

Effect of Energy Supplementation On Intake, Digestibility of Diets and Performance of Grazing Lambs During The Rainy Season

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Abstract

This study aimed to evaluate different energy sources in multiple supplements on performance, intake and digestibility of Santa Ines sheep grazing urochloa grass (*Urochloa mosambicensis*) during the rainy season. The experimental area was divided into seven paddocks of four-ha each, with an average of dry matter (DM) availability of 3213.45 kg/ha. A completely randomized design was carried out, in which there were four treatments, and each treatment was repeated six times. Twenty-four intact lambs (average: 32 kg of body weight) were supplemented with a mineral mixture, the control group (MM), mesquite pod meal (MPM), wheat bran (WB) or sorghum grain (SG) as energy sources. The digestibility of DM and crude protein (CP) in MPM, and WB is higher than in MM and SG groups. The DM digestibility was higher in the WB group; however, there was no difference between the other treatments. Neutral Detergent Fiber (NDF) digestibility was similar between supplemented lambs, and it was higher than the MM. The supplementation promoted higher weight gain than in the control group (0.125 vs. 0.61 g/day, respectively; $P < 0.001$). The supplementation increased the DM, and CP intake. The NDF intake only increased in the WB group. The CP digestibility was higher for the MPM and WB groups than for MM and SG ones ($P < 0.001$). Sheep supplementation in the rainy season increased the average daily gain (ADG). Any supplement tested in the present study can be used during the rainy season. The choice for the supplement will depend on the availability and costs of the supplement.

Introduction

Tropical grass generally may not provide required nutrients for ruminant animals (Voltolini et al., 2009); so, additional supplementation may be necessary (Fieser et al., 2007). During the rainy season, forage can reach its maximum availability and nutritional value, helping lambs to meet their nutritional requirements. However, both attributes (quality and quantity) vary and they depend on the management, soil chemical and physical characteristics, fertilization, and climatic conditions, resulting in an imbalance between supply and demand for nutrients in grazing animals.

Therefore, supplementing other carbohydrate sources in grazing sheep can improve the growth performance of animals, because it directly affects the growth of microbes in the rumen, which has a fundamental effect on the efficiency of feed conversion rate into edible animal products.

Studies have evaluated different sources of supplement for grazing lambs in the dry season (Almeida et al., 2011, 2012) but a few studies have been made during the rainy season (Godfrey and Dodson, 2003). Different sources of energy can act differently in the rumen environment and promote different responses in grazing lambs (Nascimento et al., 2010). Sorghum grain, mesquite pod meal, and wheat bran are common feedstuff used in Brazil as a source of energy. One of the reasons to use this feedstuff, as sorghum grain, is the more resistance to periods of drought (Ncube et al., 2014).

Despite the greater availability of forage during the rainy period, it is possible to obtain better results with supplementation (Fajardo et al., 2015; Silva et al., 2019). This might be due to a better synchronization of

energy and protein in the rumen. In this perspective, sources of energy such as mesquite pod meal, sorghum grain and wheat bran can be used as a source of energy. These energy sources are abundant and have low prices during the rainy season in Brazil and can be used to promote higher gains for grazing lambs as well as to accelerate the final phase and slaughter. Therefore, this study assumes that supplementing with different energy sources will have a significant impact on the performance of lamb grazing during the rainy season, and provide farmers with alternative feed during this period of low prices. This study aimed to evaluate the effect of energy supplementation for sheep grazing during the rainy season on the intake, digestibility and performance.

Materials And Methods

The experiment was conducted at Palmares farm, located in Iaçú, a semi-arid region in Bahia, Brazil (15°31'0"S, 40°14'1"W). According to Köppen climate classification, the climate of the region is tropical and wet, mesothermic, hot and rainy during the summer and cold and dry in the winter. The study was conducted during the rainy season, from January to April (Table 1).

Table 1
Rainfall (mm), average minimum temperature (Tmin) and maximum temperature (Tmax) during the experimental period

Month	Rainfall (mm)	Tmin (°C)	Tmax (°C)
January	36.0	17.5	32.5
February	40.0	21.1	38.2
March	42.0	21.4	38.8
April	40.0	17.1	38.5
Mean	39.5	19.2	37.0
Total	158.0	—	—

Twenty-four Santa Inês intact male lambs of four months of age and average initial body weight (BW) of 32 ± 2 kg were used in this study. A completely randomized design was carried out, with 4 treatments, six replicates for each treatment, and each animal within the treatment representing a replicate. Ground energy source was used to comprise the multiple supplements: mesquite pod meal (MPM), wheat bran (WB) or sorghum grain (SG) and a control group was kept just in the pasture and receiving mineral mix (MM) to supply mineral requirements. The MM was provided to all treatments *ad libitum* to avoid a mineral deficiency. Ground corn, soybean meal and urea were added to the energy sources to make the multiple supplements with 210.0 g/kg of CP and 602.2 g/kg of total digestible nutrients (TDN) on a DM basis (Table 2). Therefore, lambs were distributed to receive only the mineral mix (MM), MPM

supplement, WB supplement, and SG supplement. The chemical composition of the treatments and pasture is given below (Table 3).

Table 2

Proportion of ingredients of the mineral mix (MM) and multiples supplements (g/kg), expressed on the fresh matter basis

Ingredients	MM ¹	Treatments ²		
		MPM	WB	SG
Ground corn grain		411.5	420.0	411.5
Soybean meal		207.9	200.0	208.0
MPM		353.2	0.0	0.0
WB		0.0	352.6	0.0
SG		0.0	0.0	353.1
Urea		9.7	9.7	9.7
MM ¹	100.0	-	-	-
¹ MM (control group): calcium 120.00 g, phosphorus 87.00 g, sodium 147.00 g, sulfur 18.00 g, copper 590.00 mg, cobalt 40.00 mg, chromium 20.00 mg, iron 1,800.00 mg, iodine 80.00 mg, manganese 1,300.00 mg, selenium 15.00 mg, zinc 3,800.00 mg, molybdenum 300.00 mg and fluorine (max) 870.00 mg, per kg of the product;				
² Treatments: mineral mix (MM), mesquite pod meal (MPM), wheat bran (WB), sorghum grain (SG).				

Table 3
Chemical composition of the *urochloa* grass and the multiple supplements

Item ¹	Treatments ³			
	<i>Urochloa</i> grass	MPM	WB	SG
DM, g/kg	266.0	896.6	892.4	888.3
CP, g/kg DM	115.2	218.7	243.0	219.6
NDF, g/kg DM	678.4	321.3	409.9	296.8
ADF, g/kg DM	351.0	163.5	152.5	177.0
EE, g/kg DM	29.1	23.3	36.6	26.3
Ash, g/kg DM	148.4	57.1	67.4	54.1
Lig, g/kg DM	77.1	25.0	17.0	19.0
TCHO, g/kg DM	707.3	700.9	653.0	700.0
¹ Item: dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), ether extract (EE), lignin (Lig), total carbohydrates (TCHO).				
³ Treatments: mesquite pod meal (MPM), wheat bran (WB), sorghum grain (SG).				

The experimental area was comprised of seven paddocks of 4.0-ha of *urochloa* grass (*Urochloa mosambicensis*), equipped with drink and food troughs, and an availability of 3213.45 kg/ha of DM, 482.01 kg/ha of leaves, 2262.27 kg/ha of stems and 754.93 kg/ha of dead material (dry matter basis). To estimate the total forage availability, eight points were randomly chosen per paddock and cuts were made at each point using metal squares (0.5 × 0.5 m). All material within the square was cut at 15 cm above the ground, as described by Boswell (1977). These samples were taken to the laboratory, where they were weighed and homogenized, and two subsamples were obtained from each sample. An aliquot was used to determine the total DM content, and another one was divided into leaf, stem, and dead material components. The estimation of the quality of the consumed forage was done with the plucking-hand technique (De Vries, 1995).

According to each treatment, lambs were identified with different ear and collar tags, and all lambs belonging to each treatment were put together in a group in one paddock of 4.0-ha. Aiming to reduce the influence of a variation of forage DM availability, the animals were moved to another paddock every five days to remove the effect of the pasture in the treatments. Lambs were allowed to access the paddocks from 7:00 am to 5:00 pm and then they were taken to the pens to be supplemented in feeders. Collective pens had 1 m²/lamb, with 6 animals each. They had access to the supplementation provided in the trough at a ratio of 10 g/kg body weight, based on the mean body weight of the group, with no leftovers.

The experimental period lasted 95 days: 15 days of adaptation, 70 days for performance evaluation and 10 days for intake and digestibility evaluations.

The animals were weighed at the beginning and at the end of the experiment. Lambs were weighed on the 15th of every month to adjust the quantity of the supplement provided, and also to make up the average daily gain during this evaluation period (the fifteenth day of every month). The average daily gain (ADG) was estimated by the following equation:

$$ADG (g/day) = \frac{FBW - IBW}{N}$$

where ADG is the average daily gain; FBW is the final body weight considering the total gain, during 15 days; IBW is the initial body weight and N is the number of days of weighing (every 15 days) in the experiment.

Fecal output data was determined by using chromium oxide (Cr_2O_3) at 2 g/animal.day (Hill and Anderson, 1958) as an external marker, in the morning and in the afternoon. The external marker was packed in bags, and introduced in the esophagus of the lambs by using a PVC (Polyvinyl chloride) apparatus. Fecal samples were collected during five days from the 6th to the 10th day after starting the supply of the marker, every 3 hours directly from the animal's rectum, making up eight samples during the 24 hours of the day. Then, compound samples were made per day and frozen at $-20^{\circ}C$. Fecal recovery was measured by the ratio of the amount of marker excreted and the ingested amount. The fecal dry matter was estimated by the marker through the equation as follows:

$$\text{Dry matter fecal (mg/g)} = \frac{IM}{FM} \times 10$$

where: IM is the ingestion of the marker (mg/g; DM basis); FM is the fecal marker (mg/day; DM basis)

For the determination of the indigestible acid detergent fiber (iADF), 0.5 g of the feces were taken, supplements, and hand-plucked samples were packed in non-woven fabric (NWF-100 g/m²) of 4 × 5 cm and they were inserted in the rumen in the proportion of 20 mg of DM/cm² of the surface. The samples were triplicated and inserted in lingerie bags for each treatment, and were incubated for 264 hours (Casali et al., 2008). After removing the bags from the rumen, they were washed in running water and immediately transferred to a forced ventilation oven (60°C) for 72 hours. DM determination was done according to the method 930.14 of AOAC (AOAC, 2005). The voluntary forage intake was estimated as described by Arthington and Spears (2007). The DM intake was determined by the ratio between the fecal excretion and the internal indicator indigestibility, as described earlier, using the equation proposed by Detmann et al. (2001):

$$DMI = [(FE \times MCF) - CIS] / CIFOR + DMIS$$

where: DMI = dry matter intake (kg/day); FE = fecal excretion (kg/day); MCF = marker concentration in the animal feces (kg/kg); CIS = concentration of iADF in the supplement (kg/day); CIFOR = concentration of iADF in forage (kg/kg); and DMIS = intake of supplement DM (kg/day). Supplement intake was measured by the quantity supplied minus the refusals and then divided by the number of animals of the treatment.

The substitution rate (SR) was calculated according to Kellaway and Porta (1993) and describes the rate of substitution of forage for the supplement.

$SR = (\text{Forage intake when unsupplemented}) - (\text{Forage intake when supplemented}) / \text{Supplement intake}$
To calculate the SR, the average of forage intake of the unsupplemented animals was used.

Total carbohydrates (TCHO) were calculated according to Sniffen et al. (1992) using the equation $TCHO = 100 - (\%CP + \%EE + \%ash)$.

The NDF and ADF contents were determined according to Van Soest et al. (1991). Evaluations of DM, CP (N x 6.25) and ether extract (EE) contents were estimated by the methods 930.15, 984.13 and 920.39 of the AOAC (AOAC, 2005), whereas ash content was calculated as 100-organic matter. The lignin content was analyzed by the sulfuric acid solubilization method following the procedures described by Gomes et al. (2011).

The data was analyzed using the Statistical Analysis System (SAS, 2001), after verification of the normality by the PROC UNIVARIATE statement. The data was analyzed using the PROC GLM procedure, according to the completely randomized design model:

$$Y_{ijk} = \mu + SUP_i + \varepsilon_{ijk}$$

where Y_{ijk} is the dependent variable, μ is the overall mean, SUP_i is the fixed effect of supplements and ε_{ijk} is the random error.

The model considers the supplements as fixed effect and animals were the experimental units. The statistical analysis of the substitution rate (SR) was performed by just using the supplemented animals, because there was no effect of substitution in the animals unsupplemented. The comparisons between means were performed by Tukey's range test. In all models, the statistical significance between means was declared to be $P < 0.05$.

Results

Intake

The DMI (kg/day) was higher for MPM and WB treatments, but MM and SG had similar DMI ($P = 0.001$). However, there was no difference among the treatments in DMI expressed as %BW and DM of forage (DMf) (kg/day) ($P > 0.05$), although, the DMf expressed in %BW was higher in MM, if compared with the other treatments ($P < 0.001$). The CP intake was lower in MM treatment compared to the supplementation

($P < 0.001$), but it was similar among the supplements. However, when the ingestion of NDF was expressed in % of BW, there was an increase in NDF intake for the MM treatment, if compared with the other treatments ($P = 0.021$). No effect of supplement was reported for substitution rating ($P = 0.053$) (Table 4).

Table 4
Nutrient, total DM, forage intake and substitution rate of lambs supplemented during the rainy season

Item ²	Treatments ¹				SEM ³	P-value
	MM	MPM	WB	SG		
DMI, kg/day	0.82 ^b	1.17 ^a	1.16 ^a	0.99 ^{ab}	0.037	0.001
DMI, %BW	2.72	2.83	2.84	2.41	0.068	> 0.05
DMf, kg/day	0.76	0.76	0.75	0.58	0.027	> 0.05
DMc, kg/day	0.06 ^b	0.42 ^a	0.41 ^a	0.42 ^a	0.157	< 0.001
DMf, %BW	2.53 ^a	1.83 ^b	1.83 ^b	1.41 ^b	0.102	< 0.001
CP, g/day	88.11 ^b	169.92 ^a	168.92 ^a	147.92 ^a	7.428	< 0.001
NDF, g/day	0.582 ^b	0.69 ^{ab}	0.75 ^a	0.62 ^{ab}	0.022	0.020
NDF, %BW	1.93 ^a	1.67 ^{ab}	1.83 ^{ab}	1.49 ^b	0.056	0.021
SR	-	-1.06	-1.07	-0.64	0.128	0.053

¹Treatment: MM = mineral mix; MPM = mesquite pod meal; WB = wheat bran; SG = sorghum grain;
²Item: DM (kg/day) = total DM intake; DM (%BW) = total DM intake expressed in % of body weight;
 DMf = dry matter from forage (kg/day); DMc = dry matter intake from concentrate(kg/day); DMf (%BW) = DM of forage expressed in % of body weight; CP = crude protein intake; NDF (kg) = neutral detergent fibre intake; NDF (%BW) = neutral detergent fibre intake expressed in % of body weight; SR = substitution rate; ³SEM=standard error mean; a,b,c Means within a row with different superscripts differ.

Apparent Digestibility And Performance

The DM digestibility was higher in the WB group without difference among the other treatments ($P = 0.003$). The CP digestibility was higher for the MPM and WB groups. The MM group presented the lowest value with intermediate digestibility for the SG treatment ($P < 0.001$). The NDF digestibility was similar among the supplemented animals and higher if compared to the control group (MM) ($P = 0.002$). The supplementation of grazing lambs increased the final body weight and ADG, if compared to the MM group ($P < 0.001$). The lambs that received MPM and WB gained 6.3 kg more than the ones in the control group and 6.6 kg more for the lambs receiving SG treatment, compared to the control group ($P < 0.001$); however, there was no difference among energy source, as well as for feed conversion ($P < 0.0001$). The

lambs supplemented with SG presented higher feed efficiency than the MPM and WB treatments ($P < 0.0001$), with lower feed efficiency for the control treatment (MM) (Table 5).

Table 5
Nutrient apparent digestibility and performance of lambs supplemented during the rainy season

Item ²	Treatment ¹				SEM ³	P-value
	MM	MPM	WB	SG		
DM, g/kg	667.15 ^b	692.60 ^b	708.16 ^a	689.11 ^b	2.587	0.003
CP, g/kg DM	363.70 ^c	628.25 ^a	628.31 ^a	537.70 ^b	18.549	< 0.001
NDF, g/kg DM	624.62 ^b	666.19 ^a	678.47 ^a	657.82 ^a	3.614	0.002
IBW, kg	30.50	32.30	32.80	32.20	-	-
FBW, kg	34.80 ^b	41.10 ^a	41.10 ^a	41.40 ^a	0.590	< 0.001
ADG, kg/day	0.06 ^b	0.12 ^a	0.11 ^a	0.13 ^a	0.006	< 0.001
FC	13.47 ^b	9.33 ^a	9.75 ^a	7.53 ^a	2.564	< 0.0001
FE	7.55 ^c	10.89 ^b	10.32 ^b	13.42 ^a	2.444	< 0.0001

¹Treatments: MM = mineral mix; MPM = mesquite pod meal; WB = wheat bran; SG = sorghum grain;
²Item: DM = dry matter; CP = crude protein; NDF = neutral detergent fibre; IBW; initial body weight; FBW = final body weight; ADG = average daily gain; FC = feed conversion; FE = feed efficiency;
³SEM=standard error mean; a,b,c Means within a row with different superscripts differ. *mean of the group (n = 6).

Discussion

Intake

Supplementation is necessary when forage does not meet the nutritional requirements of animal grazing (Fieser et al., 2007). However, some aspects of this technology may occur in this situation as: an additive, substitutive or combined effect. In the present study, an additive effect was observed with increase of the total DMI when the lambs were supplemented, without a decline in the forage DMI as described in Table 4. The reduction on forage DMI is a common occurrence when a supplement is provided for animals grazing (Stockdale, 2000). Similarly to the present study, Franco et al. (2017) observed an increase of the total DMI when 16 g/kg of BW of supplementation was provided for European×Zebu young bulls. In the present study, the level of supplementation was 10 g/kg of BW. A low level of supplementation for grazing lambs improves the total DMI due to a possible improvement in the ruminal environment. When a more fermentable substrate is provided, the bacteria that degrade fiber grow faster, making it possible a rapid degradability of the digesta.

To statistically describe the degree of the SR, we performed the analysis just for supplemented groups. The average of SR was - 0.92, with the lower SR for SG treatment being - 0.64, without differences among the treatments. A $SR < 1$ implies that the total DMI of supplemented animals is higher if compared to the unsupplemented animals (Bargo et al., 2003), as shown in the present study. The lower negative value of SR in the SG treatment indicates a higher energy balance in this group, if compared to MPM and WB groups. Tedeschi et al. (2019) reported that SR is high when the energy balance is positive and the supplementation is based on starchy concentrations.

The energy of the supplement provides a negative feedback and consequently negatively impacts the voluntary feed intake (Tedeschi et al., 2019), thus, the use of a source of energy could promote a decrease in total DMI. However, in the present study, the total DMI was increased with supplementation, showing an associative effect between forage and the energy source used as a supplement.

In the present study, CP intake increased with supplementation. The average intake of the supplemented lambs was 162.25 g/day, and the lambs fed only with the MM consumed 88.11 g/day of CP per day, 74.14 g lower than the supplemented lambs. When goats were supplemented on the pasture, CP intake increased (Silva et al., 2016). Due to the high protein content of these feedstuffs, more CP intake of supplemented lambs was expected. The ingestion of more CP (g/day) implies in more nitrogen and amino acids that can be used by the microbial population in the rumen as fibrolytic and non-fibrolytic bacteria, and this is directly linked with ADG (Bishaw and Melaku, 2008). Ramos et al. (2019) observed that the increase of protein in the diet of summer grazing lambs increased the body weight gain.

The DM, CP and NDF apparent digestibility was affected by supplementation, more due to the higher digestibility of the concentrate than to the forage itself (Almeida et al., 2012), shown by the lower digestibility of NDF for the control group in this study. In the present study, better digestibility of DM in supplemented groups was obtained in WB. These results can be justified by the characteristics of the energy sources. The structure of the WB is more easily attacked by the microbial population in the rumen, increasing the digestibility by rapid fermentation. This characteristic seems to be the reason to increase the digestibility of the DM for this treatment. Habib et al. (2001) showed that WB has a maximum rate of degradation and effective degradability.

In the present study, the lambs supplemented with SG, and MPM had a lower DM and CP digestibility. However, the data does not provide a clear explanation for these results. One plausible explanation is that, these treatments had a lower retention time in the rumen due to its chemical and physical properties. Feeds with high fermentable carbohydrates pass faster through the total tract and decrease the degradation rate (Yahaghi et al., 2013). The lack of effect for energy source in NDF digestibility can be attributed to the frequency of the allowance to the supplementation, promoting low changes in the rumen environment (Dieho et al., 2017).

At grazing conditions, lambs that received supplementation had higher performance than those that were not supplemented. The pasture alone does not have the capacity to supply the total animal's nutritional requirement in all situations. Even in conditions of greater availability of the forage, a higher weight gain

is not achieved or the weight gain is smaller than the expected. The present study demonstrates that supplementation during the rainy season may be a strategy to increase weight regardless of the source of energy during the rainy season.

In the present study, the FBW, and ADG of supplemented lambs were higher than those for control group. These results reinforce the importance of supplementation, as reported by Baroni et al. (2010); Silva et al. (2014); Silva et al. (2016) in grazing systems. Greater weight gain in supplemented lambs is mainly due to the increased energy and protein intake and the ratio of metabolizable protein:energy (Singh et al., 2013). In our study, the results demonstrate that the supplementation increased the ADG two-fold if compared to the control group, explained by the increase of the energy availability provided by the diets.

Despite of that, no difference among energy source was detected, showing that any of the energy sources can be used during the rainy season. In this situation, the availability and costs of the feeds can be the factor that determine the use of one or another source of energy. Similarly, Nascimento et al. (2010) performed a study with different sources of energy supplementation and they did not observe a difference between treatments. The ADG increased 9.5% in supplemented animals when different protein supplements were used (Carvalho et al., 2015), with gains of 80 g/day, much lower than those observed in the present study. Similarly, Almeida et al. (2012) observed a higher ADG of lambs supplemented with 7.2 g/day with MM alone, a value that is lower than in the present study (61.0 g/day).

The control group needed an intake 4.5 kg/day of DM more than in the other treatments to gain 1.0 kg of body weight. This result implies that MM alone does not provide enough energy for the lambs, shown by the low digestibility of the forage. So, the results of the present study support the hypothesis that investment in supplementation is a good strategy for higher weight gains. Given the obtained results, it can be concluded that the supplementation for grazing lambs increased intake of DM, CP and NDF. Any supplement tested in the present study can be used during the rainy season. The choice of the supplement will depend on the availability and costs of the supplement.

Declarations

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Authorship Policy

ASS Contributed new methods or models, wrote the paper and analyzed data; MSP conceived of or designed study; HGOS designed the study and read and approved the paper; AAPGJ contributed new methods; PJPA conducted the study; LCR analysed data; JD read and revised the manuscript. All authors read and approved the manuscript.

Compliance with ethical standards

All the procedures with animals were approved by the Animal Care and Use Committee of Bahia Southwest State University (Protocol CEUA - n° 189/2018).

Conflict of interest

The authors declare that they have no conflict of interest.

Availability Statements

The datasets generated during and/or analysed during the current study are not publicly available due security reasons of not making public data that generated the manuscript but are available from the corresponding author on reasonable request.

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