UNIVERSIDADE FEDERAL DE PELOTAS
Faculdade de Agronomia Eliseu Maciel
Programa de Pós-Graduação em Zootecnia

Dissertação

Uso da farinha de batata doce em substituição ao milho como concentrado energético para ruminantes

Marilisa Mibach

Pelotas, 2019

Marilisa Mibach

Uso da farinha de batata doce em substituição ao milho como concentrado energético para ruminantes.

Dissertação 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 Mestre em Ciências.

Orientador: Prof. Dr. Cássio Cassal Brauner

Co-orientador: Prof. Dr. Gilberto Vilmar Kozloski

Pelotas, 2019

Universidade Federal de Pelotas / Sistema de Bibliotecas
Catalogação na Publicação

M618u Mibach, Marilisa

Uso da farinha de batata doce em substituição ao milho como concentrado energético para ruminantes / Marilisa Mibach ; Cássio Cassal Brauner, orientador ; Gilberto Vilmar Kozloski, coorientador. — Pelotas, 2019.

43 f. : il.

Dissertação (Mestrado) — Programa de Pós-Graduação em Zootecnia, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas, 2019.

1. Alimentos alternativos. 2. Carboidratos. 3. Ruminantes. I. Brauner, Cássio Cassal, orient. II. Kozloski, Gilberto Vilmar, coorient. III. Título.

CDD : 636.20852

Elaborada por Gabriela Machado Lopes CRB: 10/1842

Marilisa Mibach

Uso da farinha de batata doce em substituição ao milho como concentrado energético para ruminantes.

Dissertação aprovada como requisito parcial para obtenção do grau de Mestre em Ciências, Programa de Pós-Graduação em Zootecnia, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas.

Data da Defesa:21/02/2019

Banca examinadora:

Prof. Dr. Cássio Cassal Brauner (Orientador)
Doutor em Zootecnia pela Universidade Federal de Pelotas.

Profa. Dra. Viviane Rohrig Rabassa
Doutora em Veterinária pela Universidade Federal de Pelotas.

Profa. Dra. Carla Jóice Härter
Doutora em Zootecnia pela Universidade Estadual Paulista Júlio de Mesquita Filho.

Prof. Dr. Vinicius Coitinho Tabeleão
Doutor em Biotecnologia pela Universidade Federal de Pelotas.

Agradecimentos

Aos meus pais, Darcisio e Eunice, minha eterna gratidão por tudo que sou e tudo que fazem por mim.

À minha irmã Darciele e meu cunhado José Luis, obrigada pelo apoio, parceria e afeto.

Aos amigos de Lages, por me darem a certeza que sempre terei pra onde voltar.

Aos colegas do NUPEEC pela amizade e convivência nesses dois anos, em especial à Cláudia cuja ajuda foi fundamental para a realização deste trabalho.

Aos colegas da UFSM, em especial à Flaiane e ao Claudio, pela ajuda incansável no manejo dos animais, nas análises e nos dados.

À Dra. Carla Härter pela ajuda preciosa com a estatística.

Ao Dr. Gilberto Kozloski por ter gentilmente aberto as portas do Labrumen, e por toda a orientação ao longo do experimento.

Aos meus orientadores daUFPel, em especial ao Dr. Cássio Brauner pela compreensão e paciência.

Ao senhor Paulo Learsi e à Cooperativa Sicredi pelo financiamento do projeto e pela confiança no nosso trabalho.

Ao CNPq pela bolsa concedida.

A todos que contribuíram na minha jornada acadêmica, e aos que me ajudaram na execução deste trabalho, minha gratidão!

“Nada conclusivo tomou lugar no mundo, a última palavra do mundo e sobre o mundo ainda não foi dita, o mundo é aberto e livre, tudo ainda está no futuro e sempre estará”

Mikhail Bakhtin

Resumo

MIBACH, Marilisa. **Uso da farinha de batata doce em substituição ao milho como concentrado energético para ruminantes.**2019. 42f. Dissertação (Mestrado em Ciências) - Programa de Pós-Graduação em Zootecnia, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas, Pelotas, 2019.

A utilização de carboidratos não fibrosos como o amido na dieta de ruminantes é uma estratégia amplamente usada para aumentar a energia ingerida e produtividade destes animais. O milho é uma das fontes de amido mais utilizadas nas dietas, mas por diversos fatores, são necessárias fontes alternativas de energia em substituição a este alimento. Dentre os alimentos potencialmente utilizáveis na alimentação animal encontra-se a batata doce, um alimento rico em amido, e com taxa de degradação ruminal maior que a do milho. O objetivo deste estudo foi avaliar os efeitos de diferentes níveis de substituição do milho moído pela farinha de batata doce, sobre a ingestão, digestibilidade, síntese de proteína microbiana e retenção do N em ovinos recebendo dietas mistas à base de silagem de milho. Para isso, foram utilizados 8 ovinos machos castrados, mantidos em gaiolas metabólicas, divididos em 4 grupos. O delineamento experimental utilizado foi o Quadrado Latino, totalizando 4 períodos de 15 dias cada, sendo os 10 primeiros dias destinados à adaptação e os 5 últimos dias para coletas de amostras. As dietas foram calculadas de modo a atender a oferta de matéria seca em 3% do peso vivo. Os animais receberam proporções fixas de feno de aveia, silagem de milho e farelo de soja. A composição do concentrado energético variava nos grupos experimentais. O primeiro grupo recebeu apenas o milho moído como concentrado energético, enquanto os demais grupos receberam diferentes níveis de inclusão de farinha de batata doce (FBD) em substituição ao milho moído, nas proporções de 33%, 66% e 100% de FBD. Foi adicionada ureia para que as dietas se mantivessem isonitrogenadas. Foram realizadas coletas dos alimentos e das sobras para avaliação do consumo e análise bromatológica. A urina foi coletada para avaliação da síntese de proteína microbiana através dos derivados de purina. As fezes foram coletadas para análises e estimativa da digestibilidade. Houve uma tendência de aumento linear (P=0,07) no consumo de nitrogênio e uma redução linear no consumo de FDN com o aumento da inclusão de farinha de batata doce na dieta. Não houve diferença (P>0,05) na produção de proteína microbiana, excreção e retenção de nitrogênio e na digestibilidade dos componentes da matéria seca. A inclusão da farinha de batata doce não provocou alterações na ingestão, digestibilidade e metabolismo protéico dos animais, sugerindo que esta pode ser usada em substituição ao milho moído sem restrições, desde que se adicione ureia.

Palavras-chave: metabolismo; nutrição; ruminantes.

Abstract

MIBACH, Marilisa. **Use of sweet potato flour as a replacement for corn as an energetic concentrate for ruminants.** 2019. 42f.Dissertation (Master degree in Sciences) - Programa de Pós-Graduação em Zootecnia, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas, Pelotas, 2019.

The use of non-fiber carbohydrates such as starch in the ruminant diet is a strategy widely used to increase the energy intake and productivity of these animals. Corn is one of the most used starch sources in diets, but due to several factors, alternative energy sources are needed to replace this feed. However, changing the carbohydrate source may promote changes in the animal's metabolism. The objective of this study was to evaluate the effects of different levels of substitution of corn ground by sweet potato flour on intake, digestibility, microbial protein synthesis and N retention in sheep fed mixed diets based on corn silage. For this, eight castrated male sheep were used, kept in metabolic cages, divided into 4 groups. The experimental design used was the 4X4 Latin Square, totalizing 4 periods of 15 days each, wherein the first 10 days was for adaptation and the last 5 days for sample collection. The diets were calculated in order to meet the dry matter supply at 3% of body weight. The animals received fixed proportions of oat hay, corn silage and soybean meal. The composition of the energetic concentrate varied in the experimental groups. The first group received only ground corn as an energetic concentrate, while the other groups received different levels of inclusion of sweet potato flour (SPF) to replace ground corn, in the proportions of 33%, 66% and 100% of SPF. Urea was added so that the diets remained isonitrogenated. Food and orts samples were collected for consumption evaluation and bromatological analysis. Urine was collected for evaluation of microbial protein synthesis through the purine derivatives. Feces were collected for analysis and estimation of digestibility. According to the results, there was a trend of linear increase in nitrogen consumption ($P = 0.03$) and a linear reduction in NDF consumption ($P<0.001$) with the increase of inclusion of sweet potato flour in the diet. There was no statistical difference in the production of microbial protein, nitrogen excretion and retention and digestibility of dry matter components ($P> 0.05$). The inclusion of sweet potato flour did not cause changes in the protein metabolism of the animals, suggesting that it can be used instead of ground corn without restrictions, provided urea is added.

Key words: metabolism; nutrition; ruminant.

Lista de Figuras

Lista de Tabelas

Sumário

1 Introdução

Com a expansão dos sistemas de produção animal e a necessidade de desempenho cada vez maior, buscando maior produtividade, a nutrição de ruminantes tem se mostrado como um processo complexo e desafiador. Ruminantes são animais com sistema digestivo especializado na digestão de fibra, mas em termos de ganho de peso e desempenho, os carboidratos não estruturais, como o amido, são os maiores aliados dos nutricionistas. Sua utilização já virou uma realidade nos sistemas de produção, mas o uso exagerado destes alimentos pode causar distúrbios metabólicos. Portanto, manter o equilíbrio entre saúde animal e máxima produtividade pode ser bastante difícil em determinadas situações. A suplementação dietética com carboidratos não fibrosos (CNF) para ruminantes tornou-se uma realidade e se configura em uma estratégia bastante efetiva no que diz respeito à necessidade de atender ao requerimento energético de mantença e a máxima produtividade no sistema (CATON e DHUYVETTER, 1997).

O CNF mais utilizado na nutrição de ruminantes é o amido de diferentes fontes. Juntamente com a cevada e o trigo, uma das fontes de amido mais utilizadas nos sistemas de produção é o milho (DECKARDT et al., 2013) em suas diferentes apresentações (moído, grão inteiro, grão úmido). Tendo em vista a expansão da população mundial e o consequente aumento na demanda por alimentos, é necessário que se busque novas alternativas para a alimentação animal, dando-se preferência por alimentos que não sejam destinados ao consumo humano. Reduzir o uso do milho na alimentação de ruminantes pode favorecer os sistemas de produção de suínos e aves, que são essencialmente dependentes deste grão. Além disto, o milho também poderá ser destinado em maior quantidade à alimentação humana e à produção de combustíveis renováveis.

Dentre os alimentos ricos em amido com potencial de substituição das fontes de energia convencionalmente usadas nas dietas de ruminantes, encontra-se a batata doce (*Ipomoea batatas*). Em especial, busca-se a utilização da batata doce que não é direcionada para o mercado humano devido a alterações no formato, coloração ou tamanho. Esta batata doce que permanece sobre o solo se decompõe e desenvolve fungos que inutilizam a área para culturas futuras. Portanto, a utilização deste tubérculo na alimentação de ruminantes ainda pode contribuir com a preservação do solo.

A batata doce é um tubérculo amplamente cultivado e consumido no mundo todo. É considerada uma cultura rústica pois é resistente a várias pragas e se desenvolve em solos degradados. Não é exigente em água e, portanto, se desenvolve bem em climas secos. Além destas características, ainda possui ciclo relativamente rápido, tem baixo custo de produção pois exige menos fertilização, possui ampla janela de colheita e é protetora do solo, podendo ser usada para controle da erosão. De acordo com VELARDE et al. (2015), 95% da batata doce produzida no mundo é oriunda de países em desenvolvimento, tornando este vegetal um importante aliado no desenvolvimento econômico e social dos países emergentes.

Segundo a FAO (2017) o Brasil produz anualmente cerca de 770 mil toneladas de batata doce, sendo a região Sul do país a responsável por mais da metade deste total. Apesar disto, ao comparar-se a produção brasileira com a de outros países, pode-se perceber que o cultivo desta hortaliça ainda é pouco expressivo. O total produzido no Brasil corresponde a apenas 0,5% da produção da China, maior produtora de batata doce do mundo.

Alguns fatores podem ser considerados determinantes para a baixa produção nacional. Entre eles, o fato de a batata doce não ter potencial para exportação, o que implica em baixa tecnificação e investimentos, tornando-se uma cultura marginalizada por parte do produtor. Portanto, uma saída para estimular a produção seria utilizar esta hortaliça na alimentação animal. Esta alternativa ainda possibilitaria o aproveitamento de uma parte da lavoura que acaba não sendo destinada ao consumo humano por não se encaixar nos padrões aceitos pelo consumidor.

Nos últimos anos, o que se tem pesquisado sobre a batata doce na alimentação animal é a produção e utilização de silagem das ramas (KHALID et al., 2013; PEDROSA et al., 2015).Ainda, na área de nutrição de monogástricos, alguns autores utilizaram a batata doce na alimentação de suínos (DOM et al., 2017) e aves (DERVAN e DEREK, 2017; PANDI et al., 2018). Com relação ao uso da batata doce como concentrado energético na dieta de ruminantes, tem-se poucos dados descritos na literatura. Um deles é descrito por FRYE et al. (1948), que utilizaram a batata doce desidratada em substituição ao milho moído na ração de vacas leiteiras. Durante este período, houve mudanças tanto no cultivo da batata doce e do milho quanto na produção de ruminantes, demonstrando a necessidade de estudos mais atualizados para que se possa fazer a inclusão da batata doce nas dietas com segurança.

Do ponto de vista econômico, a substituição do milho pela batata doce na alimentação de ruminantes seria viável e até vantajosa em épocas de alto custo do milho. Na safra 2015/2016, a ocorrência do fenômeno climático El Niño desencadeou uma quebra de 10% na produção e altas de até 65% no custo da saca de 60 kg de milho, o que praticamente impossibilitou o uso do grão na alimentação animal. Vale ainda destacar que no caso de cultivo de milho duplo-propósito (grão e silagem), a redução do uso do milho como concentrado possibilita ao produtor destinar uma maior quantidade do grão para a produção de silagem.

Ainda que seja viável economicamente, para que possam ser realizadas alterações nas dietas, são necessários estudos prévios, sob pena de queda na produção por alteração da digestibilidade total, da retenção de nitrogênio e síntese de proteína microbiana ruminal ou até mesmo por distúrbios metabólicos.

O amido, principal representante dos CNF, é um polissacarídeo de reserva das plantas composto por dois tipos de moléculas: amilose e amilopectina (SANTANA e MEIRELES, 2014). A amilose é um polímero não ramificado de glicose, composto por ligações α-1,4, enquanto que a amilopectina é altamente ramificada, com ligações α-1,6 nos pontos de ramificação (KOZLOSKI, 2011). Amilose e amilopectina são hidrolisadas por amilases bacterianas, e sofrem degradações contínuas até formarem monossacarídeos que serão capazes de entrar na célula bacteriana para gerar piruvato. Entretanto, a taxa de degradação não é igual para esses dois polissacarídeos. A amilopectina é mais solúvel e tem maior degradabilidade que a amilose (KOZLOSKI, 2011).

Em geral, aproximadamente 30% do amido é formado por amilose, enquanto os outros 70% por amilopectina (GÓMEZ et al., 2016). Entretanto, estes teores podem variar entre as diferentes fontes de amido, causando diferenças nas taxas de degradação do amido. A taxa de degradação dos carboidratos tem grande influência na síntese de proteína microbiana ruminal (HOOVER e STOKES, 1991; CANTALAPIEDRA-HIJAR et al., 2014). A síntese de proteína microbiana pode sofrer decréscimos com o aumento da inclusão de CNF altamente degradáveis devido à queda no pH ruminal (NRC, 1996), mas também tem prejuízos quando são incluídas altas taxas de forragem de baixa qualidade, devido à baixa degradação dos carboidratos (UDDIN et al., 2015). Portanto, os efeitos da composição da dieta podem ser controversos, pois dependem principalmente das fontes de fibra e energia utilizadas na dieta (MOORE et al., 1999).

O milho e a batata doce possuem teores semelhantes de amido - 70% vs. 75%, respectivamente. O amido do milho é formado por 30% de amilose e 70% de amilopectina, enquanto que o amido da batata doce possui 28% de amilose e 72% de amilopectina. Apesar de semelhantes entre si, ensaios *in vitro* realizados previamente confirmaram uma diferença na taxa de degradação ruminal destes alimentos, sendo 6%/h para o milho moído e 7,4%/h para a farinha de batata doce. Sabe-se que alterações nas taxas de degradação ruminal dos alimentos podem acarretar em diferenças no metabolismo, mas existem poucas informações acerca da possibilidade de inclusão de batata doce na forma de farinha na alimentação dos ruminantes. Nesse sentido, tornou-se necessário determinar os efeitos da substituição do milho moído pela farinha de batata doce sobre a ingestão, digestibilidade, síntese de proteína microbiana e retenção do N.

2 Objetivos

2.1 Objetivo Geral

Determinar a possibilidade de inclusão da farinha de batata doce na dieta de ruminantes.

Avaliar a digestibilidade da farinha de batata doce e seus efeitos sobre o metabolismo animal.

2.2 Objetivos Específicos

Avaliar os efeitos de diferentes níveis de substituição do milho moído pela farinha de batata doce sobre a ingestão, digestibilidade, síntese de proteína microbiana e retenção do N em ovinos recebendo dietas mistas à base de silagem de milho.

3 Artigo

Use of sweet potato flour as a replacement for corn as an energetic concentrate in maintenance diets for lambs.

Marilisa Mibach, Cláudia Faccio Demarco, Claudio Antonio Pozo, Lisandre de Oliveira, Milena Bugoni, Márcio Nunes Corrêa, Gilberto Vilmar Kozloski, Cássio Cassal Brauner

Será submetido à revista Animal Feed Science and Technology

Use of sweet potato flour as a replacement for corn as an energetic concentrate in maintenance diets for lambs.

Marilisa Mibach[a], Cláudia Faccio Demarco[a], Claudio Antonio Pozo[b], Lisandre de Oliveira[a], Milena Bugoni[a], Marcio Nunes Corrêa[a], Gilberto Vilmar Kozloski[b], Cássio CassalBrauner[a*]

[a]*Federal University of Pelotas, Pelotas, RS 96010-000, Brazil.*

[b]*Federal University of Santa Maria, Santa Maria, RS 97105-900, Brazil.*

*Corresponding author: Department of Animal Science, Federal University of Pelotas, Pelotas, RS 96010-000, Brazil. E-mail address: cassiocb@gmail.com (C.C. Brauner)

*Abbreviations:*BW, body weight; CP, crude protein; DM, dry matter; EMPS, efficiency of microbial protein synthesis; ENU, Efficiency of N use for microbial protein synthesis; HOT, hepaticoxidation theory; N, total Nitrogen; NDF, neutral detergent fiber; NFC, non-fiber carbohydrates; OM, organic matter; PD, purine derivatives ; SPF, sweet potato flour; TMR, total mixed ration.

ABSTRACT

The use of non-fiber carbohydrates such as starch in the ruminant diet is a strategy widely used to increase the energy intake and productivity of these animals. Corn is one of the most used sources of starch in diets, but due to several factors, alternative energy sources are needed to replace this food. However, changing the carbohydrate source may promote changes in the animal's metabolism. The objective of this study was to evaluate the effects of different levels of substitution of corn ground by sweet potato flour on intake, digestibility, microbial protein synthesis and N retention in sheep fed mixed diets based on corn silage. For this, eight castrated male sheep were used, kept in metabolic cages, divided into 4 groups. The experimental design used was the 4X4 Latin Square, totalizing 4 periods of 15 days each, wherein the first 10 days was for adaptation and the last 5 days for sample collection. The animals received fixed proportions of oat hay, corn silage and soybean meal. The composition of the energetic concentrate varied in the experimental groups. Groups were divided in 0, 33, 66 and 100% of ground corn substitution by sweet potato flour. Urea was added so that the diets remained isonitrogenated. Food and orts samples were collected for consumption evaluation and bromatological analysis. Urine was collected for evaluation of microbial protein synthesis through the purine derivatives. Feces were collected for analysis and estimation of digestibility. According to the results, there was a trend of linear increase in nitrogen consumption ($P=0.07$) and a linear reduction in NDF consumption ($P<0.001$) with the increase of inclusion of sweet potato flour in the diet. There was no statistical difference in the production of microbial protein, nitrogen excretion and retention and digestibility of dry matter components ($P> 0.05$). The inclusion of sweet potato flour did not cause changes in the protein metabolism of the animals, suggesting that it can be used instead of ground corn without restrictions, provided urea is added.

Keywords: alternative feed, carbohydrate, ruminant.

1. Introduction

Supplementation with non-fiber carbohydrates (NFC) in ruminant diets is often used to achieve energy requirement for maintenance and even the highest productivity (Caton and Dhuyvetter, 1997). The effects of this strategy may be contradictory, as they depend, mostly, on fiber and energy sources used in the diet (Moore et al., 1999). Even the exchange between NFC sources may cause significant differences in digestibility and even metabolical disorders, inducing economic loss due to low animal production.

Starch is the most used NFC in ruminant nutrition. Starch is a polysaccharide found in different types of plants, and it is composed of two types of molecules: amylose and amylopectin (Santana and Meireles, 2014). In general, nearly 30% of starch it is formed by amylose, while the other 70% is amylopectin (Gómez et al., 2016). However, this content may vary between starch sources, which can cause differences in metabolic products. Cantalapiedra-Hijar et al. (2014) affirm that carbohydrate composition may change the use of N by the animal, even when N and energy intakes remains constant.

Along with barley and wheat, corn is one of the most used sources of starch in livestock systems (Deckardt et al., 2013) in its different presentations (ground grain, whole grain, and moisture grain). Passetti et al. (2016) conducted a study in Brazilian intensive system farms and related that all of them use corn silage and/or ground corn on cows diets. In view of the constant increase in world population and the consequent increase in demand for food, it has become necessary searching for new alternatives for animal nutrition, aiming alternative types of food that are not destinated for human consumption.

Among feed that might be possibly used in ruminant diets, is sweet potato (*Ipomoea batatas*), a tuber that is rich in starch. In particular, seeks out the utilization of sweet potato tillage that is not destinated for the human market, and remains over the soil after harvest, which might develop fungus and damage the soil. Therefore, this sweet potato byproduct could be a potential feedstuff to ruminants.

Corn and sweet potato have similar content of starch – 70% vs. 75%, respectively. Corn starch is formed by 30% of amylose and 70% of amylopectin, while sweet potato starch is formed by 28% of amylose and 72% of amylopectin. Although similar to each other, an *in vitro* assay previously conducted by our laboratory (data not published yet), confirmed a difference in ruminal degradation rate between these types of starch, being 6%/hour for corn and 7.4%/hour for sweet potato flour. It is known that changes in ruminal degradation rate can cause differences in metabolism, total tract digestibility and in nitrogen utilization by the animal. However, there is a lack of information about the possibility of inclusion of sweet potato flour in ruminant feeding.

Thus, the aim of this study was to evaluate the effects of different levels of substitution of ground corn by sweet potato flour on intake, digestibility, microbial protein synthesis and nitrogen retention in sheep receiving mixed diets based on corn silage.

2. Material and methods

The experiment was conducted at the Federal University of Santa Maria, Santa Maria, Rio Grande do Sul, Brazil. All the procedures were approved by the Ethics Committee on Animal Experimentation of Federal University of Pelotas, under the number 3255.

2.1. Animals and experimental design

A digestibility trial was conducted using eight crossbreed Corriedale lambs (19.4 $\pm$ 3.6 kg body weight (BW)), with ages between 10 and 12 months, in a 4 X 4 Latin Square design. The experimental periods were composed by 15 days, in which 10 of them were for adaptation and the last 5 days for samples collection. Lambs were kept in metabolical cages, receiving water *ad libitum*. Initially, animals were submitted to an 18-day period for gradual inclusion of concentrate feedstuff in the diet.

2.2. Experimental feeds

Diets were calculated individually, in order to meet the daily supply of dry matter (DM) at 3% of BW. Total diet was divided into 3 portions, offered at 8:30 a.m., 1 p.m. and 5 p.m. Total mixed ration (TMR) was composed by fixed proportions of oat hay, corn silage, and soybean meal (Table 2). Concentrate feedstuff varied in the different treatments. Control group (0% SPF) received only ground corn as an energetic concentrate, while treatment groups received different inclusion of sweet potato flour (SPF), in replacement of ground corn

(33%, 66% and 100% SPF). Urea was added in order to keep diets isonitrogenated. All diets were isoenergetic. In Table 2 is demonstrated proportions of the ingredients and the chemical composition in different treatments.

2.3. Sample collection

All collections were made in the morning period, before the first meal of the day. Corn silage and oat hay samples were collected at first and last day of each collection period. Offered soybean meal, ground corn, and sweet potato flour were collected once at each collection period. The orts were weighed once a day, in every day of the experiment, for consumption measurements. Samples of feedstuffs and orts were collected, dried at 55ºC for 72 hours, and stored until further analysis.

Urine was collected daily during the collection period, in buckets containing 100 mL of 7.2N H_2SO_4. Volume was measured, and a sample of 10 mL diluted in 40 mL of distilled water was stored frozen, until later analysis. At the end of the experiment, one pool by animal by period was composed, with a proportional amount of excreted urine in each day of collection.

Total excreted feces were collected everyday of collection period and stored frozen in identified buckets. At the end of the collection period, the total amount was weighed and recorded. Total excreted feces were homogenized manually, and two samples of 300g each were separated, dried at 55ºC for 72 hours, and stored until analysis.

2.4. Chemical Analysis

Samples of offered feed, orts and feces were analyzed for dry matter (DM), ash, organic matter (OM), total Nitrogen (N) and neutral detergent fiber (NDF). DM was determined by drying at 105ºC for 24 hours. Ash was determined by combusting at 600ºC for 4 hours. OM was determined by the mass difference between DM and ash. Total N was assayed by Kjeldahl method (method 984.13; AOAC (1997)). NDF content was determined based on the procedures described by Mertens (2002), with use of heat-stable α-amylase, excepted that the samples were weighed into polyester filter bags (porosity of 16 µm), and treated with neutral detergent in an autoclave at 110ºC for 40 minutes (Senger et al., 2008).

Total N of urine samples was determined by the same method previously described for feeds and orts (method 984.13; AOAC (1997)). Purine derivatives (allantoin and uric acid) in urine were determined according to Chen and Gomes (1992). Uric acid was determined using a commercial kit (LABTEST, Lagoa Santa, MG, Brazil), after xanthine and hypoxanthine were converted to uric acid with xanthine oxidase. Thus, the uric acid values were the sum of uric acid, xanthine and hypoxanthine and the total purine derivatives (PD) were the sum of uric acid and allantoin.

2.5. Calculations

Intake of compounds (DM, ash, OM, N, andNDF) was calculated my mass difference between offered feed and orts. Apparent digestibility of compounds was calculated as {[intake (g/d)] – excretion (g/d)] / intake (g/d)} × 100. True digestibility of OM was estimated considering that neutral detergent soluble fractions of the feces are from endogenous origin and only the NDF fraction of feces is originated from feed (Van Soest, 1994) as follows: [OM intake (g/d) – fecal NDF (g/d)] / OM intake (g/d).

The amount of absorbed purines (*X*, mmol/d) corresponding to the amount of PD excreted (*Y*, mmol/d, considering 158 mg/mmol of allantoin and 168 mg/mmol of uric acid), was calculated from the relationship derived by Chen and Gomes (1992):

$$Y=0.84X + (0.150\mathrm{LW}^{0.75}e^{-0.25\mathrm{X}})$$

where LW is live weight. The calculation of *X* based on the value of *Y* was made using the iterative process of Newton–Raphson as:

$$X_{(n+1)} = X_n - [((0.84X+(0.150\mathrm{LW}^{0.75}\mathrm{e}^{-0.25X})) - Y) / (0.84-(0.038\mathrm{LW}^{0.75}\mathrm{e}^{-0.25x}))].$$

The supply of microbial N (Nm) was estimated as:

$$Nm\ (g/d) = 70X / (0.116 \times 0.83 \times 1000) = 0.727X$$

assuming a digestibility of the microbial purines of 0.83, an N content in the purines of 70 mg/mmol and a ratio of purine N/microbial N of 0.116 (Chen and Gomes, 1992).

The efficiency of microbial protein synthesis was calculated by the relation between microbial N produced and OM ingested. The efficiency of N use for microbial protein synthesis was considered as the relation between produced microbial N and N ingested.

The N retention was calculated by the difference between N ingested and N excreted. The efficiency of N use by the animal was determined by the relation between N retained and N ingested.

2.6. Statistical analysis

Data were analyzed using the MIXED procedure of SAS software (2009), according to the model:

$$Y_{ijk} = \mu + A_i + P_j + T_k + e_{ijk}$$

where Y_{ijkl} = dependent variable; μ = mean of observations; A_i = random effect of animals; P_j = random effect of experimental periods; T_k = fixed effects of treatments; e_{ijk} = residual error. The effects of inclusion level of sweet potato flour on TMR was tested by orthogonal polynomial contrast (Steel and Torrie, 1980), considering linear and quadratic effects. Data are presented as adjusted means (LSMEANS). P-values $\leq$ 0.05 are considered significant and P-values $\leq$ 0.10 are considered as a tendency.

3. Results

3.1. Intake and digestibility

There was a treatment effect (P <0.05) on NDF intake (Table 3). The 0% and 33% groups had lower NDF intake than the 66% and 100% groups. In addition, there was a linear effect (P <0.001) according to the increase of the inclusion of SPF, was observed a decreased in NDF intake.

There was a trend (P =0.07) of effect of treatments on CP intake, with a significant linear effect (P =0.03).Dry matter (DM) and organic matter (OM) intake remained constant in both treatments (P =0.62 and P =0.32, respectively). Apparent digestibility of DM (P =0.94), OM (P =0.91), CP (P =0.38), NDF (P =0.34), as well as true digestibility of OM (P =0.36) did not present differences by increasing sweet potato flour inclusion on TMR.

3.2. N retention and efficiency of N use by the animal

There was a trend (P = 0.07) for treatment effects in N intake (Table 4), with a significant linear effect (P = 0.03). The other parameters (N excretion, retention and efficiency) were not affected (P > 0.05) by the treatments.

3.3. Microbial protein synthesis, efficiency of microbial protein synthesis and efficiency of N use for microbial protein synthesis

Microbial protein synthesis did not present any differences (P >0.05) between treatments (Table 5), as well as the efficiency of microbial protein synthesis (P =0.98) and the efficiency of N use for microbial protein synthesis (P =0.95).

4. Discussion

Results confirm the hypothesis that sweet potato flour can replace ground corn at any level, without compromising digestibility or proteic metabolism, if it is included urea or another nitrogen source capable of supply the protein difference between corn and sweet potato.

Considering the differences in the ruminal degradation rate of corn and sweet potato flour, it would be expected alterations in NDF digestibility. However, this study did not confirm any changes in this parameter, suggesting that there were no major changes in ruminal pH, even at the highest level of sweet potato flour inclusion. It is known that the inclusion of highly degradable carbohydrates in the diet can lead to a decrease in ruminal pH, and its consequent decrease in the fibrous fraction of the diet. A decrease in fiber digestibility may be caused by reduced microbial adhesion to particles or by fibrolytic bacteria death due to acid accumulation in intracellular medium (Russell and Wilson, 1996). When ruminal pH is below 6, fibrolytic activity becomes insignificant (Hu et al., 2005). Luo et al. (2017) found a significant decrease in NDF digestibility in animals fed with carbohydrates highly degradable on rumen. Thus, concentrate fraction of the diet presents an important role in rumen environment and, by consequence, in digestibility.

In the present study, although there was not observed any changes in NDF digestibility in the lambs supplemented with sweet potato flour, there was a linear decrease in NDF intake by increasing sweet potato flour inclusion in the diet (Fig. 1). NFC supplementation is considered a good strategy to increase energy intake. However, Johnson (1976) reports that this type of management may promote competition between amylolytic and fibrolytic bacteria, mainly by N. In this case, cellulolytic bacteria with slower growth would be prejudiced, which may reduce fiber digestibility and, by consequence, fiber intake too. In fact, Kozloski et al. (2006), working with lambs receiving dwarf elephant grass hay (*Pennisetum purpureum* Schum. cv. Mott) and supplemented with different levels of corn grain observed a substitution in hay intake in the greater energetic inclusions. In this case, the authors associated the decrease in NDF intake with the decreased fiber digestibility.

Another possible explanation for the decrease in fiber intake by increasing highly degradable NFC intake can be found at the work published by Allen (2000), about hepatic oxidation theory. According to the author, propionate generated in the rumen is directly associated to intake control. The propionate that is oxidated in the liver would act in satiety center in a most effective way than another volatile fatty acid, like acetate for example. Thus, in those lambs that received higher amounts of sweet potato flour, may be occurred a higher production of propionate when compared to those who received only ground corn as an energetic concentrate. This may have favored satiety center activation. Therefore, they opted for ingesting firstly the most palatable feed (energetic and proteic concentrate), leaving part of oat hay untouched.

A higher starch degradability in the rumen is also associated to a higher DM total tract digestibility (Larsen et al., 2009) since this feed could increase bacteria growth stimulating digestive processes due to a higher bacterial increment (Hiltner and Dehority, 1983). However, this premiss was not confirmed by the present study. Even on the highest inclusion levels of sweet potato flour, DM apparent digestibility did not change, remaining within the expected values for diets composed of fiber:concentrate ratio of 60:40. CP apparent digestibility and OM true digestibility followed the same tendency and kept similar among treatments.

Rumen degradability of CP is highly dependent on ruminal pH and the type of feed that makes up the diet (Bach et al., 2005). Although amylolytic bacteria have higher proteolytic activity than cellulolytic bacteria (Wu et al., 2006; Ramos et al., 2009), it seems that the higher bacterial increment caused by the inclusion of more degradable carbohydrates may limit the amount of N available for microbial protein synthesis. This may explain the tendency of linear increase on CP intake presented by the animals of this study (Fig. 2). Because they had a higher need of CP, they chose to eat firstly the concentrate feedstuff. This perception also explains the decrease in NDF intake and the stability of microbial protein synthesis (Table 5).

Microbial protein synthesis in the rumen is dependent on the availability of degradable protein and carbohydrates (Chumpawadee et al., 2006), and the magnitude of this process is influenced by the synchronicity between nitrogen source degradability and energy source degradability (Gehman et al., 2006). Although we have had raised starch ruminal degradation rate with sweet potato flour and raised N ruminal degradation rate with urea, there were no differences in microbial protein synthesis. This may have occurred because diets were keptisoenergetics, and urea inclusion allowed that degradation rates of energy and N sources remained in a constant ratio among treatments.

The efficiency of microbial protein synthesis (EMPS) is influenced by several factors as diet composition, rumen pH and species of bacteria in the rumen (Caton et al., 1993). EMPS values found in this study are considerably lower than those found by (Pathak, 2008), which reports values of 28 g of N produced per 1 kg of degradable OM ingested in animals receiving mixed diets. Although it is a widely used concept, EMPS do not estimate how many units of N the bacteria are able to capture per unit of available energy in the rumen (Bach et al., 2005). As an alternative, values of the efficiency of N use for microbial protein synthesis (ENU) may be used. Bach et al.(2005)affirm that microbial protein synthesis is optimal when EMPS is 29 g of microbial N produced per 1 kg of degradable OM ingested, and the ENU is 69%. Although the values found by the present work are out of the ideal reported by cited authors (mean EMPS = 18.4 and mean ENU = 44%), the absence of significant differences among the treatments suggests that ground corn replacement by sweet potato flour can be made without any prejudice to the animal proteic metabolism.

Broderick (2003) using lactating cows fed with crescent levels of crude protein, found a linear increase in fecal and urinary N excretion, related to a linear increase in CP intake. Tamminga (1996)relates that manipulate efficiency of N use by the animal is an important strategy to reduce N losses. In the present study, although CP intake has increased linearly with increasing levels of sweet potato flour, there was no increase in fecal and urinary N excretion. This result suggests a decent efficiency of N use by the animal and confirms environmental benefits of sweet potato flour use since excreted N by the animals is one of the factors that are responsible for air and soil contamination (Varel et al., 1999).

5. Conclusions

Ground corn replacement by sweet potato flour on sheep receiving mixed diets can be done at any level without compromising DM intake and digestibility, microbial protein synthesis or N retention by metabolism, if it is included urea or another nitrogen source to equalize crude protein difference between corn and sweet potato. Thus, are characterized physiological, social, economics and environmental benefits of replacement of ground corn by sweet potato flour.

Conflict of interest

The authors declare no conflict of interest related to this publication.

Acknowledgements

The authors thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Núcleo de Pesquisa, Ensino e Extensão em Pecuária (NUPEEC), Cooperativa Sicredi and Laboratório de Bromatologia de Ruminantes (Labrumen).

References

Allen, M.S., 2000. Effects of diet on short-term regulation of feed intake by lactating dairy cattle. J. Dairy Sci. 83, 1598-1624.

AOAC, 1997. Official Methods of Analysis, 17th ed., Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Bach, A., Calsamiglia, S., Stern, M.D., 2005. Nitrogen metabolism in the rumen. J. Dairy Sci. 88 (Suppl 1), 9-21.

Broderick, G.A., 2003. Effects of varying dietary protein and energy levels on the production of lactating dairy cows. J. Dairy Sci. 86, 1370-1381.

Cantalapiedra-Hijar, G., Lemosquet, S., Rodriguez-Lopez, J.M., Messad, F., Ortigues-Marty, I., 2014. Diets rich in starch increase the posthepatic availability of amino acids in dairy cows fed diets at low and normal protein levels. J. Dairy Sci. 97, 5151-5166.

Caton, J.S., Dhuyvetter, D.V., 1997. Influence of energy supplementation on grazing ruminants: requirements and responses. J. Dairy Sci. 75, 533-542.

Caton, J.S., Erickson, D.O., Carey, D.A., Ulmer, D.L., 1993. Influence of Aspergillus oryzae fermentation extract on forage intake, site of digestion, in situ degradability, and duodenal amino acid flow in steers grazing cool-season pasture. J. Dairy Sci. 71, 779-787.

Chen, X.B., Gomes, M.J., 1992. Estimation of microbial protein supply to sheep and cattle based on urinary excretion of purine derivatives- an overview of technical details. INTERNATIONAL FEED RESEARCH UNIT. Aberdeen, UK: Rowett Research Institute, 21p. (Occasional publication)

Chumpawadee, S., Sommart, K., Vongpralub, T., Pattarajinda, V., 2006. Effects of synchronizing the rate of dietary energy and nitrogen release on ruminal fermentation, microbial protein synthesis, blood urea nitrogen and nutrient digestibility in beef cattle. Asian-Aust. J. Anim. Sci. 19, 181-188.

Deckardt, K., Khol-Parisini, A., Zebeli, Q., 2013. Peculiarities of enhancing resistant starch in ruminants using chemical methods: opportunities and challenges. Nutrients 5, 1970-1988.

Gehman, A.M., Bertrand, J.A., Jenkins, T.C., Pinkerton, B.W., 2006. The effect of carbohydrate source on nitrogen capture in dairy cows on pasture. J. Dairy Sci. 89, 2659-2667.

Gómez, L.M., Posada, S.L., Olivera, M., 2016. Starch in ruminant diets: a review. Rev. Colomb. Cienc. Pec. 29, 77-90.

Hiltner, P., Dehority, B.A., 1983. Effect of soluble carbohydrates on digestion of cellulose by pure cultures of rumen bacteria. Appl. Environ. Microbiol. 46, 642-648.

Hu, Z.-H., Yu, H.-Q., Zhu, R.-F., 2005. Influence of particle size and pH on anaerobic degradation of cellulose by ruminal microbes. Int. Biodeterior. Biodegradat. 55, 233-238.

Johnson, R.R., 1976. Influence of carbohydrate solubility on non-protein nitrogen utilization in the ruminant. J. Anim. Sci. 43, 184-191.

Kozloski, G.V., Bonnecarrère Sanchez, L.M., Cadorin Jr., R.L., Reffatti, M.V., Perez Neto, D., Lima, L.D., 2006. Intake and digestion by lambs of dwarf elephant grass (pennisetum purpureum schum. cv. mott) hay or hay supplemented with urea and different levels of cracked corn grain. Anim. Feed Sci. Technol. 125, 111-122.

Larsen, M., Lund, P., Weisbjerg, M.R., Hvelplund, T., 2009. Digestion site of starch from cereals and legumes in lactating dairy cows. Anim. Feed Sci. Technol. 153, 237-248.

Luo, G., Xu, W., Yang, J., Li, Y., Zhang, L., Wang, Y., Lin, C., Zhang, Y., 2017. Effects of ruminally degradable starch levels on performance, nitrogen balance, and nutrient digestibility in dairy cows fed low corn-based starch diets. Asian-Aust. J. Anim. Sci. 30, 653-659.

Mertens, D.R., 2002. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. J. AOAC Int. 85, 1217-1240.

Moore, J.E., Brant, M.H., Kunkle, W.E., Hopkins, D.I., 1999. Effects of supplementation on voluntary forage intake, diet digestibility, and animal performance. J. Anim. Sci. 77 (Suppl 2), 122-135.

Passetti, R.A.C., Eiras, C.E., Gomes, L.C., Santos, J.F., Prado, I.N., 2016. Intensive dairy farming systems from holland and brazil: swot analyse comparison. Acta Sci., Anim. Sci. 38, 439-446.

Pathak, A.K., 2008. Various factors affecting microbial protein synthesis in the rumen. Vet. World 1, 186-189.

Ramos, S., Tejido, M.L., Martinez, M.E., Ranilla, M.J., Carro, M.D., 2009. Microbial protein synthesis, ruminal digestion, microbial populations, and nitrogen balance in sheep fed diets varying in forage-to-concentrate ratio and type of forage. J. Anim. Sci. 87, 2924-2934.

Russell, J.B., Wilson, D.B., 1996. Why are ruminal cellulolytic bacteria unable to digest cellulose at low pH? J. Dairy Sci. 79, 1503-1509.

Santana, A.L., Meireles, M.A.A., 2014. New starches are the trend for industry applications: a review. Food Public Health 4, 229-241.

Senger, C.C.D., Kozloski, G.V., Sanchez, L.M.B., Mesquita, F.R., Alves, T.P., Castagnino, D.S., 2008. Evaluation of autoclave procedures for fibre analysis in forage and concentrate feedstuffs. Anim. Feed Sci. Technol. 146, 169–174.

Tamminga, S., 1996. A review on environmental impacts of nutritional strategies in ruminants. J. Anim. Sci. 74, 3112-3124.

Van Soest, P.J., 1994. Nutritional ecology of the ruminant. 2.ed. Cornell University Press, Ithaca.

Varel, V.H., Nienaber, J.A., Freetly, H.C., 1999. Conservation of nitrogen in cattle feedlot waste with urease inhibitors. J. Anim. Sci. 77, 1162-1168.

Wu, G., Bazer, F.W., Wallace, J.M., Spencer, T.E., 2006. Board-invited review: intrauterine growth retardation: implications for the animal sciences. J. Anim. Sci. 84, 2316-2337.

Tables

Table 1

Nutritional composition of the compounds used in diets.

	Nutritional Composition[1]				
Compound	DM	OM	Ash	CP	NDF
Oathay	87.1±0.4	86.8±2.2	13.2±2.2	11.2±1.5	66.2±1.6
Corn silage	22.7±1.8	94.4±1.2	5.6±1.2	6.4±0.7	61.9±2.8
Soybean meal	88.3±2.2	89.3±3.6	10.7±3.6	49.3±7.9	23.8±7.2
Ground corn	88.1±0.8	93.2±3.5	6.8±3.5	11.8±3.1	19.6±2.6
Sweet potato flour	90.6±1.8	96.5±0.8	3.6±0.8	7.5±0.5	8.5±3.4

[1]Nutritional composition: values in % of DM ± standard deviation. Values are presented as mean values of experimental periods. DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber.

Table 2

Ingredient proportions and chemical composition of experimental diets.

Item	Treatments[1]				SD
	0%	33%	66%	100%	
Ingredients (% of DM)					
Oathay	21	21	21	21	-
Corn silage	21	21	21	21	-
Soybeanmeal	18	18	18	18	-
Ground corn	40	27	13	-	-
Sweet potato flour	-	13	27	40	-
Urea	-	0.14	0.26	0.39	-
Chemical composition					
DM (%)	73.83	74.10	74.50	74.88	0.33
Ash (% of DM)	7.93	7.58	7.18	6.93	1.24
OM (% of DM)	92.08	92.43	92.83	93.08	1.24
NDF (% of DM)	39.88	38.33	36.70	35.20	1.22
CP (% of DM)	17.18	16.93	16.25	16.30	1.83

[1]Treatments: replacement levels of ground corn by sweet potato flour as an energetic concentrate. DM: dry matter; OM: organic matter; NDF: neutral detergent fiber; CP: crude protein; SD: standard deviation.

Table 3

Intake, total tract digestibility of dry matter (DM), organic matter (OM), crude protein (CP) and neutral detergent fiber (NDF) in sheep receiving different replacement levels of ground corn by sweet potato flour as energetic concentrate. P-value $\leq$ 0.05 are considered significant and P-value $\leq$ 0.10 are considered as a tendency.

Item	Treatments[1]				SEM	P-value		
	0%	33%	66%	100%		Treatments	Linear	Quadratic
Intake (g/day)								
DM	840.72	859.28	832.69	857.21	80.51	0.62	0.75	0.85
OM	774.57	788.84	758.97	788.16	71.40	0.32	0.83	0.54
CP	149.54	145.26	153.66	164.88	16.56	0.07	0.03	0.16
NDF	318.48[a]	304.00[a]	263.75[b]	253.04[b]	31.15	<0.05	<0.001	0.79
Apparent digestibility (%)								
DM	74.68	75.48	75.39	75.90	2.91	0.94	0.59	0.92
OM	75.37	76.00	76.36	76.75	2.96	0.91	0.47	0.93
CP	75.53	72.25	76.85	74.93	3.95	0.38	0.73	0.73
NDF	60.59	62.20	56.39	56.74	4.24	0.34	0.15	0.83
True digestibility of OM[2] (%)	83.82	85.32	85.05	86.13	1.74	0.36	0.12	0.82

[1]Treatments: levels of replacement of ground corn by sweet potato flour as energetic concentrate.

[2]True digestibility of OM: [OM intake (g/d) – fecal NDF (g/d)] / OM intake (g/d).SEM: standard error of the mean.

Table 4

N Intake, N retention, and efficiency of N use by sheep receiving different replacement levels of ground corn by sweet potato flour as an energetic concentrate. P-value ≤ 0.05 are considered significant and P-value ≤ 0.10 are considered as a tendency.

Item	Treatments[1]				SEM	P-value		
	0%	33%	66%	100%		Treatments	Linear	Quadratic
Intake (g/day)	23.92	23.24	24.58	26.38	2.65	0.07	0.03	0.16
Excretion (g/day)								
Urine	11.10	10.88	11.29	11.55	1.80	0.91	0.57	0.74
Feces	5.85	6.49	5.59	6.97	1.21	0.16	0.22	0.42
Retention (g/day)	6.95	5.85	7.51	7.86	1.18	0.43	0.29	0.45
ENU[2]	0.31	0.26	0.32	0.32	0.07	0.69	0.61	0.60

[1]Treatments: levels of replacement of ground corn by sweet potato flour as energetic concentrate.

[2]Eficiency of N use by the animal (g on retained N / g of N ingested).

SEM: standard error of the mean.

Table 5

Microbial protein synthesis, efficiency of microbial protein synthesis and efficiency of N use for microbial protein synthesis by sheep receiving different replacement levels of ground corn by sweet potato flour as an energetic concentrate. P-value $\leq$ 0.05 are considered significant and P-value $\leq$ 0.10 are considered as a tendency.

Item	Treatments[1]				SEM	P-value		
	0%	33%	66%	100%		Treatments	Linear	Quadratic
Microbial protein synthesis (g of produced microbial N/day)	10.79	11.10	11.01	11.48	2.07	0.96	0.64	0.93
EMPS[2]	18.34	18.04	18.33	18.87	2.86	0.98	0.78	0.78
ENU[3]	0.45	0.46	0.43	0.43	0.03	0.95	0.69	0.87

[1]Treatments: levels of replacement of ground corn by sweet potato flour as energetic concentrate.

[2]Efficiency of microbial protein synthesis (g of produced microbial N/kg of degradable OM ingested).

[3]Efficiency of N use for microbial protein synthesis (g of produced microbial N / g of N ingested).

SEM: standard error of the mean

Figures

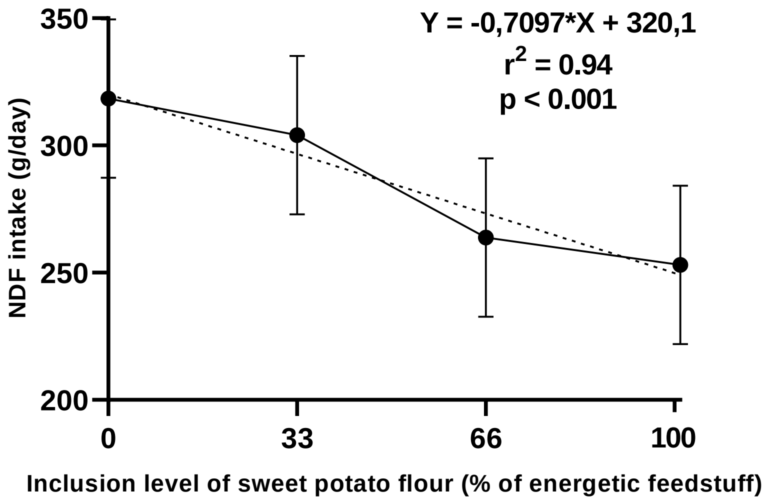

Fig. 1. NDF intake (g/day) by sheep receiving 0, 33, 66 or 100% of replacement of ground corn by sweet potato flour as an energetic concentrate. Vertical bars represent standard error of the mean. Dot line represents the tendency line of linear regression equation.

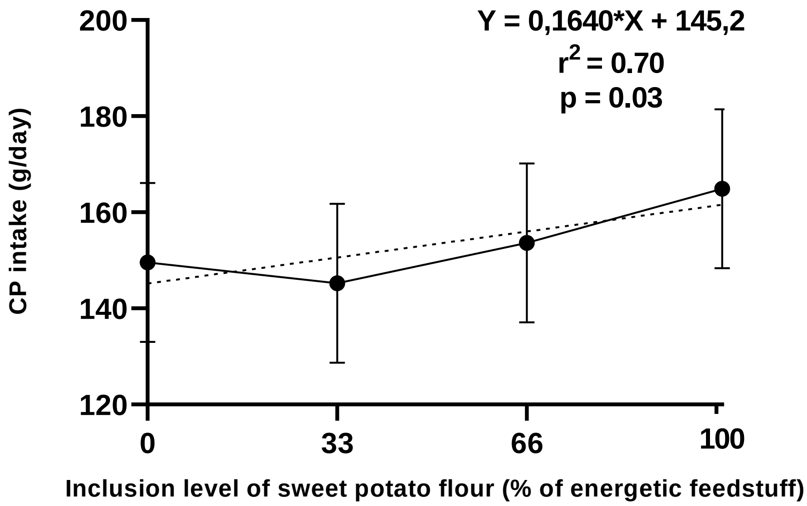

Fig. 2. CP intake (g/day) by sheep receiving 0, 33, 66 or 100% of replacement of ground corn by sweet potato flour as energetic concentrate. Vertical bars represent standard error of the mean. Dot line represents the tendency line of linear regression equation.

4 Considerações Finais

A substituição do milho pela farinha de batata doce para ovinos recebendo dietas mistas pode ser feita em qualquer nível sem que haja prejuízos na ingestão e digestibilidade da MS, na síntese de N microbiano ou na retenção do N pelo metabolismo, desde que haja inclusão de ureia ou outra fonte nitrogenada para compensar a diferença de proteína bruta entre milho e batata doce. Uma maior utilização deste tubérculo apresentará um importante papel no desenvolvimento social em propriedades que utilizam mão-de-obra majoritariamente familiar. A utilização deste alimento na nutrição animal também pode estimular a cadeia de produção e promover sustento para agricultores e pecuaristas. A redução da utilização do milho pode trazer benefícios econômicos em larga escala, já que este grão poderá ser destinado em maior quantidade na alimentação humana e na produção de combustível renovável. O meio ambiente também será favorecido com a preservação do solo, visto que a batata doce que seria descartada poderá ter um destino sustentável e facilmente aplicável.

Referências

ALLEN, M.S. Effects of diet on short-term regulation of feed intake by lactating dairy cattle. **Journal of dairy science**, v.83, n.7, p.1598-1624, 2000.

AOAC. **Official Methods of Analysis**. Association of Official Analytical Chemists, Gaithersburg, MD, USA 1997.

BACH, A.; CALSAMIGLIA, S.; STERN, M.D. Nitrogen metabolism in the rumen. **Journal of dairy science**, v.88 (Supl 1), p.9-21, 2005.

BRODERICK, G.A. Effects of varying dietary protein and energy levels on the production of lactating dairy cows. **Journal of dairy science**, v.86, n.4, p.1370-1381, 2003.

CANTALAPIEDRA-HIJAR, G.; LEMOSQUET, S.; RODRIGUEZ-LOPEZ, J.M.; MESSAD, F.; ORTIGUES-MARTY, I. Diets rich in starch increase the posthepatic availability of amino acids in dairy cows fed diets at low and normal protein levels. **Journal of dairy science**, v.97, n.8, p.5151-5166, 2014.

CATON, J.S.; DHUYVETTER, D.V. Influence of energy supplementation on grazing ruminants: requirements and responses. **Journal of animal science**, v.75, n.2, p.533-542, 1997.

CATON, J.S.; ERICKSON, D.O.; CAREY, D.A.; ULMER, D.L. Influence of Aspergillus oryzae fermentation extract on forage intake, site of digestion, in situ degradability, and duodenal amino acid flow in steers grazing cool-season pasture. **Journal of animal science**, v.71, n.3, p.779-787, 1993.

CHEN, X.B.; GOMES, M.J. **Estimation of microbial protein supply to sheep and cattle based on urinary excretion of purine derivatives- an overview of technical details**. INTERNATIONAL FEED RESEARCH UNIT. Aberdeen, UK: Rowett Research Institute, 1992. 21p (Publicação ocasional).

CHUMPAWADEE, S.; SOMMART, K.; VONGPRALUB, T.; PATTARAJINDA, V. Effects of synchronizing the rate of dietary energy and nitrogen release on ruminal fermentation, microbial protein synthesis, blood urea nitrogen and nutrient digestibility in beef cattle. **Asian-Australasian Journal of Animal Sciences**, v.19, n.2, p.181-188, 2006.

DECKARDT, K.; KHOL-PARISINI, A.; ZEBELI, Q. Peculiarities of enhancing resistant starch in ruminants using chemical methods: opportunities and challenges. **Nutrients**, v.5, n.6, p.1970-1988, 2013.

DERVAN, B.; DEREK, A. Apparent metabolizable energy of sweet potato by-products for broiler chickens. **International Journal of Agriculture, Environment and Bioresearch**, v.2, n.5, p.183-191, 2017.

DOM, M.T.; AYALEW, W.K.; GLATZ, P.C.; KIRKWOOD, R.N.; HUGHES, P.E. Nutrient utilization in grower pigs fed boiled, ensiled ormilled sweet potato roots blended with a wheat-basedprotein concentrate. **Animal Feed Science and Technology**, v.223, p.82-89, 2017.

FAO. Food and Agriculture Organization of the United Nations, FAOSTAT.2018. Disponível em: <www.fao.org/faostat/en/?#data/QC. 2017>Acesso em: 12 Jul. 2018.

FRYE, J.B.; THOMASON, J.H.; HENDERSON, H.B. Sweet potato meal versus ground corn in the ration of dairy cows. **Journal of dairy science**, v.31, p.3141-3346, 1948.

GEHMAN, A.M.; BERTRAND, J.A.; JENKINS, T.C.; PINKERTON, B.W. The effect of carbohydrate source on nitrogen capture in dairy cows on pasture. **Journal of dairy science**, v.89, n.7, p.2659-2667, 2006.

GÓMEZ, L.M.; POSADA, S.L.; OLIVERA, M. Starch in ruminant diets: a review. **Revista Colombiana de Ciencias Pecuarias**, v.29, n.2, p.77-90, 2016.

HILTNER, P.; DEHORITY, B.A. Effect of soluble carbohydrates on digestion of cellulose by pure cultures of rumen bacteria. **Applied and environmental microbiology**, v.46, n.3, p.642-648, 1983.

HOOVER, W.H.; STOKES, S.R. Balancing carbohydrates and proteins for optimum rumen microbial yield. **Journal of dairy science**, v.74, n.10, p.3630-3644, 1991.

HU, Z.H.; YU, H.Q.; ZHU, R.F. Influence of particle size and pH on anaerobic degradation of cellulose by ruminal microbes. **International Biodeterioration & Biodegradation**, v.55, p.233-238, 2005.

JOHNSON, R.R. Influence of carbohydrate solubility on non-protein nitrogen utilization in the ruminant. **Journal of animal science**, v.43, n.1, p.184-191, 1976.

KHALID, A.F.; ELAMIN, K.M.; AMIN, A.E.; TAMEEM ELDAR, A.A.; MOHAMED, M.E.; HASSAN, H.E.; MOHAMMED, M.D. Effect of feeding sweet potato (ipomoea batatas) vines silage on performance and milk production of nubian goats. **Journal of Veterinary Advances**, v.3, n.5, p.153-159, 2013.

KOZLOSKI, G.V. **Bioquímica dos Ruminantes**. 3.ed. Santa Maria: Editora UFSM, 2011. 212p.

KOZLOSKI, G.V.; BONNECARRÈRE SANCHEZ, L.M.; CADORIN JR., R.L.; REFFATTI, M.V.; PEREZ NETO, D.; LIMA, L.D. Intake and digestion by lambs of dwarf elephant grass (pennisetum purpureum schum. cv. mott) hay or hay supplemented with urea and different levels of cracked corn grain. **Animal Feed Science and Technology**, v.125, p.111-122, 2006.

LARSEN, M.; LUND, P.; WEISBJERG, M.R.; HVELPLUND, T. Digestion site of starch from cereals and legumes in lactating dairy cows. **Animal Feed Science and Technology**, v.153, p.237-248, 2009.

LUO, G.; XU, W.; YANG, J.; LI, Y.; ZHANG, L.; WANG, Y.; LIN, C.; ZHANG, Y. Effects of ruminally degradable starch levels on performance, nitrogen balance, and nutrient digestibility in dairy cows fed low corn-based starch diets. **Asian-Australasian journal of animal sciences**, v.30, n.5, p.653-659, 2017.

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, n.6, p.1217-1240, 2002.

MOORE, J.E.; BRANT, M.H.; KUNKLE, W.E.; HOPKINS, D.I. Effects of supplementation on voluntary forage intake, diet digestibility, and animal performance. **Journal of animal science**, v.77 (Supl 2), p.122-135, 1999.

NRC. **Nutrient Requirements of Beef Cattle**. 7.ed. Washington: National Academy Press, 1996.

PANDI, J.; GLATZ, P.; FORDER, R.; KOMOLONG, B.; CHOUSALKAR, K. Evaluation of the effects of sweet potato (Ipomoea batatas (L.) Lam) in broiler diets. **Journal of animal physiology and animal nutrition**, v.102, n.1, p.216-224, 2018.

PASSETTI, R.A.C.; EIRAS, C.E.; GOMES, L.C.; SANTOS, J.F.; PRADO, I.N. Intensive dairy farming systems from holland and brazil: swot analyse comparison. **Acta Scientiarum. Animal Sciences**, v.38, n.4, p.439-446, 2016.

PATHAK, A.K. Various factors affecting microbial protein synthesis in the rumen. **Veterinary World**, v.1, n.6, p.186-189, 2008.

PEDROSA, C.E.; JÚNIOR, V.C.A.; PEREIRA, R.C.; DORNAS, M.F.; AZEVEDO, A.M.; FERREIRA, M.A. Yield and quality of wilted sweet potato vines and its silages.**Horticulturabrasileira**, v.33, n.3, p.283-289, 2015.

RAMOS, S.; TEJIDO, M.L.; MARTINEZ, M.E.; RANILLA, M.J.; CARRO, M.D. Microbial protein synthesis, ruminal digestion, microbial populations, and nitrogen balance in sheep fed diets varying in forage-to-concentrate ratio and type of forage. **Journal of animal science**, v.87, n.9, p.2924-2934, 2009.

RUSSELL, J.B.; WILSON, D.B. Why are ruminal cellulolytic bacteria unable to digest cellulose at low pH? **Journal of dairy science**, v.79, n.8, p.1503-1509, 1996.

SANTANA, A.L.; MEIRELES, M.A.A. New starches are the trend for industry applications: a review. **Food and Public Health**, v.4, n.5, p.229-241, 2014.

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 fibre analysis in forage and concentrate feedstuffs. **Animal Feed Science and Technology**, v.146, p.169–174, 2008.
TAMMINGA, S. A review on environmental impacts of nutritional strategies in ruminants. **Journal of animal science**, v.74, n.12, p.3112-3124, 1996.

UDDIN, M.J.; KHANDAKER, Z.H.; KHAN, M.J.; KHAN, M.M.H. Dynamics of microbial protein synthesis in the rumen - a review. **Annals of Veterinary and Animal Science**, v.2, n.5, p.116-131, 2015.

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

VAREL, V.H.; NIENABER, J.A.; FREETLY, H.C. Conservation of nitrogen in cattle feedlot waste with urease inhibitors. **Journal of animal science**, v.77, n.5, p.1162-1168, 1999.

VELARDE, L.C.U.; QUEIROZ, R.; MARES, V.; CASIMIRO, J. Potential role of sweet potato to improve smallholder crop-livestock production systems. **International Society for Tropical Root Crops**, p.1-9, 2015.

WU, G.; BAZER, F.W.; WALLACE, J.M.; SPENCER, T.E. Board-invited review: intrauterine growth retardation: implications for the animal sciences. **Journal of animal science**, v.84, n.9, p.2316-2337, 2006.

CEEA UFPel
Comissão de Ética em Experimentação Animal

Pelotas, 03 de outubro de 2017

Certificado

Certificamos que a proposta intitulada "**Avaliação da farinha de batata-doce para alimentação de vacas leiteiras**" processo número 23110.003255/2017-39, de responsabilidade de **Márcio Nunes Corrêa** - que envolve a produção, manutenção ou utilização de animais pertencentes ao filo Chordata, subfilo Vertebrata (exceto humanos), para fins de pesquisa científica (ou ensino) – encontra-se de acordo com os preceitos da Lei nº 11.794, de 8 de outubro de 2008, do Decreto nº 6.899, de 15 de julho de 2009, e com as normas editadas pelo Conselho Nacional de Controle de Experimentação Animal (CONCEA), e recebeu parecer **FAVORÁVEL** a sua complementação pela Comissão de Ética em Experimentação Animal, em reunião de 02/10/2017.

Finalidade	(X) Pesquisa	( ) Ensino
Vigência da autorização	04/10/2017 a 31/12/2018	
Espécie/linhagem/raça	Ovinos	Bovinos
Nº de animais	16	20
Idade	12-36 meses	36-60 meses
Sexo	Machos	Fêmeas
Origem	Centro Agropecuário da Palma - UFPel	

Solicitamos, após tomar ciência do parecer, reenviar o processo à *CEEA*.

Salientamos também a necessidade deste projeto ser cadastrado junto ao *COBALTO* para posterior registro no *COCEPE* (código para cadastro nº **CEEA 3255-2017**).

M.V. Dra. Anelize de Oliveira Campello Felix

Presidente da CEEA

Ciente em: 30 / 11 /2017

Assinatura do Professor Responsável: ______

Márcio Nunes Corrêa
Professor Associado - MC/Dr.
Fac. Veterinária - UFPel/RS