



# Inclusion of levels of cotton expeller in the feeding of confined sheep: productive behavior, carcass characteristics and meat quality

Inclusión de niveles de expeller de algodón en la alimentación de ovinos confinados: comportamiento productivo, características de la canal y calidad de la carne

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## ABSTRACT

To substitute soybean meal with different levels of cottonseed meal, twelve non-castrated male Santa Inés × Dorper sheep with an average initial weight of  $27.33 \pm 0.58$  kg and age of  $225 \pm 15$  days were used. The treatments consisted of three levels of cottonseed meal (0%, 15%, and 30%), with four replicates, distributed in a completely randomized experimental design. The diets consisted of totally mixed rations, with a forage-concentrate ratio of 30:70 (dry matter basis). Cottonseed meal levels did not affect ( $p > 0.05$ ) dry matter intake for up to 28 days, then values decreased linearly. Feed conversion and daily weight gain were improved up to 28 days and then decreased linearly ( $p \leq 0.05$ ). In the same way, cooling and cooking weights losses and the shear force were affected and with a quadratic behavior ( $p \leq 0.05$ ) by the levels of cottonseed meal, standing out the level of 15%, while the live weight, hot and cold carcass weight and yield, loin eye area, the thickness of subcutaneous fat were not affected by the treatments ( $p > 0.05$ ). Cottonseed meal can replace up to 20% of the soybean meal in sheep concentrate feed for a period not to exceed 28 days.

**Keywords:** Byproduct; Dry matter intake; Feed conversion; sheep; weight gain

## RESUMEN

Para sustituir la harina de soja por diferentes niveles de harina de semilla de algodón, se utilizaron doce ovinos Santa Inés × Dorper machos no castrados con un peso inicial promedio de  $27,33 \pm 0,58$  kg y una edad de  $225 \pm 15$  días. Los tratamientos consistieron en tres niveles de harina de semilla de algodón (0%, 15% y 30%), con cuatro repeticiones, distribuidas en un diseño experimental completamente al azar. Las dietas consistieron en raciones totalmente mixtas, con una relación forraje-concentrado de 30:70 (base materia seca). Los niveles de harina de semilla de algodón no afectaron ( $p > 0,05$ ) el consumo de materia seca hasta por 28 días, luego los valores disminuyeron linealmente. La conversión alimenticia y la ganancia de peso diaria mejoraron hasta los 28 días y luego disminuyeron linealmente ( $p \leq 0,05$ ). De igual forma, las pérdidas de peso por enfriamiento y cocción y la fuerza de corte fueron afectadas y con comportamiento cuadrático ( $p \leq 0,05$ ) por los niveles de harina de semilla de algodón, destacándose el nivel de 15%, mientras que el peso vivo, canal caliente y frío peso y rendimiento, área ojo lomo, espesor de grasa subcutánea no fueron afectados por los tratamientos ( $p > 0,05$ ). La harina de semilla de algodón puede reemplazar hasta el 20% de la harina de soja en el alimento concentrado para ovejas por un período que no exceda los 28 días.

**Palabras claves:** Subproducto; Ingesta de materia seca; Conversión de alimentos; oveja; aumento de peso.

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## INTRODUCTION

Paraguayan sheep production is growing continuously due to the support provided by the public and private sectors; and the consumers' preference for this meat is increasing, becoming an alternative to bovine meat consumption, whose price in the market is high. Currently, sheep farmers plan to increase production to export, so the item presents quite an encouraging outlook and is commercially favored by the low supply and high demand existing at the regional, national, and international markets (Mongelós, 2016).

To increase the productivity, it is essential to intensify production, by using improved genetics, and slaughter younger animals to obtain better carcass and meat quality. To achieve this purpose is necessary to adopt good sanitary management and nutritional program to meet the animal's energy and protein requirements (Carvalho et al. 2014), which implies the use of higher nutritional value feeds and lower costs (Oliveira et al., 2017). Soybean meal is the most used protein source in ruminant feeding and has excellent nutritional quality (Palmieri et al., 2016), however, it has a high purchasing cost, mainly in areas distant from those soybean-producer regions making diets more expensive and reducing the livestock profitability (Dantas, 2018; Assis et al., 2019), so it

is necessary to look for alternatives feeds to replace it to make diets cheaper without reducing the animal's productive performance.

Cottonseed meal is one of the alternatives to replace soybean meal, which is an ingredient resulting from grains oil extraction by physical and chemical methods (Lima-Júnior et al. 2011; Dantas, 2018). This by-product contains high values of protein (34% to 49%) and energy (NDT: 87%) and presents a lower purchasing cost in the market compared with soybean meal (Gadelha et al. 2014).

However, the cottonseed meal contains gossypol that is toxic to animals and, it can alter the flavor of the meat, reducing its commercial value (Gadelha et al., 2014). Adult ruminants are more tolerant to the toxicity (Assis et al., 2019), which suggests that sheep will respond satisfactorily to this by-product inclusion in the diet, although it is necessary to determinate the maximum level it could be included without reducing the animals' performance parameters and meat quality.

This research aimed to evaluate the productive performance, carcass characteristics, and meat quality of confined sheep fed with diets containing different levels of cottonseed meal as a substitute for soybean meal.

## MATERIALS AND METHODS

### Location and period of investigation

The experiment was carried out in an establishment located in the Department of Presidente Hayes, Chaco, Paraguay, latitude: 25°07'15.27° S and longitude: 57°42'38.81° W; between September and November 2021. The duration of the investigation was 56 days, subdivided into four periods of 14 days. During the investigation, an average minimum temperature of 18 °C, an average maximum of 33 °C, and total precipitation of 17 mm were recorded.

### Animals, diet and facilities

In total, 12 uncastrated male Santa Inés × Dorper sheep with average initial weights of 27.33 ± 0.58 kg and ages of 225 ± 15 days were used. Initially, they were weighed individually (with solid fasting of 12 hours) and identified with caravans placed in the ear and at the same time treated against endoparasites by applying ivermectin at a rate of 1 ml per 50 kg of live weight (LW).

Subsequently, they were housed in individual pens with 2.50 m<sup>2</sup> of area per animal and equipped with food and water trays, and had wooden wall, zinc sheet metal roof and concrete floor. For feeding, isoproteic diets were formulated according to the category nutritional requirements by considering the NRC (2007) recommendation, with a forage-concentrate ratio of 30:70 (dry matter basis) (Table 1).

Animals were accustomed to the facilities and diets for 14 days, where supplied concentrates were gradually increased. The amount supplied diet was between 3 and 5% of the live weight (dry matter basis) and, the distribution was 50% at

07:00 am and the rest at 5:00 pm. These ranges were maintained during the experiment and the adjustments were made by daily feeder reading according to Lopes's (2013) methodology.

**Table 1**

Rations used to feed sheep in each treatment and their respective bromatological compositions

Ingredients	Substitution levels (%)		
	0% (T <sub>1</sub> )	15% (T <sub>2</sub> )	30% (T <sub>3</sub> )
Pangola hay	30.0	30.0	30.0
Ground corn	42.0	42.0	42.0
Soybean meal	23.50	20.0	16.50
Cotton seed meal	0.0	3.50	7.0
Lime carbonate	1.20	1.20	1.30
Minerals <sup>1</sup>	3.30	2.90	2.40
Urea	0.0	0.40	0.80
<b>Total</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>
<b>Nutritional composition</b>			
CP (%)	18.00	18.00	18.00
TDN (%)	78.51	77.59	76.68
NDF (%)	32.67	32.91	33.16
ADF (%)	24.13	24.69	25.26
Fat (%)	4.57	4.50	4.42
Ca (%)	0.11	0.11	0.10
P (%)	0.06	0.05	0.05

<sup>1</sup>Composition of the mineral supplement: vit. A = 135,000 UI; vit. D3 = 68,000 UI; vit. E = 450 mg; Ca = 240 g; P = 71 g; K = 28.2 g; S = 20 g; Mg = 20 g; Co = 30 mg; 119 Cu = 400 mg; Cr = 10 mg; Fe = 2500 mg; I = 40 mg; Mn = 1,350 mg; Se = 15 mg; Zn = 1,700 mg.

### Measures of performance and feed efficiency

The animals' live weights (kg) measurements were carried out at 14, 28, 42, and 56 days with a prior 12 hours solid fasting. From the differences between the initial and final weight divided by the

days of each experimental period, it is determined the daily weight gain (DWG, g day<sup>-1</sup>).

Dry matter intake (DMI) was determined by weighing food before offering, as well as the leftovers from the previous day, and the values were related to each animal live weight at 14, 28, 42, and 56 days. The feed conversion (FC, kg kg<sup>-1</sup>) was determined by the relationship between the DMI and the DWG for each experimental period.

#### Slaughter and carcass characteristics

At end of the trial (at 56 days), the animals were fasted from solid food for 12 h, weighed (slaughter body weight - SBW) were stunned for electro-narcosis and then the jugular veins and carotid arteries were sectioned for bleeding, according to the procedures that characterize humane slaughter.

All the non-carcass components were removed, and carcasses were weighed to obtain the hot carcass weight (HCW, kg). After weighing the hot carcasses, they were placed in a cold chamber at 4 °C for 24 h. Then the cold carcass weight (CCW) was determined, and the HCW and CCW were used to calculate the following carcass-related parameters: hot carcass yield (HCY) = (HCW/SBW) × 100; cold carcass yield (CCY) = (CCW/SBW) × 100, and cooling loss (CL) = [(HCW - CCW) × 100]/HCW (Pérez & Carvalho 2002).

#### Measures meat quality

To evaluate the quality of the meat, the carcasses were taken to the Meat Quality Laboratory of the Faculty of Agricultural Sciences, National University of Asuncion, where they were sectioned with a band saw and then the eye area of the loin (LEA, cm<sup>2</sup>) was measured in the 12<sup>th</sup> and 13<sup>th</sup> intercostal space, using the transparent checkered template with an area of 1 cm<sup>2</sup> cell<sup>-1</sup>, and the thickness of subcutaneous fat (TSF) was also measured with a caliper (Cezar & Sousa, 2018).

Subsequently, two fillets with 2.54 cm thickness were extracted; following the transverse direction of the muscle fibers and, they were weighed and vacuum packed, and cooked in water bath (at 70 °C) for 15 minutes. The samples were removed and weighed again to determine the difference in weight and calculate the percentage loss by cooking (WLC, %).

To determine the shear force (SF, kgf), three sub-samples of the cooked samples were extracted with a 2.54 cm thick and 1.27 cm diameter punch and were positioned perpendicular to the Warner-Bratzler equipment blades (1.1684 mm thick). The equipment was calibrated with a standard weight of 5 kg. The device's descent rate was 200 mm/min (AMSA, 2015).

#### Statistical analyses

Obtained data were subjected to analysis of variance (ANOVA) using the Fischer test ( $p \leq 0.05$ ) using the InfoStat® software (Di Rienzo et al., 2015) adopting a completely randomized experimental design, with 3 treatments consisting of cottonseed meal levels (T1: 0%; T2: 15% and T3: 30%) and 4 repetitions (4 sheep). The treatments means were compared by the Tukey test ( $p \leq 0.05$ ) and the mathematical model used for the analysis was the following:

$$Y_{ijk} = \mu + G_i + \varepsilon_{ijk} \quad (1)$$

Where  $Y_{ij}$ : the value of the dependent variable referring to the observation  $k$ , of cotton seed meal level  $i$ , in the repetition  $j$ ;  $\mu$ : the overall average;  $G_i$ : effect of cottonseed meal levels  $i$ ; ( $i = 1, 2, 3$ );  $\varepsilon_{ij}$ : the random error associated with each observation.

In addition, when significant effects were registered in some variables, a regression analysis was carried out at 5% significance for a better description of the treatments behavior and to determine the maximum level of cottonseed meal to be used.

## RESULTS AND DISCUSSION

#### Dry matter intake and feed conversion

No significant effect of the cottonseed meal levels (15 and 30%) was observed on the sheep DMI up to 28 days of experimentation (Table 2;  $p > 0.05$ ). However, after 42 days, consumption decreased linearly ( $p \leq 0.05$ ) and on average was 6.78%

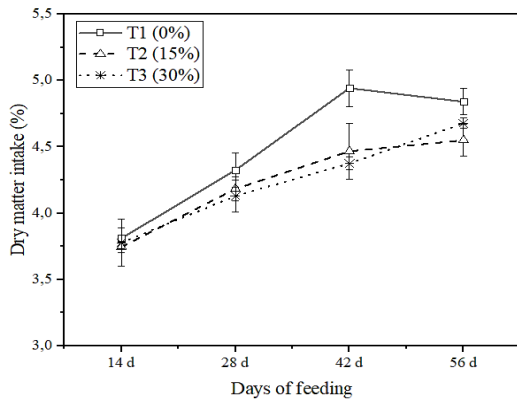
(Figure 1). On the other hand, FC was linearly improved by 32% at 14 days; while at 28 days an improvement of 19.91% was observed (Figure 2) only with the inclusion of 15% (T<sub>2</sub>) and after 42 days, conversion decreased linearly by 32%.

**Table 2**

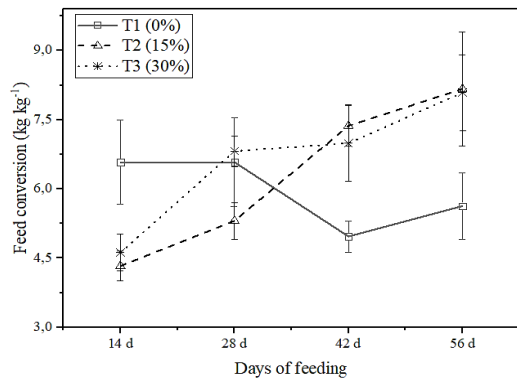
Dry matter intake and feed conversion of confined sheep receiving different levels of cottonseed meal with a substitute for soybean meal in the feed

Variables	Cottonseed meal (%)			S.D.	Regression equation	r <sup>2</sup>
	0 (T <sub>1</sub> )	15 (T <sub>2</sub> )	30 (T <sub>3</sub> )			
<b>Dry matter intake (%LW)</b>						
At 14 days	3.81	3.75	3.78	0.10	$\hat{y} = 3.78$	-
At 28 days	4.33	4.18	4.13	0.11	$\hat{y} = 4.21$	-
At 42 days	4.94	4.47	4.38	0.13	$\hat{y} = -1.8667x + 4.8767^*$	0.87
At 56 days	4.84	4.55	4.68	0.11	$\hat{y} = -0.5333x + 4.77^*$	0.30
Mean	4.48	4.24	4.24	0.10	$\hat{y} = -0.8x + 4.44^*$	0.75
<b>Feed conversion (kg kg<sup>-1</sup>)</b>						
At 14 days	6.58	4.33	4.62	0.54	$\hat{y} = -0.98x + 7.1367^*$	0.64
At 28 days	6.58	5.31	6.82	0.56	$\hat{y} = 61.778x^2 - 17.733x + 6.58^*$	0.99
At 42 days	4.97	7.37	6.99	0.54	$\hat{y} = 1.01x + 4.4233^*$	0.61
At 56 days	5.63	8.17	8.09	0.93	$\hat{y} = 1.23x + 4.8367^*$	0.73
Mean	5.94	6.45	6.63	0.22	$\hat{y} = 0.345x + 5.5967^*$	0.99

\* Significant at 5% probability by the F test. S.D.: standard deviation. r<sup>2</sup>: regression coefficient



**Figure 1.** Dry matter intake of sheep (%LW) fed with different levels of cottonseed meal instead of soybean meal at 14, 28, 42, and 56 days.



**Figure 2.** Feed conversion of sheep (kg kg<sup>-1</sup>) fed with different levels of cottonseed meal instead of soybean meal at 14, 28, 42, and 56 days.

The FC improvement up to 28 days and subsequent decrease in parallel to DMI by including the cottonseed meal, could be a consequence of the cumulative toxic of ingested gossypol effect on the liver and kidney (Kim et al., 1996; Gadelha et al., 2014), in addition to causing anorexia in animals (Velasquez-Pereira et al., 1998); whose degree of toxicity depends on the animal age, with youngsters being more susceptible (Rocha, 2016; Mello et al., 2018) and adults tolerant (Assis et al., 2019). In study, 7.5 months of age were used, which allows us to infer that they are moderately resistant to said toxicity, so they responded well in the two initial periods of the experiment and then decreased ingestion and feed conversion.

**Table 3**

Live weight and daily weight gain of sheep in confinement receiving different levels of cottonseed meal with a substitute for soybean meal in the feed

Variables	Cottonseed meal (%)			S.D.	Regression equation	r <sup>2</sup>
	0 (T <sub>1</sub> )	15 (T <sub>2</sub> )	30 (T <sub>3</sub> )			
<b>Live weight (kg)</b>						
Initial	27.0	28.0	27.0	1.84	$\hat{y} = 27.27$	-
At 14 days	30.17	33.0	30.17	1.98	$\hat{y} = 31.11$	-
At 28 days	33.33	37.0	33.33	2.07	$\hat{y} = 34.55$	-
At 42 days	36.77	40.0	36.77	2.03	$\hat{y} = 37.85$	-
At 56 days	41.43	43.0	41.43	2.08	$\hat{y} = 41.95$	-
<b>Daily weight gain (g day<sup>-1</sup>)</b>						
At 14 days	240.50	373	346	38.97	$\hat{y} = -0.3544x^2 + 14.15x + 240.5^*$	0.99
At 28 days	226	296	214	23.78	$\hat{y} = -0.3378x^2 + 9.7333x + 226^*$	0.99
At 42 days	245.25	186	195	40.75	$\hat{y} = 208.75$	-
At 56 days	333.25	220	218	38.80	$\hat{y} = -3.8417x + 314.71^*$	0.76
Mean	261.5	269	243	18.27	$\hat{y} = 257.83$	-

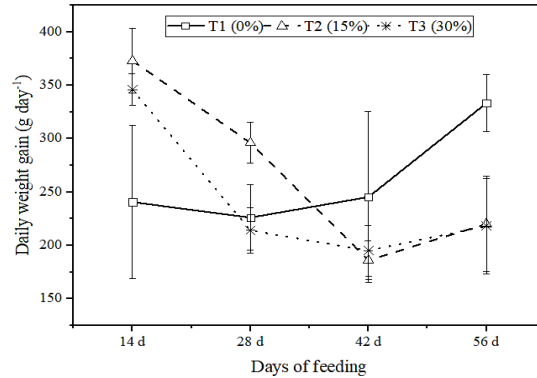
\* Significant at 5% probability by the F test. S.D.: standard deviation. r<sup>2</sup>: regression coefficient.

Lima-Junior et al. (2011) included the extruded cottonseed meal up to a level of 40% without harming the DMI of sheep without a defined breed. They did not find negative effects on this variable during the 67-day experiment, which does not coincide with observed in this study. Negrão et al. (2020) including cottonseed meal up to 21% instead of soybean meal recorded a decrease in DMI in Santa Inês sheep. On the other hand, Rocha (2016) did not observe significant effects on the FC of lamb when substituting up to 100% of the soybean meal for cotton cake.

**Productive performance**

The levels of cottonseed meal did not influence (Table 3; p > 0.05) the LW of the sheep during the experimental period. However, they significantly influenced DWG (p ≤ 0.05); with a quadratic behavior until 28 days of experimentation, reaching maximum peaks with an inclusion level of 20%, which coincides with reported by Viana (2011). However, no effects were observed at 42 days, as well as in the average DWG, but a theoretical linear reduction of 3.842 g is recorded for each increased percentage of this by-product at 56 days.

Figure 3 shows that the cottonseed meal levels (15 and 30%) improved DWG by 49.48% at 14 days, meanwhile, at 28 days; the inclusion of 30% of cottonseed meal (T<sub>3</sub>) already reduced the weight gain in comparison to the first measurement and was similar to the control (T<sub>1</sub>), while the inclusion of 15% (T<sub>2</sub>) continues to stand out with a higher value of 34.55%.



**Figure 3.** The behavior of the DWG of the sheep (g day<sup>-1</sup>) fed with different levels of cotton expeller instead of soybean expeller at 14, 28, 42, and 56 days.

Although no differences were observed at 42 days, it is already appreciated that the control showed a tendency to outperform the other treatments, confirming this at 56 days, where it registered a higher result of 34.28% at both levels. Based on the behavior of this study, it can be stated that for the category of ovine used, it is possible to replace the soybean meal with a cottonseed meal for no more than 28 days, since it is counterproductive in the long term (Gadelha et al., 2011; Viana 2011; Gadelha et al., 2014). As for the trend of decreasing DWG reported in the last periods of this study, it is probably due to the lower consumption and conversion presented by the animals (Table 2), since there are 90% correlations between these variables (Mertens, 1994; Dantas, 2018).

As in this study, Rocha (2016) when substituting the soybean meal for cotton cake in confinement sheep feeding observed that up to 68 days after his experimentation, the substitution did not influence on the DWG, while it decreases from then on. The author also reported a linear reduction trend with increasing levels of this by-product (33%, 67% and 100%). Similarly, Absalan et al. (2011) observed DWG in Zandi sheep when using 16% cottonseed meal in the diet, while incorporating 8%; reported significant improvement in the values of this variable.

#### Carcass characteristics and meat quality

No effects of cottonseed meal levels were observed on HCW, HCY, CCW, CCY, LEA, TSF, and WLC (Table 4;  $p > 0.05$ ). However, significant

effects ( $p \leq 0.05$ ) were appreciated on the carcass WLC and the TSF, confirming a quadratic trend, where better values were obtained with the level corresponding to 15% ( $T_2$ ) for both variables. The carcass yields (hot and cold) achieved in this study were similar to those obtained by Silva (2017) in Santa Inés sheep but they are lower than those reported by Pompeu et al. (2012) in crossbred lamb ( $\frac{1}{2}$  Morada Nova Red variety  $\times \frac{1}{2}$  without defined racial pattern).

Regarding the lower WLC presented by  $T_2$ , it could be due to the greater TSF presented, although statistically, it was not different from the other treatments, however, the fat in the carcass exerts a protective function against moisture loss (Cunha et al., 2016), and the greater the loss when the TSF is lower (Silva-Sobrinho et al. 2005). In general, the WLC recorded in this study is relatively low compared to the average considered acceptable, which is 2.5% (Martins et al., 2000) and is lower than the losses reported by Cunha et al. (2016), Cesco (2015) and Dantas (2018).

Regarding to the meat tenderness, the results obtained in this study can be classified as tender according to the scale of Hopkins et al. (2006). Therefore, it can be affirmed that the meat obtained in the sheep is of excellent quality and more so with the cottonseed meal level corresponding to 15% ( $T_2$ ), this could be due to the greater coverage of FT which prevented cold hardening. The results obtained in this study were better than reported by Urbano (2011) and Silva et al. (2014).

**Table 4**

Characteristics of the carcass and meat quality of sheep in confinement receiving different levels of cottonseed meal with a substitute for soybean meal in the diet

Variables	Cottonseed meal (%)			SD	Regression equation	$r^2$
	0 ( $T_1$ )	15 ( $T_2$ )	30 ( $T_3$ )			
<b>Carcass characteristics</b>						
HCW (kg)	16.05	17.40	16.20	2.00	$\hat{y} = 16.55$	-
HCY (%)	39.90	42.26	41.73	3.09	$\hat{y} = 41.30$	-
CCW (kg)	16.08	17.25	16.00	2.10	$\hat{y} = 16.44$	-
CCY (%)	38.33	41.34	40.24	2.91	$\hat{y} = 39.97$	-
WLC (%)	1.57	0.92	1.49	0.18	$\hat{y} = 0.61x^2 - 2.48x + 3.44^*$	0.99
<b>Meat quality</b>						
LEA (cm <sup>2</sup> )	19.0	19.50	19.50	3.30	$\hat{y} = 19.25$	-
TSF (mm)	1.25	1.0	1.0	0.16	$\hat{y} = 1.08$	-
WLC (%)	23.82	21.87	25.19	2.83	$\hat{y} = 26.63$	-
SF (kgf)	1.97	1.41	1.57	0.26	$\hat{y} = 0.56x^2 - 2.24x + 3.65^*$	0.99

\* Significant at 5% probability by the F test. SD: standard deviation.  $r^2$ : regression coefficient.

## CONCLUSIONS

Under the conditions in which the present investigation was carried out, it is concluded that the use of cottonseed meal instead of soybean meal in confined lamb feeding improves feed conversion, daily weight gain, and meat tenderness and

reduces weight loss by cooling and cooking. However, it did not affect the other variables.

It is possible to substitute the soybean expeller for cotton expeller in the feeding of sheep up to a level of 20% and for some time no longer than 28 days.

## REFERENCES

- Absalan, M., Afzalzade, A., Mirzaee, M., Sharifi, S.D., Khorvash, M., & Kazemi-Benchenari, M. (2011). Feeding of whole cottonseed on performance, carcass characteristics and intestinal morphology of Zandi lambs. *South African Journal of Animal Science*, 41(3), 309-317. <http://dx.doi.org/10.4314/sajas.v41i3.14>
- Almeida, J. A. de. (2020). Características físico-químicas e sensoriais da carne ovina submetida a diferentes métodos de cocção. Dissertação (Mestrado). Universidade Estadual Paulista Júlio de Mesquita Filho Faculdade de Engenharia, Ilha Solteira, 46 p.
- American Meat Science Association (AMSA). (2015). AMSA Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of fresh meat. 2nd ed. (Versión 1). USA, Chicago, Champaign-Illinois: American Meat Science Association, 104 p.



- Andrade, M. B., Macedo, F. A. F., Jobim, C.C., Lombardi, L., Macedo, F.G., & Gasparino, E. (2009). Características da carcaça e da carne de cordeiros terminados com dietas contendo diferentes proporções na silagem de grãos de milho. *Acta Scientiarum. Animal Sciences*, 31(2), 183-189.
- Assis, D. Y. C. de., Carvalho, G. G. P. de., Santos, E. M., Oliveira, F. A. de., Araújo, M. L., & Pina, D. (2019). Cottonseed cake as a substitute of soybean meal for goat kids. *Italian Journal of Animal Science*, 18(1), 124-133. <https://doi.org/10.1080/1828051X.2018.1490633>
- Carvalho, D. M. G. de., Reverdito, R., Cabral, L. da S., Abreu, J. A. de., Galati, R. L. de., Souza, A. L., Monteiro, I. J. G., & Silva, A. R. da. (2014). Concentrate levels on sheep diets: intake, digestibility and ruminal parameters. *Semina: Ciências Agrárias*, 35(5), 2649-2658.
- Cesco, G. (2015). Desempenho e características de carcaça de cordeiros Laucane alimentados com níveis de gordura protegida de óleo de palma. Dissertação (Mestrado). Universidade Tecnológica Federal do Paraná, Programa de Pós-graduação em Zootecnia, 141 p.
- Cézar, M. F., & Sousa, W. H. (2010). Proposta de avaliação e classificação de carcaças de ovinos deslançados e caprinos. *Tecnologia & Ciência Agropecuária*, 4(4), 41-51.
- Cunha, C., Cornélio, T., Fernandes, A. R., Seno, L., Ricardo, H., Osório, J. C., Osório, M. T., Alves, L. G., & Oliveira, E. (2016). Carcass traits and meat quality of Pantaneiro lambs fed with increasing levels of crude glycerin. *Revista Brasileira de Saúde e Produção Animal, Salvador*, 17(4), 729-743. <http://dx.doi.org/10.1590/S1519-99402016000400016>
- Dantas, J. L. S. (2018). Fontes proteicas alternativas na alimentação de ovinos em confinamento. Dissertação (mestrado). Universidade Federal do Rio Grande do Norte, Unidade Acadêmica Especializada em Ciências Agrárias, 44 p.
- Di Rienzo, J. A., Casanoves, F., Balzarini, M. G., Gonzalez, L., Tablada, M., & Robledo, C. W. 2015. InfoStat versión 2015. Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina. <http://www.infostat.com.ar>
- Gadelha, I. C. N., Rangel, A. H. N., Silva, A. R., & Soto-Blanco, B. (2011). Effects of gossypol on animal reproduction. *Acta Veterinaria Brasílica*, 5(2), 129-135.
- Gadelha, I. C., Fonseca, N. B., Oloris, S. C., Melo, M. M., & Soto-Blanco, B. (2014). Gossypol toxicity from cottonseed products. *Scientific World Journal*, 2014, 231635. <https://doi.org/10.1155/2014/231635>
- Hopkins, D. L., Hegarty, R. S., Walker, P. J., & Pethick, D. W. (2006). Relationship between animal age, intramuscular fat, cooking loss, pH, shear force and eating quality of aged meat from sheep. *Australian Journal of Experimental Agriculture*, 46(7), 879-884. <https://doi.org/10.1071/EA05311>
- Kim, H. L., Calhoun, M. C., Stipanovic, R. D. (1996). Accumulation of gossypol enantiomers in ovine tissues. Comparative Biochemistry and Physiology Part B. *Biochemistry and Molecular Biology*, 113(2), 417-420. [https://doi.org/10.1016/0305-0491\(95\)02061-6](https://doi.org/10.1016/0305-0491(95)02061-6)
- Lima-Júnior, D. M. de., Braga, A. P., Rangel, A. H. do., Braga, Z. C., Barreto, H. F., & Maciel, M. (2011). Extruded cottonseed meal (*Gossypium* spp.) in the diet of ruminants: intake and digestibility. *Acta Veterinaria Brasílica*, 5(1), 68-75.
- Lindsey, A., Hawkins, G. E., & Guthrie, L. D. (1980). Physiological responses of lactating cows to gossypol from cottonseed meal rations. *Journal of Dairy Science*, 63(4), 562-573. [https://doi.org/10.3168/jds.S0022-0302\(80\)82972-9](https://doi.org/10.3168/jds.S0022-0302(80)82972-9)
- Lopes, R. B. (2013). Manejo nutricional em um confinamento de bovinos de corte. Porto Alegre. Trabalho de Conclusão de Curso (Faculdade de Agronomia). Universidade Federal do Rio Grande do Sul, 38p.
- Martins, R. C., Oliveira, N., & Osorio, J. C. S. (2000). Peso vivo ao abate como indicador do peso e das características quantitativas e qualitativas das carcaças em ovinos jovens da raça Ideal. Bagé: Embrapa Pecuária Sul, 29p.
- Mello, R. R. C., Moreira, E. M., Susin, I., & Pires, A. V. (2018). Efeitos do caroço de algodão sobre a reprodução de bovinos. *Pubvet*, 12, 1-8. <https://doi.org/10.31533/pubvet.v12n10a188.1-8>
- Mertens, D. R. (1994). Regulation of forage intake. In: Fahey-Junior, G.C. (Ed.). Forage quality, evaluation and utilization. Madison: Wisconsin, p. 448-478.
- Mongelos, A. J. (2016). Proyecto rentable de negocio agro-ganadero para la producción y comercialización en el mercado nacional de carne de ovinos santa Inés en la ciudad de Pirayú del departamento de Paraguari de Paraguay". Trabajo de Maestría (Formulación, Evaluación y Gestión de Proyectos). Universidad Nacional de Asunción, Facultad de Ciencias Económicas, Administrativas y Contables, 176p.
- Negrão, F., Zanine, A., Ribeiro, M., Ferreira, D., Souza, A., Parente, M., Parente, H., Geron, L., Lima, A., Reis, R., & Lins, T. (2020). By-Product of Cotton Agribusiness as an Alternative Protein Source for Rams. *Agriculture*, 10(280), 1-11. <https://doi.org/10.3390/agriculture10070280>
- National Research Council (NRC). (2007). Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids, 1st ed. National Academy Press, Washington, DC. 384 p. <https://doi.org/10.17226/11654>
- Oliveira, J. P. de., Ferreira, M., Freitas, A. P. D. de., Urbano, S. A., & Silva, A. E. da. (2017). Carcass characteristics in Santa Inês sheep fed with mazoferm as a substitution for soybean meal. *Revista Ciência Agronômica*, 48(4), 708-715. <https://doi.org/10.5935/1806-6690.20170082>
- Palmieri, A. D., Carvalho, G. G. de., Tosto, M., Leite, V. M., Santos, S., Borja, M., Azevêdo, J. A., Freitas-Júnior, J. E. de., Leite, L., Ayres, M. C., & Rufino, L. M. (2016). Nutritional and productive performance of goats kids fed diets with detoxified castor meal. *Animal Feed Science and Technology*, 216(1), 81-92. <https://doi.org/10.1016/j.anifeedsci.2016.03.015>
- Pérez, J. R. O., & Carvalho, P. A. (2002). Considerações sobre carcaças ovinas. Ovinocultura: aspectos produtivos. Universidade Federal de Lavras. Lavras, MG: GAO: p.122-144.
- Pompeu, R. C. F. F., Cândido, M. J. D., Pereira, E. S., Bomfim, M. A. D., Carneiro, M. S. S., Rogério, M. C. P., Sombra, W. A. S., & Lopes, M. N. (2012). Performance and carcass traits of sheep in feedlot and fed diets containing detoxified castor cake replacing soybean meal. *Revista Brasileira de Zootecnia*, 41(3), 726-733. <https://doi.org/10.1590/S1516-35982012000300036>
- Rocha, A. A. (2016). Efeito da Substituição de Farelo de Soja por Torta de Algodão Moída no Confinamento de Ovinos. Dissertação (Mestrado em Ciências Veterinárias no Semiárido). Universidade Federal do Vale do São Francisco, Campus Ciências Agrárias, Petrolina, 46 p.
- Silva, M. O. (2017). Caracterização biológica e econômica da carcaça e cortes comerciais de cordeiros terminados em confinamento. Dissertação (Mestrado). Centro de Ciências Agrárias da Universidade Federal da Paraíba, 81 p.
- Silva, N. V. da., Costa, R. G., Medeiros, G. R. de., Medeiros, A. N. de., Gonzaga Neto, S.; Cezar, M. F., & Cavalcanti, M. C. A. (2014). Carcass characteristics of sheep fed with guava by-product. *Arquivo de Zootecnia*, 63(241), 25-35.
- Silva-Sobrinho, A. G., & Moreno, G. M. B. (2009). Produção de carnes ovina e caprina e cortes da carcaça. In: XIII Seminário Nordestino de Pecuária – Pecuária Nordeste. Fortaleza. Anais... p. 1-37.
- Silva-Sobrinho, A. G., Purcha, R. W., Kadim, I. T., & Yamamoto, S. M. (2005). Meat quality in lambs of different genotypes and ages at slaughter. *Revista Brasileira de Zootecnia*, 34, 1070-1078. <https://doi.org/10.1590/S1516-35982005000300040>
- Soto-Blanco, B. (2008). Gossypol e fatores antinutricionais da soja," In: Toxicologia Aplicada à Medicina Veterinária, HS Spinosa, SL Górnica, and JP Neto, Eds., Manole, Barueri, Brazil, pp. 531-545.
- Tripathi, M. K., Raghuvansi, S. K. S., Mondal, D., & Karim, S. A. (2014). Effect of Bt-cottonseed meal feeding on performance, fermentation, ciliates population and microbial hydrolytic enzymes in lamb. *African Journal of Biotechnology*, 13(3), 509-522. <https://doi.org/10.5897/AJB2013.13111>
- Urbano, S. A. (2011). Características de carcaça e qualidade da carne de ovinos alimentados com casca de mamona em substituição ao feno tifton. Dissertação (Mestrado). Universidade Federal Rural de Pernambuco, Departamento Zootecnia, Recife, 92 p.
- Velasquez-Pereira, J., McDowell, L. R., Risco, C. A., Prichard, D., Martin, F. G., Calhoun, M.C., & Ogebe, P. (1998). Effects on performance, tissue integrity, and metabolism of vitamin E supplementation for beef heifers fed a diet that contains gossypol. *Journal of Animal Science*, 76, 2871-2884. <https://doi.org/10.2527/1998.76112871x>
- Viana, P.G. (2011). Desempenho e avaliação da carcaça de ovinos Santa Inês suplementados com caroço de algodão (*Gossypium* spp.) e seus coprodutos. Dissertação (Mestrado). Brasília: Faculdade de Agronomia e Medicina Veterinária da Universidade de Brasília, 50p.
- Wang, C. W., Li, Y. Q., Di, T., Yang, H. J., Yang, K. L. (2020). Effect of dietary gossypol supplement on fermentation characteristics and bacterial diversity in the rumen of sheep. *Journal Plos One*, 15(6), e0234378. <https://doi.org/10.1371/journal.pone.0234378>