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Effect of dried distillers grains (DDGS) on diet digestibility, growth performance, and carcass characteristics in Creole wool lambs fed finishing diets

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Abstract

Dried corn distillers grains with solubles (DDGS) can partially replace grains and forages in diets for ruminants. The objective of this research was to evaluate the effect of replacing grains and soybean meal with DDGS (0%, 15%, 30% and 45%) in the diet of lambs. Thirty-two native lambs were used (initial bodyweight = 28.6 ± 2.19 kg) in a completely randomized design. Initial body weight was a co-variable, and the means were compared with the Tukey test. The dry matter intake was significantly higher in DDGS containing diet than in the control treatment. The daily weight gain was higher in the diets with 15% of DDGS compared with the control. Dry matter digestibility was lower by 7% with 45% of DDGS. The hot and cold carcass weights were significantly higher by 8% in DDGS treatments compared to the control. The inclusion of increasing levels of DDGS in the diet of fattening lambs increased their dry matter intake, improved carcass weight, and did not adversely affect carcass characteristics.

Keywords: Carcass, by-products, animal production, ruminant nutrition
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Introduction

In Mexico, the lamb breeding industry registered an increase of over 1.3 million lambs between 2005 and 2014. Although the production of lamb meat reached 70 009 tons in 2015, the country still depends on imports to satisfy the demand (SIAP, 2015). Grains are one of the primary sources for fattening lambs. However, at global level, the price of grain tends to rise, as well as its use for the production of ethanol (USDA, 2015). This results in less grain being destined for the consumption of humans and livestock, especially corn, thus affecting the national market, which presents highly fluctuating prices. Therefore, finding alternative alimentary sources has become a necessity to reduce costs and to achieve a better yield in the production of lamb meat. As an alternative, dried corn distillers grains (DDGS), the main by-product of the production of ethanol, with high contents of energy and protein, may replace up to 40% of grain (Klopfenstein *et al*., 2008) and 25% of forages (Li *et al*., 2011) in diets for ruminants. The use of DDGS in animal feed is rising because they can replace conventional ingredients, generating a favourable economic result, and its availability has increased owing to the growth of the ethanol industry. Chemical composition and feeding value of DDGS differ among types of raw material and ethanol production plants. Within plants, coefficients of variation range from 3% for crude protein (CP) and metabolizable energy, to 25% for starch, sugar and sodium (Böttger & Südekum, 2017)

To obtain ethanol, the starch of the grain is fermented and removed, which increases the concentration of CP, neutral detergent fibre (NDF) and fat up to three times in DDGS (Spiehs *et al*., 2002). DDGS contains more than 30% of CP, of which 73% is not degradable in the rumen, and 40% of NDF and 11% of fat (NRC, 2007).

Investigations related to the use of DDGS suggest that the adequate level for its inclusion in cattle diets for fattening (steers and heifers) ranges between 20% and 30% of dry matter (DM) (Depenbusch *et al*.,

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2009; Ceconi *et al*., 2014). In lambs, 20% inclusion of DDGS did not affect the dry matter intake (DMI) (Schauer *et al*., 2008) and improved weight gain (Felix *et al*., 2012), but when 25% of DDGS was included in the diet, the concentration of ammonia nitrogen in the rumen and the digestibility of DM decreased (Uwituze *et al*., 2010). However, DDGS could replace soybean meal as a nitrogen (N) source for growing lambs to reduce N excretion without adversely affects animal performance (Shen *et al.*, 2018).

Adding from 40% to 60% of DDGS to the diet reduced the digestibility of DM and fat, but when 20% of DDGS was added, these remained unaffected (Felix *et al*., 2012). Nonetheless, the inclusion of up to 30% of DM decreased DMI and augmented daily weight gain (Crane *et al*., 2017). Moreover, DDGS have been used successfully at a level of 60% in diets for lambs without affecting their growth or health (Schauer *et al*., 2008).

Given that DDGS is imported from the United States, transport conditions may modify its nutritional content. Böttger & Südekum (2017) reported DDGS mean values of 31.1% CP, 2.73% starch and 6.08% ash in US plants, while Castro Pérez *et al*. (2014) determined that the DDGS from Mexican importers used in their experiment contained 29.7% CP, 4.3% starch and 5.7% ash.

Considering the characteristics of the central Mexican region for fattening lambs (wool breeds of lambs fattened up to 40 kg), it is relevant to study their behaviour with various inclusions of DDGS in their diets. There is great interest among farmers in having information on including DDGS in the diets of lambs, especially its effect on consumption, growth and feed conversion, which are productive parameters associated with the livelihood of the lamb farmer. Therefore, the objective of the present investigation is to evaluate the effect of including 15%, 30% and 45% of DDGS in the diet of lambs for fattening in order to study their animal performance, digestibility and carcass characteristics.

Materials and Methods

Animal care and management procedures involving lambs were conducted according to the guidelines approved by the Mexican official norms (NOM-051-ZOO-1995: Humanitarian Care of Animals during Mobilization; NOM-033-ZOO-1995: Slaughter of Domestic and Wild Animals). The experiment was performed in the facilities adjacent to the Feedlot Lamb Research Unit of the Experimental Farm of the Departamento de Zootecnia in Universidad Autónoma Chapingo, Chapingo, Estado de México, which is located at latitude 19 22” north, longitude 98 35” west, and at 2250 metres above sea level. With a sub-humid temperate climate presenting rains in summer and droughts in winter, the average annual temperature is 15.2 °C, and the average annual precipitation is 664.8 mm.

The diets were formulated to cover the nutritional requirements of lambs in intensive fattening, but the percentage of CP exceeded requirements owing to the high CP content in DDGS (NRC, 2007). The objective was to partially replace conventional grains (corn and sorghum) and soybean meal with DDGS. The diets with 15% and 30% of DDGS were balanced to have the same amount of CP (14.5%) as the diet with 0% of DDGS (control). However, in the diet containing 45% of DDGS, it was not possible to maintain such a level, resulting in 17.5% CP, while keeping all other nutrients balanced, and the forage proportion was constant. The base diet consisted of ground corn, ground sorghum, soybean meal, oat straw and minerals (Tables 1 and 2). Corn and sorghum grains were partially replaced as energy sources, and soybean meal as a protein source was replaced with DDGS containing 32% CP, 5.5% ether extract (EE), 42.1% NDF and 19.8% acid detergent fibre (ADF). The 14% oat straw was kept as a main source of forage.

The samples from the diets were processed in a Thomas Wiley mill (model 4, Arthur H. Thomas Company, Philadelphia, PA, USA) using a 2-mm mesh. Then, the DM (method 930.15), CP (method 984.13), ash (method 942.05), EE (method 954.02) (AOAC, 2005), NDF, and ADF contents were determined (Van Soest *et al*., 1991). The laboratory tests were undertaken in the Animal Nutrition Laboratory of the Postgrado en Ganadería, Campus Montecillo, Colegio de Postgraduados, Montecillo, Estado de México.

The experimental period lasted 56 days, with 12 days of adaptation to the diets in each treatment. Thirty-two Creole lambs crossbred with Rambouillet were used, with an average initial body weight (IBW) of 28.6 ± 2.19 kg and an average age of 4.0 ± 0.5 months (n = 8). In the beginning of the experiment, the lambs were treated for endoparasites with Ivermectina (Ivomec F®), injected with Vigantol ADE Fuerte® at a dose of 2 mL/animal, and vaccinated with Bacterina Bovac 8. The lambs were weighed (IBW), identified, and randomly distributed in individual metabolism cages provided with feeders and troughs with fresh, clean water. During the experimental phase, food was offered twice a day (9:00 and 16:00) in a proportion of 60% and 40%, respectively, allowing a 5% to 10% rejection. The lambs received oat hay for five days before the adaptation period.

The feed offered and rejected were weighed individually each day to determine the DMI. The lambs were weighed every 14 days before being fed to measure their average daily gain (ADG). Feed conversion (FC) was calculated by dividing the DMI by the ADG.

Table 1 Ingredient composition of the experimental diets with different level of dried distillers grains

Ingredients	Dried distillers grains in diet %, dry matter basis			
	0	15	30	45
Corn grain	30	25	15	7.5
Sorghum grain	30	20	15	7.5
DDGS	0	15	30	45
Soybean meal	13.6	6.5	1.5	0
Molasses	6	6	6	6
Bypass fat	1.9	1.5	1.5	1.3
Wheat bran	1.2	4	6	7.2
Soybean hull	0	5	8	8.5
Calcium carbonate	1	1	1.5	1.5
Premixed minerals[α]	1	1	1	1
Urea	0.8	0.5	0	0
Salt	0.5	0.5	0.5	0.5
Barley straw	14	14	14	14

[a] Includes: Ca, 24%; Cl, 12%; P, 3%; K, 0.50%; Na, 8%; S, 0.50%; Cr, 5 mg/kg DM; Co, 60 mg/kg DM; I, 100 mg/kg DM; Fe, 2 000 mg/kg DM; Mn, 4 000 mg/kg DM; Se, 30 mg/kg DM; Zn, 5 000 mg/kg DM; iasolacid, 2 000 mg/kg DM; vitamin A, 500 000 UI/kg; vitamin E, 1 000 UI/kg
DDGS = dried distillers grains, DM = dry matter

Table 2 Nutritional composition of the experimental diets with different level of dried distillers grains

Item	Dried distillers grains in diet %, dry matter basis			
	0	15	30	45
Dry matter (%)	88.1	88.6	89.1	89.5
Ash (%)	6.12	6.41	6.32	6.47
Crude protein (%)	14.50	14.59	14.68	17.55
Ether extract (%)	4.51	5.12	6.06	6.77
NDF (%)	23.82	30.12	35.45	40.52
ADF (%)	18.11	24.14	28.37	32.44

NDF, neutral detergent fibre; ADF, acid detergent fibre

Two days before slaughter, live fat thickness of each animal was measured at the 12th and 13th rib using a Sonovet 600 ultrasound device (Universal Medical System Inc.) with a transducer of 7.5 MHz (Delfa *et al*., 1995). At the end of the experiment, all the lambs were weighed (FW: final weight) and then taken to the slaughterhouse where they had a 12-hour fast and were weighed once more (SW: slaughter weight) before slaughter. Once obtained, the carcasses were weighed to obtain the hot carcass weight (HCW) and then chilled to 4 °C for 24 hours to obtain the cold carcass weight (CCW) to calculate the yield of the hot carcass and the cold carcass (Hernández-Cruz *et al*., 2009).

To determine total tract apparent digestibility (TAD) of dry matter (DDM), NDF (DNDF) and ADF (DADF), the acid insoluble ash (AIA) technique was used (Van Keulen & Young, 1977), applying hydrochloric acid (HCl) at a concentration of 2 N. Samples of the food offered to the lambs (100 g) and faeces (100 g, approximately) were taken for three consecutive days after having weighed the lambs every 14 days. The samples were dried in a forced-air oven at 55 °C for 24 hours and then ground using a Thomas Wiley mill (Model 4, Arthur H. Thomas Company, Philadelphia, PA, USA) with a 1-mm mesh. The food and

faeces samples of each lamb were mixed separately to obtain a compounded mixture per animal and per period to determine the concentration of AIA in each. To following formula was used to calculate digestibility:

Digestibility (%) = 100 – [(food marker / faeces marker) x (nutrient in faeces / nutrient in food)]
TAD = % of AIA in faeces / % of AIA in food

All data were analysed as a completely random design using generalized linear models with SAS 9.0 version (SAS Institute Inc., 2002), considering IBW as a co-variable. The animal was considered the experimental unit in the statistical design and analysis. The treatment means were compared with the Tukey test, and were considered different if $P \leq 0.05$.

Results and Discussion

The results obtained on animal performance and carcass characteristics are shown in Table 3. The DMI was lower ($P \leq 0.05$) in the treatment without DDGS. The daily live weight gain was greater ($P \leq 0.05$) in the treatment with 15% of DDGS than in the control. FC was lower ($P \leq 0.05$) in the control treatment than with 30% of DDGS ($P \leq 0.05$). The DMI and the ADG reported in this study were similar to those reported by other authors (Schauer *et al.*, 2008). Thus, the higher intake of DDGS was not reflected as a higher ADG, which affected the FC negatively.

Table 3 Animal performance and carcass characteristics of the Creole wool lambs

Item	Dried distillers grains in diet %, dry matter basis				SEM[£]
	0	15	30	45	
DMI (kg/d)	1.40[a]	1.71[b]	1.75[b]	1.65[b]	0.066
ADG (kg/d)	0.238[a]	0.288[b]	0.265[ab]	0.261 [ab]	0.015
FC (intake/gain)	5.88[a]	5.93[ab]	6.71[b]	6.32[ab]	0.281
IW (kg)	28.27	26.58	28.21	26.48	0.836
FW (kg)	39.47[a]	42.71[b]	42.83[b]	41.10[b]	0.525
SW (kg)	35.43[a]	38.87[b]	38.65[b]	37.04[b]	0.343
HCW (kg)	17.56[a]	19.17[b]	19.35[b]	18.79[b]	0.166
CCW (kg)	17.21[a]	18.82[b]	19.04[b]	18.49[b]	0.167
HCY (%)	49.58[a]	49.31[a]	50.07[b]	50.76[b]	0.251
CCY (%)	48.57[a]	48.43[a]	49.28[b]	49.94[b]	0.247
FT (mm)	2.68	2.67	2.62	2.77	0.029

[a,b] Averages with different superscripts in the same row are different ($P \leq 0.05$)
DMI: dry matter intake; ADG: average daily gain; FC: feed conversion; IW: initial weight; FW: final weight; SW: slaughter weight; HCW: hot carcass weight; CCW: cold carcass weight; HCY: hot carcass yield; CCY: cold carcass yield; FT: fat thickness
[£]Standard error of the mean

The ADG matched the one reported by Schauer *et al.* (2008). There was no lineal effect in the ADG when increasing the inclusion of DDGS, as observed in hair lambs (Castro-Pérez *et al*., 2014), or a decrease of the ADG when increasing the DDGS in the diet (Avila-Stagno *et al*., 2013), since, in the present study, the treatment with 45% of DDGS showed no difference from the control treatment. It was thought that the increase in caloric density of the diets containing DDGS, derived from the fat concentration, may explain the increase in the ADG (McKeown *et al.,* 2010). In addition, the protein levels in diets with DDGS for lambs generally exceed the recommended requirements (Avila-Stagno *et al*., 2013); combined with the fat they contain, they may affect the intake and animal performance (Schauer *et al.,* 2008). The elevated level of CP in the treatment with 45% DDGS in the present study did not affect the productive response of the lambs directly, given that the response in FC was similar to the control treatment, disregarding confusing effects for the lack of equilibrium of CP between treatments.

Reports say that the DMI increases in accordance with the rise in fibre in the diet in rations high in concentrate for lambs (Fimbres *et al*., 2002). In this study, although the amount of fibre increased in the diets with a higher content of DDGS, the DMI was increased in accordance with the control treatment, but it was no different in the diets with various contents of DDGS.

The DMI increased when cotton husk was added as forage in diets containing DDGS (Whitney & Braden, 2010). This is related to an augmentation in the effective fibre intake, which may reduce digestive problems in the rumen associated with the intake of high-protein and high-energy diets. A low-fibre diet may diminish adequate rumination, reducing ruminal pH and animal performance (Felix *et al*., 2012).

Final weight of the animals was lower in the control treatment ($P \leq 0.05$) than in the treatments with DDGS. FW and SW were higher with 6.5% and 7.2% ($P \leq 0.05$), respectively, in lambs consuming DDGS than in the control treatment, but with no differences between treatments with DDGS.

When alfalfa and barley hay were replaced with 60% DDGS in lamb diets, animal performance and the quality of the carcass were not affected (Schauer *et al*., 2008). Adding 22.9% of DDGS to replace soybean paste and corn did not affect alimentary efficiency of the lambs. However, when dried wheat distillers grains (DWDGS), were included, there was a 12.1% decrease in alimentary efficiency (McKeown *et al*., 2010). This difference can be attributed partially to the higher content of EE in the diet with DDGS. Nonetheless, in the present study, the FC of the lambs fed with the control diet that had a lower quantity of EE was similar to that of the lambs fed with a 15% content of DDGS in their diet. On the other hand, Lodge *et al*. (1997) reported that replacing 40% of rolled corn for DDGS did not affect alimentary efficiency. Although the quadratic effects in the DMI and ADG were in accord with the increase of DDGS levels in the diet (Schauer *et al*., 2008), there was a certain coincidence that the best lamb behaviour was achieved with inclusion of 20% of DDGS in the diets. Other authors (Felix *et al*., 2012) reported that the highest ADG in lambs is obtained with 20% of DDGS, but with a higher DMI.

The DDM was lower ($P \leq 0.05$) in the treatment with 45% of DDGS than in the others, but with no difference ($P \leq 0.05$) between the control treatment and the treatments with 15% and 30% of DDGS. DNDF was higher ($P \leq 0.05$) in the treatments with 15% and 30% of DDGS than in the control treatment, with no difference ($P \leq 0.05$) between treatments with 45% of DDGS. DADF was higher ($P \leq 0.05$) in the treatment with 30% of DDGS than in the other treatments (Table 4). DDM was similar in the control diets and also with 15% and 30% of DDGS, but lower in the diet containing 45% of DDGS. This is a reflection of the increase in the DNDF and DADF in diets with 15% and 30% of DDGS. It is also reported that the digestibility of the NDF and ADF of the DDGS is higher than in forages (Nuez Ortín & Yu, 2009), with percentages of 65% and 59%, respectively (Van De Kerckhove *et al*., 2011), which would explain the increase of the DDM when including DDGS in the diets.

Table 4 Total tract apparent digestibility of the dry matter, neutral detergent fibre and acid detergent fibre in the experimental diets with different levels of dried distillers grains

Variable	Dried distillers grains in diet %, dry matter basis				SEM[£]
	0	15	30	45	
DDM	74.19[a]	74.68[a]	74.12[a]	69.01[b]	0.506
DNDF	43.48[a]	45.08[b]	47.94[b]	44.61[ab]	0.370
DADF	37.71[a]	40.25[b]	43.08.[c]	39.83[ab]	0.454

[a,b] Means with distinct literals in the same row are different ($P \leq 0.05$).
DDM: total tract apparent digestibility of the dry matter; DNDF: total tract apparent digestibility in neutral detergent fibre; DADF: total tract apparent digestibility of the acid detergent fibre
[£]Standard error of the mean

The decrease in the digestibility of fibre when increasing the level of DDGS may have been due to a decline in the capacity of the cellulolytic bacteria to degrade it in the rumen, resulting in a decreased pH, or due to an increase in the passage rate, given the size of the particle (Fimbres *et al*., 2002). In addition, DDGS have a lower digestibility than corn and sorghum grains (Nuez Ortín & Yu, 2009). The decreased digestibility of fibre is also associated with high contents of fat in the diet (Jenkins *et al*., 2011). In this study, the lower digestibility of fibre was found in the diet with 45% of DDGS and 6.7% of EE. Nevertheless, the ADG was similar to the other treatments that contained DDGS.

The HCW and CCW were lower ($P \leq 0.05$) in the control treatment than in those with DDGS, with no differences among them ($P \leq 0.05$). The HCY and the CCY were lower ($P \leq 0.05$) in the control treatments and with 15% of DDGS than in the treatments with 30% and 45% of DDGS. There was no difference ($P \leq 0.05$) in the fat thickness among treatments.

Greater IW and SW were registered in the lambs consuming DDGS than in the control treatments, similar to what Felix *et al.* (2012) reported of a quadratic effect in such variables. This affected the HCW and the CCW, given that when including DDGS, they were superior to the control treatment.

The HCW and CCW yields were no different between the treatments that included DDGS. HCY and CCY were higher at 2.0% and 2.2%, respectively, in animals consuming 30% and 45% DDGS than in those consuming 0.0% and 15% of DDGS. There was no effect on FT, although it is reported that DDGS can increase it (Gibb *et al*., 2008).

DDGS as feed for lambs does not affect HCW or fat thickness (McKeown *et al*., 2010). The inclusion of up to 60% of DDGS does not affect the HCW or the carcass yield. It was also reported that the FW, ADG, FC, mortality and fat content were affected in lambs fed with various levels of DDGS (Schauer *et al*., 2008).

The variability in the results reported in the literature may be related to several factors: breed and handling of the animals, type of DDGS (corn, wheat, sorghum, and barley), type and extension of the processing of the grains in the attainment of ethanol and their curing, the quantity of solubles in the DDGS (Liu & Rosentrater, 2011), the variability in the digestibility and proportion of the ingredients used in the formulation of the diets, the quantity of fat in the DDGS (Nuez Ortín & Yu, 2009), and the means of transport from the ethanol facility to the place where the experiments were performed.

Conclusions

According to the results of the present investigation, the authors concluded that the inclusion of DDGS up to 30% in the diet of lambs, partially replacing corn and sorghum grains and soybean meal, increases the DMI and improves the weight of the carcass, without negatively affecting its characteristics, such as the fat thickness of lambs in fattening under the stabling conditions. The decision to include DDGS may depend on the price and availability in comparison to cereals and oilseeds on the market.

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Authors' Contributions

KRCL conducted the research and wrote the manuscript, based on the bachelor's thesis of KRCL, under the supervision of JRBG and CSdR. For laboratory analyses JCEE, MIRM, and DFPD collaborated. For lamb handling and slaughter, and carcass characteristics EASG and EJFS collaborated. JRBG led the data analysis and interpretation of results, with the assistance of CSdR. Critical revision of the version to be published was performed by JRBG, CSdR, and KRCL.

Conflict of Interest Declaration

The authors certify that they have no affiliations with any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

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