

# Effect of protein source and nonroughage NDF content in finishing diets of feedlot cattle fed free-choice hay on growth performance and carcass characteristics

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**ABSTRACT:** One-hundred twenty crossbreed steers (initial body weight (BW)  $566 \pm 42$  kg) were used to evaluate the interaction of protein source (PS) and nonroughage NDF content (NRFC) in finishing diets of feedlot cattle fed free-choice hay on performance and carcass characteristics. Steers were stratified by BW and randomly assigned to 8 pens ( $2 \times 2$  factorial) and fed for  $104 \pm 10$  d. Four dietary treatments were investigated: (1) distillers' dry grains with solubles (DDGS) and a low NRFC (DLF), (2) DDGS and a high NRFC (DHF), (3) soybean meal (SBM) and a low NRFC (SLF), (4) SBM and a high NRFC (SHF). Free-choice grass hay and concentrates were offered in a different bunk. Data were analyzed as a randomized complete block design. Do to the confounded effect of PS and protein intake, a linear regression was used to evaluate the effect of protein intake in growth performance. For gain to feed ratio (G:F) an interaction tended to occur ( $P = 0.10$ ) between PS and NRFC. Steers on the DHF treatment had a lower G:F compared with SLF and SHF. Feeding SBM increased ( $P = 0.05$ ) final BW, tended to increase

( $P = 0.06$ ) average daily gain (ADG), and decreased ( $P = 0.05$ ) hay intake (HI) compared with steers fed DDGS. There was a positive association ( $P < 0.01$ ) of crude protein intake with ADG and FBW. Dietary NRFC did not change ( $P \geq 0.3$ ) final BW, ADG, DMI, and HI. Protein source did not affect ( $P \geq 0.16$ ) hot carcass weight (HCW), longissimus muscle (LM) area, dressing, 12th rib fat thickness, or marbling score (MS). No differences were detected between NRFC for dressing, HCW, LM area, or MS ( $P \geq 0.18$ ); but diets with greater NRFC decreased ( $P = 0.03$ ) the 12th rib fat thickness. Steers in the SHF treatment presented the lesser kidney-pelvic-heart fat compared with the remaining treatments (PS  $\times$  NRFC interaction,  $P = 0.04$ ). Soybean meal inclusion/increase in protein intake improved growth performance of feedlot steers compared with DDGS, despite protein intake meet the protein requirement. Increasing the NRFC did not affect growth or HI but decreased feed efficiency of steers fed DDGS.

**Key words:** distillers' grains, growth performance, nonroughage NDF, roughage intake, soybean meal

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## INTRODUCTION

Reducing roughage utilization in beef finishing diets could be cost effective, facilitate diet

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handling, and improve feed conversion efficiency (May et al., 2010). Recent surveys indicated that in feedlot finishing diets roughage inclusion represents, on average, 8%–10% of the diet dry matter (DM; Vasconcelos and Galyean, 2007; Samuelson et al., 2016). Yet, beef cattle seemed to prefer a diet with a lower roughage content if given the possibility to select their own feed ingredients when a grain-based mix of concentrates and a roughage source were offered ad libitum and in separate bunks (Iraira et al., 2015; Pittaluga et al., 2021).

Increasing dietary neutral detergent fiber (NDF) by including high fiber by-products might be an effective alternative to decrease dietary roughage without compromising growth performance of feedlot cattle (Depenbusch et al., 2009). Special care should be taken when dry distillers' grains with solubles (DDGS) are fed in grain-based diets with low roughage due to its contents content of sulfuric acid, as it could predispose feedlot cattle to metabolic upsets by acidifying ruminal pH (Felix et al., 2012b). Sulfuric acid, utilized by ethanol plants to clean fermentation tanks and control pH during starch hydrolysis, remains in DDGS and acidifies the rumen (Felix and Loerch, 2011). In this context, including a different protein source such as soybean meal (SBM) with low acidity, might be advantageous over DDGS in grain-based diets with low NDF content. Despite the lower feed value of soybean hulls (SH) relative to corn (Ludden et al., 1995), increasing the content of NDF by replacing ground corn (GC) with SH in diets of feedlot heifers offered free-choice hay, led to a decrease in hay intake with no detriment in growth performance (Pittaluga et al., 2021). We hypothesized that (1) including SBM as an alternative protein source to DDGS will improve the finishing performance of feedlot steers fed a GC-based diet and free-choice hay; (2) increasing the nonroughage NDF content (NRFC) of the diet with greater SH inclusion rates will improve growth performance of steers fed DDGS but will negatively affect growth performance of steers fed SBM; (3) roughage intake will decrease with greater NRFC without negatively affecting growth performance of feedlot steers. The objective of this experiment was to evaluate the interaction of different protein sources and NRFC in finishing diets of feedlot cattle fed free-choice hay on growth performance and carcass characteristics.

## MATERIALS AND METHODS

All experimental procedures were approved by The Ohio State University Institutional Animal

Care and Use committee of (#2018A00000031) and followed the guidelines recommended in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 2010).

### *Animals, Experimental Design, and Treatments*

To determine the effect of protein source and NRFC in finishing diets of feedlot steers on growth performance and carcass characteristics, 120 Angus × SimAngus-crossbred steers ( $566 \pm 42$  kg initial BW) were fed a GC-based diet for  $104 \pm 10$  d at The Ohio State University Eastern Agricultural Research Station (Belle Valley, Noble County, OH). The experiment was conducted as a randomized complete block design with a  $2 \times 2$  factorial arrangement of treatments. Steers were blocked by BW, steers within each block were randomly assigned to pens (8 pens with 15 steers in each pen). Pens within each block were assigned randomly to 1 of 4 treatments (2 pens per treatment). Treatments included a GC-based diet with DDGS and a low NRFC (DLF), a GC-based diet with DDGS and a high NRFC (DHF), a GC-base diet with SBM and a low NRFC (SLF), a GC-based diet with SBM and a high NRFC (SHF). Each concentrate mix was pelletized and the NRFC of dietary treatments was modified replacing GC for SH at different rates (Table 1). One steer on the DHF treatment was removed from the experiment for reasons not related to the treatments. Dietary treatments were formulated to sufficiently provide protein, vitamins, and minerals to exceed nutrient recommendations for growing steers (NASEM, 2016) and offered for ad libitum intake. Grass hay (Table 2) was utilized as the roughage source for dietary treatments and was offered as long cut and ad libitum in a different bunk, separate from the concentrate mix.

Steers were weighed on two consecutive days at the beginning and end of the experiment.

Steers were weaned (7 months old) and fed SH and grass hay for 30 d. Afterwards, steers were group fed 3–3.5 kg/d of a backgrounding ration (BR; 60% GC, 10% SBM, 28% SH, and 2% AV (animal-vegetable blend fat)) and ad libitum access to grass hay for 6 months. Subsequently, the BR offered to steers was increased to 4.5 kg/d and continued with ad libitum access to grass hay for another 6 months. Following the 12-month backgrounding period, cattle entered the feedlot and started the adaptation to the finishing diet. At the beginning of the adaptation period, steers received a blend of 50% BR and 50% dietary treatments at a rate of 4.5 kg/head/d for 3 d. In the following 4 d,

**Table 1.** Ingredients and analyzed nutrient content of the concentrates mix of dietary treatments

Item	Treatments			
	DLF	DHF	SLF	SHF
Ingredient, % of DM				
Ground corn	75	70	78.5	73.5
Dried distillers grains with solubles	15	15	–	–
Soy hulls	–	5	3	8
Soybean meal	–	–	8.5	8.5
Supplemental premix <sup>1</sup>	10	10	10	10
Analyzed composition, % of DM				
CP <sup>2</sup>	12.2	12.8	14.1	14.6
NDF <sup>3</sup>	10.2	14.4	10.3	13.7
ADF <sup>4</sup>	3.9	7.5	2.8	6.4
EE <sup>5</sup>	4.4	3.9	3.6	2.3
S <sup>6</sup>	0.38	0.27	0.28	0.29
NE <sub>m</sub> <sup>7</sup> , Mcal/kg	2.37	2.30	2.14	2.19

<sup>1</sup> 57.18% ground corn, 4.57% urea, 10.5% soybean meal, 10.06% limestone, 4.57% NaCl, 0.35% Se, 6.4% CaSO<sub>4</sub>, 2.74% KCl, 0.06% CuSO<sub>4</sub>, 0.16% ZnSO<sub>4</sub>, 0.11% MnSO<sub>4</sub>, 0.001% CaCO<sub>3</sub>, 0.068% vitamin A-30, 0.068% vitamin D-3, 0.2% vitamin E, 0.156% Rumensin 90, 2.76% Av Blend.

<sup>2</sup> Crude protein.

<sup>3</sup> Neutral detergent fiber.

<sup>4</sup> Acid detergent fiber.

<sup>5</sup> Ether extract.

<sup>6</sup> Sulfur.

<sup>7</sup> NE<sub>m</sub> = Estimated net energy for maintenance.

**Table 2.** Analyzed nutrient content of grass hay

Item	
Analyzed composition, % of DM	
CP <sup>1</sup>	7.7
NDF <sup>2</sup>	62.3
ADF <sup>3</sup>	41.5
EE <sup>4</sup>	2.1
S <sup>5</sup>	0.10
NE <sub>m</sub> <sup>6</sup> , Mcal/kg	1.27

<sup>1</sup> Crude protein.

<sup>2</sup> Neutral detergent fiber.

<sup>3</sup> Acid detergent fiber.

<sup>4</sup> Ether extract.

<sup>5</sup> Sulfur.

<sup>6</sup> NE<sub>m</sub> = Estimated net energy for maintenance.

dietary treatments were progressively increased in the until reaching 100% of the blend while maintaining the amount of feed offered. Subsequently, feed quantity was increased by 0.45 kg/head/d every 2 d until pens began to leave refusal. To reach ad libitum intake of dietary treatments, a 28-d period was needed.

Steers were housed in pens (7.3 × 37.2 m) that included an area covered by a metal roof (7.3 × 8.5 m) and an outside loafing area (7.3 × 28.6 m). The flooring material under the covered space was comprised of crushed, compacted limestone (screenings), and the outside loafing area was concrete.

Each pen contained 2 GrowSafe bunks (automatic feeding system, GrowSafe®, GrowSafe Systems Ltd., Airdrie, AB, Canada; 0.91 m × 0.53 m × 0.38 m). The grass hay and the concentrate mix were offered separately by placing each feed on a different GrowSafe bunk within the pen. GrowSafe bunks allowed only one animal to eat at a time and recorded individual feed intake based on an electronic ear tag. Adaptation to the feeding units was conducted as described previously (Freitas et al., 2017).

### Data Collection and Laboratory Analysis

Individual weights were recorded at 28-d intervals throughout the experimental period. Steers were weighed before the morning feeding and were not withheld from feed or water. When animals had approximately 1.50 cm of fat thickness at the 12th rib by visual appraisal, they were weighed off test and harvested at the commercial abattoir (E.R. Boliantz Co, Ashland, OH). Two animals from each pen, within each block, were sent to slaughter at the same time; therefore, all dietary treatments were represented in each off-test day. Carcass data were provided by a USDA grader.

Feed ingredient samples of both concentrates and hay were collected every week and frozen at –20 °C throughout the entire period of the trial. Equal portions of each ingredient were composited and shipped for

nutrient composition analysis (Rock River Laboratory Inc., Agricultural Analysis; Wooster, OH). Composite samples were dried and ground through a Wiley mill (1 mm screen, Arthur H. Thomas, Philadelphia, PA). Ingredients were analyzed for DM by oven-drying (24 h at 105 °C), NDF and acid detergent fiber (Ankom Technology method 5 and 6, respectively; Ankom 200 Fiber Analyzer, Ankom Technology), crude protein (CP; Leco TruMac, LECO Corporation, St. Joseph, MI), ether extract (Ankom method 2; Ankom Technology), and ash (600 °C for 2 h; Thermolyte muffle oven Model F30420C; Thermo Scientific, Waltham, MA). The NE content of the diets was estimated as reported by Schwab et al. (2003).

### Statistical Analysis

All statistical analyses were conducted using the MIXED procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC) for a randomized complete block design with a 2 × 2 arrangement of treatments. Because each animal had free access to hay or concentrate, the daily ration of each animal within each pen differed; and therefore, the animal was used as the experimental unit. The model was fitted with individual animal data and included the protein source, nonroughage NDF, and their interaction as fixed effects, as well as block and animal within block as random effects. The PDIF option of SAS was used for mean separation, and superscripts were utilized to indicate differences between means. Despite diets were formulated to be

isonitrogenous, the CP content of the diets with SBM was greater than the ones from DDGS; therefore, there is a confounding effect of PS and protein content. For this reason, the data where PS had a significant effect and did not interact with NRFC was also analyzed as the effect of CP intake, a linear regression, on growth performance. For the regression analysis, a mixed mode procedure, with the SOLUTION option of SAS was used where crude protein intake and NRFC were included as fixed effect and block was included as random effects. Statistical differences were determined at  $P \leq 0.05$ , with tendencies defined as  $0.05 < P \leq 0.10$ .

## RESULTS

There were no PS × NRFC interactions ( $P \geq 0.12$ ; Table 3) detected for any growth performance traits except for G:F. Protein source tended ( $P = 0.10$ ; Table 3) to interact with NRFC, where steers on the DHF treatment had a lower gain to feed ratio compared with SLF and SHF. Both DMI and NEm intake did not differ ( $P \geq 0.26$ ; Table 3) between PS. Feeding SBM as the protein source increased final BW (FBW;  $P = 0.05$ ; Table 3), tended to increase average daily gain (ADG;  $P = 0.06$ ; Table 3), but decreased ( $P = 0.05$ ) HI. Feeding diets with varying NRFC did not affect ( $P \geq 0.30$ ; Table 3) any of the evaluated growth performance traits. Based on the linear regression analysis of CP intake, increases in crude protein intake

**Table 3.** Effect of protein source and nonroughage NDF content on the growth performance of feedlot steers fed free-choice hay

Item	Treatment <sup>1</sup>				SEM <sup>2</sup>	P-values		
	DLF	DHF	SLF	SHF		PS <sup>3</sup>	NRFC <sup>4</sup>	PS×NRFC
<i>n</i>	30	29	30	30				
IBW <sup>5</sup> , kg	566	561	573	566	31.6	0.26	0.30	0.81
FBW, kg	726	724	735	737	7.9	0.05	0.97	0.71
ADG, kg/d	1.56	1.52	1.63	1.66	0.069	0.06	0.87	0.55
DMI, kg/d	11.3	11.8	11.5	11.4	0.39	0.78	0.49	0.23
HI <sup>6</sup> , kg/d	1.36	1.48	1.25	1.09	0.125	0.05	0.90	0.26
G:F	0.138 <sup>ab</sup>	0.128 <sup>b</sup>	0.142 <sup>a</sup>	0.147 <sup>a</sup>	0.0044	0.01	0.64	0.10
NE <sup>7</sup> , Mcal/d	25.3	25.6	23.5	24.0	0.88	0.35	0.30	0.12

<sup>a-b</sup> Within a row, means without a common superscript differ ( $P \leq 0.05$ ).

<sup>1</sup> DLF = DDGS and low non-roughage NDF content; DHF = DDGS and high non-roughage NDF content; SLF = SBM and low non-roughage NDF content; SHF = SBM and high non-roughage NDF content.

<sup>2</sup> Pooled standard error of treatment means,  $n = 30$  and 29 steers/treatment.

<sup>3</sup> PS = main effect of the protein source.

<sup>4</sup> NRFC = main effect of the non-roughage NDF content.

<sup>5</sup> BW of steers was registered on d 0 of the trial.

<sup>6</sup> Hay dry matter intake.

<sup>7</sup> NEm = Net energy for maintenance. Calculated as concentrate mix and hay intake multiplied by their respective NEm content.



linearly increased ( $P < 0.01$ ) ADG and FBW, but it does not affect HI ( $P = 0.69$ ) (Table 4).

No PS  $\times$  NRFC interactions were detected for any carcass characteristic (Table 5) except for kidney-pelvic-heart fat (KPH;  $P = 0.04$ ). Protein source interacted with NRFC ( $P = 0.04$ ), where steers on the SHF treatment presented the lesser KPH fat compared with the remaining dietary treatments. Protein source did not affect ( $P \geq 0.16$ ) hot carcass weight (HCW), longissimus muscle (LM) area, dressing, 12th rib fat thickness, or marbling score (MS). No differences were detected for dressing, HCW, LM area, or MS ( $P \geq 0.18$ ) as a result of different NRFC. Feeding experimental diets with greater NRFC decreased ( $P = 0.03$ ) the 12th rib fat thickness.

## DISCUSSION

Experimental diets were formulated to be isonitrogenous, but differences between tabular values and nutrient content analysis led to a greater CP

**Table 4.** Simple linear regression of crude protein intake on average daily gain (ADG), final body weight (FBW), and hay intake (HI) for the 104-d study period

Item	Intercept	CPI <sup>1</sup>
ADG, kg/d	0.10	1.04**
FBW, kg	521.10*	145.87**
HI, kg/d	1.55	-0.08

\*  $P$ -value between 0.05 and 0.01.

\*\*  $P$ -value  $< 0.01$ .

<sup>1</sup> Crude protein intake, expressed in kg/d.

content of the dietary treatments with SBM, which confounds the effect of the protein source and crude protein intake. For that reason, the data were analyzed in two different ways, the first one as the experiment was design and the second one as a linear regression on the effect of crude protein intake. Based on the effect of PS on growth performance, steers fed SBM expressed a greater ADG and FBW. The linear regression analysis performed herein to better comprehend the observed results, showed that ADG and FBW were positively associated with crude protein intake. Nevertheless, because CP intake cannot be separated from the PS effect, whether differences in growth performance are due to crude protein intake or PS is not clear. Although no differences were observed in energy intake and all dietary treatments supplied sufficient crude protein to satisfy steers requirements to grow at a rate of 1.66 kg/d (highest ADG among treatments; NASEM, 2016). The extended backgrounding period of steers in this trial could have contributed to the observed results. Growing rates during the backgrounding phase can effectively alter body composition prior to the finishing phase (Schoonmaker et al., 2003; Sharman et al., 2013), where lower ADG can promote protein accretion and increase the proportions of skeletal muscle of the BW gain (Owens et al., 1995). Steers may have started the trial with a more muscular BW and greater protein requirements than estimated using NASEM (2016) equations. Therefore, the greater crude protein intake of steers fed diets with SBM translated into greater ADG and FBW.

**Table 5.** Effect of protein source and nonroughage NDF content on the carcass characteristics of feedlot steers fed free-choice hay

Item	Treatment <sup>1</sup>				SEM <sup>2</sup>	$P$ -values		
	DLF	DHF	SLF	SHF		PS <sup>3</sup>	NRFC <sup>4</sup>	PS $\times$ NRFC
<i>n</i>	30	29	30	30				
Dressing <sup>5</sup> , %	61.7	61.6	61.8	61.0	0.40	0.43	0.18	0.37
HCW, kg	427	424	432	428	4.2	0.24	0.40	0.86
LM area, cm <sup>2</sup>	96.8	96.4	99.9	96.9	1.53	0.24	0.26	0.38
12th rib fat, cm	1.43	1.33	1.47	1.22	0.08	0.61	0.03	0.33
MS <sup>6</sup>	692	701	689	638	23.5	0.16	0.36	0.20
KPH, %	2.2 <sup>a</sup>	2.3 <sup>a</sup>	2.3 <sup>a</sup>	2.1 <sup>b</sup>	0.078	0.08	0.40	0.04

<sup>a-b</sup> Within a row, means without a common superscript differ ( $P \leq 0.05$ ).

<sup>1</sup> DLF = DDGS and low non-roughage NDF content; DHF = DDGS and high non-roughage NDF content; SLF = SBM and low non-roughage NDF content; SHF = SBM and high non-roughage NDF content.

<sup>2</sup> Pooled standard error of treatment means,  $n = 30$  and 29 steers/treatment.

<sup>3</sup> PS = main effect of the protein source.

<sup>4</sup> NRFC = main effect of the non-roughage NDF content.

<sup>5</sup> Calculated from HCW and FBW with a 4% pencil shrink applied.

<sup>6</sup> Marbling score; scale: 400–490 = slight, 500–590 = small, 600–690 = modest, 700–790 = moderate, 800–890 = slightly abundant.

Although growth performance of finishing cattle fed corn-based diets with SBM is not believed to be limited by the supply of essential amino acids (Hussein and Berger, 1995), opting for DDGS as the supplementary protein source might create a lysine deficiency, as the content of this amino acid in corn grain and corn by-products is low (Lancaster et al., 2016). Accordingly, moderate inclusions of rumen-protected lysine in corn-based diets increased ADG of feedlot steers, particularly in the early feeding stages (Klemesrud et al., 2000). However, Heiderscheid and Hansen (2020) did not observe any benefit in the finishing performance of feedlot steers by increasing the lysine balance of a corn-based diet with either SBM or rumen-protected lysine. While it is possible that the differences in lysine or other amino acids supply between SBM and DDGS containing diet might be influencing the observed results, the experimental design of this trial constraints our ability to evaluate this argument.

Alternatively, the lower ADG and FBW of steers fed diets with DDGS could be explained by a lower fiber digestibility. Although not measured in the present experiment, it is plausible that due to a less appropriate ruminal environment for cellulolytic bacteria activity induced by a greater titratable acidity of DDGS, compromised the digestibility of dietary fiber which negatively affected growth performance. When rumen pH decreases, fiber digestibility gets compromised due to impeded growth of structural carbohydrate-fermenting bacteria (Hoover, 1986). A detrimental effect on growth performance associated to the high titratable acidity of distillers grains and lower fiber digestibility has been reported for feedlot lambs and cattle when including up to 60% of DDGS (DM basis) to the diet (Felix et al., 2012a, 2012b). Furthermore, increasing the supply of dietary fiber to a more acidic ruminal environment by replacing GC for SH might explain the lower G:F observed for the DHF treatment compared with SLF and SHF. In addition, the greater HI observed for steers fed DDGS might underscore the necessity for more rumination and salivation to buffer rumen pH depressions.

We anticipated that greater nonroughage NDF inclusion was going to decrease HI; also that nonroughage NDF inclusion improves growth performance only on the steers fed DDGS; however, we could not confirm these hypothesis based on the results of the current experiment. Even though rumen conditions were not measured, the relatively low nonroughage NDF inclusion in the present experiment was plausibly not enough to significantly modify the rumen environment. It has been suggested that larger, rather

than smaller, changes in the rumen environment are expected to alter subsequent diet selection (James and Kyriazakis, 2002), which affect animal growth.

The lesser FBW of steers fed experimental diets with DDGS compared with SBM did not translate into lesser HCW, which contrasts with previous results (Zinn et al., 1997; Uwituze et al., 2011; Felix et al., 2012a). Apparently, the 11 kg superiority in FBW of steers fed SBM was not sufficient to generate heavier carcasses. Steers in the SHF treatment presented the lesser KPH fat compared with the remaining dietary treatments. In addition, increasing dietary nonroughage NDF with greater NRFC decreased the 12th rib fat thickness. Likewise, Bittner et al. (2016) reported on their second experiment that replacing up to 37.5% of corn grain by SH and concomitantly increasing dietary NDF, linearly decreased fat thickness at the 12th rib of beef steers. Oppositely, Pittaluga et al. (2021) and Bittner et al. (2016), in their first experiment, did not observe differences in the 12th rib fat thickness of beef steers when substituting corn grain by SH. The inconsistency of the results from previous trials could be attributed to differences in the nutrient composition of the basal diet and inclusion levels of SH. Nevertheless, the reasons that explain the 12th rib fat thickness and KPH fat results found herein are not known by the authors.

In conclusion, opting for SBM as the supplementary protein source in finishing diets improved growth performance of feedlot steers compared with DDGS when hay is provided as free-choice. Nevertheless, whether differences in the growth performance of feedlot steers are explained by daily crude protein intake or characteristics of the protein sources requires further elucidation. Increasing the content of nonroughage NDF by replacing GC for SH, did not affect growth performance or HI but decreased feed efficiency of steers fed DDGS.

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