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ANIMAL PRODUCTION

Morphometric measurements of sheep fed with increasing levels of sunflower meal

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ABSTRACT. The objective of this work was to evaluate the performance, body morphometric measurements and testicular development in lambs fed with different rates of sunflower meal inclusion. The animals (24) were randomly distributed in treatments with 0, 10, 20 and 30% of sunflower meal in the dry matter of the diet, in six replicates, during 56 days of confinement. The addition of the coproduct at increasing dietary rates increased linearly the dry matter intake in the percentage of live weight and neutral detergent fiber. Despite this, there was a linear reduction in ether extract intake and chest width. On the other hand, there was no difference in daily, total and final weight gains. The body condition score; height of withers, croup and thorax; length of body and croup; width of fore croup, hind croup and chest; thoracic and neck diameters also did not change with the addition of the coproduct. The testicular measures 26.76; 6.11; 6.08; 5.22; 5.21; 4.80, and 4.81cm varied quadratically with the inclusion. Therefore, the inclusion of 30% of the coproduct changes nutrient intake and testicular biometry, but does not interfere in the body weight and development, being an economical alternative.

Keywords: coproduct; feedlot; *Helianthus annus L*; lamb; performance.

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Introduction

Sheep farming is an extremely profitable agricultural activity due to its characteristics such as short productive cycle, quick financial turnover, good animal adaptability and viability of small properties (Ávila et al., 2013). The systems of feedlot or semi-feedlot allow even greater liquidity of the productive chain due to the anticipation of the animals' slaughter age (Pompeu et al., 2012). Nevertheless, despite the attractiveness offered and the considerable Brazilian herd, exceeding 18,410,551 heads (Anuário da Pecuária Brasileira [ANUALPEC], 2017), the production of sheep meat still does not meet the demand of the internal market, ending up with the need of importation. This way, the scientific and financial investment, especially regarding nutritional management, which represents the determining factor of the herd productivity, is essential for the intensification of sheep production. Usually, most ruminant diets recommend the use of corn and soybeans as energetic and protein sources (Rodrigues et al., 2013). The constant oscillation in the price of these concentrates, however, discourages the breeder and makes it difficult to maintain the activity. Garcia et al. (2006) found a savings in diet cost of 13.64, 28.20, and 47.10% when using levels of 15, 30, and 45% of sunflower meal in substitution of soybean meal, respectively, for growing dairy cattle. In this context, the use of coproducts from agriculture, such as sunflower meal, stands out as an economically promising alternative due to its low cost (Ahmed & Abdalla, 2005).

According to Oliveira et al. (2012), sunflower meal, which results from the extraction of sunflower oil, is a product rich in protein, essential amino acids, calcium, and phosphorus, as well as B vitamins and unsaturated fatty acids, including oleic and linoleic acids. Its composition and nutritional value, however, is very changeable, since it depends on the amount of husk that is removed and the oil extraction process used (press or solvent). According to Alcaide, Ruiz, Moumen, and Garcıa (2003), its crude protein content varies around 28% and the neutral detergent fiber content can exceed 40%, being lignin a good part of this fiber, which can compromise the digestibility.

Nonetheless, despite the high protein value and economic viability, there are still few reports on the use of this residue in sheep feed and its effects in terms of body development. The present study had the objective to evaluate the performance, morphometric measures, and testicular development in lambs fed with increasing levels of sunflower meal inclusion.

Material and methods

The research project was approved by the Committee of Ethics in Animal Experimentation of Universidade Federal de Minas Gerais (Protocol No. 189/2015), being held in the period from April to August 2016, in Montes Claros, Minas Gerais, Brazil, latitude 16°44 '06 "S, 44°55'00" W, and 465 meters of altitude in relation to sea level.

Twenty-four "Dorper x Santa Inês" lambs, 4 months old, were distributed in four treatments with increasing inclusion levels of sunflower meal (0, 10, 20, and 30%), allocated in three groups according to experimental design, randomized with six replicates per treatment. The groups were defined according to the initial body weight of the animals, the mean live weight being 28.18 ± 3.2 kg in the first group, 26.76 ± 3.8 kg in the second, and 24.78 ± 3.1 kg in the third.

The animals were confined for 56 days in individual stalls with 2.0 m length, 1.20m width, and 1.10m height, equipped with feeders, and drinking fountains. The first 10 days were used to adapt the animals to the environment, and diet, during which time they were weighed, identified, and dewormed. Experimental diets were based on forage (corn silage), and concentrate (soybean meal, corn, sunflower meal, and mineral mix) with forage:concentrate ratio (40:60) (Table 1).

Diets were given to the animals twice a day, in sufficient quantity to have leftovers of 20% of that provided. Diets and leftovers were weighed daily, sampled weekly, and stored in a freezer (-20°C) for further bromatological analysis, as recommended by the National Institute of Science and Technology of Animal Sciences (INCT-CA) (Detmann et al., 2012).

In the samples of the diet and leftovers, the following contents were analyzed: dry matter (DM), mineral matter (MM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), neutral detergent insoluble nitrogen (NDIN), acid detergent insoluble nitrogen (ADIN), and ashes. The percentages of total carbohydrates (CHt) and non-fibrous carbohydrates (NFC) were obtained according to the equations: $CH_t = 100 - (CP + MM + EE$ and $FC = 100 - (CP + MM + EE + NDF)$, respectively. The total digestible nutrient values observed were estimated for each diet by the equation: $TDN = CPdigestible + (EEdigestible \times 2 \cdot 25) + NDFdigestible + NFCdigestible)$(Sniffen, O'Connor, Van Soest, Fox, & Russell, 1992).

Table 1. Percentage composition of the ingredients and nutritional value of the experimental diets based on the dry matter content.

Ingredients	Percentage Composition				
	0% SM	10% SM	20% SM	30% SM	Sunflower Meal (SM)
Corn Silage	40.00	40.0	40.00	40.00	-
Soybean meal	26.40	19.60	11.80	1.8	-
Corn	31.50	28.10	25.60	26.16	-
Sunflower meal	-	10.00	20.00	30.00	-
Vitamin mineral premix[1]	1.05	1.50	2.20	2.04	-
Dicalcium phosphate	1.05	0.8	0.40	-	-
Nutrients	Nutrition facts				
DM (% da NM)	64.34	64.17	65.33	65.88	92.19
MM (% da DM)	4.50	4.32	4.57	4.61	5.97
CP (% da DM)	20.79	20.38	19.56	17.95	34.10
NDF (% da DM)	27.34	28.99	31.29	33.31	43.53
ADF (% da DM)	17.63	21.25	22.72	30.28	30.64
EE (% da DM)	4.52	4.32	4.18	4.05	1.92
NFC (% da DM)	42.85	41.34	40.40	40.08	14.48
CHt (% da DM)	70.19	70.33	71.69	73.39	58.01
TDN (% da DM)	74.47	73.66	66.68	66.20	-
NDN (% Ntotal)	13.15	8.44	7.56	4.77	-
ADN (% Ntotal)	6.91	3.36	2.89	3.31	-

NM – natural matter; DM – dry matter; MM – mineral matter; CP – crude protein; NDF – neutral detergent fiber; ADF – acid detergent fiber; EE – ether extract; NFC – non-fibrous carbohydrate; CHt – total carbohydrates; NDN – neutral detergent nitrogen; ADN – acid detergent nitrogen; Ntotal – total nitrogen; TDN – total digestible nutrients. [1] Composition of vitamin mineral premix: calcium - 150 g; phosphorus - 65 g; sodium - 130 g; fluorine - 50 mg; sulfur - 12 g; magnesium - 10 g; iron - 1000 mg; manganese - 3000 mg; cobalt - 80 mg; zinc - 5000 mg; iodine - 60 mg; selenium - 10 mg; vitamin A - 50000 U. I.; vitamin E - 312 U. I.

Bodyweight (BW), body condition score (BCS), and morphometric measurements (MMs) were measured weekly, as well as on the first and last day of the confinement period, always by the same person, before the first feeding, totaling 10 records animal^{-1}. The BW was evaluated in the scales, BCS was determined by means of visual evaluation, and palpation in the sternal and lumbar regions, with scores of 1 to 5 varying from 0.5, while the MMs were obtained using metric tape and metal tape. The morphometric measurements were: withers height (WH), croup height (CH), thorax height (TH), body length (BL), croup length (CL), fore croup width (FCW), hind croup width (HCW), chest width (CW), chest diameter (CD), neck diameter (ND), testicular diameter (TD), right testicle dorso ventral length (RTDVL), left testicle dorso ventral length (LTDVL), right testicle cranio caudal length (RTCCL), left testicle cranio caudal length (LTCCL), right testicle latero medial width (RTLMW), and left testicle latero medial width (LTLMW).

Data were submitted to regression analysis, using the statistical system SAEG (2007) in a model including the effect of inclusion level of sunflower meal in the diet (linear and quadratic effects).

Results and discussion

As shown in Table 2, no significant difference was found in the final live weight (FLW), mean daily weight gain (MDWG), and total live weight gain (TLWG) with the inclusion levels of sunflower meal ($p > 0.05$).

According to Mertens (1994), 60 to 90% of difference in animal performance occur as a consequence of intake, and 10 to 40% because of digestibility. In confinement, normally greater weight gain can be obtained as a result of higher intake of nutrients, and dry matter (Barroso, Araújo, Silva, Gonzaga Neto, & Medina, 2006). In the present study, the inclusion of the coproduct did not change the dry matter intake nor the total weight gain (Table 2), justifying the similar final weight of the animals among the treatments, which is adequate for the age of the animals, according to National Research Council (NRC, 2007).

The NDF content of the food is one of the factors that can inhibit the intake of DM due to its slow degradation and low rate of passage through the rumen (Agy et al., 2012). However, despite the variation in NDF content in the diets (Table 1), there was no change in DMI (g day^{-1}). One possible explanation is the physical processing of the meal, since the milling of this coproduct results in particles of the same size as the traditional concentrated food included in the diet (ground corn and soybean meal), which reduced the physical effectiveness of the fibrous fraction.

The DM intake, as a percentage of live weight (LW), had a quadratic behavior ($p < 0.05$) with the increase of the coproduct inclusion, with a minimum intake point of 3.53% with an inclusion level of 0.035%. A similar value was reported by Pompeu et al. (2012), with a mean DMI (% LW) of 3.1% in goats fed with cotton meal, sunflower meal, and castor bean cake. According to Mertens (1994), if the energy density is high or the fiber concentration is reduced in relation to the requirements, the intake becomes limited by the physiological energy demand. Thus, the quadratic response for the DM intake in % of LW in the diets with sunflower meal, observed in this study, is probably related to the energy density of the diet that was reduced with the inclusion of the coproduct in substitution for corn, which is rich in starch and highly energetic (Table 1).

Despite the percentage difference of 10.20% in the TLWG between the animals that did not receive the coproduct and those who received the diet with 30% of sunflower meal, this difference was not significant ($p > 0.05$). Likewise, there was no effect of SM inclusion ($p > 0.05$) on CP consumption in g day^{-1} or % LW. However, there was selection of protein concentrates by the animals, since the coproduct diets contained average protein content close to 19.67% in DM (Table 1), and CP consumption by the animals was close to 25.1% (Table 2). This result may be related to the absence of particle selectivity due to the similarity in physical size.

The average consumption of CP in g/day or % LW of treatments was 404.6 g per animal a day and 0.91% LW, higher than that required for growing sheep (180g per animal a day) recommended by the NRC (2007). Cavalcanti et al. (2008) evaluating the intake and ingestive behavior of goats and sheep fed with "Palma Gigante" (Opuntiaficus-indica Mill), "Palma orelha-de-elefante" (*Opuntia* sp.), and soybean meal, observed a linear increase in the intake of CP, and justified such behavior because these animals have high capacity to select the ingredients of the meal and, this way, to modify the proportion of the nutrients of the diet.

Table 2. Means and coefficients of variation (CV) of the final live weight (FLW), daily average weight gain (DAWG), total live weight gain (TLWG), dry matter intake (DMI), crude protein intake (CPI), neutral detergent fiber intake (NDFI), and ether extract intake (EEI), due to the inclusion of sunflower meal (SM) in the sheep diet.

Variables	SM inclusion levels				CV	p	
	0%	10%	20%	30%	(%)	Linear	Quadratic
FLW (Kg)	46.58	46.16	44.06	41.83	5.56	NS	NS
TLWG (Kg)	17.21	18.30	16.26	15.20	13.12	NS	NS
DAWG (g day^{-1})	300.44	326.78	290.47	271.42	13.12	NS	NS
DMI (g day^{-1})	1,648	1,588	1,590	1,621	3.21	NS	NS
DMI (% LW)[1]	3.54	3.45	3.63	3.87	4.45	**	**
CPI (g day^{-1})	416	399	402	399	3.60	NS	NS
CPI (% LW)	0.897	0.870	0.920	0.956	5.49	NS	NS
NDFI (g day^{-1})[2]	319	421	569	697	4.89	**	**
NDFI (% LW)[3]	0.685	0.914	1.296	1.668	4.27	**	**
EEI (g day^{-1})[4]	98	73	59	54	3.93	**	**
EEI (% LW)[5]	0.212	0.158	0.132	0.129	3.10	**	**

[1] $y = 3.539 + 0.001x - 0.014x^2$ $R^2 = 0.88$; [2] $y = 316.2 + 10.84x + 0.065x^2$ $R^2 = 0.96$; [3] $y = 1.134 + 0.003x - 0.012x^2$ $R^2 = 0.96$; [4] $y = 98.90 - 3.160x + 0.059x^2$ $R^2 = 0.95$; [5] $y = 1.001 + 0.001x - 0.001x^2$ $R^2 = 0.98$; NS: Not significant (P > 0.05); **Significant difference (p < 0.05).

With the increase of sunflower meal inclusion in the diet, there was a linear increase ($p < 0.05$) of NDFI, both in g day^{-1} and in percentage of LW. According to Allen (2000), the NDF content is the best component for the evaluation of the dry matter intake by ruminants, since the proportion of indigestible dietary fiber can change dry matter intake. However, given the similarity of the DMI of the diets in the present study, the increase of NDFI can be justified by the increase in the concentration of NDF in the diets with SM (Table 1).

For EEI, a significant ($p < 0.05$) decreasing effect was observed with the increase of SM inclusion. Probably, this behavior of the EEI is due to the reduction of the EE content in the nutritional composition of the diets with the inclusion of the coproduct (Table 1). The EEI values of this assay were higher than those obtained by Ávila et al. (2013), who reported an average of 26g day^{-1} of EEI for treatment containing SM at 20% inclusion levels.

With respect to morphometric measures, increasing levels of SM inclusion did not interfere in the body development since no significant difference between treatments ($p > 0.05$) was observed for most of the analyzed parameters (Table 3).

Similar results were reported by Fernandes Júnior et al. (2015), when evaluating performance, consumption, and morphometry of Santa Inês lambs fed with diets containing sunflower cake in substitution of cottonseed meal. According to Pinheiro and Jorge (2010), the body biometry allows to predict, in a practical and economic way, the nutritional status of the animal.

The difference found for the chest width measurement, which presented a linear reduction with a minimum point of 21.2 cm with inclusion level of 2.81% of the coproduct ($p < 0.05$), is more related to the individual body pattern than was evidenced in the average of the animals of the group than to the effect of the treatments. Therefore, separately, it cannot be used as a parameter to estimate body development. Similar results were obtained by Sousa et al. (2009) i animals of different genetic groups. The evaluation of the testicular dimension is a very important parameter, since it allows to predict, in a practical and economic way, the state of productive performance of the animal (Fernandes Júnior et al., 2015; Pinheiro & Jorge, 2010). In the present study, it was found that the inclusion of increasing levels of the coproduct in the sheep diet resulted in a quadratic effect ($p< 0.05$) for all variables analyzed (Table 4).

The CV, RTDVL, LTDVL, RTCCL, and LTCCL showed quadratic effect with minimum points of 25.15cm; 6.64cm; 5.72cm; 4.88cm, and 4.85cm with the inclusion of SM at levels of 2.73; 1.87; 2.67; 2.70, and 2.75% respectively. This result demonstrates that testicular dimensions are directly related to the nutritional aspect, so that the higher the amount of energetic concentrate and the lower the fiber intake, with consequent reduction in the NDFI (Table 2), the better the testicular development. Such behavior corroborates the findings of Fernandes Júnior et al. (2015), who evaluated the effects of the inclusion of sunflower cake protein in substitution of the cottonseed protein in the meal on the parameters of performance, consumption, and morphometric measures of Santa Inês lambs finished in confinement. These authors observed that supplemented animals had better testicular biometry results.

Table 3. Means and coefficients of variation (CV) of the body condition score (BCS), withers height (WH), croup height (CH), thorax height (TH), body length (BL), croup length (CL), fore croup width (FCW), hind croup width (HCW), chest width (CW), thoracic diameter (THD), and neck diameter (ND) of crossbred sheep submitted to diets with the inclusion of sunflower meal.

Variables	SM inclusion levels				CV	p	
	0%	10%	20%	30%	(%)	Linear	Quadratic
BCS	2.68	2.6	2.51	2.43	10.81	NS	NS
WH (cm)	65.64	65.27	65.71	65.60	3.35	NS	NS
CH (cm)	66.03	66.41	66.26	66.06	3.82	NS	NS
TH (cm)	29.25	28.67	29.58	28.21	2.52	NS	NS
BL (cm)	63.81	64.04	63.75	62.34	2.52	NS	NS
CL (cm)	14.54	14.89	14.71	14.14	4.25	NS	NS
FCW (cm)	16.68	16.57	16.74	15.80	6.63	NS	NS
HCW (cm)	21.27	21.44	21.48	20.34	4.85	NS	NS
CW[1](cm)	22.00	21.70	21.31	19.35	6.02	**	**
THD (cm)	75.55	75.25	75.34	73.05	3.62	NS	NS
ND (cm)	34.94	34.80	32.85	32.61	7.02	NS	NS

[1]$y = -0.833x^2 + 23.17$; $R^2 = 0.97$; NS: Not significant; ** Significant difference ($p < 0.05$).

Table 4. Means and coefficients of variation (CV) of testicular development with respect to scrotal circumference (SC), right testicle dorso ventral length (RTDVL), left testicle dorso ventral length (LTDVL), right testicle cranio caudal length (RTCCL), left testicle cranio caudal length (LTCCL), right testicle latero medial width (RTLMW), and left testicle latero medial width (LTLMW) of sheep fed with different levels of sunflower meal inclusion.

Variables	SM inclusion levels				CV	p	
	0%	10%	20%	30%	(%)	Linear	Quadratic
CV[1](cm)	28.70	26.08	25.24	27.03	5.36	NS	**
CTD[2](cm)	6.61	5.91	5.68	6.24	6.65	NS	**
CTE[3](cm)	6.50	5.90	5.70	6.24	6.64	NS	**
CCD[4](cm)	5.65	5.01	4.91	5.34	5.68	NS	**
CCE[5](cm)	5.68	5.01	4.86	5.28	6.18	NS	**
LLD[6](cm)	5.12	4.64	4.61	4.95	5.38	NS	**
LLE[7](cm)	5.15	4.60	4.58	4.94	5.56	NS	**

[1]$y = 33.95 - 6.43x + 1.175x^2$; $R^2 = 44.55$; [2]$y = 8.020 - 1.170x + 0.3125x^2$; $R^2 = 42.02$; [3]$y = 7.751 - 1.5167x + 0.2833x^2$; $R^2 = 37.53$; [4]$y = 6.801 - 1.417x + 0.262x^2$; $R^2 = 42.87$; [5]$y = 6.904 - 1.489x + 0.270x^2$; $R^2 = 48.76$; [6]$y = 5.916 - 0.983x + 0.183x^2$; $R^2 = 39.03$; [7]$y = 6 \cdot 070 - 1 \cdot 165x + 0 \cdot 220x^2$; $R^2 = 41.09$; NS: Not significant; ** Significant difference ($p < 0.05$).

The right testicle latero medial width (RTLMW) and left testicle latero medial width (LTLMW) presented quadratic behavior with minimum points of 4.59 and 2.64 cm with 2.68 and 2.6% of inclusion, respectively. Analyzing the volume and testicular shape characteristics in young Nellore zebu cattle to characterize their importance in the evaluation and selection of breeders, Macedo Júnior et al. (2014) revealed variation in testicular width as a function of weight, as food availability influences growth and testicular dimensions. Thus, the variations observed in the lateral testicular dimensions of the animals, possibly, can be explained by the differences in the energy intake of the diets (Table 1). In addition, the lateral measurements show a direct correlation with the other testicular dimensions.

Conclusion

The inclusion of up to 30% of sunflower meal in the diet does not change the weight gain nor the body development of crossbred lambs. However, it promotes changes in nutrient intake with significant implications on testicular biometry and, possibly, on the reproductive potential of these animals. Additional studies are necessary to consolidate the use of sunflower meal as an economically viable nutritional alternative.

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