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# Effects of added protein and dietary fat on lamb performance and carcass characteristics when fed differing levels of dried distiller's grains with solubles

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ABSTRACT

The objectives of this study were to evaluate the influence of dietary protein and fat in dried distiller's grains with solubles (DDGS) on feedlot performance and carcass characteristics finishing lambs. Sixty crossbred lambs (29.16 ± 4.59 kg) were allotted into pairs (ewe and wether; 6 pairs/trt) and fed one of five isocaloric dietary treatments: (1) a corn based diet with DDGS included to meet CP requirements (∼25% of DM; CON), (2) CON with DDGS included at twice the amount of CON (∼50% of DM; 50DDGS), (3) CON with added corn protein in the form of gluten meal to be similar of CP in the 50DDGS diet (CON + CP), (4) CON with added vegetable oil to be similar to the crude fat in the 50DDGS diet (CON + VO), and (5) CON with corn protein and vegetable oil added to be similar to the CP and crude fat in the 50DDGS diet (CON + CPVO). Wether lambs were harvested when they obtained a common 12th rib fat depth endpoint of 0.5 cm. Ewe lambs were returned to the flock. Data were analyzed using the MIXED procedure of SAS. Contrasts between (1) CON vs. elevated CP diets (50DDGS, CON + CP, and CON + CPVO; PRO), (2) CON vs. elevated fat diets (50DDGS, CON + VO, and CON + CPVO; FAT) and (3) CON vs. diets with both elevated CP and fat (50DDGS and CON + CPVO; PF) were analyzed. Final BW, days on feed, and G:F did not differ as a result of dietary treatment ($P \geq 0.29$). However, DMI was decreased ($P = 0.03$) in the lambs fed PRO diets compared with CON fed lambs. Average daily gain tended ($P = 0.08$) to decrease in the lambs fed the PRO diets compared with the lambs fed CON. Lambs did not differ ($P > 0.05$) in HCW, dressing percentage, 12th rib fat depth, LM area, body wall thickness, yield grade, flank streaking, leg score, percent boneless, closely trimmed retail cuts, and LM ether extract. Therefore, these data indicate that DDGS can be included in feedlot lamb diets at levels up to 50% of DM without negatively affecting feedlot performance, carcass quality, and metabolite concentrations.



## 1. Introduction

Bio-fuel production is driving an unprecedented change in animal agriculture throughout the United States. The growing corn ethanol and soy-diesel industries provide significant economic benefits to grain producers, however, the resulting increases in feed prices and lack of suitable alternative energy-dense feedstuffs presents serious challenges for traditional livestock production systems.

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Traditionally, byproducts have been included at low to moderate levels in rations as a source of protein. However, increased byproduct availability coupled with increased corn prices has led to livestock producers utilizing dried distiller's grains with solubles (DDGS) as both a crude protein (CP) source and an energy substitute for corn.

Klopfenstein et al. (2008) reported that DDGS had an increased feeding value compared with corn when included between 10% and 20% of feedlot steer rations. Additionally, Ham et al. (1994) suggested that steers fed finishing diets with 40% DDGS or 40% wet distillers byproducts achieved greater average daily gain (ADG), dry matter intake (DMI), and feed efficiency (G:F) when compared with a dry rolled corn control diet. However a meta-analysis of reported data suggested that as DDGS levels increase from 0% to 40% of the dietary ration in feedlot steers, marbling score decreases linearly with a concomitant linear increase in yield grade (Klopfenstein et al., 2008). Limited data in finishing lambs has suggested that DDGS included at 23% of the ration does not have a negative effect on feedlot performance and carcass quality (Huls et al., 2006). Additioanlly, Schauer et al. (2008) observed no differences in carcass characteristics in finishing lambs when corn was substituted with DDGS at up to 60%. However, DMI linearly increased with increasing concentrations of DDGS in the diet (Schauer et al., 2008).

Therefore, our hypothesis was that feeding DDGS as an energy source in finishing lamb diets (50% of diet DM) would not negatively affect lamb performance or carcass characteristics. Consequently, the objectives of this study were to determine if elevated levels of DDGS in the diet, and specifically the crude fat, crude protein, or a combination of both found in DDGS, affect feedlot performance and carcass characteristics of finishing lambs.

## 2. Materials and methods

### 2.1. General

The Purdue University Animal Care and Use Committee approved all procedures involving animals for this study. Sixty crossbred (Suffolk crossed) lambs (29.16 ± 4.59 kg; 30 ewes and 30 wethers; average age 5 months old) were allotted to one of five isocaloric dietary treatments (Table 1) formulated to meet or exceed the NRC (1985) requirements of a finishing lamb: (1) a corn based diet with DDGS included to meet CP requirements of finishing lambs (~25% of DM; CON), (2) CON with DDGS included at twice the amount of CON (~50% of DM; 50DDGS), (3) CON with added corn protein in the form of corn gluten meal to be similar to the CP level in the 50DDGS diet (CON + CP), (4) CON with added vegetable oil to be similar to the crude fat level of the 50DDGS diet (CON + VO), and (5) CON with corn gluten meal and vegetable oil added to be similar to that of the CP and fat levels of the 50DDGS diet (CON + CPVO). Chemical analysis of DDGS was previously reported by Gunn et al. (2009) and is reported located in Table 1. Diets CON + CP, CON + VO and CON + CPVO were formulated to determine if potential differences in performance and carcass quality, associated with feeding increased levels of DDGS, are due to increased levels of dietary CP, increased levels of dietary fat, or a synergistic effect of both elevated levels of CP and dietary fat. All lambs were supplemented with 150 mg $d^{-1}$ thiamin to help prevent sulfur toxicities.

Lambs were stratified by weight and blocked into pairs of one ewe and one wether and housed in 1.83 m × 1.83-m pens on a mesh wire floor inside of a curtain sided finishing building. Initial body weight (BW) and final BW were the average of two weights taken on consecutive days. Body weights were taken every 21 d to measure feedlot performance. Feed was offered for ad libitum consumption once daily at 0800 h and lambs had free access to water. Three lambs were removed from the study due to non-treatment related illness and the remaining single lambs were retained in their original pens for the duration of the trial. Feed refusals were collected twice weekly, weighed to accurately determine DMI, and discarded.

Wether lambs were selected for harvest when they obtained an approximate 12th rib fat depth of 0.5 cm as determined by trained university personnel. Upon harvest of wether lambs, the ewe lamb pen mate was returned to the university flock. Lambs were harvested at a common 12th rib fat depth to determine differences in carcass characteristics due to increased dietary levels of crude protein, crude fat, or both. Hot carcass weights were obtained immediately following evisceration, while other carcass data were collected by trained personnel following a 24-h chill. Yield grade was calculated utilizing the formula in Aberle et al. (2001). The right and left side LM and s.c. adipose tissue samples from the 12th–13th rib interface were obtained and stored at −20 °C until ether extract analysis.

### 2.2. Sampling and laboratory analysis

Dietary samples were collected every three weeks and were dried in a forced air oven for 48 h at 60 °C for analysis of DM and then ground to pass a 1 mm screen. Approximately 6 g from each sample was weighed and composited across each sample date within dietary treatment. Samples were analyzed for neutral detergent fiber and acid detergent fiber (ANKOM$^{200/220}$ Fiber Analyzer; ANKOM Technology, Fairport, NY) and for nitrogen content using the combustion method (AOAC, 2000; method 990.03; Leco Instruments Inc., St. Joseph, MI), and multiplied by 6.25 to obtain CP. Dietary and longissimus muscle (LM) tissue samples were analyzed for crude fat using the ether extraction method (AOAC, 2000; method 934.01). Ether extract was analyzed using right side LM samples, which were cubed prior to being placed in the extraction thimbles.

### 2.3. Statistical analysis

Performance and carcass data were analyzed as a randomized complete block design using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The model included the main effect of treatment, rep, and all possible interactions for performance and carcass characteristics data. Additionally, three contrasts were also used to test treatment effects: (1) CON diet vs. diets containing elevated CP levels (50DDGS, CON + CP, and CON + CPVO; PRO), (2) CON diet vs. diets containing elevated fat levels (50DDGS, CON + VO, and CON + CPVO; FAT), and (3) CON diet vs. diets containing both elevated CP and fat levels (50DDGS and CON + CPVO; PF).

## 3. Results

### 3.1. Performance

Initial BW was not different ($P > 0.05$) due to stratification within dietary treatments. Days on feed, G:F and final BW were not affected ($P > 0.05$; Table 2) by elevated fat, protein, or both in the diets. Dry matter intake of lambs was reduced for lambs fed PRO diets ($P = 0.03$).

### 3.2. Carcass characteristics

Hot carcass weight; dressing percentage; 12th rib fat depth; LM area; body wall thickness; yield grade; flank streaking; leg score; boneless, closely trimmed retail cuts (% BCTRC); and ether extract were not altered as a result of elevated fat, protein, or both in the diets ($P \geq 0.05$; Table 3). The lack of differences in 12th rib fat depth due to dietary treatment was expected as lambs were finished to a common depth for harvest.

## 4. Discussion

In a thorough meta-analysis, Klopfenstein et al. (2008), reported that beef cattle reach a plateau for DMI and ADG

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**Table 1**
Dietary ingredients and chemical composition of diets fed to finishing lambs.

| Item | Dietary treatments[a] | | | | |
|---|---|---|---|---|---|
| | CON | 50DDGS | CON + CP | CON + VO | CON + CPVO |
| Ingredients, % of DM | | | | | |
| Dry-rolled corn | 59.4 | 34.2 | 48.4 | 48.5 | 37.7 |
| Distiller's dried grains[b] | 25.7 | 51.2 | 25.7 | 25.8 | 25.8 |
| Ground hay | 10.7 | 10.4 | 10.6 | 10.7 | 10.7 |
| Corn gluten meal | – | – | 11.1 | – | 10.4 |
| Soybean hulls | – | – | – | 8.3 | 8.4 |
| Vegetable oil | – | – | – | 2.5 | 2.8 |
| Molasses | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Supplement[c] | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Analyzed composition, % of DM | | | | | |
| CP | 14.58 | 18.45 | 20.26 | 15.49 | 19.76 |
| Ether extract | 3.53 | 6.00 | 4.63 | 6.29 | 7.01 |
| ADF | 11.76 | 14.15 | 12.90 | 15.40 | 16.08 |
| NDF | 21.72 | 24.17 | 20.52 | 25.07 | 23.27 |
| DM | 89.69 | 90.48 | 90.50 | 90.59 | 90.57 |

[a] CON: 25% DDGS; 50DDGS: 50% DDGS; CON + CP: control + corn protein; CON + VO: control + vegetable oil; CON + CPVO: control + both corn protein and vegetable oil.
[b] Distiller's dried grains contained (DM basis): 29.5% CP, 13.9% fat, 14.3% ADF, 0.85% P, 0.04% Ca, 1.03% K, 0.27% Mg, 0.71% S, and 0.26% Na (Gunn et al., 2009).
[c] Supplement included 150 mg head$^{-1}$ d$^{-1}$ thiamin to help prevent sulfur toxicities.

**Table 2**
Effects of differing levels of CP and dietary fat from distiller's dried grains with solubles on performance of finishing lambs.

| Item | Dietary treatments[a] | | | | | | *P*-Value[b] | | |
|---|---|---|---|---|---|---|---|---|---|
| | CON | 50DDGS | CON + CP | CON + VO | CON + CPVO | SEM[c] | PRO | FAT | PF |
| Initial BW (kg) | 28.98 | 29.30 | 28.83 | 29.38 | 29.32 | 2.04 | 0.94 | 0.97 | 0.78 |
| Final BW (kg) | 54.95 | 55.49 | 55.40 | 57.44 | 56.25 | 1.57 | 0.65 | 0.49 | 0.29 |
| Days on feed | 96.67 | 101.33 | 120.00 | 107.67 | 108.33 | 12.58 | 0.37 | 0.38 | 0.47 |
| ADG (kg/lamb/d) | 0.27 | 0.26 | 0.22 | 0.27 | 0.25 | 0.01 | 0.08 | 0.16 | 0.45 |
| DMI (kg/lamb/d) | 1.13 | 1.04 | 1.04 | 1.15 | 1.03 | 0.03 | 0.03 | 0.20 | 0.34 |
| G:F | 0.24 | 0.25 | 0.21 | 0.23 | 0.24 | 0.01 | 0.65 | 0.49 | 0.90 |

[a] CON: 25% DDGS; 50DDGS: 50% DDGS; CON + CP: control + corn protein; CON + VO: control + vegetable oil; CON + CPVO: control + both corn protein and vegetable oil.
[b] PRO: CON vs. elevated CP diets (50DDGS, CON + CP, and CON + CPVO); FAT: CON vs. elevated fat diets (50DDGS, CON + VO, and CON + CPVO); PF: CON vs. both elevated CP and fat diets (50DDGS and CON + CPVO).
[c] Greatest SEM presented ($n$ = 6 for CON, CON + CP, and CON + VO; $n$ = 5 for 50DDGS; $n$ = 6 for CON + CPVO).

**Table 3**
Effects of differing levels of CP and dietary fat from distiller's dried grains with solubles on the carcass characteristics of finishing lambs.

| Item | Dietary treatment[a] | | | | | | *P*-Value[b] | | |
|---|---|---|---|---|---|---|---|---|---|
| | CON | 50DDGS | CON + CP | CON + VO | CON + CPVO | SEM[c] | PRO | FAT | PF |
| Hot carcass weight (kg) | 32.40 | 32.81 | 31.27 | 32.97 | 32.53 | 1.12 | 0.87 | 0.76 | 0.83 |
| Dressing percentage | 57.64 | 56.77 | 55.36 | 57.03 | 56.02 | 0.89 | 0.11 | 0.29 | 0.16 |
| 12th rib fat depth (cm) | 0.65 | 0.57 | 0.55 | 0.56 | 0.54 | 0.07 | 0.18 | 0.20 | 0.21 |
| LM area (cm[b]) | 19.01 | 19.81 | 18.12 | 18.33 | 19.81 | 1.11 | 0.84 | 0.79 | 0.54 |
| Body wall thickness (cm) | 2.70 | 2.29 | 2.46 | 2.53 | 2.45 | 0.18 | 0.13 | 0.16 | 0.32 |
| Yield grade | 2.96 | 2.63 | 2.54 | 2.60 | 2.51 | 0.27 | 0.17 | 0.20 | 0.21 |
| Flank streaking[d] | 20.67 | 19.80 | 20.17 | 19.83 | 20.50 | 0.51 | 0.36 | 0.26 | 0.25 |
| Leg score[d] | 13.00 | 13.20 | 13.00 | 12.83 | 12.83 | 0.41 | 0.98 | 0.92 | 0.86 |
| BCTRC (%[e]) | 46.25 | 47.20 | 46.65 | 46.28 | 47.09 | 0.79 | 0.25 | 0.34 | 0.75 |
| LM ether extract, % DM | 9.37 | 9.00 | 11.55 | 8.17 | 6.33 | 1.95 | 0.84 | 0.46 | 0.82 |

[a] CON: 25% DDGS; 50DDGS: 50% DDGS; CON + CP: control + corn protein; CON + VO: control + vegetable oil; CON + CPVO: control + both corn protein and vegetable oil.
[b] PRO: CON vs. elevated CP diets (50DDGS, CON + CP, and CON + CPVO); FAT: CON vs. elevated fat diets (50DDGS, CON + VO, and CON + CPVO); PF: CON vs. both elevated CP and fat diets (50DDGS and CON + CPVO).
[c] Greatest SEM presented (n = 6 for CON, CON + CP, CON + VO, and CON + CPVO; n = 5 for 50DDGS).
[d] Flank streaking and leg score: 1 = cull to 15 = Prime$^+$.
[e] Percent boneless, closely trimmed, retail cuts (% BCTRC) = [49.936 – (0.0848 × 2.204 × Hot Carcass Weight, kg) – (4.376 × 0.393 × 12th rib fat thickness, cm) – (3.53 × 0.393 × body wall thickness, cm) + (2.456 × 0.155 × LM area, cm$^2$)].

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with inclusion of DDGS between 20% and 30% of the ration and the optimal G:F threshold occurred between 10% and 20% DDGS inclusion. The authors suggested that the optimal inclusion level of DDGS should be approximately 20% of the ration to maximize both ADG and G:F in cattle. However, previous research in sheep (Estrada-Angulo et al., 2008; Schauer et al., 2008) suggest that finishing lambs can be fed levels upwards of 40% DDGS in the diet without deleterious effects on performance or carcass quality. For example, 30% inclusion of DDGS in finishing lamb diets resulted in linear increases in ADG (Schauer et al., 2006), and the inclusion of DDGS up to 60% of the diet resulted in no effects on feedlot lamb performance (Schauer et al., 2008; Neville et al., 2010). In the current study, a reduction in DMI was observed for lambs on the PRO dietary treatments, however, ADG and G:F were not affected. Similar to the results from the current study, no differences in ADG or feed efficiency with Pelibuey sheep fed 25% and 40% DDGS diets were reported (Estrada-Angulo et al., 2008).

It appears that cattle and sheep utilize energy substrates at differing efficiencies. Gunn et al. (2009) reported a decrease in performance and efficiency independent of DMI in feedlot beef steers fed diets with elevated protein levels. The authors suggested that decreased metabolic efficiency associated with the assimilation of energy from excess protein resulted in the decrease in performance and efficiency. However, in the current study as well as results from other studies, it appears that lambs are able to utilize protein as an energy source with greater efficiency than beef cattle.

In agreement with the current study, no differences in growth performance were reported when either heifers or finishing steers were fed diets containing elevated levels of fat from corn oil and wet distillers grains plus solubles or tallow and dried distillers grains plus solubles, respectively (Vander Pol et al., 2009). However, increased dietary fat (7.3% of DM) from safflower seeds resulted in increased ADG and feed efficiency in wether lambs compared with lambs not supplemented (2.5% of DM) with safflower seeds (Kott et al., 2003). Zinn (1989) reported an increase in final BW, ADG, and daily DMI in feedlot steers when supplemented with dietary fat (4 and 8%). In the current study, elevated dietary fat did not produce similar performance results as previous research. This was not expected, as dietary fat levels were similar to those in Kott et al. (2003) and Zinn (1989). Perhaps the difference in fatty acid profile between safflower seeds in the Kott et al. (2003) study and the DDGS in the current study could have resulted in the differences in DMI response. Overall, data in the current study as well as previous research indicate that finishing lambs may have more tolerance for diets with increased CP and fat.

The lack of differences in carcass quality due to elevated DDGS were unexpected based on previous research in beef cattle that suggests a reduction in carcass quality with increasing levels of DDGS in the ration. Klopfenstein et al. (2008) noted a linear increase in yield grade and a linear decrease in marbling score as the inclusion level of DDGS increased from 0% to 40% of the diet in finishing cattle. However, a finishing steer study by Gunn et al. (2009), which had similar dietary premises as the current study, dressing percent, fat thickness, and LM area were not affected by dietary treatment. Similar to the current study, Estrada-Angulo et al. (2008) observed no differences in HCW, dressing percentage, fat thickness, ribeye area, carcass length, and leg circumference between lambs fed a 25% DDGS diet and a 40% DDGS diet, suggesting that lambs respond differently to increasing dietary inclusion of DDGS than cattle. Differences in carcass quality in sheep due to level of dietary fat have been scarcely reported in the literature. No differences in carcass characteristics were observed in finishing steers fed increased dietary fat from tallow or DDGS (Vander Pol et al., 2009). Similarly, no differences were observed in LM area and back fat thickness in feedlot steers supplemented with 0, 4, or 8% dietary fat (Zinn, 1989). However, carcass weight; kidney, pelvic, and heart fat; and marbling score increased linearly as dietary fat increased from 0% to 8% (Zinn, 1989). Elevated dietary fat levels from safflower seeds did not alter dressing percent, LM area, or kidney fat compared with lambs not supplemented with safflower seeds (Kott et al., 2003). However, lambs fed safflower seeds had increased fat content in muscle tissue and tended to have increased back fat thickness and heavier loins compared with lambs not supplemented with safflower seeds (Kott et al., 2003). The differences in 12th rib fat depth were not observed in the current study because lambs were finished to a common fat depth of 0.5 cm. Similar to the current study, Schauer et al. (2008) reported no deleterious effects on carcass characteristics when lambs were fed up to 60% DDGS in the diet. Although some carcass characteristics of steers (Zinn, 1989; Klopfenstein et al., 2008) and lambs (Kott et al., 2003) were altered due to dietary fat, the results are not consistent across the literature. In the current study, elevated dietary protein, fat, or both did not produce any deleterious effects on the lamb carcass characteristics. Similar results have been observed in both cattle (Gunn et al., 2009) and lambs (Estrada-Angulo et al., 2008; Schauer et al., 2008) when fed dried distiller's grains with solubles.

The current study as well as previous research in finishing lambs suggest that lambs can be fed up to 50% DDGS without negative effects feedlot performance. Furthermore, the current study also suggests that increased dietary fat, CP, or a combination of both does not cause negative effects on carcass characteristics.

Heat damaged protein occurs during the drying process to produce DDGS. Heat treatment of feed produces Maillard reactions by denaturing proteins and forming protein-carbohydrate and protein-protein cross-links causing a shift in rumen degradable protein (RDP) to rumen undegradable protein (RUP) and can reduce the biological value of the RUP by producing indigestible Maillard products (Nakamura et al., 1994; Yu, 2005). Although heat treatment of soybeans has been reported to increase the RUP fraction, the nutritional value, measured as intestinally available lysine, was variable and dependent on heat treatment (Faldet et al., 1992). Although the heating of DDGS may cause an increase in the RUP fraction, the results from the current study would suggest that there was no deficiency in apparent digestibility of crude protein or available energy.

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## 5. Conclusions

Although a reduction in DMI in lambs fed diets containing elevated protein was observed, feedlot performance was not altered. Therefore, these data strongly suggest that DDGS can be added to a finishing lamb ration at 50% of dietary DM as well as increased dietary fat or CP without negatively effecting feedlot performance or carcass characteristics. However, more research needs to be conducted to determine the critical inclusion level of DDGS, fat, or CP in finishing lamb rations when performance and carcass characteristics would be compromised as well as, the differences associated between the effects of increased DDGS between cattle and sheep.

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