. Effects of bacterial direct-fed microbials and yeast on site and extent of digestion, blood chemistry, and subclinical ruminal acidosis in feedlot cattle. **Journal of Animal Science**, v.81, n.6, p.1628–1640, 2003.

BEN-SALEM, H.; NEFZAOUI, A.; BEN-SALEM, L.; TISSERAND, J.L. Different means of administering polyethylene glycol to sheep: effect on the nutritive value of Acacia cyanophylla Lindl. **Foliage Animal Science**, v.68, p809–818, 1999.

BERRY, B.A.; CONFER, A.W.; KREHBIEL, C.R.; GILL, D.R.; SMITH, R.A.; MONTELONGO, M. Effects of dietary energy and starch concentrations for newly received feedlot calves: II. Acute-phase protein response. **Journal of Animal Science**, v.82, p.845–850, 2004.

BLÜMMEL, M.; BECKER, K. The degradability characteristics of fifty-four roughages and roughage neutral detergent fibers as described by *in vitro* gas production and the relationship to voluntary feed intake. **British Journal of Nutrition**, v.77, p.757–768, 1997.

BOGGS, D.L.; SMITH, E.F.; SCHALLES, R.R.; BRENT, B.E.; CORAH, L.R.; PRUITT, R.J. Effects of milk and forage intake on calf performance. **Journal of Animal Science**, v.51, p.550-553, 1980.

BRAUNER, C.C.; PIMENTEL, M.A.; LEMES, J.S.; PIMENTEL, C.A.; MORAES, J.C.F. Desempenho reprodutivo pós-parto de vacas de corte submetidas a indução/sincronização de cio. **Revista Brasileira de Zootecnia,** v.38, p.99-103, 2009.

BRAUNER, C.C.; PIMENTEL, M.A.; MENEZES, L.M.; MACHADO, J.P.M.; MORAES, J.C.F. Effect of short period feed supplementation during early lactation on performance of cows and calves raised in extensive system. **Revista Brasileira de Zootecnia***,* v.40, p.1381-1387, 2011.

BRAUNER, C. C.; PIMENTEL, M. A.; LEMES, J. S.; PIMENTEL, C. A.; MORAES, J. C. F. Desempenho reprodutivo pós-parto de vacas de corte submetidas a

indução/sincronização de cio. **Revista Brasileira de Zootecnia**, v.38, n.1, p.99-103, 2009.

BREWER, L.R.; CAI, L.; SHI, Y.C. Mechanism and enzymatic contribution to *in vitro* test method of digestion for maize starches differing in amylose content. **Journal of Agricultural Food and Chemical**, v.60, p.4379–4387. 2012.

BROOM, D.M. Transport stress in cattle and sheep with details of physiological, ethological, and other indicators. **Deutsche tierarztliche Wochenschrift, v.**110, p.83-89, 2003.

BROWN, M.A.; BROWN, A.H.; JACKSON, W.G.; MIESNER, J.R. Milk production in Angus, Brahman, and reciprocal-cross cows grazing common bermuda grass or endophyte-infected tall fescue. **Journal of Animal Science***,* v.74, p.2058-2066, 1996.

BROWN, M.A.; BROWN, A.H.; JACKSON, W.G.; MIESNER, J.R. Genotype × environment interactions in milk yield and quality in Angus, Brahman, and reciprocal-cross cows on different forage systems. **Journal of Animal Science** v. 79, p.1643–1649. 2001

BUNTYN, J.O.; SCHMIDT, T.B.; NISBET, D.J.; CALLAWAY, T.R. The Role of Direct-Fed Microbials in Conventional Livestock Production. **Annual Review of Animal Biosciences**, v.4, n.1, p.335-355, 2016.

BUTLER, W.R. Nutritional interactions with reproductive performance in dairy cattle. **Animal Reproduction Science***,* v.60, p.449–457, 2000.

CALDAS NETO, S.F.; ZEOULA, L.M; BRANCO, A.F.; PRADO, I.N.; SANTOS, G.T.; FREGADOLLI, F.L.; KASSIES, M.P.; DALPONTE, A.O. Mandioca e resíduos das farinheiras na alimentação de ruminantes: digestibilidade total e parcial. **Revista Brasileira de Zootecnia**, v.29, n.6, p.2099-2108, 2000.

CARROLL, J.A.; REUTER, R.R.; CHASE JR, C.C,; COLEMAN, S.W.; RILEY, D.G.; SPIERS, D.E.; ARTHINGTON, J.D.; GALYEAN, M.L. Profile of the bovine acute-phase response following an intra- venous lipopolysaccharide challenge. **Innate Immunity**, v.15, p.81–89, 2009.

CATON, J.S.; DHUYVETTER, D.V. Influence of energy supplementation on grazing ruminants: requirements and responses. **Journal of. Dairy Science**, v.75, p.533-542, 1997.

CHAI, W.Z.; VAN GELDER, A.H.; CONE, J.W. Relationship between gas production and starch degradation in feed samples. **Animal Feed Science and Technology**, v.114, p.195-204, 2004.

CHATTOPADHYAY, MK. Use of antibiotics as feed additives: a burning question. **Frontiers in Microbiology**, v.5, p.334, 2014.

CHIBISA, G.E.; VINYARD, J.R.; LAARMAN, A.H. Short communication: Effects of meloxicam administration on protein metabolism and growth performance in transported Jersey calves. **Journal of Dairy Science***,* v.12, p.11435-11440, 2018.

CLUTTER, A.C.; NIELSEN, M.K. Effect of level of beef cow milk production on pre- and post-weaning calf growth. **Journal of Animal Science**, v.64, p.1313–1322, 1987.

CONE, J.W.; WOLTERS, M.G.E. Some properties and degradability of isolated starch granules. **Starch**, v.42, p.298–301. 1990.

COOKE, R.F.; BOHNERT, D.W. Bovine acute-phase response following corticotrophin-release hormone challenge. **Journal of Animal Science***,* v.89, p.252–257, 2011.

COOKE, R.F.; ARTHINGTON, J.D. Concentrations of haptoglobin in bovine plasma determined by ELISA or a colorimetric method based on peroxidase activity. **Journal of Animal Physiology and Animal Nutrition***,* v.97, n.3, p.531-536, 2012.

COOKE, R. F.; GUARNIERI FILHO, T.; CAPPELLOZZA, B.; BOHNERT, D. Rest stops during road transport: Impacts on performance and acute-phase protein responses of feeder cattle. **Journal of Animal Science**, v.91, n.11, p.5448-5454, 2013.

COOPER, S.M.; OWEN-SMITH, N. Condensed tannins deter feeding by browsing ruminants in a South African savanna. **Oecologia,** v.67, p.142–146, 1985.

DAWSON, K.A. Designing the yeast culture of tomorrow—mode of action of yeast culture for ruminants and non-ruminants. **In: Biotechnology in the Feed Industry. Proc. Alltech's 6th Annual Symposium Lexington**, KY. Alltech Tech. Publ., Nicholasville, KY, p. 59, 1990.

DECKARDT, K.; KHOL-PARISINI, A.; ZEBELI, Q. Peculiarities of enhancing resistant starch in ruminants using chemical methods: opportunities and challenges. **Nutrients**, v.5, p.1970-1988, 2013.

DEIGNAN, T.; ALWAN, A.; KELLY, J.; MCNAIR, J.; WARREN, T.; FARRELLY, C.O. Serum haptoglobin: An objective indicator of experimentally- induced salmonella infection in calves. **Research in Veterinary Science,** v.69, p.153–158, 2000.

DEKKERS, J.C.M.; TEN HAG, J.H.; WEERSINK, A. Economic aspects of persistency of lactation in dairy cattle. **Livestock Science**, v.53, p.237-252, 1998.

DELCURTO, T.; HESS, B.W.; HUSTON, J.E.; OLSON, K.C. Optimum supplementation strategies for beef cattle consuming low-quality roughages in the western United States. **Journal Animal Science**, v.77, p.1–16, 2000.

DICKS, L. M.; BOTES, M. Probiotic lactic acid bacteria in the gastro-intestinal tract: health benefits, safety and mode of action. **Beneficial Microbes**, v.1, n.1, p.11-29, 2010.

DO CARMO, M.; CLARAMUNT, M.; CARRIQUIRY, M.; SOCA, P. Animal energetics in extensive grazing systems: Rationality and results of research models to improve energy efficiency of beef cow-calf grazing Campos systems. **Journal of Animal Science**, v.94, p.84–92, 2016.

DSCHAAK, C.M.; WILLIAMS, C.M.; HOLT, M.S.; EUN, J.S.; YOUNG, A. J.; MIN, B.R. Effects of supplementing condensed tannin extract on intake, digestion, ruminal fermentation, and milk production of lactating dairy cows. **Journal of Dairy Science,** v.94, n.5, p.2508-2519, 2011.

DUFF, G.C.; GALYEAN, M.L. Board-invited review: recent advances in management of highly stressed, newly received feedlot cattle. **Journal Animal Science**, v.85, n.3, p.823-840, 2007.

EARLEY, B.; O'RIORDAN, E.G. Effects on transporting bulls at different space allowances on physiological, haematological and immunological responses to a 12-h journey by road. **Irish Journal of Agricultural and Food Research**, v.45, p.39–50, 2006.

ECCC. 1990–2015 Air pollution emission inventory report. **Environment Climate Change**, Canada, Gatineau, QC. 2016.

EDWARDS, S.R.; HOBBS, J.D.; MULLINIKS, J.T. High milk production decreases cow-calf productivity within a highly available feed resource environment. **Translational Animal Science***,* v.1, n.1, p.54-59, 2017.

ELAM, N.A.; GLEGHORN, J.F.; RIVERA, J.D.; GALYEAN, M.L.; DEFOOR, P.J.; BRASHEARS, M.M.; YOUNTS-DAHL, S.M. Effects of live cultures of *Lactobacillus acidophilus* (strains NP45 and NP51) and *Propionibacterium freudenreichii* on performance, carcass and intestinal characteristics, and *Escherichia coli* strain O157:H7 shedding of finishing beef steers. **Journal of Animal Science**, v.81, p.2686–2698, 2003.

EVANS, E.; MESSERSCHMIDT, U. Review: Sugar beets as a substitute for grain for lactating dairy cattle. **Journal of Animal Science and Biotechnology**, v.8, n.25, 2017.

FDA. Direct-Fed Microbial Products in Compliance Policy Guides. Washington, D.C, 2015. Available from: <http://www.fda.gov/ICECI/ComplianceManuals/CompliancePolicyGuidanceManual/ucm074707.html.>

FERRELL, C.L.; JENKINS, T.G. Cow type and the nutritional environment: nutritional aspects. **Journal Animal Science**, v.61, p.725–741, 1985.

FIKE, K.; SPIRE, M.F. Transportation of cattle. **Veterinary Clinics of North America: Food Animal Practice**, v.22, p.305-320, 2006.

FOCANT, M.; FROIDMONT, E.; ARCHAMBEAU, Q.; DANG VAN, Q.C.; LARONDELLE, Y. The effect of oak tannin (Quercus robur) and hops (Humulus lupulus) on dietary nitrogen efficiency, methane emission, and milk fatty acid composition of dairy cows fed a low-protein diet including linseed. **Journal of Dairy Science***, v.*102, p.1144-1159. 2019.

FORSTER, K.M.; PIMENTEL, M.A.; MORAES, J.C.F. Disponibilidade de energia líquida no leite e desempenho ponderal de bezerros Hereford e Aberdeen Angus do nascimento à desmama. **Revista Brasileira de Zootecnia***,* v.39, p.2545-2552, 2010.

FREETLY, H.C.; NIENABER, J.A.; BROWN-BRANDL, T. Partitioning of energy during lactation of primiparous beef cows. **Journal of Animal Science***,* v.84, p.2157–2162, 2006.

FRIZZO, L.S.; SOTO, L.P.; ZBRUN, M.V.; BERTOZZI, E.; SEQUEIRA, G.; RODRIGUEZ ARMESTO, R.; ROSMINI, M.R. Lactic acid bacteria to improve growth performance in young calves fed milk replacer and spray-dried whey powder. **Animal Feed Science Technology**, v.157, n.3, p.159–167, 2010.

FRUTOS, P.; HERVAS, G.; GIRÁLDEZ, F. J.; MANTECÓN, A. Tannins and ruminant nutrition. **Spanish Journal of Agricultural Research**, v.2, n.2, p.191-202, 2004.

FRYE, J. B.; HAWKINS, G. E.; HENDERSON, H. B. The value of winter pasture and sweet potato meal for lactating dairy cows. **Journal of Dairy Science**, v. 31, n. 10, p. 897-903, 1948.

GALES, P.W. Moisture in Malt – Gravimetric Method, Method 935.29. (In Kenneth Herlich, Ed.) **Official Methods of Analysis of the Association of Official Analytical Chemists, 15th Ed**. AOAC (Inc: Arlington, VA), 1990.

GALINDO, J.; ELIAS, A.; ALDANA, A.I.; TORRES, V.; SARDUY, L. Effect of the inclusion of starchy sources on the population of methanogenic bacteria and ruminal methane in diets with sugarcane (*Saccharum officinarum*) fermented *in vitro*. **Journal of Agricultural Science**, v.43, n.2, p.135-141.

GHORBANI, G.; MORGAVI, D.; BEAUCHEMIN, K.; LEEDLE, J. Effects of bacterial direct-fed microbials on ruminal fermentation, blood variables, and the microbial populations of feedlot cattle. **Journal of Animal Science**, v.80, n.7, p.1977-1985, 2002.

GIUBERTI, G.; GALLO, A.; MASOERO, F.; FERRARETTO, L.F.; HOFFMAN, P.C.; SHAVER, R.D. Factors affecting starch utilization in large animal food production system: A review. **Starch - Stärke**, v.66, n.1-2, p.72-90, 2014.

GÓMEZ, L.M.; POSADA, S.L.; OLIVERA, M. Starch in ruminant diets: a review. **Revista Colombiana de Ciencias Pecuarias**, v.29, p.77-90, 2016.

GOZHO, G.; PLAIZIER, J.; KRAUSE, D.; KENNEDY, A.; WITTENBERG, K. Subacute ruminal acidosis induces ruminal lipopolysaccharide endotoxin release and

triggers an inflammatory response. **Journal of dairy science**, v.88, n.4, p.1399-1403, 2005.

GOZHO, G.N.; MUTSVANGWA, T. Influence of carbohydrate source on ruminal fermentation characteristics, performance, and microbial protein synthesis in dairy cows. **Journal of Dairy Science**, v.91, n.7, p.2726-35, 2008.

GUILLEN, L.M. **Determination of the Mechanism (S) by Which Direct-fed Microbials Control Escherichia coli O157:H7 in Cattle** (Doctoral dissertation). Oklahoma State University at Stillwater, 2009.

HAGERMAN, A.E.; BUTLER, L.G. Tannins and lignins. In: Rosental, G.A., Berenbaum, M.R. (Eds.), Herbivores: Their Interaction with Secondary Plant Metabolites. **Academic Press**, San Diego, p. 355–376, 1991.

HARDER, B.; BENNEWITZ, J.; HINRICHS, D.; KALM, E. Genetic parameters for health traits and their relationship to different persistency traits in German Holstein dairy cattle. **Journal of Dairy Science***, v.*89, p.3202–3212, 2006.

HARLAND, R.J.; JIM, G.K.; GUICHON, P.T.; TOWNSEND, H.G.; JANZEN, E.D. Efficacy of parenteral antibiotics for disease prophylaxis in feedlot calves. **The Canadian Veterinary Journal**, v.32, p.163, 1991.

HATEW, B.; PODESTA, S.C.; VAN LAAR, H.; PELLIKAAN, W.F.; ELLIS, J.L.; DIJKSTRA, J.; BANNINK, A. Effects of dietary starch content and rate of fermentation on methane production in lactating dairy cows. **Journal of Dairy Science**, v.98, n.1, p.486-499, 2015.

HERNANDEZ, P.; SALEM, A.Z.M.; LÓPEZ, S.; SUN, X.Z.; ROJO, R.; CAMACHO, L.M.; ELGHANDOUR, M.M.Y.; RONQUILLO, M.G. Influence of Salixbabylonica and Leucaena leucocephala leaf extracts on ruminal fermentation characteristics, urinary purine derivative excretion and microbial protein synthesis of lambs. **Livestock Science**, v.163, p.80–84, 2014.

HESS, B.W.; LAKE, S.L.; SCHOLLJEGERDES, E.J.; WESTON, T.R.; NAYIGIHUGU, V.; MOLLE, J.D.C.; MOSS, G.E. Nutritional controls of beef cow reproduction. **Journal of Animal Science**, v.83, p.90–106, 2005.

HOLZAPFEL, W.H.; HABERER, P.; SNEL, J.; SCHILLINGER, U.; HUIS IN'T VELD, J.H.J. Overview of gut flora and probiotics. **International Journal of Food Microbiology**, v.41, p.85–101, 1998.

HOOVER, R. Composition, molecular structure, and physicochemical properties of tuber and root starches: a review. **Carbohydrate Polymers**, v.45, n.3, p.253-267, 2001.

HRISTOV, A. N.; HANIGAN, M.; COLE, A.; TODD, R.; MCALLISTER, T.A.; NDEGWA, P. M.; ROTZ, A. Review: Ammonia emissions from dairy farms and beef feedlots. **Canadian Journal of Animal Science**, v.91, p.1–35, 2011.

HUANG, C.J.; WEBB, H.E.; ZOURDOS, M.C.; ACEVEDO, E.O. Cardiovascular reactivity, stress, and physical activity. **Frontiers in Physiology**, v.4, p.314, 2013.

HUANG, C.J.; LUI, X.; ZHAO, G.; HU, T.; WANG, Y. Potential and challenges of tannins as an alternative to in-feed antibiotics. **Animal Nutrition**, v.4, p. 137-150. 2018.

HUFFMAN, R.P.; KARGES, K.K.; KLOPFENSTEIN, T.J.; STOCK, R.A.; BRITTON, R.A.; ROTH, L.D. The effect of Lactobacillus acidophilus on subacute ruminal acidosis. **Journal of Animal Science**, v.70, p.87, 1992.

IGBE. **Produção Agrícola Municipal - Lavoura temporária**. 2018. Disponível em: < https://cidades.ibge.gov.br/brasil/pesquisa/14/10233> Acesso em: 03 janeiro de 2020.

ISIK, M.; EKIMLER, F.; OZEN, N.; FIRAT, M.Z. Effects of using probiotics on the growth performance and health of dairy calves. **Turkish Journal of Veterinary and Animal Sciences**, v.28 n.1, p.63–69, 2004.

ISOLAURI, E.; SUTAS, Y.; KANKAANPAA, P.; ARVILOMMI, H.; SALMINEN, S. Probiotics: Effects on immunity. **American Journal of Clinical Nutrition**, v.73 (Suppl. 2), p.444S–450S, 2001.

JENKINS, T.G.; FERRELL, C.L. Lactation characteristics of nine breeds of cattle fed various quantities of dietary energy. **Journal of Animal Science**, v.70, p.1652–1660, 1992.

JENKINS, T.G.; FERRELL, C.L.; ROBERTS, A.J. Lactation and calf weight traits of mature crossbred cows fed varying daily levels of metabolizable energy. **Journal of Animal Science**, v.78, p.7-14, 2000.

KAUPPINEN, A.; SUURONEN, T.; OJALA, J.; KAARNIRANTA, K.; SALMINEN, A. Antagonistic crosstalk between NF-kappaB and SIRT1 in the regulation of inflammation and metabolic disorders. **Cell Signal,** v.25, p.1939–1948, 2013.

JOHNSON, C.R.; LALMAN, D.L.; BROWN, M.A.; APPEDDU, L.A.; BUCHANAN, D.S.; WETTEMANN, R.P. Influence of milk production potential on forage dry matter intake by multiparous and primiparous Brangus females. **Journal of Animal Science**, v.81, p.1837–1846, 2003.

JOHNSON, R.W. Inhibition of growth by pro-inflammatory cytokines: An integrated view. **Journal of Animal Science,** v.75, p.1244–1255, 1997.

JOUANY, J.P. Optimizing rumen functions in the close-up transition period and early lactation to drive dry matter intake and energy balance in cows. **Animal Reproduction Science**, v.96, n.3, p.250–264, 2006.

KIRKPATRICK, J. G.; STEP, D. L.; PAYTON, M. E.; RICHARDS, J. B.; MCTAGUE, L. F.; SALIKI, J. T.; CONFER, A. W.; COOK, B. J.; INGRAM, S. H.; WRIGHT, J. C. Effect of age at the time of vaccination on antibody titers and feedlot performance in

beef calves. **Journal of the American Veterinary Medical Association**, v.233, p.136–142, 2008.

KMET, V.; FLINT, H.J.; WALLACE, R.J. Probiotics and manipulation of rumen development and function. **Archives of Animal Nutrition***, v.*44, p.1–10, 1993.

KNOWLES, T.G. A review of the road transport of cattle. **Veterinary Record**, v.144, p.197-124, 1999.

KOZLOSKI, G.V., ROCHA, J.B.T,; RIBEIRO FILHO, H.M.N.; PEROTTONI, J. Comparison of acid and amyloglucosidase hydrolysis for estimation of non-structural polysaccharides in feed samples. **Journal of the Science of Food and Agriculture**, v.79, n.8, p.1112-1116, 1999.

KREHBIEL, C.; RUST, S.; ZHANG, G.; GILLILAND, S. Bacterial direct-fed microbials in ruminant diets: Performance response and mode of action. **Journal of Animal Science**, v.81, n.14 (suppl 2), p.E120-E132, 2003.

KRUEGER, W.K.; GUTIERREZ-BANUELOS, H.; CARSTENS, G.E.; MIN, B.R.; PINCHAK, W.E.; GOMEZ, R.R.; ANDERSON, R.C.; KRUEGER, N.A.; FORBES, T.D.A. Effects of dietary tannin source on performance, feed efficiency, ruminal fermentation, and carcass and non-carcass traits in steers fed a high-grain diet. **Animal Feed Science Technology**, v.159, p.1–9, 2010.

KUMAR, R.; SINGH, M. Tannins: their adverse role in ruminant nutrition. **Journal of Agricultural and Food Chemistry**, v.32, p.447-453, 1984.

KUNG, L.M., HESSION, A.O. Preventing *in vitro* lactate accumulation in ruminal fermentations by inoculation with Megasphaera elsdenii. **Journal Animal Science,** v.73, n.1, p.250-6, 1995.

LAKE, S.L.; SCHOLLJEGERDES, E.J.; ATKINSON, R.L.; NAYIGIHUGU, V.; PAISLEY, S.I.; RULE, D.C.; MOSS, G.E.; ROBINSON, T.J.; HESS, B.W. Body condition score at parturition and postpartum supplementation fat effects on cow and calf performance. **Journal of Animal Science**, v.83, p.2908–2917, 2005.

LANDAU, S.; SILANIKOVE, N.; NITSAN, Z.; BARKAI, D.; BARAM, H.; PROVENZA, F.D.; PEREVOLOTSKY, A. Short-term changes in eating patterns explain the effects of condensed tannins on feed intake in heifers. **Applied Animal Behaviour Science**, v.69, p.199–213, 2000.

LAUNCHBAUGH, K. L.; HUNT, C.W. New approaches for enhancing grazing productivity: Meeting the challenges of variable environments. **Journal Animal Science**, v.79, p.1–7, 2000.

LEE, Y. K.; PUONG, K. Y.; OUWEHAND, A. C.; SALMINEN, S. Displacement of bacterial pathogens from mucus and Caco-2 cell surface by lactobacilli. **Journal of Medical Microbiology**, v.52, p.925-930, 2003.

LEHLOENYA, K. V.; KREHBIEL, C. R.; MERTZ, K. J.; REHBERGER, T. G.; SPICER, L. J. Effects of Propionibacteria and yeast culture fed to steers on nutrient intake and site and extent of digestion. **Journal of Dairy Science**, v.91, n.653-662, 2008.

LI, J.H.; VASANTHAN, T.; ROSSNAGEL, B.; HOOVER, R. Starch from hul-less barley. II. Thermal, rheological and acid hydrolysis characteristics. **Food Chemistry**, v.74, n.4, p.407–415. 2001.

LIU, Y. F.; ZHAO, H. B.; LIU, X. M.; YOU, W.; CHENG, H. J.; WAN, F. C.; ZHANG, X. L. Substitution of Wheat for Corn in Beef Cattle Diets: Digestibility, Digestive Enzyme Activities, Serum Metabolite Contents and Ruminal Fermentation. **Asian-Australasian journal of animal sciences**, v.29, p.1424–1431. 2016.

LOMBORG, S.R.; NIELSEN, L.R.; HEEGAARD, P.M.H.; JACOBSEN, S. Acute phase proteins in cattle after exposure to complex stress. **Veterinary Research Communications**, v.32, p.575–582, 2008.

LUAN, S. **Effects of Nutritional Strategies on Rumen Environment and Performance in Dairy Cows** (MS thesis). University of Illinois at Urbana-Champaign. 2014.

LUNSIN, R.; WANAPAT, M.; WACHIRAPAKORN, C.; NAVANUKRAW, C. Effects of pelleted cassava chip and raw banana (Cass-Bann) on rumen fermentation and utilization in lactating dairy cows. **Journal of Animal and Veterinary Advances**, v.9, n.17, p.2239-2245, 2010.

LUTAKOME, P.; KABI, F.; TIBAYUNGWA, F.; LASWAI, G.H.; KIMAMBO, A.; EBONG, C. Rumen liquor from slaughtered cattle as inoculum for feed evaluation. **Animal Nutrition**, v.3, n.3, p.300-308, 2017.

LYNCH, E.M.; EARLEY, B.; MCGEE, M.; DOYLE, S. Effect of abrupt weaning at housing on leukocyte distribution, functional activity of neutrophils, and acute phase protein response of beef calves. **BMC Veterinary Research***, v.*6, p.39, 2010.

MAKIMURA, S.; SUZUKI, N. Quantitative determination of bovine serum haptoglobin and its elevation in some inflammatory disease. **Japanese Journal of Veterinary Science**, v.44, p.15–21, 1982.

MAKKAR, H.P.S. Effects and fate of tannins in ruminant animals, adaptation to tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. **Small Ruminant Research,** v.49, p.241–256, 2003.

MANGAN, J.L. Nutritional effects of tannins in animal feeds. **Nutrition Research Reviews**, v.1, p.209-231, 1988.

MARQUES, R.S.; COOKE, R.F.; FRANCISCO, C.L.; BOHNERT, D.W. Effects of twenty-four-hour transport or twenty-four-hour feed and water deprivation on physiologic and performance responses of feeder cattle. **Journal of Animal Science**, v. 90, p.5040–5046, 2012.

MARTI, S.; WILDE, R.E.; MOYA, D.; HEUSTON, C.E.; BROWN, F.; SCHWARTZKOPF-GENSWEIN, K.S. Effect of rest stop duration during long-distance transport on welfare indicators in recently weaned beef calves. **Journal of Animal Science**, v.95, p.636-644, 2017.

MATHER, R.E.; LINKOUS, W.N.; EHEART, J.F. Dehydrated Sweet Potatoes as a Concentrate Feed for Dairy Cattle. **Journal of Dairy Science**, v.31, n.7, p.569-576, 1948.

MATSUGUCHI, T.; TAKAGI, A.; MATSUZAKI, T.; NAGAOKA, M.; ISHIKAWA, K.; YOKOKURA, T. Lipoteichoic acids from Lactobacillus strains elicit strong tumor necrosis factor a-inducing activities in macrophage through Toll-like receptor 2. **Clinical and Diagnostic Laboratory and Immunology**, v.10, p.259-266, 2003.

MCALLISTER, T. A.; BEAUCHEMIN, K. A.; ALAZZEH, A. Y.; BAAH, J.; TEATHER, R. M.; STANFORD, K. Review: The use of direct fed microbials to mitigate pathogens and enhance production in cattle Canadian. **Journal of Animal Science**, v.91, n.2, p.193-211, 2011.

MCALLISTER, T.A.; PHILLIPPE, R.C.; RODE, L.M.; CHENG, K.J. Effect of the protein matrix on the digestion of cereal grains by ruminal microorganisms. **Journal of Animal Science**, v.71, p.205–212, 1993.

MCGRANCE, S.J.; CORNELL, H.J.; RIX, C.J. A Simple and Rapid Colorimetric Method for the Determination of Amylose in Starch Products. **Starch - Stärke**, v.50, n.4, p.158-163, 1998.

MCLEOD, M.N. Plant tannins - Their role in forage quality. **Nutrition abstracts and reviews**, v.44, p.803-812, 1974.

MCNABB, W.C.; WAGHORN, G.C.; PETERS, J.S.; BARRY, T.N. The effect of condensed tannin in Lotus pedunculatus upon the solubilization and degradation of ribulose 1,5-bisphosphate carboxylase protein in the rumen and on sites of digestion. **British Journal of Nutrition**, v.76, n.4, p.535-49, 1996

MCSWEENEY, C.S.; PALMER, B.; MCNEILL, D.M.; KRAUSE, D.O. Microbial interactions with tannins: nutritional consequences for ruminants. **Animal Feed Science and Technology**, v.91, p.83–93, 2001.

Meat Market Review, April 2018. FAO, Rome. 2018.

MERTENS, D.R. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. **Journal of AOAC International, v.**85, p.1217–1240, 2002.

MEZZOMO, R.; PAULINO, P.V.R.; DETMANN, E.; VALADARES, S.C.; PAULINO, M.F.; MONNERAT, J.P.I.S.; DUARTE, M.S.; SILVA, L.H.P.; MOURA, L.S. Influence of condensed tannin on intake, digestibility, and efficiency of protein utilization in beef steers fed high concentrate diet. **Livestock Science**, v.141, p.1–11, 2011.

MIETTINEN, M.; VUOPIO-VARKILA, J.; VARKILA, K. Production of human necrosis factor a, interleukin 6, and interleukin 10 is induced by lactic acid bacteria. **Infection and Immunity**, v.64, p.5403-5405, 1996.

MILLER, A. J.; FAULKNER, D. B.; KNIPE, R. K.; STROHBEHM, D. R.; PARRETT, D. F.; BERGER, L. L. Critical control points for profit- ability in the cow-calf enterprise. **Professional Animal Scientist**, v.17, p.295–302, 2001.

MIN, B. R.; MCNABB, W. C.; BARRY, T. N.; PETERS, J. S. Solubilization and degradation of ribulose-1,5-*bis*phosphate carboxy-lase/oxygenase (EC 4.1.1.39; Rubisco) protein from white clover (*Trifolium repens*) and *Lotus corniculatus* by rumen microorganisms and the effect of condensed tannins on these processes. **The Journal of Agricultural Science (Cambridge)**, v.134, p.305–317, 2000.

MIN, B.R.; ATTWOOD, G.T.; REILLY, K.; SUN, W.; PETERS, J.S.; BARRY, T.N.; MCNABB, W.C. Lotus corniculatus condensed tannins decrease in vivo populations of proteolytic bacteria and affect nitrogen metabolism in the rumen of sheep. **Canadian Journal of Microbiology**, v.48, p.911–921, 2002.

MIN, B.R.; BARRY, T.N.; ATTWOOD, G.T.; MCNABB, W.C. The effect of condensed tannins on the nutrition and health of ruminants fed fresh temperate forages: A review. **Animal Feed Science and Technology**, v.106, p.3–19, 2003.

MINTON, J.E. Function of the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system in models of acute stress in domestic farm animals. **Journal Animal Science**, v.72, p.1891–1898, 1994.

MOE, P. W.; TYRRELL, H. F.; FLATT, W. P. Partial efficiency of energy use for maintenance, lactation, body gain and gestation in the dairy cow. Proc. 5th Symposium on Energy Metabolism. **European Ass. Anim. Prod. Publ. v.**13, p.65–68, 1970.

MOENNIG V, EICKEN K, FLEBBE U, FREY HR, GRUMMER B, HAAS L, GREISER-WILKE I, MOHARRERY, A.; LARSEN, M.; WEISBJERG, M.R. Starch digestion in the rumen, small intestine, and hind gut of dairy cows - A meta-analysis. **Animal Feed Science and Technology**, v.192, p.1–14, 2014.

MOLAN, A.L.; ATTWOOD, G.T.; MIN, B.R.; MCNABB, W.C. The effect of condensed tannins from *Lotus pedunculatus* and *Lotus corniculatus* on the growth of proteolytic rumen bacteria *in vitro* and their possible mode of action. **Canadian Journal of Microbiology**, v.47, p.626–633, 2001.

MONTEIRO, A. B. Silagens de cultivares e clones de batata doce para alimentação animal visando sustentabilidade da produção agrícola familiar. **Cadernos de Agroecologia**, v. 2, n. 2, 2007.

MORAES, J.C.F.; SOUZA, C.J.H.; JAUME, C.M. Body condition score to predict the postpartum fertility of crossbred beef cows. **Pesquisa Agropecuaria Brasileira**, v.42, p.741-746, 2007.

MORMEDE, P.; ANDANSON, S.; AUPERIN, B.; BEERDA, B.; GUEMENE, D.; MALMKVIST, J.; MANTECA, X.; MANTEUFFEL, G.; PRUNET, P.; VAN REENEN, C.G.; RICHARD, S.; VEISSIER, I. Exploration of the hypothalamic-pituitaryadrenal function as a tool to evaluate animal welfare. **Physiology & Behavior**, v.92, p.317–339, 2007.

MOULD, F.L.; MORGAN, R.; KLIEM, K.E.; KRYSTALLIDOU. A review and simplification of the *in vitro* incubation medium. **Animal Feed Science and Technology**, v.123–124, p.155-172, 2005.

MUELLER-HARVEY, I. Unravelling the conundrum of tannins in animal nutrition and health. **Journal of the Science of Food and Agriculture**, v.86, p.2010–2037, 2006.

MUELLER-HARVEY, I.; McALLAN, A.B. Tannins. Their biochemistry and nutritional properties. **In: Advances in plant cell biochemistry and biotechnology**, Vol. 1 (Morrison I.M., ed.). JAI Press Ltd., London (UK), p. 151-217, 1992.

MUIR, J. P.; TERRILL, T. H.; MOSJIDIS, J. A.; LUGINBUHL, J.-M.; MILLER, J. E.; BURKE, J. M.; COLEMAN, S. W. Season Progression, Ontogenesis, and Environment Affect Herbage Condensed Tannin, Fiber, and Crude Protein Concentrations. **Crop Science**, v.57, n.1, p.515, 2017.

MULLINIKS, J.T.; BEARD, J.K. BEEF SPECIES–RUMINANT NUTRITION CACTUS BEEF SYMPOSIUM: Sustainable and economically viable management options for cow/calf production through enhanced beef cow metabolic efficiency, **Journal of Animal Science,** v.97, n.3, p.1398–1406, 2019.

MURDIATI, T.B., MCSWEENEY, C.S, LOWRY, J.B. Complexing of toxic hydrolysable tannins of yellow-wood (Terminalia oblongata) and harendong (Clidemia hirta) with reactive substances: An approach to preventing toxicity. **Journal of Applied Toxicology**, v.11, p.333-338, 1991.

MURRAY, C. F.; WINDEYER, M. C.; DUFFIELD, T. F.; HALEY, D. B.; PEARL, D. L.; WAALDERBOS, K. M.; LESLIE, K. E. Associations of serum haptoglobin in newborn dairy calves with health, growth, and mortality up to 4 months of age. **Journal of Dairy Science**, v.97, n.12, p.7844-7855, 2014.

NCSS. NCSS: statistical system for Windows: user guide V. Kaysville, 2007. 565p.

NEVILLE, W.E.; WARREN E.P.; GRIFFEY, W.A. Estimates of age effects on milk production in Hereford cows. **Journal of Animal Science**, v.38, p.1-10, 1974.

NEWCOMER, B.W.; WALZ, P.H.; GIVENS, M.D.; WILSON, A.E. Efficacy of bovine viral diarrhea virus vaccination to prevent reproductive disease: a meta-analysis. **Theriogenology***, v.*83, p.360-365, 2015.

NOVAK, K.N.; DAVIS, E.; WEHNES, C.A.; SHIELDS, D.R.; COALSON, J.A.; SMITH, A.H.; REHBERGER, T.G. Effect of supplementation with an electrolyte containing a

Bacillus-based direct-fed microbial on immune development in dairy calves. **Research in Veterinary Science**, v.92, n.3, p.427–434, 2012.

NRC. Nutrient requeriments of dairy cattle. 7ª ed. Washinton: DC. **National Academy of Sciences**, 381p., 2001.

NUNES, J.K.; MAIER, J. C.; GON«ALVES, F. M.; GENTILINI, F. P.; ANCIUTI, M. A.; RUTZ, F. Desempenho produtivo de frangos de corte alimentados com farinha de batata doce em substituição parcial ao milho, com ou sem suplementação enzimática. **Ars Veterinaria**, v. 26, n. 3, p. 170-177, 2011.

OETZEL, G.R.; EMERY, K.M.; KAUTZ, W.P.; NOCEK, J.E. Direct fed microbial supplementation and health and performance of pre-and postpartum dairy cattle: A field trial. **Journal of Dairy Science**, v.90, p.2058–2068, 2007.

OLIVEIRA, A.P.; SILVA, J.E.L.; PEREIRA, W.E.; BARBOSA, L.J.N. Produção de batata-doce e teor de amido nas raízes em função de doses de P_2O_5. **Acta Scientiarum Agronomy**, v.27, p.747-745, 2005.

OLIVEIRA, A.P.; GONDIM, P.C.; SILVA, O.P.R.; OLIVEIRA, A.N.P.; GONDIM, S.C.; SILVA, J.A. Produção e teor de amido da batata-doce em cultivo sob adubação com matéria orgânica. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.17, n.8, p.830-834, 2013.

O'LOUGHLIN, A.; MCGEE, M.; DOYLE, S.; EARLEY, B. Biomarker responses to weaning stress in beef calves. **Research in Veterinary Science**, v.97, n.2, p.458-463, 2014.

PADMORE, J.M. Protein (Crude) in Animal Feed – Combustion Method, Method No. 990.03, In Kenneth Helrich (ed.) Official Methods of Analysis of the Association of **Official Analytical Chemists,** 15th Edition, First Supplement. AOAC. pp. 3-4. (Arlington, VA 22201), 1990.

PATLE, B.R.; MUDGAL, V. D. Maintenance requirements for energy in cross-bred cattle. **British Journal of Nutrition**, v.33, p.127– 139, 1975.

PATRA, A.K.; SAXENA, J. Exploitation of dietary tannins to improve rumen metabolism and ruminant nutrition. **Journal of the Science of Food and Agriculture,** v.91, p.24–37, 2011.

PATTON, R.A.; PATTON, J.R.; BOUCHER, S.E. Defining ruminal and total-tract starch degradation for adult dairy cattle using in vivo data. **Journal of Dairy Science**, v.95, n.2, p.765-82, 2012.

PEREIRA, M.N.; PINHO, R.G.V.; BRUNO, R.G.S.; CALESTINE, G.A. Ruminal degradability of hard or soft texture corn grain at three maturity stages. **Scientia Agricola**, v.61, n.4, p.358-363, 2004.

PITTROFF, W.; CARTWRIGHT, T.C.; KOTHMANN, M.M. Perspectives for livestock on grazinglands. **Archivos Latinoamericanos de Produccíon Animal,** v.10, p.133–143, 2002.

PLACE, S.E.; MITLOEHNER, F.M. Invited review: Contemporary environmental issues: A review of the dairy industry's role in climate change and air quality and the potential of mitigation through improved production efficiency. **Journal of Dairy Science**. v. 93, p. 3407– 3416. 2010.

PUCHALA, R.; MIN, B.R.; GOETSCH, A.L.; SAHLU, T. The effect of condensed tannin-containing forage on methane emission by goats. **Journal Animal Science**, v. 83, p.182–186, 2005.

QIU, X.; ARTHINGTON, J.D.; RILEY, D.G.; CHASE JR, C.C.; PHILLIPS, W.A.; COLEMAN, S.W.; OLSON, T.A. Genetic effects on acute phase protein response to the stresses of weaning and transportation in beef calves. **Journal of Animal Science, v.**85, p.2367–2374, 2007.

REYNOLDS, C.K.; TYRRELL, H.F. Energy metabolism in lactating beef heifers. **Journal Animal Science**, v.78, p.2696–2705, 2000.

REYNOLDS, C.K., HARMON, D.L.; CECAVA, M.J. Absorption and delivery of nutrients for milk protein synthesis by portal-drained viscera. **Journal of Dairy Science,** v.77, n.9, p.2787–2808, 1994.

RICACHESKI, S.T.; HENRIQUE, D.S.; MAYER, L.R.R.; OLIVEIRA, J.G.; ROSLER, J.A.; FLUCK, A.C. Chemical composition and ruminal degradation kinetics of white oat (Avena sativa L.) IPR 126. **Revista Brasileira de Saúde e Produção Animal**, v.18, p.50-61, 2017.

RIVERA-MÉNDEZ, C.; PLASCENCIA, A.; TORRENTERA, N.; ZINN, R.A. Effect of level and source of supplemental tannin on growth performance of steers during the late finishing phase. **Journal of Applied Animal Research**, v.45, p.199–203, 2017.

ROBISON, O.W.; YOUSEFF, M.K.M.; DILLARD, E.U. Milk production in Hereford cows I. Means and correlations. **Journal of Animal Science**, v.47, p.131–136, 1978.

ROSTAGNO, H.S. **Tabelas Brasileiras para Aves e Suínos** – Composição de Alimentos e Exigências Nutricionais**.** 3ª ed. Viçosa: UFV, Departamento de Zootecnia, 2005.

RUSSELL, J.B.; BALDWIN, R.L. Substrate preferences in rumen bacteria: evidence of catabolite regulatory mechanisms. **Applied and Environmental Microbiology**, v.36, n.2, p.319–329, 1978.

RUTLEDGE, J.J.; ROBISON, O.W.; AHLSCHWEDE, W.T.; LEGATES, J.E. Milk yield and its influence on 205-day weight of beef calves. **Journal of Animal Science** v. 33, p. 563–567, 1971

SALEM, A.Z.M.; LÓPEZ, S.; RANILLA, M.J.; GONZÁLEZ, J.S. Short- to medium-term effects of consumption of quebracho tannins on saliva production and composition in sheep and goats. **Journal Animal Science**, v.91, p.1341–1349, 2013.

SALMINEN, S.; ISOLAURI, E.; SALIMEN, E. Clinical uses of probiotics for stabilizing the gut mucosal barrier: successful strains and future challenges. **Antonie Leeuwenhoek**, v.70, p.347– 358, 1996.

SAMINATHAN, M.; SIEO, C.C.; GAN, H.M.; ABDULLAH, N.; WONG, C.M.V.L.; HO, Y.W. Effects of condensed tannin fractions of different molecular weights on population and diversity of bovine rumen methanogenic archaea *in vitro*, as determined by high-throughput sequencing. **Animal Feed Science and Technology**, v.216, p.146–60, 2016.

SANTANA, A.L.; MEIRELES, M.A.A. New starches are the trend for industry applications: a review. **Food Public Health**, v.4, p.229-241, 2014.

SARTORI, R.; GUARDIEIRO, M.M. Fatores nutricionais associados à reprodução da fêmea bovina. **Revista Brasileira de Zootecnia**, v.39, p.422-432, 2010.

SAS. **SAS/STAT user's guide**: Version 9.1. Cary (NC): SAS Institute. 2004.

SCHOFIELD, P.; PITT, R.E.; PELL, A.N. Kinetics of fiber digestion from *in vitro* gas production. **Journal of Dairy Science**, v.72, n.11, p.2980-299, 1994.

SENGER, C.C.D.; KOZLOSKI, G.V.; SANCHEZ, L.M.B.; MESQUITA, F.R.; ALVES, T.P.; CASTAGNINO, D.S. Evaluation of autoclave procedures for fiber analysis in forage and concentrate feedstuffs. **Animal Feed Science and Technology**, v.146, p.169-174, 2008.

SEO, J.K.; KIM, S.W.; KIM, M.H.; UPADHAYA, S.D.; KAM, D.K.; HA, J.K. Direct-fed microbials for ruminant animals. **Asian- Australasian Journal of Animal Sciences**, v.23, p.1657–1667, 2010.

SHORT, R.E.; BELLOWS, R.A.; STAIGMILLER, R.B.; BERARDINELLI, J.G.; CUSTER, E.E. Physiological mechanisms controlling anestrus and infertility in postpartum beef cattle. **Journal of Animal Science, v.**68, p.799–816, 1990.

SILVA, J. B.; LOPES, C. A.; MAGALHÃES, J. S. Batata-doce (Ipomoea batatas). **Embrapa Hortaliças.** 6, 2008.

SILVA, A.M.A.; ALVES, S.V.; BEZERRA, L.R.; CARNEIRO, H.; OLIVEIRA, R.L.; MEDEIROS, F.F.; PREIRA FILHO, J.M.; ARAUJO, D.R. Potential *in vitro* degradability and gas production of the byproducts of the biodiesel chain. **Ciencia e Investigación Agraria**, v.42, n.2, p.285-293, 2015.

STEP, D. L.; KREHBIEL, C. R.; DEPRA, H. A.; CRANSTON, J. J.; FULTON, R. W.; KIRKPATRICK, J. G.; GILL, D. R.; PAYTON, M. E.; MONTELONGO, M. A.; CONFER, A. W. Effects of commingling beef calves from different sources and

weaning protocols during a forty-two-day receiving period on performance and bovine respiratory disease. **Journal of Animal Science**, v.86, n.11, p.3146-3158, 2008.

STEVNEBØ, A.; SEPPÄLÄB, A.; HARSTADA, O.M.; HUHTANENB, P. Ruminal starch digestion characteristics *in vitro* of barley cultivars with varying amylose content. **Animal Feed Science and Technology**, v.148, n.2, p.167-182, 2009.

SUFFREDINI, A. F., FANTUZZI, G., BADOLATO, R., OPPENHEIM, J. J., & O'GRADY, N. P. New insights into the biology of the acute phase response. **Journal of clinical immunology**, v.19, p.203-214, 1999.

TANURE, S.; BAA, P.; LOBATO, J.F.P. Natural and improved natural pastures on the reproductive performance of first-calf beef cows. **Revista Brasileira de Zootecnia**, v.40, n.3, p.690-699, 2011.

THRUSFIELD, M. Veterinary epidemiology. London: Butterworths, 280p. (University of Edinburgh). 1986.

TIZARD, I. Veterinary Immunology. St. Louis, MO: **Saunders Elsevier**. 2009.

TOURLOMOUSSIS, P.; ECKERSALL, P. D.; WATERSON, M. M.; BUNCIC, S. A comparison of acute phase protein measurements and meat inspection findings in cattle. **Foodborne Pathogens Disease**, v.1, p.281–290, 2004.

TRINDER, P. Determination of Glucose in Blood Using Glucose Oxidase with an Alternative Oxygen Acceptor. **Annals of Clinical Biochemistry**, v.6, n.1, p.24-27, 1969.

USEPA. National Emissions Inventory (NEI). **US Environmental Protection Agency**, Washington, DC, 2014. Available from: <https://www.epa. gov/air-emissions-inventories/2014-national-emissions-in- ventory-nei-data> (Accessed 29 November 2017.)

VAN SOEST, P.J. **Nutritional ecology of the ruminant.** 2nd ed. (Cornell Univ. Press, Ithaca, NY). 1994.

WAGHORN, G. Condensed tannins and nutrient absorption from the small intestine. In: Rode LM, editor. **Proceedings Canadian Society of Animal Science Annual Meeting**. Canada: Lethbridge; p.175– 194, 1996.

WAGHORN, G. Beneficial and detrimental effects of dietary condensed tannins for sustainable sheep and goat production – Progress and challenges. **Animal Feed Science and Technology**, v.147, p.116−139, 2008.

WANAPAT, M.; KANG, S. Cassava chip (Manihot esculenta Crantz) as an energy source for ruminant feeding. **Animal Nutrition**, v.1, n.4, p.266-270, 2015.

WANG, Y.; MCALLISTER, T.A.; ACHARYA, S. Condensed tannins in sainfoin: composition, concentration, and effects on nutritive and feeding value of sainfoin forage. **Crop Science**, v.55, n.1, p.13-22, 2015.

WASSELL, J. Haptoglobin: Function and polymorphisms. **Clinical laboratory,** v.46, p.547–552, 2000.

WEARY, D.M.; JASPER, J.; HÖTZEL, M.J. Understanding weaning distress. **Applied Animal Behaviour Science***, v.*110, p.24-41, 2008.

WHEATLEY, C.C.; SCOTT, G.J.; BEST, R. Adding value to root and tuber crops: a manual on product development. **International center for tropical agriculture,** v.247, 264 p, 1995.

WILLIAMS, D.L.; MAHONEY, J.H. Pre-weaning and post- weaning nutrition. **In Proc. 17th *Annual Conference of the American Association of Bovine Practitioners,*** pp. 98, 1984.

WOLIN, M.J. A theoretical rumen fermentation balance. **Journal of Dairy Science**, v.43, n.10, p.1452–1459, 1960.

WOODWARD, S.L.; WAGHORN, G.C.; LABOYRIE, P. Condensed tannins in birdsfoot trefoil (Lotus corniculatus) reduced methane emissions from dairy cows. **Proceedings of the New Zealand Society of Animal Production**, v.64, p.160–164, 2004.

YANG, K.; WEI, C.; ZHAO, G.Y.; XU, Z.W.; LIN, S.X. Effects of dietary supplementing tannic acid in the ration of beef cattle on rumen fermentation, methane emission, microbial flora and nutrient digestibility. **Journal of Animal Physiology and Animal Nutrition (Berl)**, v.101, n.2, p.302-310, 2017.

YANG, W.Z.; BEAUCHEMIN, K.A.; VEDRES, D.D.; GHORBANI, G.R.; COLOMBATTO, D.; MORGAVI, D.P. Effects of direct-fed microbial supplementation on ruminal acidosis, digestibility, and bacterial protein synthesis in continuous culture. **Animal Feed Science and Technology**, v.114, n.1-4, p.179-193, 2004.

YOON, I.K.; STERN, M.D. Influence of directfed microbials on ruminal microbial fermentation and performance of ruminants: a review. **Asian Australasian Journal Animal Science**, v.8, p.533–555, 1995.

ZINN, R.A.; CALDERON, J.F.; CORONA. L.; PLASCENCIA, A.; MONTAÑO, M.F.; TORRENTERA, N. Phase feeding strategies to meet metabolizable amino acid requeriments of calf-fed Holstein steers. **The Professional Animal Scientist**, v.23, p.33–39, 2007.

ZUCKER, W.V. Tannins: does structure determine function? An ecological perspective. **The American Naturalists**, v.121, p.335-365, 1983.