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Lauren A. Ovinge
University of Nebraska - Lincoln

Mitch M. Norman
University of Nebraska-Lincoln, mnorman2@unl.edu

Hannah C. Wilson
University of Nebraska-Lincoln, hhamilton6@unl.edu

Kaylee E. Wheeler
University of Nebraska - Lincoln

Galen E. Erickson
University of Nebraska - Lincoln, gerickson4@unl.edu

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Summary with Implications

A 2 × 3 factorial metabolism study using 6 ruminally and duodenally cannulated heifers evaluated the site and amount of nutrient digestion when feeding high protein dry distillers grains plus solubles (DDGS) or conventionally produced DDGS at 30% inclusion compared to feeding no distillers in either dry-rolled or steam-flaked corn diets. Apparent total tract starch digestibility was unaffected by distillers treatment in SFC-based diets, but decreased from 95.1% to 92.0% when DDGS was added to DRC diets, and further decreased to 88.7% for HiPro diets. Dry matter and OM digestibilities were lower types of when either DDGS diets were fed, but no differences were observed between conventional or high protein DDGS. Feeding high protein DDGS did not change digestion compared to conventional DDGS, despite higher CP content. Digestion is greater when cattle are fed steam-flaked corn compared to dry-rolled corn.

Introduction

High protein DDGS is the result of fractionation during ethanol production to produce a concentrated protein byproduct. This feed may result in extra benefit for producers feeding DRC-based diets, because the bypass protein fraction of DDGS, when used for energy by the cattle, contributes to the positive performance observed when cattle are fed DDGS (2016 Nebraska Beef Cattle Report, pp. 124–127). Starch digestion can be limited in ruminants due to limited α-amylase production from the pancreas at the entry of the small intestine. There has been some research suggesting increasing protein post ruminally stimulates the pancreas to release more α-amylase, thus enhancing starch digestion and absorption in ruminants, potentially improving performance. Steam flaked corn has more readily available and fermentable starch than DRC, so improvements in starch digestion are more likely to be observed in DRC-based diets. Therefore, the objective of this study was to evaluate feeding high protein (HiPro) DDGS compared to conventionally produced DDGS on starch digestibility throughout the digestive tract in either dry-rolled or steam-flaked corn-based diets.

Procedures

A 2 × 3 factorial metabolism study evaluated the effect of no distillers included in the diet (CON), a diet containing 30% conventionally produced DDGS (DDGS), or diet including 30% high protein DDGS (HiPro) in either dry-rolled (DRC) or steam-flaked (SFC corn diets. Six ruminally and duodenally cannulated beef heifers were utilized in a 6 × 6 Latin square with six treatment periods. Heifers were housed individually in concrete slatted pens with ad libitum access to feed and water. They were assigned randomly to each treatment for six, 21-d periods, each allowing for 14-d of adaptation followed by 7-d of collection. Diets (Table 1) were mixed twice weekly and stored in a cooler (0°C) to ensure fresh feed for animals. Supplement included 30 g/ton DM of Rumensin (Elanco Animal Health) and 8.8 g/ton of Tylan (Elanco Animal Health). Heifers were dosed with 5.0 g/heifer of titanium dioxide inserted through the rumen cannula twice daily at 0800 and 1600 h beginning on d-7 of each period. Fecal and duodenal samples (approximately 300 g each) were collected at 0800, 1200, 1600 and 2000 h from days 17 to 20 of each period. Whole rumen contents and rumen fluid were collected on d-21 for VFA, NH_3, and purine analysis. Fecal samples were composited by day and freeze dried and composited by period, whereas duodenal samples were freeze dried then composited by day then period. Samples were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), organic matter (OM), starch, titanium, crude protein and whole rumen contents and duodenal samples were analyzed for purine concentration to analyze microbial flow. The purine: nitrogen ratio measured was 0.153 ± 0.011 and individually measured ratios were used to determine nutrient flow through each animal within each period. Whole rumen microbial isolates were composited by treatment and analyzed for OM and starch to correct microbial OM and starch reaching the duodenum, thus calculating true ruminal digestibility. Orts were removed daily and dried for 48h in a 60°C forced-air oven to determine DMI. Feed ingredients and diet refusals were analyzed for the same nutrients analyzed in fecal and duodenal samples. Ruminal pH was recorded every minute using wireless pH probes inserted in the rumen from days 15 to 21.

Nutrient digestibility, VFA and NH_3 analysis were analyzed using the MIXED procedures of SAS, with period and treatment considered fixed effects, and heifer within period considered a random effect. Heifer within the period was considered the experimental unit. Ruminal pH parameters were analyzed using the GLIMMIX procedure of SAS. *P*-values below 0.05 were considered significant.

Results

There was an interaction ($P \leq 0.02$) between corn processing and DDGS treatment for apparent total tract starch digestibility and post ruminal starch digestibility (Table 2). For apparent total tract starch digestibility, SFC-based diets had similar starch digestibility ($P > 0.10$) whether feeding 0% or 30% DDGS or HiPro. Apparent total tract starch digestibility was 95.1% for DRC-CON, was decreased ($P < 0.01$)

Table 1. Diet composition (DM basis) fed to fistulated steers to evaluate nutrient digestion.

	Treatment[1]					
	CON		DDGS		HiPro	
	DRC	SFC	DRC	SFC	DRC	SFC
Ingredient						
Dry-Rolled Corn	87.0	-	57.0	-	57.0	-
Steam Flaked Corn	-	87.0	-	57.0	-	57.0
DDGS	-	-	30.0	30.0	-	-
High Protein DDGS	-	-	-	-	30.0	30.0
Sorghum Silage	8.0	8.0	8.0	8.0	8.0	8.0
Dry Supplement[2]	5.0	5.0	5.0	5.0	5.0	5.0
Nutrient Composition[3]						
Crude Protein, %	12.91	12.64	15.22	15.04	17.50	17.33
Starch, %	62.68	62.85	44.58	44.70	44.13	44.20
NDF, %	14.35	13.44	21.73	21.73	23.39	22.80
ADF, %	7.53	7.25	10.56	10.37	12.97	12.80
Ether Extract, %	3.96	3.10	5.35	4.79	5.17	4.61

[1]Treatments were control (CON), conventionally produced DDGS included in the diet at 30% (DDGS) or high protein DDGS included in the diet at 30% (HiPro), fed with either dry rolled corn (DRC) or steam flaked corn (SFC)

[2]Supplement formulated to be fed at 5.0% of diet DM. Supplement consisted of 1.3925% fine ground corn in the CON supplement and 2.7925% fine ground corn in the DDGS and HiPro supplement, and 1.4% urea in the CON supplement and 0% urea in the DDGS and HiPro supplements, 1.50% limestone, 0.125% tallow, 0.30% salt, 0.05% trace mineral package, 0.015% Vitamin A-D-E package as a percentage of the final diet. It was also formulated for 30 g/ton Rumensin®(Elanco Animal Health, DM Basis) and 8.8 g/ton Tylan® (Elanco Animal Health, DM basis).

[3]Based on analyzed nutrients for each ingredient.

to 92.0% for DRC-DDGS, and further decreased ($P < 0.01$) to 88.7% for DRC-HiPro. Post ruminal starch digestibility followed a similar trend, where SFC-based treatments did not differ from one another ($P > 0.10$) However, cattle fed DRC-based diets had-decreased post ruminal starch digestibility with the inclusion of either DDGS source. Digestibilitywas 77.6% for DRC-CON, 74.7 for DRC-DDGS, and 59.3% for DRC-HiPro.No other interactions were observed.

Distillers Grains plus Solubles Treatment

Feeding either conventional DDGS or HiPro resulted in greater DMI, OMI, NDF and ADF intake ($P < 0.01$) compared to not including DDGS in the diet, with no differences ($P > 0.10$) between the two DDGS treatments for these variables ($P < 0.01$; Table 2). Starch intake was similar between the DDGS treatments ($P = 0.15$), suggesting that even though cattle consuming DDGS or HiPro had lower starch in the diet, they consumed enough DM to compensate. This increased flow and volume of feed through the digestive tract may partially explain the observed lower starch and OM digestibility for DDGS and HiPro treatments as compared to CON. Total tract dry matter digestibility was lower in diets containing conventional DDGS and HiPro diets (71.7 and 68.1%, respectively) as compared to CON diets (76.9%) ($P < 0.01$). Similar results were also observed for OM digestibility. Neutral detergent fiber and ADF digestibility were not different between dietary treatments ($P \geq 0.36$), despite cattle consuming DDGS and HiPro having greater NDF and ADF consumption due to the inclusion of DGS in the diet ($P < 0.01$). As with DMD and OMD, digestible energy of the diet was lower for cattle consuming DDGS and HiPro as compared to the CON treatment ($P < 0.01$). Apparent OM rumen digestibility was lower ($P = 0.02$) for DDGS and HiPro fed cattle as compared to CON, but this was not observed when microbial activity was considered and true OM digestibility was calculated ($P = 0.38$; Table 3). Apparent ruminal starch digestibility was similar to apparent ruminal OM digestibility, in that DDGS and HiPro had lower apparent ruminal starch digestibility than CON ($P < 0.01$). However, this did not translate to differences in true ruminal starch digestibility ($P = 0.11$). Microbial OM flow to the duodenum was greater for DDGS and HiPro (5.40 and 6.26 lb/d, respectively ($P = 0.05$)) as compared to CON (3.44 lb/d). As a result of increased intake and microbial OM flow to the duodenum, total OM flow to the duodenum was greater for DDGS and HiPro as well. Microbial efficiency (g N produced/kg truly fermented OM) was unaffected by treatment ($P = 0.13$), but microbial starch content was greater for DDGS and HiPro fed cattle($P < 0.01$) suggesting some starch engulfing by protozoa may have occurred in the rumen, allowing for flow past the rumen and digestion in the small intestine. There were no differences between treatments for total starch flow to the duodenum ($P = 0.31$), likely because cattle consuming DDGS and HiPro consumed enough extra DMI to make up for their lower starch diets.

Ammonia levels were lower for DDGS and HiPro diets as compared to CON ($P < 0.01$), but the supplement for CON treatments included urea, while this was not included in DDGS and HiPro treatments (Table 4). Rumen ammonia levels were below the minimum 5.0 mg/dL in the SFC-HiPro treatment and were around 8.0 mg/dL for the DDGS treatment, suggesting RDP in the diet may have limited microbial activity. Measured ruminal pH parameters such as maximum, minimum and average ruminal pH were not affected by DGS treatment ($P \geq 0.21$). Ruminal pH variance was greater for the CON treatments as compared to DDGS and HiPro treatments ($P < 0.01$), and the HiPro treatment tended to spend less time below a pH of 5.6 compared to other treatments ($P = 0.08$).

Corn Processing Treatment

Consistent with other research trials, SFC tended to have greater OM digestibility than DRC ($P = 0.08$) and had lower NDF and ADF digestibility than DRC ($P \leq 0.03$; Table 2). Gross energy intake was greater for DRC, likely due to the tendency for greater DMI for the DRC treatment ($P = 0.07$). Total digestible nutrients and DE as a percent of GE were not different between corn processing treatments , averaging 70.6% DE for DRC and 72.3% for SFC. Apparent ruminal OM digestibility was greater for SFC ($P = 0.05$) but was reversed and

Table 2. Effect of high protein DDGS and corn processing method on apparent total tract nutrient digestibility of dry rolled corn or steam flaked corn-based diets

	Treatment[1]							P-Value[2]		
	CON		DDGS		HiPro					
Item	DRC	SFC	DRC	SFC	DRC	SFC	SEM	Corn	Distiller	Int.
Dry Matter										
Intake, lb/day	17.50	12.79	19.00	18.45	19.78	18.87	2.12	0.07	0.01	0.26
Digestibility, %	76.1	77.6	71.3	72.1	66.0	70.1	1.91	0.13	0.01	0.56
Organic Matter										
Intake, lb/day	17.13	12.41	18.32	17.75	19.22	18.30	2.033	0.06	0.02	0.24
Digestibility, %	77.8	79.8	73.0	74.1	67.5	71.9	1.94	0.08	0.01	0.59
NDF										
Intake, lb/day	2.58	1.74	4.17	3.92	4.52	4.21	0.454	0.09	0.01	0.62
Digestibility, %	54.6	26.7	52.8	37.8	46.4	34.3	5.30	0.01	0.49	0.23
ADF										
Intake, lb/day	1.34	1.01	1.92	1.83	2.49	2.34	0.238	0.18	0.01	0.73
Digestibility, %	54.0	39.9	54.9	43.1	56.4	52.1	5.63	0.03	0.36	0.60
Starch										
Intake, lb/day	11.24	8.55	8.97	8.58	9.04	8.60	1.043	0.03	0.15	0.13
Digestibility, %	95.1[a]	97.8[d]	92.0[b]	96.1[ad]	88.7[c]	96.2[ad]	0.71	0.01	0.01	0.01
Energy										
GE Intake, Mcal/d	36.35	25.35	41.17	39.16	43.28	40.39	4.238	0.04	0.01	0.27
DE Intake, Mcal/d	27.00	19.39	28.95	27.76	28.11	27.87	3.017	0.08	0.04	0.18
DE, % of GE	75.3	76.6	70.7	71.2	65.7	69.0	1.91	0.24	0.01	0.70
TDN	78.58	76.04	76.68	75.68	72.00	74.02	2.057	0.74	0.08	0.48

[1]Treatments were control (CON), conventionally produced DDGS included in the diet at 30% (DDGS) or high protein DDGS included in the diet at 30% (HiPro), fed with either dry rolled corn (DRC) or steam flaked corn (SFC)

[2]Int = *P*-value for the interaction of corn processing method and DGS treatment. Corn = *P*-Value for the main effect of corn processing effect. Distiller = *P*-Value for the main effect of DDGS treatment

tended to be lower when microbial OM was considered ($P = 0.09$; Table 3). Apparent and true ruminal starch digestibility were greater ($P < 0.01$) for SFC as compared to DRC. Apparent ruminal NDF was lower for SFC as compared to DRC ($P < 0.01$). Microbial, feed, and total starch entering the duodenum was greater for DRC as compared to SFC ($P \leq 0.04$), likely due to lower starch digestibility and greater starch intake of the DRC-based diets. These results were anticipated, as cattle consuming SFC typically eat less due to the fermentability and availability of starch in the grain. Ammonia concentration in the rumen was lower for SFC than DRC ($P < 0.01$), suggesting less fermentation, of DRC-based diets (Table 4). Measured ruminal pH parameters were not different between corn processing treatments ($P \geq 0.21$).

Conclusions

Feeding high protein distillers grains as compared to conventional DDGS did not result in any appreciable differences in rumen fermentation, but feeding high protein distillers decreased digestion of DM and OMStarch digestion was decreased by feeding either type of DDGS in DRC diets but was did not impact starch digestion in diets based on SFC. Starch digestion was not improved by high protein DDGS as hypothesized but actually decreased digestion some compared to conventional DDGS.

Lauren A. Ovinge, graduate student

Mitch M. Norman, research technician

Hannah C. Wilson, research technician

Kaylee E. Wheeler, undergraduate research assistant

Galen E. Erickson, professor, Animal Science, University of Nebraska, Lincoln Neb.

Table 3. Effect of high protein DDGS on ruminal and duodenal total tract nutrient digestibility of dry rolled corn or steam flaked corn-based diets

	Treatment[1]									
	Control		DDGS		HiPro			*P*–Value[2]		
Item	DRC	SFC	DRC	SFC	DRC	SFC	SEM	Corn	Distiller	Int.
Ruminal Digestibility, %										
Apparent OM	47.6	41.9	34.4	35.7	40.4	29.7	3.85	0.05	0.01	0.15
True OM	66.6	72.7	64.3	67.0	62.9	71.2	3.99	0.09	0.38	0.71
Apparent Starch	75.9	84.6	66.4	77.7	71.6	72.7	3.92	0.01	0.01	0.15
True Starch	76.9	86.8	68.6	83.0	75.6	85.3	3.60	0.01	0.11	0.67
Apparent NDF	56.4	11.7	47.4	31.1	52.0	22.7	7.00	0.01	0.80	0.13
Duodenal Flow, lb/d										
Microbial OM	3.06	3.81	5.34	5.49	4.23	7.65	1.010	0.08	0.05	0.19
Feed OM	5.93	3.42	6.77	5.89	7.36	5.16	1.177	0.04	0.25	0.73
Total OM	8.99	7.23	12.10	11.38	11.62	11.42	1.552	0.63	0.01	0.31
Microbial Efficiency[3]	14.40	16.22	21.71	17.23	16.07	19.87	2.143	0.81	0.13	0.10
Microbial Starch	0.11[a]	0.17[a]	0.20[a]	0.46[b]	0.35[ab]	1.0[c]	0.106	0.01	0.01	0.02
Feed Starch	2.76	1.23	3.00	1.57	2.25	1.26	0.529	0.01	0.21	0.71
Total Starch	2.87	1.43	3.20	2.01	2.60	2.36	0.569	0.01	0.31	0.21
Post Ruminal Digestibility, % Entering										
OM	56.8[b]	65.4[c]	58.6[bc]	59.5[bc]	45.5[a]	59.2[bc]	2.75	0.01	0.01	0.05
Starch	77.5[bc]	86.0[8]	74.7[c]	82.4[ab]	59.1[d]	83.5[ab]	3.34	0.01	0.01	0.02

[1]Treatments were control (CON), conventionally produced DDGS included in the diet at 30% (DDGS) or high protein DDGS included in the diet at 30% (HiPro), fed with either dry rolled corn (DRC) or steam flaked corn (SFC)

[2]Int = *P*-value for the interaction of corn processing method and DDGS treatment. Corn = *P*-Value for the main effect of corn processing effect. Distiller = *P*-Value for the main effect of DDGS treatment

[3]Bacterial Efficiency, g N/kg of OM truly fermented

Table 4. Effect of DDGS type and corn processing method on ruminal VFA and ammonia concentration

	Treatment[1]									
	Control		DDGS		HiPro			*P*–Value[2]		
Item	DRC	SFC	DRC	SFC	DRC	SFC	SEM	Corn	Distiller	Int.
Ammonia, mg/dL	19.99	14.01	10.25	6.15	8.80	3.93	1.449	0.01	0.01	0.73
Ruminal pH										
Minimum pH	5.19	5.42	5.44	5.35	5.41	5.74	0.162	0.21	0.21	0.35
Maximum pH	6.78	6.76	6.67	6.61	6.54	6.78	0.213	0.75	0.78	0.70
Average pH	5.87	6.08	6.01	5.91	5.94	6.28	0.185	0.30	0.62	0.41
pH Variance	0.153	0.139	0.072	0.107	0.068	0.069	0.0276	0.73	0.01	0.63
Time < 5.6 min/d	534	352	435	422	195	58	157	0.40	0.08	0.86

[1]Treatments were control (CON), conventionally produced DDGS included in the diet at 30% (DDGS) or high protein DDGS included in the diet at 30% (HiPro), fed with either dry rolled corn (DRC) or steam flaked corn (SFC)

[2]Int = *P*-value for the interaction of corn processing method and DDGS treatment. Corn = *P*-Value for the main effect of corn processing effect. Distillers = *P*-Value for the main effect of DDGS treatment

[3]Ruminal volatile fatty acids (VFA).

[4]VFA concentration in mol/100 mol

[5]Acetate:Propionate