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High performance of growing lambs grazing *Paspalum notatum* INIA Sepé with energy-protein supplement including sorghum-DDGS

Alto desempeño de corderos pastoreando *Paspalum notatum* INIA Sepé con suplementación energético-proteica que incluye DDGS-sorgo

Alto desempenho de cordeiros pastando *Paspalum notatum* INIA Sepé com suplemento protéico-energético incluindo sorgo-DDGS

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Abstract

Sorghum dried distillers' grain with soluble (S-DDGS) has not been utilized as supplement in lamb growing and finishing diets under grazing conditions in summer. The hypothesis was that the performance of post-weaning lambs grazing *Paspalum notatum* (PN) INIA Sepé supplemented with an energy-protein diet (whole sorghum grain [SG], and soybean meal [SM]) is not reduced by the inclusion of 40% S-DDGS. During 82 days, in summer, 42 Merino Dohne male lambs (130 ± 7.6 days of age, 32 ± 2.4 kg of body weight [BW], and 2.2 ± 0.2 body condition score [BCS]) were evaluated, in a completely random experimental design with three treatments and two replicates each (n = 14 each one). All lambs grazed PN INIA Sepé and in two treatments they were daily supplemented (1.7% BW) with different components. The treatments were: PN (control group, no supplementation), SGSM (70% SG, 30% SM) and DDGS (45% SG, 40% S-DDGS, and 15% SM). Supplemented lambs had higher (P<0.0001) body weight gain (BWG), final BW and wool growth (140 and 126 g/a/d, 43.5 and 42.4 kg; 1814 and 1892 μg/cm^2/d for DDGS and SGSM, respectively) than control lambs (40 g/a/d; 35.5 kg; 1353 μg/cm^2/d) (P<0.0001), without differences between supplemented groups. Gastrointestinal nematodes infestation (GIN) was affected by the treatments on day 69, where supplemented animals showed lower infestation levels than control lambs (P=0.0024). The inclusion of S-DDGS in the supplement did not reduce the productive performance of the lambs when the concentration of crude protein and energy remained constant.

Keywords: lambs, body weight gain, wool growth, DDGS, grazing

Resumen

El grano de destilería seco con solubles de sorgo (DDGS-S) no se ha utilizado como suplemento en dietas de engorde de corderos bajo pastoreo en verano. La hipótesis planteada es que el desempeño de corderos posdestete pastoreando *Paspalum notatum* (PN) INIA Sepé y suplementados con una ración energético-proteica (grano entero de sorgo y harina de soja) no se reduce con la inclusión de un 40% de DDGS-S. El diseño experimental fue completamente al azar con tres tratamientos y dos repeticiones cada uno (n = 14 cada uno), evaluando 42 corderos machos Merino Dohne (130 ± 7,6 días de edad, 32 ± 2,4 kg de peso vivo [PV], y 2,2 ± 0,2 de condición corporal [CC]) en verano (84 días). Todos los corderos pastorearon PN INIA Sepé, dos tratamientos fueron suplementados diariamente (1,7% PV). Los tratamientos fueron: PN (sin suplementación), SGSM (70% grano sorgo, 30% harina de soja) y DDGS (45% grano sorgo, 40% DDGS-S y 15% harina de soja). Los corderos suplementados tuvieron mayor (P<0,0001) ganancia de peso, peso final y crecimiento de lana (140 y 126 g/a/d; 43,5 y 42,4 kg; 1814 y 1892 µg/cm^2/d para DDGS y SGSM, respectivamente) que los corderos control (40 g/a/d; 35,5 kg; 1353 µg/cm^2/d) (P<0,0001), sin diferencias entre los suplementados. La infestación por nematodos gastrointestinales fue afectada por los tratamientos en el día 69, los animales suplementados mostraron menores niveles de infestación que los corderos control (P=0.0024). La inclusión de DDGS-S en el suplemento no redujo el desempeño productivo de los corderos cuando la concentración de proteína cruda y la energía permanecieron constantes.

Palabras clave: corderos, ganancia de peso, crecimiento de lana, DDGS, pastoreo

Resumo

Grãos de destilaria desidratados de sorgo com solúveis (DDGS-S) não têm sido utilizados como suplemento em dietas de crescimento e terminação de cordeiros em condições de pastejo no verão. Postulamos que o desempenho de cordeiros pós-desmame em *Paspalum notatum* (PN) INIA Sepé suplementado com uma ração energético-protéica (grão de sorgo e farelo de soja) não é reduzido pela inclusão de 40 % DDGS-S. Em um delineamento experimental inteiramente casualizado com três tratamentos e duas repetições cada (n = 14 cada um), avaliamos 42 cordeiros Merino Dohne (130 ± 7,6 dias de idade, 32 ± 2,4 kg de peso corporal -PC- e 2,2 ± 0,2 escore de condição corporal) no verão (84 dias). Todos os cordeiros foram alimentados com PN INIA Sepé e dois tratamentos suplementados diariamente (1,7 % do PC). Os tratamentos foram: PN (sem suplementação); SGSM (70 % grão de sorgo, 30 % farelo de soja) e DDGS (45 % grão de sorgo, 40 % DDGS-S e 15 % farelo de soja). Cordeiros suplementados tiveram maior (P<0.0001) ganho de peso corporal, peso corporal final e crescimento de lã (140 e 126 g/a/d; 43,5 e 42,4 kg; 1814 e 1892 µg/cm^2/d para DDGS e SGSM, respectivamente) do que cordeiros controle (40 g/a/d; 35,5 kg; 1353 µg/cm^2/d) (P<0.0001), sem diferenças entre os suplementados. A infestação por nematóides gastrointestinais foi afetada pelos tratamentos no dia 69, animais suplementados tiveram uma infestação menor do que os cordeiros controle (P=0.0024). A inclusão de DDGS-S no suplemento não reduziu o desempenho produtivo dos cordeiros quando a concentração de proteína bruta e energia desta permaneceu constante.

Palavras-chave: cordeiros, ganho de peso corporal, crescimento de lã, DDGS, pastagem

1. Introduction

Weaning can be defined as a complete physical separation between dam and lamb, and is a stressful time for lambs, and a critical management period[1]. During post-weaning, the first year of life, lambs have relative higher energy and crude protein (CP) requirements than adult sheep[2]. Furthermore, grazing animals have even higher maintenance energy requirements than feedlot or housed animals, partly because of forage search and harvesting activities[3]. In the first year of life, important mortality rates have been reported in Merino lambs, which vary between 4.5% to 26.8%, and represent high costs for farmers and animal welfare concerns[4]. The mortality risk is higher in lambs with less than 22 kg at weaning, and it decreases with increasing body weight (BW)[4]. Also, growth rate post-weaning should be considered, which ideally should not be less than 50 g/a/d[4]. However, lambs grazing native summer pastures might not reach a high growth rate and wool production[5]. Another concern when grazing lambs are gastrointestinal nematodes (GIN) infestations, which are a serious challenge to the health and performance of ruminants[6]. A GIN infestation decreases dry matter intake, increases endogenous protein loss into the gastrointestinal tract, as well as reorients the use of nutrients to repair damaged tissue instead of production functions. Of the several aspects of integrated control against

GIN[7], feeding strategy has a major impact. Therefore, inadequate post-weaning nutrition limits lamb growth and development, increasing their susceptibility to GIN and increasing morbidity.

The Rio de la Plata Grassland (28°S-38°S, 50°W-61°W) is characterized by the dominance of grasslands and is one of the largest natural ecoregions of the world. These grasslands in South America (*campos* in Portuguese, *pastizales* or *pampa* in Spanish) include three countries: Uruguay (fully included), central-eastern Argentina and part of southern Brazil[8]. Native pastures are highly diverse with the coexistence of C_3 and C_4 species. Growth during summer is dominated by C_4 grasses, with *Paspalum notatum* (PN) as one of the most frequent species in native pastures. In line with this, the genetic variability of PN in Uruguay has been analyzed and valued. The product of this large-scale germplasm collection and evaluation was *Paspalum notatum* INIA Sepé[9]. Similarities in chemical composition between native pastures and PN INIA Sepé can be observed, but not in the growth rate, where INIA Sepé is much higher. During summer, native pastures have low quality, decreasing the growth potential rate of lambs[10]. The crude protein (CP) content varies between 6 and 15% according to season, maximum in winter and early spring, and minimum in summer. The dry matter digestibility (DMD) varies between 50 and 61%, while metabolizable energy (ME) does so between 1.8 and 2.2 Mcal/kg DM[11]. The DMD and CP contents are related to ruminal degradability and function, digesta kinetics, mean retention time and level of intake; the nutritive values of summer can limit animal performance[12][13][14]. In this situation, supplemental feeding is necessary to complement nutrients, reduce or avoid protein deficiency, and enhance relative intake[15].

The plant-based ethanol industry is growing, and a primary by-product called dried distillers' grain with soluble (DDGS) is an excellent energy and protein source for ruminants. Rations with 30% of corn DDGS resulted in the highest gross margin and economic efficiency with the lowest fed cost per kg of weight gain[16]. Traditional supplements like soybean meal (SM) or yellow corn can be replaced by DDGS (sorghum, corn or barley[17]). Particularly, sorghum DDGS (S-DDGS) has a high nutritional value (30.2% CP; 9.4% ether extract; 2.8 Mcal ME/kg DM, and 46 % neutral detergent fibre), about 60% of the protein is rumen by-pass protein and it is highly palatable[18][19]. Finishing steers fed with SM, S-DDGS and corn DDGS (200 g/kg DM) showed no differences in performance among diets[20]. Different studies evaluated dietary corn DDGS levels for growing and finishing lambs. Inclusion of corn DDGS from 20%, 30% up to 60% has been used as an energy and protein source[21][22], increasing about 25% of body weight gain (BWG) with level 30% corn DDGS[16]. Therefore, DDGS has a high nutritional value, can be used in lamb diets and is less costly for the farmer than other feed sources, such as corn or SM[22]. However, S-DDGS has not been utilized as a supplement in lamb growing and finishing diets when grazing.

This study aims to evaluate the effect of partial substitution of SG and SM by S-DDGS on the performance of post-weaning lambs grazing *Paspalum notatum* INIA Sepé, in summer. The working hypothesis was that the performance of post-weaning lambs grazing *Paspalum notatum* INIA Sepé supplemented with an energy-protein diet (SG and SM) is not reduced by the substitution of 40% of the supplement with S-DDGS.

2. Materials and methods

2.1 Location and period

The experiment was carried out at Glencoe Research Station of the *Instituto Nacional de Investigación Agropecuaria* (INIA, National Agricultural Research Institute; Paysandú, Uruguay; latitude 32°01'32''S, longitude 57°00'39''W) during summer 2017, from January 12 (Day 0) to April 6 (Day 84). The Animal Ethics Committee of INIA (approval N° INIA 2016.51) approved all procedures.

2.2 Animals and management

Forty-two Dohne Merino male lambs were weaned on pasture (96 ± 6.9 days of age, 28.8 ± 2.8 kg of BW) and supplemented with commercial ration (at 1.5% of BW; CP 16%) until the start of the experiment. The average age of lambs at the beginning of the experiment (Day 0) was 130 ± 7.6 days, with an average BW of 32 ± 2.4 kg, and body condition score (BCS, score 1 to 5[23]) of 2.2 ± 0.2. The lambs had free access to clean water, mineral blocks and collective shade (1.8 m^2/lamb) during the experiment. All lambs were drenched by a suppressive dose at the beginning of the experiment (Day 0) to GIN control (Naftalophos 15%; Vermkon®, Lab König, Buenos Aires, Argentina; 35 mg kg BW^{-1}). Every 14 days, faeces were sampled from all lambs. Whenever the faecal egg count (FEC) was over 500 eggs per gram of faeces in 50% of animals/plot and anaemia score (Famacha®, 1 = optimal to 5 = fatal) was above 3 in 20% of animals/plot, the lambs were drenched. The Famacha® test was used as support tool when making the decision to drench. All the animals were drenched on Day 50 (03/3; Naftalophos 15%) and Day 78 (03/31; Ivermectina 0.2% plus Levamisol 8% plus Rafoxanide 7.5%; Ranizole®, Lab Cibeles, Montevideo, Uruguay; 1 mL kg BW^{-1}).

2.3 Experimental design

A completely random plot design with three treatments, with two replicates each, was used. Treatments were as follows: 1) *Paspalum notatum* INIA Sepé (PN group, n=14); 2) PN supplemented with 70% SG and 30% SM (SGSM group, n=14), and 3) PN supplemented with 45% SG + 40% S-DDGS + 15% SM (DDGS group, n=14).

2.4 Supplement management

The adaptation period lasted 13 days, until the target intake level was reached (1.70 % of BW). Every 14 days, adjustments of the amount of supplement were made, according to the average BW of each replicate. The lambs received half the daily ration twice a day at 9 am and 5 pm. The linear space of the feeder was more than 30 cm for each animal.

2.5 Forage management

The lambs grazed on *Paspalum notatum* INIA Sepé, which was sown in November 2015 (7 kg/ha, two fertilizations with granulated urea). The grazing system was continuous with a fixed stocking rate of 24 lambs/ha. The height of pasture was maintained at approximately 17.2 cm (ruler) and 12 cm (rising plate meter [RPM]), and five mechanical interventions with a mower were needed (Days 7, 14, 29, 43 and 60) to maintain pasture within the expected height.

2.6 Animal measurements

Every 14 days the lambs were weighed unfasted, and BCS and Famacha® were recorded by the same person throughout the study. Wool growth was measured with the mid-side patch method[24] using Herons area formula: = √s (s-a) (sb) (s-c)[25]. Wool growth rate was calculated with the following equation: [(wool weight (g) / patch's area (cm^2) / days of experiment) × 1000000]. Feed conversion of the supplement was calculated using the following formula: [(kg supplement (DM)) / (kg BW (SGSM or DDGS) – kg BW control (PN))]. Production of BW per hectare was calculated as [(BWG × total days of the experiment / 1000) × (stocking rate)].

2.7 Pasture measurements

Herbage mass dry matter (kg DM/ha) of each plot was estimated weekly within six quadrants of 20 cm × 50 cm (0.1 m^2). Pasture was cut with a manual scissor (above 3 cm), each sample was individually fresh weighed and then pooled. Two subsamples were fresh weighed (each 100 g) and dry weighed (after 72 h, at 60 °C) for dry matter content estimation. One of them was separated into fresh and dead forage and weighed. The average of these estimations was applied to each of the six fresh weights. Herbage mass (kg DM/ha) was estimated using the following equation: [(fresh weigh × % DM × 10000)/0.1/1000]. Pasture height was measured using RPM (50 times) and ruler (20 times), and normalized difference vegetation index (NDVI) was estimated through a 25 m diagonal per plot with a GreenSeeker® (Trimble®, Sunnyvale, USA). Botanic composition was estimated to register the species with the highest frequency[26].

2.8 Pasture and supplement chemical composition

To estimate the pasture and supplement chemical composition, samples were sent to the Animal Nutrition Laboratory of *INIA La Estanzuela* (Colonia, Uruguay). For pasture, ground samples analysed CP according to the procedure described by AOAC[27]; ME was calculated according to the ARC[28] equation: [(4.4 x 0.82 x % DMD)/100]; acid detergent fibre was analysed with tool ANKOM 220 and ANKOM A 2000 I. Nitrogen content for CP estimation was calculated using DESTILLATION KJELTEC 8200 FOSS and DESTILLATION KJELTEC 2200 FOSS; DMD was calculated according to the following equation: [(88.9 - (% ADF x 0.779)][29], and analytic dry matter was estimated according to AOAC[30]. For supplement chemical composition, 200 g of each component (SG, S-DDGS and SM) were sent to the laboratory. In addition to the same variables as the pasture, neutral detergent fibre and ashes were estimated according to the procedure described by AOAC[30]. Results are reported on a dry basis. The CP and ME data of each supplement were extracted from the laboratory analysis and from FEDNA table (Spanish Foundation for the Development of Animal Nutrition) for CP and ME, respectively, and the total value of CP and ME offered by the diet was calculated according to the proportion of each component. The information on forage and supplement offered is presented in Table 1.

Table 1. Means (µ ± SEM) of herbage mass, final herbage mass, green fraction, growth rate, normalized differentiated vegetation index, height determined by sward and Rising Plate Meter, and chemical composition of the forage and supplement offered for each nutritional treatment (PN, SGSM, DDGS)

	Treatments				
Parameter	**PN**	**SGSM**	**DDGS**	**µ**	**SEM**
Herbage mass (kg DM/ha)	6976	6877	7357	7070	179.4
Final herbage mass (kg DM/ha)	2325	2316	2477	2373	83.1
Green fraction (kg DM/ha)	1961 [b]	2191 [a]	1857 [b]	2003	62.4
GR (kg DM/ha/d)	60	57	64	60	6.1
NDVI	0.61	0.62	0.62	0.62	0.01
Sward height (cm)	17.1	17.3	17.1	17.2	0.95
RPM height (cm)	12.2	12.2	11.7	12.0	0.49
CP (%)	9.8	9.6	9.6	9.6	0.21
ME (Mcal kg/DM)	2.06	2.07	2.06	2.06	0.01
ADF (%)	40.7	40.8	40.5	40.7	0.48
DMD (%)	57.2	57.1	57.3	57.2	0.24
Supplement offered					
CP (%)	-	20.9	19.1	-	-
ME (Mcal kg/DM)	-	2.8	2.8	-	-

GR = growth rate; NDVI = normalized differentiated vegetation index; RPM = Rising Plate Meter; CP = crude protein; ME = metabolizable energy; ADF = acid detergent fiber; DMD = digestibility of dry matter; PN = *Paspalum notatum* INIA Sepé; SGSM = PN + 70% whole sorghum grain + 30% soybean meal; DDGS = PN + 45% whole sorghum grain + 40% Sorghum Distillers Dried Grains with Soluble + 15% soybean meal; a, b = means with different letters between columns are statistically different (P<0.05); SEM = standard error of the mean; (-) = not applicable

2.9 Environmental measurements

Temperature (Campbell CR 1000 automatic station; CampbellSci, Campbell Scientific, Logan, Utah, USA) and precipitation (rain gauge) were recorded at the meteorological station of Glencoe Research Station. The average temperature was 23.4 °C for January and February, and 20.7 °C for March. The rainfall records were 375 mm, with the following distribution: 14 mm in January, 288 mm in February and 73 mm in March.

2.10 Statistical analysis

Animal and forage data were analysed using a mixed model of the statistical package Infostat (Grupo Infostat Student, FCA, Universidad Nacional de Córdoba, Argentina)[31]. Animal model included 'replicates', 'diet' and their 'interaction' as fixed effects, while 'lamb' and 'plot' were random effects. Initial BW and initial BCS were used as covariates for subsequent analysis of those variables. Body weight gain and FEC were analysed as repeated measures over time, 'date' and their interaction with 'diet' were included in the animal model as fixed effects. Body weight gain was calculated based on the difference between BW measurements. For the analyses of forage related traits (herbage mass, sward height and NVDI) the model included 'diet' and 'replicates' as fixed effects, while 'plot' was a random effect. Differences were considered statistically significant when P<0.05.

2.11 Transparency of data

Data not available: The data set that supports the results of this study is not publicly available.

3. Results

An effect of supplementation (P<0.0001) but not on the type of supplement (P>0.05) was observed in some of the variables analysed: BW, BWG, wool growth and productivity per hectare (Table 2). On the other hand, differences in final BCS were observed among all the treatments (Table 2). The increases obtained in the parameters measured in the supplemented groups compared to the control group were: 17% higher for BW, 3.3 and 1.6 times higher for BWG and BCS, respectively, 27% higher wool growth, and 3 times higher productivity per hectare.

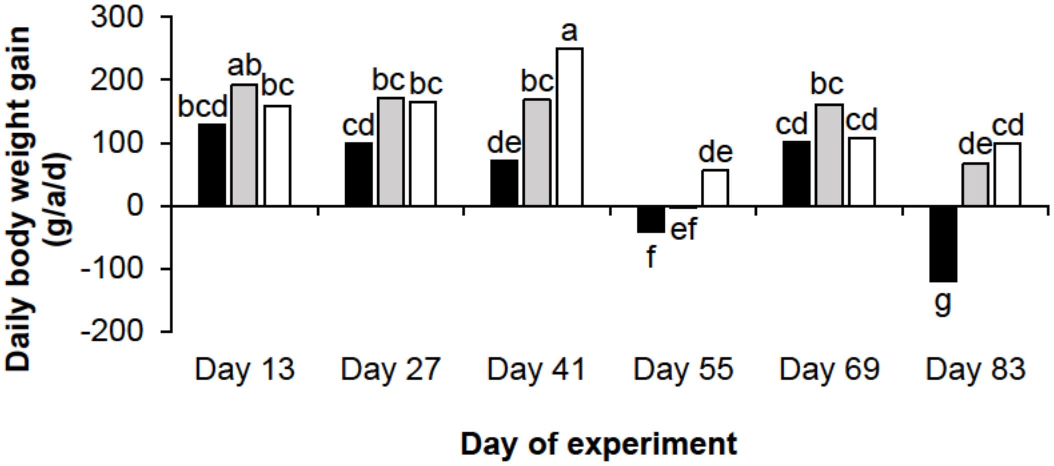
Table 2. Means (± SEM) of initial and final body weight, body weight gain, initial and final body condition score, wool growth, supplement conversion rate, productivity of body weight per hectare for each nutritional treatment (PN, SGSM, DDGS)

	Treatments			
Parameter	**PN**	**SGSM**	**DDGS**	**SEM**
Initial BW (kg)	32.2	32.0	31.9	0.68
Final BW (kg)	35.5 [b]	42.4 [a]	43.5 [a]	0.72
BWG (g/a/d)	40 [b]	126 [a]	140 [a]	5.7
Initial BCS (units)	2.2	2.2	2.2	0.07
Final BCS (units)	2.4 [c]	3.7 [b]	3.9 [a]	0.07
Wool growth (μg/cm^2/d)	1353 [b]	1892 [a]	1814 [a]	68.0
Supplement conversion rate (kg supplement/kg BW additional)	-	7.1	6.1	-
Productivity (kg BW/ha)	87 [b]	248 [a]	288 [a]	0.16

BW = body weight; BWG = body weight gain; BCS = body condition score; PN = *Paspalum notatum* INIA Sepé; SGSM = PN + 70 % whole sorghum grain + 30 % soybean meal; DDGS = PN + 45 % whole sorghum grain + 40 % Sorghum Distillers Dried Grains with Soluble + 15 % soybean meal; a, b = means with different letters within lines are statistically different (P<0.05); SEM = standard error of the mean; (-) = not applicable

All treatments ended the study with a positive BWG (Table 2); however, SGSM and DDGS, respectively, were 86 and 100 g/d superior to the control group. An interaction between date and treatments was detected at three time points, days 41, 55 and 83 (02/22, 03/08, 04/05; P=0.0044), in which lambs in the control group presented lower average BWG than lambs from supplemented groups, not showing an interaction between them, except for the day 41, where differences were found among the three groups (Figure 1).

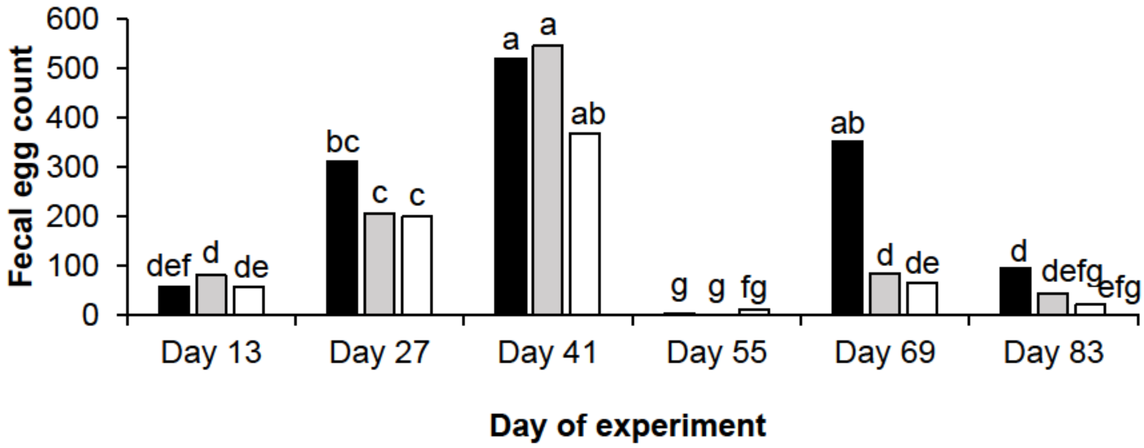
Figure 1. Evolution of daily body weight gain (g/a/d) according to nutritional treatment PN (■), SGSM (□), DDGS (□) throughout the experimental period



a, g = means with different letters between columns and day of experiment are statistically different (P<0.05); PN = *Paspalum notatum* INIA Sepé; SGSM = PN + 70% whole sorghum grain + 30% soybean meal; DDGS = PN + 45% whole sorghum grain + 40% Sorghum Distillers Dried Grains with Soluble + 15% soybean meal

FEC varied during the experimental period; however, in most of the dates there were no differences between the treatments (Figure 2). Interaction between date and treatments was observed on day 69 (03/22). On this day, the supplemented groups presented lower FEC than the control group (P=0.0024), with no differences between them (P>0.05). The highest FEC on day 69 was presented by the control group, determining drenching in all the animals. On day 83 (04/05), FEC differed for the PN and DDGS treatments (P=0.0024), without differences between PN and SGSM (P>0.05). The reduction in FEC observed between days 69 and 83 responds to the use of an effective anthelmintic (day 78).

Figure 2. Faecal egg count according to nutritional treatment PN (■), SGSM (▒), DDGS (□) and sampling date, with dosages at three times (Day 0, 50 and 78)



a, g = means with different letters between columns and day of experiment are statistically different (P<0.05); PN = *Paspalum notatum* INIA Sepé; SGSM = PN + 70% whole sorghum grain + 30% soybean meal; DDGS = PN + 45% whole sorghum grain + 40% Sorghum Distillers Dried Grains with Soluble + 15% soybean meal

4. Discussion

This experiment evaluated the effect of partial substitution of SG and SM by S-DDGS in the supplemental diet on the productive performance of post-weaning lambs grazing *Paspalum notatum* INIA Sepé, during the summer. The hypothesis that the performance of post-weaning lambs would not be reduced by the inclusion of 40% S-DDGS was confirmed. The supplemented groups (SGSM and DDGS) had higher productive performance and a lower FEC, compared to the control group (PN), without differences between them. Sorghum-DDGS is a valid source of nutrients and allows its inclusion as a component of an energy-protein supplementation (SG and SM). The improvement in the productive performance of post-weaned lambs fed with iso-energetic and iso-protein supplements and grazing *Paspalum notatum* INIA Sepé can be maintained even with S-DDGS in the diet.

A grazing-based production system has certain limitations in achieving high animal performances, and a balanced diet is essential for exploiting the growth and development potential of post-weaned lambs. An improvement in the diet by supplementation leads to enhanced overall performance. The differences found between supplemented and non-supplemented lambs could be due to the contribution of extra nutrients (energy and protein), the better energy/protein balance, and the decrease in the requirements due to reduced grazing activity in supplemented animals compared to the only grazing group[32]. Additionally, it is important to mention the differential partition of the energy offered, since the lambs in the control treatment were forced to spend more time searching for and harvesting forage to cover their maintenance and production requirements. Instead, supplemented lambs were able to allocate their time differently, dedicating it to other activities, such as rest and shade use, reducing their requirements[3]. Furthermore, results reported by Ramos and others[5] indicate that the use of supplement (2% BW) in post-weaned lambs can reduce grazing time in a native pasture by approximately 47%. Moreover, in our study, the performance of the supplemented groups allowed us to verify that the use of one or another source of nutrients, SGSM or S-DDGS, does not alter animal performance[16]. The nutritional contribution in terms of CP and ME offered by both supplements was similar (Table 1), and animals did not differ in their productive performances. According to Grazfeed software[33], the net energy gain efficiency for the supplemented treatments was the same, 0.39 for SGSM and DDGS, while for PN it was 0.30. In addition, the net energy destined to weight gain (without considering wool growth) showed a similar behaviour to the efficiency, presenting higher values the supplemented treatments (0.61 Mcal DDGS, and 0.65 Mcal SGSM) compared to the control (0.44 Mcal PN). This partition of energy could be the basis for the difference observed in the performance of the animals. Supplementing lambs in the rearing stage during the summer period could be an appropriate tool to achieve higher animal performances.

Strategic supplementation is a tool used for animals grazing on pastures of different quality to add energy and protein to their diets, especially to categories with high requirements[34]. This also allows higher stocking rates in grazing-based production systems. The results of BW, BCS and BWG obtained in the present study were similar to those reported by Piaggio and others[35], and Ramos and others[5]. Although it is worth noting the important difference in stocking rate. In this study, the use of PN contributed to being able to use higher stocking rate (24 lambs/ha) than other experiments evaluated in native pastures (10 lambs/ha). According to Grazfeed predictions[33], there could have been a possible substitution of forage by supplements in the supplemented groups, because estimated total intake of control treatment (PN) and supplemented treatments (SGSM, DDGS) was similar (PN = 1.63; SGSM = 1.61; DDGS = 1.55 kg/DM/a/d). Therefore, the intake of protein and energy may have been higher for the supplemented lambs than the non-supplemented ones, allowing the animals to achieve higher BWG. The assumed substitution would not only have allowed the animals to decrease their energy requirements (less grazing time) and improve their grass selectivity, but would also have given them the opportunity to create an improved diet in terms of ME, protein content, in favour of better animal performance. On the other hand, the supplementation allowed to triple the productivity per hectare. The results reported by Piaggio and others[35] are lower than those of the present study, 46 kg BW/ha at a rate of 10 lambs/ha in native pastures, while for the treatment of native pasture and supplementation with soybean expeller the value was 71 kg BW/ha. Additionally, the treatments ended with different stocking rates in BW terms (35.5*24=852 *versus* 43.5*24=1044), 20% higher in the supplemented treatments. Supplementation of animals with high requirements is a valid tool that allows adding energy and protein to diets of animals grazing on pasture of varying quality, and permits higher stocking rates, resulting in increased productivity per hectare.

Many studies indicate a linear relationship between BW and BCS in sheep, but the increase in BW for each BCS unit varies by breed[36]. In this experiment, the difference detected in BCS between control and supplemented lambs was 1.4 units and was associated with a change in BW of 7.45 kg. Our results agree with Coop and Sykes[37], who say that higher weight gain rates lead to higher proportions of animal fat, improving body condition and body weight. In this way, the supplemented lambs would have the adequate BW and BCS for slaughter according to the Uruguayan meat industry requirements. The higher BW and BCS achieved by the supplemented lambs were due to higher daily gains of these lambs compared to control lambs. This better performance achieved by the supplemented lambs reveals a possible association between BWG, FEC and rainfall.

The weather conditions that occurred during the current experiment were beneficial for the development of the nematodes. These nematodes affected the animals differently depending on the treatment to which they were subjected, which can be seen in Figure 2 (FEC). Clearly, this different infestation, added to other factors, such as nutrition, resulted in different BWG between animals (Figure 1).

The wool growth of grazing sheep depends largely on their genetic potential and their ability to meet their energy and amino acid requirements on pasture[38]. Lower wool growth was associated with lower quality diet (PN), while higher wool growth was observed in the supplemented lambs, with no differences between them (SGSM, DDGS). These results are in agreement with Kempton and others[39], who reported that the availability of energy and protein determines the wool growth and the BWG, with the availability of protein as the limiting factor, which, when increased, stimulates wool growth and BWG. Wool growth trends were essentially similar to those of body weight, which were similar to the results found by Ramos and others[5], who obtained the maximum wool growth with the treatment with 20% CP. The authors argued that the differences found in the protein/energy content of the diet, and the additional estimated intake of the supplement, would provide more protein and energy, and therefore increase wool production. In this sense, Reis and others[40] report that increases in the protein content of the diet favour the production of wool, while feeds with high energy content increase the production of wool only if the protein level is adequate. On the other hand, Nagorcka[41] mentions a directly proportional relationship between the estimated intake of digestible feeds and wool growth.

In susceptible categories such as weaners, sanitary control is key to achieve adequate animal performance, and FEC acquires practical importance, monitoring an epidemiological situation that may be unstable. The FEC varied during the experimental period, which could be due to various factors, such as the environmental conditions (temperature and rainfall), and the effect of diet, as the control treatment presented higher levels of GIN infestation. The results of higher levels of FEC in lambs of the control group could be due to a greater parasite challenge, as reported by Ramos and others[5], as lambs fed exclusively on pastures spend more time grazing (47% extra) than supplemented animals. Higher pasture intake would be equal to higher larvae (L3) intake[5]. Additionally, there is a direct relationship between the number of animals per surface area and the number of larvae (L3), where a higher parasite load implies a greater number of infested animals[42]. In the present study this aspect would be relevant given the high stocking rate utilized (24 lambs/ha). This could be indicative of a relationship between the nutritional level and the susceptibility of the animal to parasite infestation, showing that a diet with a higher contribution of nutrients (energy and protein) leads to lower parasite infestation in animals. In this sense, Coop and Sykes[37] establish that protein supplementation has a positive effect on the expression of immunity against GIN; and Goldberg and others[43] mention that better-fed lambs will be less susceptible to parasitic infestations. The lambs presented differences in their productive performance at the same parasite load, which may be evidence for increased resilience. The epidemiological cycle of GIN is governed by contamination of the pasture and its transfer to the animal. Infestation of the animal will be seasonally limited by the supply of larvae from the pasture, with *Haemonchus contortus* being the most prevalent nematode in the summer if the weather conditions are favourable[42]. The high parasite load negatively and differentially affected the productive performance of the lambs. The diet had a clear effect on the FEC, allowing it to be lower in the supplemented treatments, associated with better nutritional balance and resilience[6].

5. Conclusions

The partial substitution of the supplement (SGSM) with S-DDGS allowed similar animal performances maintaining the crude protein and energy concentrations in the final supplement. The productive performance of lambs, evaluated as body weight, body condition score, body weight gain, wool growth, and productivity per hectare, was affected by supplementation, as well as gastrointestinal nematodes infestation. Supplementation gave the animals a greater opportunity to resume productivity in the face of an adverse epidemiological situation.

Author contribution statement

ER: data collection, results interpretation and article writing; AIT: data collection, results interpretation and article writing; EvL: experiment design, results interpretation and article writing; RR: experiment design and results interpretation; IDB: experiment design, results interpretation and article writing.

Authors would like to indicate that Romaniuk and Tafernaberry are co-first authors, having contributed equally to the article.

References

1. Karakus F. Weaning stress in lambs. Agriculture & Food. 2014;2:165-70.

2. NRC. Nutrient requirements of small ruminants. Washington: National Academy Press; 2007. 384 p.

3. Geenty K, Rattray P. The energy requirements of grazing sheep and cattle. In: Nicol A, editor. Feeding livestock on pastures. New Zeland: New Zeland Animal Production; 1987. p. 39-53. (Occasional publication; 10).

4. Campbell A, Vizard A, Larsen J. Risk factors for post-weaning mortality of Merino sheep in south-eastern Australia. Aust Vet J. 2009;87(8):305-12.

5. Ramos Z, De Barbieri I, van Lier E, Montossi F. Body and wool growth of lambs grazing on native pastures can be improved with energy and protein supplementation. Small Rumin Res. 2019;171:92-8.

6. Crawford C, Mata-Padrino D, Belesky D, Bowdridge S. Effects of supplementation containing rumen by-pass protein on parasitism in grazing lambs. Small Rumin Res. 2020;190:106-61.

7. Cei W, Salah N, Alexandre G, Bambou J, Archimede H. Impact of energy and protein on the gastro-intestinal parasitism of small ruminants: a meta-analysis. Livest Sci. 2018;212:34-44.

8. Soriano A, León RJC, Sala OE, Lavado RS, Deregibus VA, Cahuepé MA, Scaglia OA, Velázquez CA, Lemcoff JH. Río de la Plata grasslands. In: Coupland RT, editor. Ecosystems of the world 8A: natural grasslands: introduction and western hemisphere. New York: Elsevier; 1992. p. 367-407.

9. Reyno R, Narancio R, Speranza P, Do Canto J, López-Carro B, Hernández P, Burgueño J, Real D, Dalla Rizza M. Molecular and cytogenetic characterization of a collection of bahiagrass (Paspalum notatum Flügge) native to Uruguay. Genet Resour Crop Evol. 2012;59:1824-32.

10. Piaggio L, Marichal M, Del Pino M, Deschenaux H. Growth rate of weaned lambs grazing brown midrib sorghum (Sorhgum bicolor) supplemented with increasing levels of soybean meal. Anim Prod Sci. 2014;54(9):1278-81.

11. Berretta E, Risso D, Montossi F, Pigurina G. Campos in Uruguay. In: Lemaire G, Hodgson J, de Moraes A, Nabinger C, Carvalho F, editors. Grassland ecophysiology and grazing ecology. Oxfordshire: Cab International; 2000. p. 377-94.

12. Hodgson J. Grazing Management: Science into Practice. Londres: Longman Scientific & Technical; 1990. 203p.

13. Freer J, Dove M, Nolan H. Nutrient Requirements of Domesticated Ruminants. Collingwood: CSIRO; 2007. 270p.

14. Keser O, Bilal T. Effect of different dietary crude protein levels on performance, N digestibility and some blood parameters in kivircik lambs. Acta Vet. 2008;8(5-6):487-98.

15. Freer M, Dove H. Sheep Nutrition. Wallingford: CABI; 2002. 385p.

16. Etman K, El-Monayer T, Sayed S, El-Sayed F, Farag M. Some Studies on using different levels of dried distilers grains with solubles (DDGS) on animal performance: Effect of Feeding Different Levels of DDGS as a source of Energy on sheep performance. J Anim Poult Prod. 2014;5(2):27-41.

17. Curzaynz, K, Santillán-Gómez E, Flores-Santiago E, Bárcena-Gama R, Escobar-España J, Real C, Rivas-Martínez M, Portela D. Effect of dried distillers grains (DDGS) on diet digestibility, growth performance, and carcass characteristics in Creole wool lambs fed finishing diets. S Afr J Anim Sci. 2019;49(1):56-62.

18. Huls JT, Barosh AJ, Daniel JA, Zelinsky RD, Held J, Wertz-Lutz AE. Efficacy of Dried Distiller’s Grains with Solubles as a replacement for soybean meal and a portion of the corn in a finishing lamb diet. Sheep and Goat Research Journal. 2006;21:30-4.

19. Blas C, Mateos G, García-Rebollar P. Composición y valor nutritivo de los alimentos para la fabricación de piensos compuestos. 3rd ed. Madrid: Fundación Española para el Desarrollo de la Nutrición; 2010. 423p.

20. Wood KM, Salim H, McEwen PL, Mandell IB, Miller SP, Swanson KC. The effect of corn or sorghum dried distillers grains plus solubles on growth performance and carcass characteristics of cross-bred beef steers. Anim Feed Sci Technol. 2011;165(1-2):23-30.

21. Schauer CS, Stamm M, Maddock TD, Berg PB. Feeding of DDGS in lamb rations: feeding dried distillers grains with solubles as 60 percent of lamb finishing rations results in acceptable performance and carcass quality. Sheep goat res j. 2008;23:15-9.

22. Sahin I, Kaya O, Aksu D, Elmali K. Effects of dietary supplementation with distiller dried grain with solubles in growing lambs on growth, nutrient digestibility and rumen parameters. Rev Med Vet (Toulouse). 2013;168(4):173-8.

23. Jefferies B. Condition scoring and its use in management. Tasmanian J Agr. 1961;39:19-21.

24. Langlands JP, Wheeler JL. The dyebanding and tattooed patch procedures for estimating wool production and obtaining samples for the measurement of fibre diameter. Austral J Exp Agric Anim Husb. 1968;8(31):265-9.

25. De Barbieri I, Hegarty RS, Li L, Oddy VH. Association of wool growth with gut metabolism and anatomy in sheep. Livest Sci. 2015;173:38-47.

26. Ellenberg D, Mueller-Dombois D. Aims and Methods of Vegetation Ecology. New York: Wiley; 1974. 547p.

27. AOAC. Official methods of analysis. 14th ed. Washington: AOAC; 1984. p. 249-52.

28. ARC. The Nutrient requirements of ruminant livestock: technical review. Farnham Royal (UK): Agricultural Research Council; 1980. 351p.

29. Lithourgidis AS, Vasilakoglou IB, Dhima KV, Dordas CA, Yiakoulaki MD. Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. Field Crops Res. 2006;99(2-3):106-13.

30. Rybak-Chmielewska H. Honey. In: Tomasik P, editor. Chemical and functional properties of food saccharides. Boca Raton: CRC Press; 2004. p. 83-9.

31. Di Rienzo JA, Casanoves F, Balzarini MG, González L, Tablada M, Robledo CW. InfoStat [Internet]. Version 2012. Córdoba: Universidad Nacional de Córdoba, Facultad de Ciencias Agropecuarias; 2014 [cited 2022 Feb 8]. Available from: https://bit.ly/3dDvIyu.

32. Krysl LJ, Hess BW. Influence of supplementation on behavior of grazing cattle. J Anim Sci. 1993;71(9):2546-55.

33. Freer M, Moore AD, Donnelly JR. GRAZPLAN: decision support systems for Australian grazing enterprises: II. the animal biology model for feed intake, production and reproduction and the GrazFeed DSS. Agric Syst. 1997;54(1):77-126.

34. Moore JE, Brant MH, Kunkle WE, Hopkins DI. Effects of supplementation on coluntary forage intake, diet digestibility, and animal performance. J Anim Sci. 1999;77:122-35.

35. Piaggio L, Marichal M, Pastorín A. A 'protein bank' of Lotus uliginosus cv. Maku as an alternative to conventional protein supplements for weaned lambs grazing on natural pastures during summer and autumn. J Anim Sci. 2015;55(1):27-30.

36. Kenyon PR, Maloney SK, Blache D. Review of sheep body condition score in relation to production characteristics. New Zealand J Agric Res. 2014;57(1):38-64.

37. Sykes A, Coop RL. Interaction between nutrition and gastrointestinal parasitism in sheep. N Z Vet J. 2002;49(6):222-6.

38. Rogers GE, Schlink AC. Wool growth and production. In: Cottle DJ, editor. International sheep and wool handbook. Nottingham: Nottingham University Press; 2010. p. 373-94.

39. Kempton TJ, Nolan JV, Leng RA. Protein nutrition of growing lambs: 2. Effect on nitrogen digestion of supplementing a low-protein-cellulosic diet with either urea, casein or formaldehyde-treated casein. Br J Nutr. 1979;42(2):303-15.

40. Reis P, Tunks D, Munro S. Effects of abomasal protein and energy supply on wool growth in Merino sheep. Aust J Agric Res. 1992;43(6):1353-6.

41. Nagorcka BN. The Description and Analysis of Wool Growth. Aust J Agric Res. 1977;28:737-56.

42. Nari A, Cardozo H. Nemátodos Gatrointestinales. In: Bonino J, Durán del Campo A, Mari J. Enfermedades en los lanares. Montevideo: Hemisferio Sur; 1987. p. 1-51.

43. Goldberg V, Ciappesoni G, De Barbieri I, Rodríguez A, Montossi F. Factores no genéticos que afectan la resistencia a parásitos gastrointestinales en Merino en Uruguay. Producción Ovina. 2011;21:1-11.