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Substitution of soybean meal with dried distillery grains on performance and carcass quality of feedlot lambs

Influência da substituição do farelo de soja por grão seco de destilaria no desempenho e características de carcaça de ovinos confinados

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Highlights:
DDGS is an alternative feeding source that can be included in feedlot lambs.
DDG can be used without impairing performance or intake in growing lambs.
DDG can be an alternative to decrease the lambs production cost.

Abstract

The objective of this work was to evaluate the effect of inclusion of dried distillery grains (DDGS) as a replacement for soybean meal in the diet of lambs in feedlot and to evaluate the performance, yield characteristics, and meat quality. Three diets with different DDGS levels were provided: diet with soybean meal (control); diet with 50% replacement of soybean meal by DDGS; diet with 100% replacement of soybean meal with DDGS. The average feed intake of the animals and the difference between the leftovers showed no difference among the treatments. No differences of average daily weight gain, body score and feed conversion index were observed among treatments. The same was observed for biometric measurements. However, warm carcass weight and chest perimeter were higher without the use of DDGS. The final weight, muscle, bone, intermuscular, subcutaneous and total fat weight did not differ among treatments. No difference was also found for tissues color. The kilogram of the concentrate mixture that uses soybean meal as the main source of protein (control) was approximately 12% more expensive than the mixture using DDGS (100%). The use of DDGS as an alternative source in confined lamb feeding may be recommended in up to 24% replacement in dietary dry matter.
Key words: Co-products. Economic cost. Protein source. Supplementation. Young sheep.

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Resumo

O Objetivo desse trabalho foi avaliar o efeito da inclusão de grão seco de destilaria com solúveis (DDGS) como substituto a farelo de soja na dieta de cordeiros em confinamento. E avaliar a influência dessa inclusão sobre as características de desempenho, rendimento e qualidade de carne. Foram usados 30 animais, sendo 15 machos e 15 fêmeas, distribuídos em três tratamentos. Foram elaboradas dietas com três níveis de inclusão de DDGS, sendo: Tratamento 1 - dieta com farelo de soja (controle, 0% de inclusão de DDGS); Tratamento 2 - dieta com 50% de substituição do farelo de soja por DDGS; e Tratamento 3 - dieta com 100% de substituição do farelo de soja por DDGS. Foi avaliado o consumo médio dos animais, suas medidas biométricas, além de parâmetros de qualidade de carne e custo das dietas. A avaliação do consumo e a diferença entre as sobras não mostraram diferença entre os tratamentos. Também não foram observadas diferenças entre os ganhos de peso médio diário, ganho de peso total, escore corporal, índice de conversão alimentar e eficiência alimentar entre os tratamentos. O mesmo foi observado para as medidas biométricas. Não houve diferenças para a circunferência externa e interna, conformação, musculatura e largura da garupa e do tórax. No entanto, o peso da carcaça quente e o perímetro torácico foram maiores no tratamento sem o uso de DDGS. O peso final, peso dos músculos, peso ósseo, peso de gordura intermuscular, peso de gordura subcutânea, peso total de gordura também não diferiram entre os tratamentos. Nenhuma diferença foi encontrada para cor do músculo ou da gordura intermuscular e subcutânea. O valor gasto no custo do quilograma da mistura de concentrado que utilizava farelo de soja como principal fonte de proteína (controle) foi aproximadamente 12% mais caro que a mistura usando DDGS (100%), o que permitiu concluir que o uso de DDGS como fonte alternativa na alimentação de cordeiros confinados pode ser recomendado em até 24% de substituição na matéria seca da dieta.

Palavras-chave: Co-produtos. Custos econômicos. Fonte proteica. Suplementação. Ovinos jovens.

Introduction

Successful sheep farming is closely related to feeding management because it represents the largest production cost in a sheep enterprise. Feeding costs include expenses associated with pasture management and forage, concentrate, and mineral supplementation.

The central-western region of Brazil has been outstanding in the finishing of animals under feedlot owing to the great supply of grains because most feedlots have been using raw material such as soybeans, corn, and millet.

Aiming at intensifying livestock production and providing conditions needed for maximum animal performance, the use of feedlot for finishing lambs is well established. This system allows a faster commercialization and production of high-yielding and better conformed carcasses that meet the demands of the modern consumer, who is increasingly interested in better tasting meat. However, high input prices are the critical point in feedlot systems, and it should be lowered whenever appropriate to enable feedlot operations (Andrade et al., 2014).

Finishing lambs in a feedlot system should be well planned, seeking to integrate genetics, feeding, and management to obtain adequate economic return. In this sense, the use of co-products is essential to reduce feeding costs. The use of dried distillery grains with soluble (DDGS), which are co-products of the ethanol production process, has been highlighted as it can act as a substitute for conventional feedstuff sources, such as soybean meal and corn. In addition, the fibers found in this co-product have high digestibility; thus, DDGS can act as a partial substitute for forage and concentrate in animal feeding (United States Grains Council [USGC], 2012).

Only few studies have focused on DDGS as feed for sheep. The aim of this study was to evaluate the effect of substitution of soybean meal with DDGS on the performance of feedlot lambs as well as on carcass traits and meat quality.

Material and Methods

The experiment was conducted at the Animal welfare center in the city of Sinop-MT, Latitude: -11.873, Longitude: -55.4982 11° 52′ 23″ Sul, 55° 29′ 54″ Oeste, Brazil, between March and June 2015. Thirty lambs were used (15 males and 15 females) shortly after weaning. The animals were identified, weighed, and divided into three treatments to allow a mean weight of approximately 18 kg within each treatment. The animals were housed in collective pens of 0.8 m^2/lamb with 10 animals each (5 males and 5 females for each treatment) for 90 days. Animals had free access to mineral salt, water, and to a total mixed ration according to the treatment, which was given twice a day.

The diets were formulated for nutritional requirements of Santa Inês lambs with an average weight of 18 kg, considering an average feed intake of 3% live weight (DM) and a forage:concentrate ratio of 60:40; according to the National Research Council [NRC] (2007).

Three diets with different DDGS levels were evaluated: diet using soybean meal (control); 50% substitution of soybean meal with DDGS; and 100% substitution of soybean meal with DDGS, maintaining crude protein levels around 16%, as can be seen in Table 1. The ingredients were analyzed according to Silva and Queiroz (2002) at the Mato Grosso State University Nutrition Laboratory, Sinop-MT.

Table 1
Diet supplied during the experimental period

Ingredients	TS	DM	DM	CP	CP	TDN	TDN	NDF	NDF
	($g\ kg^{-1}$DM)	(g)	($g\ kg^{-1}$)	(g)	($g\ kg^{-1}$)	(g)	($g\ kg^{-1}$)	(g)	($g\ kg^{-1}$)
Replacement level 0%									
Corn grain	690.00	87.64	604.70	9.11	62.90	87.24	602.00	13.98	96.50
Soybean hulls	140.00	89.8	125.70	11.65	16.30	68.77	96.30	68.4	95.80
Soybean meal	120.00	88.61	106.30	48.78	58.50	81.54	97.80	14.61	17.50
Urea	10.00	97.53	09.80	282.02	28.20		0.00		0.00
Salt	10.00	99.07	09.90		0.00		0.00		0.00
Limestone	10.00	99.27	09.90		0.00		0.00		0.00
Dicalcium phosphate	20.00	98.57	19.70		0.00		0.00		0.00
Total	1000.00		886.10		165.90		796.10		209.80
Replacement level 50%									
Corn grain	680.00	87.64	596.00	9.11	61.90	87.24	593.20	13.98	95.10
Soybean hulls	80.00	89.8	71.80	11.65	09.30	68.77	55.00	68.4	54.70
Soybean meal	60.00	88.61	53.20	48.78	29.30	81.54	48.90	14.61	08.80
DDGS	120.00	90	108.00	30	36.00	88	105.60	44	52.80
Urea	10.00	97.53	09.80	282.02	28.20		0.00		0.00
Salt	10.00	99.07	09.90		0.00		0.00		0.00
Limestone	10.00	99.27	09.90		0.00		0.00		0.00
Dicalcium phosphate	30.00	98.57	2.96		0.00		0.00		0.00
Total	1000.00		888.10		164.70		802.80		211.40

continue

continuation

Replacement level 100%									
Corn grain	660.00	87.64	578.40	9.11	60.10	87.24	575.80	13.98	92.30
Soybean hulls	40.00	89.8	35.90	11.65	04.70	68.77	27.50	68.4	27.40
DDGS	240.00	90	216.00	30	72.00	88	211.20	44	105.60
Urea	10.00	97.53	09.80	282.02	28.20		0.00		0.00
Salt	10.00	99.07	09.90		0.00		0.00		0.00
Limestone	10.00	99.27	09.90		0.00		0.00		0.00
Dicalcium phosphate	30.00	98.57	29.60		0.00		0.00		0.00
Total	1000.00		889.50		165.00		814.50		225.30

TS: Total supplied; DM: Dry Matter; CP: Crude Protein; TDN: Total Digestible Nutrients; NDF: Neutral Detergent Fiber.

After the adaptation period, the animals were weighed every 28 days and the average feed intake per pen basis was calculated. Biometric measurements were also taken: anterior height (distance between withers and distal forelimb region); posterior height (distance between sacral tuberosity and distal hind limb); body length (distance between cervical-thoracic articulation and tail base in the first intercoccygeal joint); chest girth (using the sternum bone and withers as a base, taken around the chest just behind the front legs); rump width (maximum width between the trochanters of the femurs); chest width (distance between lateral sides of scapular-humeral joint); leg circumference (at its mid-point, above the tibiofemoral joint) (Osório, Osório and Jardim,1998).

On the basis of the data collected during this period, an economic evaluation was carried out, considering costs and feed intake. Input prices used were quoted in Sinop - MT from February to March 2015. To calculate the costs, the average intake per animal of each treatment was used to know the average intake of concentrate and forage. This value was then multiplied by the concentrate cost per kilo + forage cost per kilo per animal/day of each treatment during the 90 days of experiment.

When lambs reached 30 kg of live weight, they were solid fasted for 16 hours and then slaughtered in a commercial slaughterhouse. After bleeding, the skin was removed, avoiding cuts that depreciate the carcass to maintain the integrity of the fat layer for further evaluation.

The carcass was weighed to obtain the hot carcass weight (HCW) and to calculate the carcass yield (CY), according to Osório et al. (1998):

$$CY = HCW/\text{Live weight} \times 100.$$

At slaughtering, the following morphometric measurements were taken: external carcass length: from the last sacral vertebra to the base of the neck; internal carcass length: maximum distance between the front edge of the pubic bone and the front edge of the first rib at its midpoint; chest girth, taken around the chest just behind the front legs; leg circumference, considering the trochanters of the femurs; chest width, the maximum distance between the spine and sternum bone, using calipers; rump width: maximum width between the trochanters of the femurs, using a tape, following the recommendations of Osório et al. (1998). According to the same authors, carcasses were subjectively evaluated for meat proportion and fat coverage, ranging from 1 to 5.

After measurements, commercial meat cuts were taken from carcass, removing the shoulders, which were frozen for further dissection.

Approximately 12 hours before dissection, the shoulder was removed from the freezer and placed in a refrigerator to thaw at 15° C. Subsequently, it was weighed and dissected to determine the proportion of muscle, bone, and fat (subcutaneous and intermuscular) and others, according to the methodology described by Osório et al. (1998).

After dissection, tissue samples were divided into three similar parts (cuts of at least 1-cm thick) and left exposed to natural light for 30 minutes after thawing to allow them to return to normal color. Subsequently, readings were taken using the Minolta Chroma Meter MCR-300b colorimeter, calibrated to a white tile standard. The CIE L*a*b* system was used, where L* corresponds to the lightness, a* to the redness, and b* to the yellowness, according to (Bressan, Prado, Pérez, Lemos, & Bonagurio, 2001). In each cut of the muscles and fats, three readings were performed at different points, and the averages of readings were used for the statistical analyzes.

The variables were analyzed in a completely randomized design (CDR) and in a factorial arrangement using analysis of variance and the Statistical Analyses System PROC GLM (Statistical Analysis System [SAS], 2001). The means were compared by the Tukey's test (P < 0.05), according to Model 1.

Model 1

$$Yijk = \mu + Ti + Sj + T * Sij + eijk,$$

Yijk = characteristics evaluated in animal k, sex j and treatment i;

μ = inherent constant in the data;

Ti = Treatment effects i, i = 1: 0% replacement level, 2: 50% replacement level, 3: 100% replacemtent level;

Sj = Sex effects j, j = 1: male e 2: female;

T * SIJ = interaction effects between treatment i and sex j;

eijk = random error Yijk, NID, (0, σ_e^2).

Results

The average feed intake was 2.278 kg from 0 to 30 days, 2.560 kg from 30 to 60 days, and 2.762 kg from 60 to 90 days, and the quantity of orts were not different among treatments (P>0.05) (Table 2).

Table 2
Averages for intake (Kg) per animal during the experimental period

	SUPPLIED / ORTS – Kg animal Day^{-1}										
Replacement level	0 – 30 Days			30 – 60 Days			60 - 90 Days			Mean Supplied	Mean Orts
	Supplied	Orts	Consumed	Supplied	Orts	Consumed	Supplied	Orts	Consumed		
0%	2.272	0.248	2.024	2.560	0.229	2.331	2.748	0.530	2.218	2.527	0.336
50%	2.281	0.269	2.012	2.560	0.271	2.289	2.758	0.464	2.294	2.533	0.335
100%	2.281	0.261	2.020	2.560	0.243	2.317	2.779	0.337	2.442	2.540	0.280

Means followed by different letters differ by the Tukey's test (P<0.05).

Averages for body weight and body condition score of lambs during the experimental period are shown in Table 3, and no statistical difference was observed among treatments (P>0.05).

In this experiment, the use of DDGS as an alternative to soybean meal, even at 100% substitution, did not change lamb weight gain (P>0.05) (Table 4).

Another important issue to be evaluated is the efficiency of use of DDGS. Although it was accepted and consumed by the animals, it could have a low utilization rate, leading to low conversion rates. However, when evaluating feed efficiency and conversion indexes (Table 5), even at the highest inclusion level, the efficiency values did not differ (P>0.05) from that observed in soybean-based diets.

Table 3
Averages for body weight and body condition score according to the treatments

Variable[1]	Mean	Replacement level			Sex		CV (%)
		0%	50%	100%	Male	Female	
Initial weight	18.27	17.65	18.84	18.25	18.40	18.16	13.88
Initial BCS	1.82	1.81	2.00	1.67	1.93	1.73	38.32
Weight at 28 days	24.26	21.51	24.32	26.40	24.50	24.06	24.06
Weight at 56 days	28.47	25.18	28.95	30.67	29.96	27.28	23.03
Weight at 84 days	31.58	27.98	32.18	33.91	33.44	30.09	36.83
Final Weight	29.74	27.97	30.06	30.87	28.93	30.38	197.08
Final BCS	2.92	2.83	3.08	2.86	3.12	2.7	14.51

[1]Kg; Means followed by different letters differ by the Tukey's test (P<0.05).

Table 4
Averages for daily weight gain (ADG) of lambs during the experimental period

Variable	Mean	Replacement level		
	(Kg)	0%	50%	100%
ADG 0 - 28 dias	0.214	0.138	0.196	0.291
ADG 29 - 56 dias	0.182	0.134	0.180	0.221
ADG 57 - 84 dias	0.158	0.123	0.159	0.186
ADG 85 – 90 dias	0.127	0.115	0.125	0.140
Média 90 dias	0.170	0.127	0.165	0.209

Means followed by different letters differ by the Tukey's test (P<0.05).

Table 5
Calculation of Feed Conversion and Feed Efficiency Indexes

Replacement level	ADG	Intake	Feed Conversion Index	Feed Efficiency Index
	(Kg)	Animal day-[1] (Kg)	(Kg)	(%)
0%	0.127	2.191	17.25	5.7
50%	0.165	2.980	18.06	5.5
100%	0.209	2.260	10.81	9.2

ADG: Average daily weight gain; Means followed by different letters differ by the Tukey's test (P<0.05).

The same response was observed for the biometric measurements of lambs (P>0.05) (Table 6). The biometric measurements of carcass taken shortly after slaughtering (Table 7), and according to the data, there was also no difference (P>0.05) on external and internal length, leg circumference, conformation, muscle score, chest width, and rump width of the carcass. However, hot carcass weight and chest girth were different (P<0.05) among treatments.

Lambs fed diets using 100% substitution of soybean meal with DDGS had lower carcass weight than that of the control group. However, animals fed 50% and 100% substitution diets had similar biometric measurements. Animals fed a control diet and diets using 50% DDGS had higher chest girth than that of animals fed 100% DDGS.

Table 6
Averages for biometric measurements (cm) according to the treatments

Variable	Mean	Replacement level			Sex		CV (%)
		0%	50%	100%	Male	Female	
Initial body length	54.94	55.37	56.22	53.45	56.58	53.63	16.06
Final body length	62.61	62.87	66.00	59.35	65.87	60.00	17.16
Initial anterior height	54.64	54.87	56.66	52.65	57.66	52.23	20.03
Final anterior height	61.20	63.43	63.83	57.05	64.25	58.76	17.08
Initial posterior height	55.91	55.87	58.38	53.73	58.54	53.82	20.14
Final posterior height	62.85	63.87	67.00	58.030	65.58	60.66	17.52
Initial chest girth	61.00	61.02	63.44	58.75	63.33	59.13	15.99
Final chest girth	71.92	71.50	74.11	70.30	75.54	69.03	16.35
Initial barrel girth	67.05	66.00	70.44	64.93	69.41	65.22	26.43
Final barrel girth	80.30	82.81	85.33	73.77	77.79	82.31	19.41
Initial leg circumference	24.97	25.43	26.27	23.42	26.12	24.05	22.28
Final leg circumference	33.20	33.68	30.72	35.05	30.12	35.66	59.30
Initial rump width	16.27	13.93	14.77	19.50	14.54	17.66	39.37
Final rump width	17.61	16.31	16.77	19.40	16.54	18.46	55.63
Initial chest width	16.46	13.81	15.16	19.75	15.16	17.50	48.39
Final chest width	17.33	16.65	15.94	19.25	15.62	18.78	15.86

Means followed by different letters differ by the Tukey's test (P<0.05).

Table 7
Biometric carcass measurements of lambs fed different proportions of DDGS

Variable	Replacement level			CV (%)
	0%	50%	100%	
Fasted live weight (Kg)	35.22	34.50	34.96	2.87
Hot carcass weight (Kg)	17.10a	16.10^{b}c	16.40c	3.34
External carcass length (cm)	18.20	61.40	61.00	3.57
Internal carcass length (cm)	54.60	55.40	55.67	4.55
Chest girth (cm)	70.00a	67.60^{a}b	66.67b	2.16
Leg circumference (cm)	31.90	31.80	30.34	6.00
Fat cover (1-5 grade)	2.45	2.30	2.50	11.20
Meat proportion (1-5 grade)	2.65	2.60	2.58	15.13
Rump width (cm)	16.70	16.00	16.17	6.42
Chest width (cm)	15.30	15.10	14.50	5.56

CV: Coefficient of variation. Means followed by different letters differ by the Tukey's test (P<0.05).

In the present study, there was no difference (P>0.05) on fat cover and meat proportion score among the three treatments and the coefficient of variation was low (Table 7).

Averages for variables related to dissection of the shoulder (Table 8), such as final weight, shoulder weight, muscle weight, bone weight, intermuscular fat weight, subcutaneous fat weight, total fat weight, and other components (g), had no difference (P>0.05) between dietary DDGS levels.

When evaluating the color of muscle and intermuscular tissues and subcutaneous fat, no difference was found for the variables as a function of dietary DDGS levels (Table 9).

Table 8
Averages for shoulder composition of lambs fed different levels of DDGS

Variable	Replacement level			CV (%)
	0%	50%	100%	
Final weight (Kg)	35.17	35.50	34.08	7.35
Shoulder weight (g)	1623.72	1541.45	1529.69	6.66
Muscle weight(g)	1011.19	918.50	902.90	10.23
Bone weight (g)	310.56	338.62	333.62	10.78
Intermuscular fat weight (g)	127.04	75.15	103.90	40.26
Subcutaneous fat weight (g)	37.05	71.50	59.46	66.65
Total fat weight (g)	164.09	146.65	163.37	29.72
Other components (g)	44.85	44.16	46.49	22.59

Means followed by different letters differ by the Tukey's test (P<0.05).

Table 9
Colorimetry of shoulder components of lambs fed different levels of DDGS

Variable	Replacement level 0%	50%	100%	P-value	CV (%)
		Muscle			
L*	15.59	16.55	17.22	0.5355	12.75
a*	0.94	1.11	2.28	0.4495	116.36
b*	72.45	72.93	75.06	0.1336	2.63
		Intermuscular fat			
L*					
a*	3.92	5.24	4.70	0.4638	32.79
b*	8.14	7.58	6.93	0.356	16.04
		Subcutaneous fat			
L*	72.36	73.18	72.12	0.6969	2.80
a*	2.70	3.95	3.94	0.1371	26.63
b*	7.25	7.41	7.05	0.8829	15.89

L* (lightness). a* (green/red color component) e b* (yellow/blue color component).

Knowing that lamb performance was not affected, the feeding cost relative to the average feed intake during the 90 days of experiment becomes an important factor in the decision-making on the use of DDGS (Table 10).

Table 10
Averages for cost of diet per animal/day

Replacement level	Concentrate (R$ Kg-^{1})	Forage (R$ Kg^{-1})	Concentrate Intake (Kg)	Forage Intake (Kg)	TS cost Animal day^{-1}
0%	0.49	0.080	0.739	1.788	R$ 0.51
50%	0.47	0.080	0.741	1.792	R$ 0.49
100%	0.43	0.080	0.743	1.797	R$ 0.46

TS: Total supplied; Means followed by different letters differ by the Tukey's test (P<0.05).

When the feeding cost was analyzed, it was observed that the price of concentrate (kg) using soybean meal as the main protein source (0% of replacement) was approximately 12% higher than that using DDGS as the main protein source (100% replacement).

Discussion

DDGS did not affect the acceptability in lambs even at greater inclusion, which could be a crucial factor for this substitution since its viability could be lost if the animals showed no interest in consuming DDGS. However, based on the uniformity of feed intake, this possibility is not considered and the use of DDGS can be indicated.

Our observation of similar performance is an interesting result, considering that high-quality feedstuffs such as soybean meal are costly ingredients, whereas industrial co-products such as DDGS, with a good nutritional value, can be used to reduce feeding cost without impairing animal performance. Therefore, DDGS can be considered as a potential feed alternative for feedlot lambs.

Buckner et al. (2008) observed results similar to those of this study when comparing the dietary inclusion of DDGS for feedlot cattle at 100 g kg^{-1}, 200 g kg^{-1}, 300 g kg^{-1}, and 400 g kg^{-1} DM inclusion and a control group that was fed corn. The recommended inclusion level was 200 g kg^{-1} DDGS for the highest weight gain. Similarly, in the present study, DDGS levels of 0 g kg^{-1}, 120 g kg^{-1}, and 240 g kg^{-1} DM were compared with a control group using soybean meal, and the best result was obtained at 240 g kg^{-1} DDGS based on the data of average diet intake during the experiment.

The similar biometric measurements among the treatments suggest that the substitution with DDGS does not cause negative effects on the growth of lambs and does not impair their body development and tissue deposition.

Studies on carcass traits are based on the evaluation of objective and subjective measurements that allow comparisons between different breeds, body weights, slaughtering ages, and feeding systems. In addition, it is possible to establish correlations with other components or with carcass tissues to estimate their physical traits. Jorge, Fontes, Paulino, Gomes and Ferreira (1999) justified that the estimation of carcass traits is of paramount importance to complement the evaluation of animal performance during its development.

According to Osório et al. (1998), because of the different production systems and breeds, lamb meat market has great variability in the quantitative and qualitative traits due to the different types of carcasses sold.

The same conformation and musculature presented by sheep proves that the groups were homogeneous within the treatments. According to Stanford, McAllister, MacDougall and Bailey (1995), meat breeds have better carcass conformation owing to the development of muscle mass and adequate amount and distribution of fat. In this study, feeding DDGS did not change the gains of muscle or fat in lambs, and so, it can be used as an alternative feedstuff source.

The low coefficients of variation for carcass measurements found in this study are consistent with those presented by Shahin, Soliman and Moukhtar (1993), who observed a coefficient of variation between 5% and 14% in measurements of carcass length (reflecting bone growth) and width (reflecting the development of adipose and muscular tissue). The variation found in carcass measurements is explained by their inter-correlations with other measurements. Considering that the other variables evaluated were not different, this variation indicates that, under the same nutrition conditions, the treatments studied may have similar values for each variable of animal performance.

The muscle is considered the carcass component of major quantitative importance, followed by fat and bone, considering that bone has a relatively constant proportion compared to the other two carcass tissues (muscle and fat). The relative percentage variation of muscle and fat is important; however, the variability of fat tissue in the carcass and its quality are crucial and variations in the proportion of muscle are associated with variations in the fat coverage in the carcass (Osório et al., 2002).

According to Bueno, Cunha, Santos, Roda and Leinz (2000), the physical separation of the carcass tissues showed that the increase in age and slaughter weight of Suffolk lambs led to a linear decrease in the percentage of bones and an increase in fat, without altering the muscle percentage. As carcass weight increases, the percentage of muscle remains almost constant, whereas bone percentage decreases and that of fat increases since high weight implies greater fat accumulation. In this study, no difference was observed between muscle, bone, and fat composition among treatments, which can be attributed to the fact that they were lambs of the same breeding group that were fed at a good nutritional level regardless of the ingredients used.

According to Santos, Pérez, Siqueira, Muniz and Bonagurio (2001), muscles have a faster growth in younger animals and fat noticeably increases in older animals, whereas bones have a slower growth rate than that of the other components. Osório et al. (2002) states that the speed of muscle growth is similar to that of body weight, but the proportion of muscle in relation to body weight decreases at the onset of maturity. They also highlight that most differences in tissue composition in animals of the same age or slaughter weight reflect differences in maturity between breeds. When animals are slaughtered at the same stage of maturity, these differences are minimized, as observed in this study.

Rosa, Cleber, Silva, Motta and Colomé (2002) observed that the proportion of fat in relation to slaughter weight in Texel lambs was higher in animals slaughtered at 33 kg of live weight, indicating that the increase in slaughter weight leads to a higher fat deposition, decreasing the percentage of bone and muscle. The authors concluded that carcasses with high percentage of muscle and adequate percentage of fat are obtained when the lambs are slaughtered at approximately 30 kg. In this study, the animals were slaughtered at a mean weight of 35 kg ± 0.97, a likely reason for the highest percentage of fat in the carcass.

In a study conducted by Hashimoto et al. (2012) evaluating carcass quality, parts, and tissue development of lambs finished in three systems, the development of shoulder, leg, and ribs in males was shown to be influenced by the finishing system. The same response was not observed in this study.

In practical terms, nutrition has a great influence on tissue deposition rates and on fat, the most variable animal body tissue.

According to Costa et al. (2011b), deliberate changes in concentrate levels supplied to ruminants directly interfere with the lipid metabolism of the animal and, therefore, the amount of fatty tissue deposited in the carcass. Rosa et al. (2002) evaluated the relative growth of bone, muscle, and fat in several meat cuts of lambs and ewes in different feeding methods and concluded that the muscle growth of the shoulder occurs earlier in males than in females. Therefore, in young animals at the same carcass weight, males have more muscle in this meat cut than do females.

Color plays an important role in the sensory quality of meat and it stands out as the most important factor in consumer purchasing decision, indirectly determining shelf life unless other factors are markedly deficient, such as odor (Pinheiro et al., 2009). Generally, meat color is determined by the total concentration of myoglobin (protein involved in muscle oxygenation processes) and by the relative proportions of this pigment in muscle tissue, which can be found in the form of reduced myoglobin (purple), oxymyoglobin (bright red color), and metmyoglobin (usually brown) (Costa et al., 2011a).

According to Bressan et al. (2001), color can be measured by the objective method using a colorimeter, which determines the color components L* (lightness), a* (redness), and b* (yellowness). Low L* and high a* content is usually found in redder meat (Simões & Ricardo, 2000).

Russo, Preziuso, Casarosa, Campadoni and Ciancia (1999) studied the effect of different energy sources in lambs and found no effect of diet ($P>0.05$) on meat color (L*, a*, and b*), averaging 41.66, 17.06, and 6.51, respectively.

The color of the shoulder was not influenced by dietary DDGS levels ($p>0.05$). According to Renerre (1990), the redness can be influenced by the slaughter age as an increase in myoglobin concentration occurs as the animals grew older. Lambs of the present study were slaughtered at approximately the same age (on average, a year and a half), justifying the lack of difference of red intensity.

According to Butterfield (1988) and Butterfield and Thompson (1983), subcutaneous fat (which reflects the degree of fattening) has the highest coefficient of variation, being affected by the proportion between animal weight at slaughter and its mature weight, which also explains the values obtained in this study.

Finishing lambs in a feedlot system minimizes problems with internal parasites and intensifies meat production by increasing growth speed of animals. Nonetheless, feeding represents a considerable part of the cost of production in this system. Our study results show that it is possible to use co-products to reduce the cost in sheep production systems.

Considering that there was no difference in lamb performance among treatments when analyzing the final feeding cost in relation to the average intake per animal at the different DDGS substitution levels, 100% substitution of soybean meal with DDGS is approximately 10% cheaper than the cost of the control treatment. Apparently, this difference is small, but the option to reduce feeding costs by up to 10% in a large-scale production system by using co-products instead of soybean meal certainly favors lamb production and makes investment more attractive to the farmer.

Conclusions

In the search for alternative industrial co-products to reduce the production costs, DDGS is an alternative feeding source that can be included at up to 24% dry matter in feedlot lambs without impairing performance, intake, and meat quality parameters such as deposition of muscle, fat, and color.

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