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Sweet potato (Ipomea batatas) feed affects intake, digestibility and nitrogen retention of ovine fed with ryegrass hay (*Lolium multiflorum Lam*)

[*Influência da inclusão de farinha de batata-doce (Ipomoea batatas) sobre a digestibilidade, o consumo e a retenção de nitrogênio em ovinos alimentados com feno de azevém anual* (Lolium multiflorum Lam)]

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ABSTRACT

This study aimed to evaluate sweet potato feed as an alternative energy supplement for ovine. A latin-square design was used to assess the effects of feeding the animals 0, 0.5, 1 and 1.5% their body weight in sweet potato as well as ryegrass hay (*Lolium multiflorum*) twice daily, mineral salt and water *ad libitum.* During this study 8 males were housed in metabolic cages with urine and feces collectors. Each round of experimentation consisted of 14 days adaptation followed by 5 days evaluating the diet, left-overs, feces, and urine to determine intake, digestibility, and nitrogen retention. The results show a linear increase in intake of ryegrass hay, FDN, DM and OM because of the increasing supplementation levels. Similarly, we observed a linear increase in DM and OM intake, as well as in the OM digestibility. Additionally, BP digestibility decreased considering nitrogen excretion. In conclusion, sweet potato feed is a viable alternative for ovine receiving ryegrass hay since it increased DM and OM digestibility, albeit reducing NDF and BP digestibility.

Keywords: nutrition, ruminants, energy

RESUMO

*O presente estudo teve como objetivo determinar a viabilidade da inclusão da farinha de batata-doce na ração de ovinos, como estratégia alimentar alternativa ao uso de outras culturas, tradicionalmente utilizadas como suplemento energético. Para isso, foi realizado delineamento em quadrado latino para avaliar os efeitos da suplementação de 0, 0,5, 1 e 1,5% do PV de farinha de batata-doce, para ovinos alimentados duas vezes ao dia com feno de azevém anual (*Lolium multiflorum*) e com acesso a sal mineral e a água* ad libitum. *Durante o período de estudo, oito machos da raça foram alojados em gaiolas metabólicas com coletores de urina e fezes. Cada rodada do experimento consistiu em 14 dias de adaptação da dieta e cinco dias de coleta, que incluíram consumo, dieta, sobras, fezes, urina, a fim de determinar consumo, digestibilidade e retenção de N. Como reflexo dos níveis crescentes de suplementação, os resultados demonstraram um padrão linear tanto de redução da ingestão do feno de azevém e da FDN quanto de aumento do consumo total de MS e MO. Da mesma forma, foi observado um padrão linear de aumento na digestibilidade da MS, da MO e na digestibilidade verdadeira da MO, assim como de diminuição na digestibilidade da PB (com base na eliminação de N). Conclui-se que a inclusão de farinha de batata-doce na alimentação de ovinos alimentados com feno de azevém é viável e que aumentou a ingestão e a digestibilidade da MS e da MO, embora tenha reduzido a digestibilidade da FDN e da PB.*

Palavras-chave: nutrição, ruminantes, energia

INTRODUCTION

Food source diversification promotes food security for livestock. Therefore, alternative food sources for ruminants are essential to guarantee sustainability and continued development of the livestock industry. Food source diversification promotes food security for herds. Corn is an essential energy source in rations and forage for livestock herds in the USA and worldwide

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(Klopfenstein *et al*., 2013). For this reason, demand is high leading to significant variations in availability and market cost. Other starch sources can be used such as oat, wheat, sorghum, and barley, which are highly energetic cereals with varying solubility (Malaguez *et al*., 2021). Starch is the main energy source utilized for ruminants (Ortega and Mendonza, 2003). Corn is made up of 70% starch in its dry matter (DMM) and is the main energy source used for livestock (Deckardt *et al*., 2013). Nevertheless, starch is also present in roots and tubers (Zeoula *et al.*, 2006). The search for alternative ingredients to replace corn is important considering the variable price of this commodity (Malaguez *et al*., 2021).

Sweet potato (Ipomea batatas) is a plant native to the Americas considered easy to grow and producing high yields (Veasey *et al*., 2008). It contains high levels of starch, similar to corn, and superior to other frequently used energy sources such as wheat bran, soy husk and citric pulp (Akoetey *et al*., 2017). Sweet potato produces more gas and is fermented faster than corn making it a suitable replacement, however its use requires further investigation. Since sweet potato is mainly commercialized for humans, it goes through rigorous quality control to guarantee the product is suitable for consumption (Van Hal, 2000). Any product not meeting the quality standards of size and form is not harvested becoming susceptible to contamination by disease that spreads onto subsequent crops (Malaguez *et al*., 2021).

Microbial protein in the rumen is the main source of protein arriving in the small intestine representing 50 to 80% of the total amount absorbed (Storm and Ørskov, 1983). In order to produce protein efficiently, ruminal microorganisms need to receive carbohydrate and nitrogen sources in a synchronized manner (Ekinci and Broderick, 1997). Therefore, food sources with different degradation rates can affect protein synthesis in the rumen and, consequently, the animal's productivity. Forage composes more than half a ruminant's diet affecting overall intake and ingested energy (Kendall *et al*., 2009). To use sweet potato feed for ruminants as a replacement for corn we need to understand the interaction between sweet potato feed and forage. Thus, the goal of this study was to evaluate the intake and digestibility of increasing levels of sweet potato feed in ovine also receiving ryegrass hay.

MATERIALS AND METHODS

The experiment was carried out in a total 73 days at the Bromatology and Ruminant Nutrition Laboratory of Universidade Federal de Santa Maria, Rio Grande do Sul, Brasil. All procedures were approved by the Animal Experimentation Ethical Committee of the Universidade Federal de Pelotas registered under 3255.

Eight male castrated Corriedale sheep (37,47kg±4,58kg), aged between 13 and 15 months were used in a Latin-square 4X4 double design. The animals were housed in metabolic cages with mineral salt and water *ad libitum*. The ovine were fitted with urine collectors attached to a container with 100 mL sulfuric acid at 20% and the cages were equipped with trays for feces collection.

The diet was composed of ryegrass (*Lolium multiflorum*) hay *ad libitum* and sweet potato feed. The treatments were: Ryegrass hay without supplementation, or supplemented with 0.5%, 1% or 1.5% the animal's body weight in sweet potato feed. Both ingredients in the diets were adjusted with urea and ammonium sulfate (9:1 ratio) until reaching 16% the total protein to keep the diets isoproteic (Table 1).

Before the experiment, animals were treated for worms. The animals had a two-week period before the experiment to adapt to the metabolic enclosures. The experiment occurred in four periods of 19 days. The first 14 days of each period were for the animals to adapt to the diet followed by five days of sampling and data collection. The chemical composition of the diet presented in table 1.

Table 1. Composition of Dry matter (DM), Total protein (PB), neutral detergent fiber (NDF), and mineral matter (MM) in sweet potato feed and rye grass hay

Item (%)	Sweet potato feed	Rye grass hay
DM	83.58	70.03
PB	16.07	16.88
NDF	9.08	66.55
MM	2.92	8.79

The animals were fed twice a day (morning and evening), always at the same time with ryegrass hay and sweet potato feed. The amount of food offered was adjusted daily based on the intake observed in the previous day, maintaining the leftovers at 10 to 15% of the total offered. Leftovers were collected daily, weighed, dried in an incubator (55ºC) for at least 72 h, ground and stored. At the end of each period, they were sampled for analysis. Feces were collected, weighed, dried in an incubator (55ºC) for at least 72 h, ground (filter with 1mm pore) and stored for the for the duration of the collection period. At the end of each period the daily samples (10% of total) for each animal were pooled and stored for analysis.

Ovine were fitted with a urine collector. The total volume produced was stored in a container with 100mL 20% sulfuric acid solution (3.6M) to reduce the pH below 2. After the urine volume was measured in the morning, the urine was filtered with gaze, and a 10 mL aliquot was diluted in 40 mL distilled water and stored at 10ºC. At the end of each period samples were pooled maintaining the proportion of the daily production of each animal.

The ratios of forage:concentrate for the diets were 100:0, 82:18, 65:35 and 53:47 for the treatments with sweet potato feed supplementation at 0, 0.5, 1, 1.5% the animal's body weight, respectively. Samples of the diet, feces and leftovers were analyzed to determine dry matter (DM), mineral matter (MM), organic matter (OM) and neutral detergent fiber (NDF). All samples were pre dried in an incubator at 55ºC, then ground in a willey mill using a filter with 1 mm pores. Subsequently the samples were transferred to an incubator and maintained at 105ºC for 24 h to determine DM, then at 600ºC for 4 h to determine MM. OM was determined based on the difference between DM and MM. FDN analysis was based on procedures previously described by Mertens (2002) using thermostable α-amylase, without sodium sulfite, except for samples weighed in polyester bags (Komarek, 1993) and treated with neutral detergent in an autoclave at 110ºC during 40 minutes (Senger *et al.*, 2008). NT and PB analysis were carried out on the diet, leftovers, feces and urine using the KJELDAHL method (Official…, 1995, method 984.13).

Apparent digestibility of DM, OM, MM, NT (including urine) and FDN was calculated based on the difference between intake and excretion, as described previously (Merchen 1988). Intake (volume and composition) was determined based on the difference between the diet offered and leftovers. Nitrogen retention was calculated using the difference between ingested and excreted N in feces and urine. To determine how efficiently the animal used N we analyzed the difference between retained N and ingested N (Matterson *et al.*, 1965).

The total intake and digestibility data were analyzed according to the model:

$$Yijkl = \mu + Ai + Pj + Tk + QLl + TQLkl + eijlkl$$

where: Yijkl= dependent variable, μ = average of observation, Ai= random effect of the animal Pj = random effect of the period Tk = fixed effect of the treatment QLl= fixed effect of the Latin-square TQLkl= fixed effect of the interaction between the Latin-square and the treatment. eijkl= residual error

The data were analyzed using ANOVA and Tukey in the software NCSS 2005 SAS (2009), considering the Latin-square model. When the treatment effect was significant ($P \leq 0,10$) it was analyzed in two ways: (i) the control treatment was compared with the others using the orthogonal contrast technique; (ii) the effect of supplementation was analyzed by regression, including a linear and quadratic effect. The effect of the level of inclusion of increasing amounts of sweet potato were tested using the polynomial orthogonal contrast method considering linear and quadratic effects (Steel and Torrie 1980). Data are presented as adjusted averages (LSMEANS). $P < 0.05$ was considered significant and $0.05 < p < 0.10$ was considered a trend.

RESULTS

Mean intake and digestibility values for the main nutritional fractions of the diet are presented in Table 2.

Increasing the sweet potato feed supplementation caused a linear decrease in intake ($p<0.01$). Supplemented animals ingested on average 17% less forage than non-supplemented. The increase in supplementation also increased the intake in total DM and OM compared to control.

Supplemented animals ingested 26% more total OM and 29% more digestible OM (p<0.01). Intake of the NDF fraction decreased with the increase in supplementation (p<0.01). The intake of PB did not differ among treatments.

Table 2. Intake and digestibility of dry matter (DM), organic matter (OM), total protein (PB), neutral detergent fiber (NDF) in ovine fed with rye grass hay and increasing levels of sweet potato feed (0, 0.5, 1 and 1.5%)

Item	Treatments				SEM	P-value
	0%	0.5%	1%	1.5%		Linear[1]
Intake(g/d)						
DM of rye grass hay	915.50	873.87	740.87	664.37	48.32	<0.01
Total OM	835.06	988.40	1064.95	1172.20	50.42	<0.01
Total DM	915.50	1071.12	1141.62	1247.60	54.66	<0.01
PB in total DM	162.42	179.00	174.43	190.05	12.79	0.18
NDF in total DM	504.40	470.56	405.32	377.71	30.81	<0.01
Apparent digestibility (%)						
DM	54,98	61,79	69,28	71,19	1,96	<0,01
OM	61	67	73	74	1,63	<0,01
PB	84,22	83,84	81,70	80,02	1,30	0,01
NDF	61,21	59,14	58,91	54,36	2,55	0,07
True digestibility of OM (%)	71,85	76,36	81,86	82,89	1,48	<0,01

[1] P values <0,05 are considered significant and P values <0,10 are considered a trend.

Apparent OM digestibility responded positively to supplementation and was 10% higher than the control, true digestibility was 8.5% higher.

There was a linear decrease in NDF digestibility with the increase in supplementation, although this was a trend (p=0,07). The linear decrease in PB digestibility with increasing supplementation was statistically significant (p<0,05). The decreases observed in NDF and PB digestibility were modest, 2.8% and 6.1%, respectively in comparison to the control.

The mean nitrogen intake and excretion values are presented in Table 3. There was a linear increase in intake and efficiency of N usage with the increase in sweet potato supplementation (P=0.09 and P=0.07, respectively). N excretion in feces and in urine+feces had a linear increase with increased supplementation (P=0.002 and P=0.05).

Table 3. Nitrogen (N) intake, excretion in urine, feces and urine + feces; and nitrogen usage efficiency in ovine fed with rye grass hay and increasing levels of sweet potato feed (0, 0.5, 1 and 1.5%)

Item	Treatments				SEM	P-Value
	0%	0.5%	1%	1.5%		Linear[1]
N intake (g/d)	25.98	28.63	27.91	30.40	1.60	0.0993
N excretion in urine (g/dia)	12.23	11.67	13.24	15.82	1.72	0.1289
N excretion in feces (g/d)	4.01	4.65	4.97	5.91	0.37	0.0027
N excretion in urine + feces (g/d)	16.24	16.33	18.21	21.73	1.96	0.0535
Total N usage efficiency	0.36	0.43	0.31	0.27	4.63	0.0757

[1] P values <0.05 are considered significant and P values <0.10 are considered a trend.

DISCUSSION

Supplementation with sweet potato caused a reduction in the intake of forage, possibly since the animals substitute it for food with more concentrated energy, reducing the fiber intake. The sweet potato was composed of approximately 65 to 85% starch, which has two fractions of amylose and amylopectin (Alcázar-alay and Meireles, 2015).

Sweet potato starch is more fermentable due to the high amylopectin content. Amylopectin contains α-1.6 bonds which are highly ramified and, therefore, more susceptible to degradation by ruminal microorganisms (Malaguez *et al*., 2021). This increases the production of volatile fatty acids (VFA), mainly propionate, which becomes an ingestion regulator when it is oxidized in the liver (Allen, 2000). Signal transmission to the satiation center is determined by the number of stimuli to epithelial receptors in the rumen and liver. These are activated in the presence of VFA and electrolytes which are modulated by the fermentation rate and extent (Allen, 2000). Similar results were obtained in a previous study evaluating increasing supplementation at 0, 0.5, 1 and 1.5% the animal's body weight in corn. In this study authors observed a decreased intake of 666, 610, 534, 408g for lambs per day in hay and elephant grass (*Pennisetum purpureum)* (Kozloski *et al*., 2006). These results differed in another study where the increasing levels of concentrate in the diet of ovine did not influence DM and OM intake (Carvalho *et al*., 2014).

DM and OM intake modulation is influenced by the type of diet considering forage activates the satiation center via expansion of the gastrointestinal tract and concentrate does this by altering the energy flux (Leek 1986). Reduction in the intake of forage caused a reduction in NDF intake. This happens since NDF content of forage is higher than that of sweet potato feed (Table 1).

Supplementation with sweet potato feed increased the intake of DM and OM. Similar results were observed in a previous which showed that a less full rumen due to decreased fiber intake stimulates a higher total intake (Kozloski *et al*., 2006; Leek,1986). Increased intake associated with increased digestibility of DM and OM is directly linked to better productivity of the animals. It provides higher nutrient intake, more efficient nutrient usage and zootechnical advantages.

The linear reduction of PB digestibility may have been caused by the reduction in pH since previous phases of this research showed pH reduction of 6.52, 6.38, 6.13 and 5.72 for supplementation with sweet potato at 0, 0.5, 1.0 1.5% the animal's body weight, respectively, characterizing a negative linear effect for ruminal pH (Malaguez *et al*., 2021). The pH is used to determine the concentration of H^+ in a solution, with physiologically accepted values for the rumen are between 6.0 and 7.0 (Malaguez *et al*., 2021).

The decrease in pH is related to the increased degradation rate which is influenced by the enzymatic hydrolysis of starch. This results in an accumulation of propionic acid producing conditions favorable to the growth of lactic acid producing microbes in the rumen, which contributes to ruminal acidification (Krause and Oetzel, 2006; Malaguez *et al*., 2021). This acidification is a limiting factor for the growth of other ruminal microbes such as proteolytic and ureolytic, reducing by 50% the digestibility of protein at pH 5.7 relative to 6.7 (Ladeira *et al*., 1999). In ideal pH, utilization of rapidly fermented carbohydrates optimizes the protein efficiency in the diet. When protein arrives in the rumen it is rapidly transformed into ammonia and carbon dioxide (CO_2) due to the activity of enzyme produced by ruminal bacteria. These products of fermentation are used by ureolytic and proteolytic microbes for protein synthesis.

The decreased NFD digestibility can be related to this increase in ruminal pH, which can cause changes in the microbial population, since it characterized by a significant growth of amylolytic bacteria. The main amylolytic bacteria being *Streptococcus bovis* which utilizes carbohydrates to produce lactic acid leading to a reduction in ruminal pH. This interferes directly in the motility of cellulolytic bacteria and protozoa, possibly leading to the death of these microbes when prolonged for a long time (Malaguez *et al*., 2021). According to Contreras and Noro (2010) pH values below 5.8 affect fermentation by cellulolytic bacteria, for which the ideal pH is 6.2-6.8, and directly reduce fermentation of dietary fiber.

A reduction in dietary fiber digestibility can negatively influence nitrogen usage for microbial protein synthesis, reducing PB digestibility (Cantalapiedra-Hijar *et al*., 2014). This occurs because this acidified environment reduced bacterial adhesion to food particles reducing these microbes' ability to capture substrate in the ruminal environment (Kozloski *et al*., 2006; Kozloski, 2011). This can explain the result in this study since sweet potato is highly fermentable and, therefore, has high pH reducing potential, reducing PB and NFD digestibility.

The increased N excretion observed in this study is due to increased N intake, which can negatively influence dietary protein digestibility. Caldas Neto *et al*. (2007) evaluated different degradable protein sources in the rumen using increasing amounts of starch in the diet and observed a linear additive effect in weight gain and food conversion. In the present study, the increase in starch intake resulted in better usage of dietary nitrogen, demonstrating that physiological nitrogen recycling mechanisms reduce nitrogen excretion and environmental contamination. These data are consistent with previous results by Cole and Todd (2008).

Rapid sweet potato fermentation can alter the ruminal flora, interfering in ruminal health and nutrient digestibility. Therefore, it is important to know the supplementation levels in the diet (Deckardt *et al*., 2013; Bevans *et al*., 2005). Monitoring intake, digestibility and nitrogen balance are important steps when evaluating alternative energy supplementation sources. Digestibility allows the identification of each nutrient's percentage in the food (Van Soest, 1994). The nitrogen balance determines the nitrogen suage efficiency by ruminants (Gentil *et al*., 2007). The amount of nitrogen excreted in feces increases with the fermentation activity in the large intestine due to the increased uptake of microbial nitrogen.

CONCLUSION

Supplementation with sweet potato feed increases total intake, reduces NDF intake and improves OM and DM digestibility. Nevertheless, it reduces PB digestibility, which increases N excretion in feces and urine.

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