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Effect of supplemental fat from dried distillers grains with solubles or corn oil on nutrient digestibility[1]

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SUMMARY

The objective of this experiment was to determine the effects of supplemental fat from either dried distillers grains with solubles (DDGS) or raw corn oil on the digestibility of nutrients and long chain fatty acids. When compared to corn grain and grass hay, DDGS have considerably greater levels of fat, which may negatively influence rumen microbes and nutrient digestibility. Six medium-framed crossbred steers (initial BW = 602 ± 23.6 lb) were used in a Latin square design to determine apparent total tract digestibility of diets formulated with no supplemental fat or supplemental fat from either DDGS or raw corn oil. Steers were randomly assigned to of 1 of 3 dietary treatments: 1) supplemental fat from DDGS (DG); 2) supplemental fat from corn oil (OIL); 3) no supplemental fat (NO OIL; Table 1). The DG treatment was comprised solely of dried distillers grains with solubles (DDGS). The OIL treatment was comprised of a combination of high-protein dried distillers grains (HP DDG), corn bran, and corn oil formulated to be isonitrogenous and isolipid to the DG treatment. The final dietary treatment (NO OIL) was a combination of HP DDG and corn bran formulated to be isonitrogenous to the DG and OIL treatments, but with no additional fat. Treatment diets were administered over 3 consecutive 19 d feeding periods that consisted of 14 d diet adaptation followed by 5 d total collection. No differences were observed for DM, OM, ADF, NDF, or N, digestibility. Ether extract digestibility was lower in NO OIL compared to DG and OIL. Apparent digestibility of C17:0 was the lowest for OIL and greatest for DG; NO OIL was intermediate but different from both DG and OIL. C18:0 apparent digestibility was greatest for DG, lowest for OIL; NO OIL was intermediate but not different from either DG and OIL. C18:1*c*9 digestibility was greatest for DG, intermediate for OIL and least for NO OIL. Apparent digestibility of C20:3, C20:5, C22:2, total C20, and total conjugated linoleic acid were greater in DG and OIL than in NO OIL. These results suggest that providing low concentrations of supplemental fat as either DDGS or raw corn oil to growing steers on high forage diets will not influence digestibilities of DM, OM, ADF, NDF, or N. Digestibilities of ether extract and certain FA are affected by fat inclusion. Low levels of supplemental fat from either DDGS or corn oil may be included in high-forage rations fed to growing beef steers with no adverse affects on digestibility of nutrients or FA.

INTRODUCTION

Additional dietary lipid increases available energy to the animal; however, but does not provide fermentable energy to rumen microbes. Dried distillers grains with solubles contain between 10-12% fat, large amounts of NDF and low amounts of lignin; which ultimately provides a readily digestible fiber source to serve as a partial replacement for forages or concentrates. When compared to corn grain and grass hay, DDGS has considerably greater levels of fat, which may negatively influence rumen microbes

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and nutrient digestibility. Whitney et al. (2000) reported decreased dry matter (DM) digestibility when heifers on high-forage rations were fed 6% supplemental fat from soybean oil, but not when fed 3% supplemental fat from soybean oil. In addition, Vander Pol et al. (2007) reported in high-grain diets, the digestibility of fat from corn oil was 70%, but digestibility of fat from wet distillers grains with solubles was 81%. The objective of this experiment was to examine the affects of supplemental fat from either dried distillers grains with solubles or raw corn oil on the digestibility of nutrients and long chain fatty acids (LCFA; C12:0 and greater).

MATERIALS AND METHODS

Six medium-framed crossbred steers (initial BW = 602 ± 23.6 lb) were used in a Latin square design to determine apparent total tract digestibility of diets formulated with no supplemental fat or supplemental fat from either DDGS or raw corn oil. The South Dakota State University Animal Care and Use Committee approved all care, handling, and sampling procedures used in this experiment prior to trial initiation.

Twenty-one days prior to trial initiation, steers were brought to an indoor metabolism experiment facility and placed in slatted-floor pens. Steers were fed a common diet of 65% medium-quality grass hay and 35% DDGS beginning at 2.0% of their BW until approximate *ad libitum* intake was reached. A 5 d mock collection period took place 14 d prior to the initiation of the experiment to adapt the steers to collection procedures. After the mock collection, animals were randomly assigned to of 1 of 3 dietary treatments: 1) supplemental fat from DDGS (DG); 2) supplemental fat from corn oil (OIL); 3) no supplemental fat (NO OIL; Table 1). The DG treatment was comprised solely of dried distillers grains with solubles (DDGS). The OIL treatment was comprised of a combination of high-protein dried distillers grains (HP DDG), corn bran, and corn oil formulated to be isonitrogenous and isolipid to the DG treatment. The final dietary treatment (NO OIL) was a combination of HP DDG and corn bran formulated to be isonitrogenous to the DG and OIL treatments, but with no additional fat. A vitamin and mineral supplement formulated to meet or exceed NRC (2000) requirements was incorporated into the treatment when the treatments were mixed together. All 3 treatments received a basal diet of medium-quality grass hay.

A summary of diet composition and nutrient analysis is presented in Table 1. Fatty acid compositions of the grass hay and the concentrate portion of each treatment diet are presented in Table 2. The DG, OIL, and NO OIL treatments comprised 35% of the diet DM to provide the maximum amount of fat possible from DDGS without inducing health problems due to S intake. All dietary ingredients and available water were analyzed for S concentration prior to trial initiation to compare S intake with the maximum tolerable S concentration of 0.5% of diet DM for cattle on forage-based diets (NRC, 2005).

Table 1. Diet composition.

	Treatment[1]		
	DG	OIL	NO OIL
Item	---------- % of diet, DM-basis ----------		
Grass hay	61.36	62.11	62.10
DDGS[2]	35.00	---	---
Corn bran	---	24.28	23.94
HP DDG[3]	---	8.33	11.06
Corn oil	---	2.39	---
Supplement[4]	3.64	3.64	3.64
Nutrient analysis	---------- % ----------		
DM	92.38	91.87	91.65
CP	14.54	14.84	14.83
Ash	9.65	8.15	7.86
ADF	27.25	28.63	29.07
NDF	50.94	53.73	55.82
EE	4.52	4.45	2.24

[1]DG = supplement comprised of dried distillers grains with solubles; OIL = supplement comprised of high protein dried distillers grains with solubles, corn bran, and corn oil; NO OIL = supplement comprised of high protein dried distillers grains with solubles and corn bran.
[2]DDGS = dried distillers grains with solubles.
[3]HP DDG = high protein dried distillers grains.
[4]Formulated to meet or exceed NRC (2000) requirements for vitamins and minerals.

Table 2. Fatty acid composition of feeds.

		Treatment[2]		
Fatty acid[1]	Grass hay	DG	OIL	NO OIL
	---------- g/100g ----------			
C12:0	0.32	---	---	---
C14:0	2.65	0.15	0.88	0.38
C16:0	14.10	13.05	13.57	12.26
C18:0	1.14	2.24	2.90	2.76
C18:1 (*cis* 9)	2.29	12.84	10.92	13.64
C18:1 (*cis* 11)	0.28	0.41	0.39	0.41
C18:2	9.04	60.45	52.01	60.29
C18:3 (*n*-3)	24.30	2.37	8.03	3.35
C18:3 (*n*-6)	2.10	0.34	0.93	0.39
C20:0	1.73	0.48	0.44	0.47
C20:5	3.54	2.44	2.58	1.32
C22:4	0.73	0.18	0.21	0.15
Others	12.81	2.89	1.60	1.79

[1]Fatty acids expressed as number of carbons:number of double bonds; C18:3 (*n*-3) = γ-linolenic acid; C18:3 (*n*-6) = α-linolenic acid; Others = sum of C14:1, C16:1, C20:1, C20:2, C20:3, and C24:1.
[2]DG = supplement comprised of dried distillers grains with solubles; OIL = supplement comprised of high protein dried distillers grains with solubles, corn bran, and corn oil; NO OIL = supplement comprised of high protein dried distillers grains with solubles and corn bran.

The experiment was conducted as a replicated Latin square design with 3 consecutive 19 d feeding periods that consisted of 14 d diet adaptation followed by 5 d collection. Steers were fed twice daily (0700 and 1900) in 2 equal feed deliveries that, together, approximated *ad libitum* intake. If a steer had no feed refusals for 3 consecutive d, feed delivered was increased by 0.5 lb of DM. Feed delivery was decreased by 0.5 lb DM if a steer's daily feed refusal was more than 2 lb per d for 3 consecutive d.

Feed ingredients and dietary treatments were sampled on each treatment mixing date and stored at -20^{o}C until laboratory analysis. Treatments were mixed in allocations large enough to provide adequate supply throughout each adaptation and collection period. Feed refusals were removed, weighed, and individually stored at -20^{o}C before each morning's feed delivery.

On d 12, steers were moved to collection stanchions for a 2 d acclimation period followed by a 5 d collection period. On d 13 of each diet adaptation period, the sheath of each steer was closely clipped to minimize hair contamination of urine samples. Fecal pans and urine collection harnesses were placed on the steers after 0700 feed delivery on d 14. Clean plastic sheeting was placed behind each fecal collection pan to facilitate total fecal collection. While in the stanchions, steers remained on the twice daily feeding schedule (0700 and 1900).

Feces and urine were collected after the 0700 feed delivery over 5 consecutive d using fecal collection pans and urine collection bags. Fecal pans were emptied at the end of each 24 h period. Feces was weighed wet, mixed, and sampled in two 10% aliquots (by wet weight) prior to being frozen at -20^{o}C. Urine was collected in waterproof canvas pouches worn by the steers and aspirated off immediately via continuous vacuum into glass carboys. Squares of cheesecloth covered the end of the aspiration tube that was placed into the urine collection bag to further minimize contamination of urine samples. Urine bags were checked every 2 to 4 h to ensure total collection occurred. Carboys contained 200 mL of 6 *N* hydrochloric acid to maintain urine pH between 2-3. Urine was emptied from carboys as required, but at least every 24 h at which time carboys were replenished with acid. Urine was weighed and quantified volumetrically prior to the collection of two 10% aliquots (by volume), which were then stored at -20^{o}C until laboratory analysis.

Individual dietary feed ingredients and orts were dried using a forced air induction oven at 60^{o}C for 24 h or until no further water loss occurred. Dried samples were ground in a Wiley mill to pass through a 1 mm screen. One 10% aliquot of fecal material from each steer per period was dried at 60^{o}C in a forced air induction oven until no further water loss occurred (typically between 48 and 72 h). Fecal samples from each steer in each period were corrected for DM content and composited into a 50 g laboratory subsample. The remaining composited fecal material was stored at -20^{o}C. Ground feed and fecal samples were stored individually at room temperature in plastic bags until laboratory analysis. Subsamples were assayed for CP, NDF and ADF, ash, ether extract (EE), and LCFA concentrations.

Apparent total tract digestibility of each nutrient and fatty acid were calculated using the following equation:

Apparent total tract digestibility (%) = [(DM consumed)(Proportion of nutrient in feed DM) – (Fecal DM)(Proportion of nutrient in feces DM) / (DM consumed) (Proportion of nutrient in feed DM)] * 100.

The experiment was conducted as a Latin square design with steer as the experimental unit. Nutrient and fatty acid apparent total tract digestibility were analyzed using the PROC GLM method of SAS (SAS

Inst. Inc., Cary, NC). Means were separated using the PDIFF option and significance was declared at $P < 0.10$.

RESULTS AND DISCUSSION

Steer Performance

Steer performance data are presented in Table 3. Calculations were averaged across treatments for the duration of the digestibility trial, as interim body weights were not recorded during this experiment. Steers consumed between 1.75 and 2.44% of their body weight (DM basis).

Table 3. Steer performance.

Item	Average	SD	Range
DMI, lb/d	12.7	1.2	10.8 – 13.9
DMI, % BW	2.11	0.24	1.75 – 2.44
ADG, lb/d	1.35	0.46	0.33 – 0.85
G:F	0.104	0.028	0.067 – 0.140

Nutrient Digestibility

Nutrient digestibility data are presented in Table 4. No differences were observed for DM, OM, ADF, NDF, or N, digestibility.

Table 4. Intake and apparent total tract digestibility.

	Treatment[1]				
Item	DG	OIL	NO OIL	SEM[2]	*P*-value
Intake, lb/d					
DM	12.70	12.79	12.86	0.26	0.915
OM	11.47	11.75	11.84	0.24	0.544
ADF	3.46[a]	3.66[b]	3.73[b]	0.07	0.071
NDF	6.46[a]	6.88[b]	7.17[b]	0.13	0.022
EE	0.57[a]	0.57[a]	0.29[b]	0.01	<0.001
Nitrogen	0.31	0.31	0.31	0.01	0.172
Apparent total tract digestibility, %					
DM	59.2	57.7	58.5	1.7	0.825
OM	62.5	60.8	61.9	1.4	0.719
ADF	49.5	49.0	51.8	2.2	0.633
NDF	56.0	54.8	56.9	1.9	0.748
EE	86.6[a]	86.1[a]	75.6[b]	2.0	0.008
Nitrogen	53.6	55.9	57.4	2.2	0.508

[1]DG = supplement comprised of dried distillers grains with solubles; OIL = supplement comprised of high protein dried distillers grains with solubles, corn bran, and corn oil; NO OIL = supplement comprised of high protein dried distillers grains with solubles and corn bran.
[2]SEM = standard error of the mean.
[a,b]Means within a row lacking common superscripts differ.

Acid detergent fiber and NDF intake were lower (*P* = 0.071 and 0.022, respectively) for DG when compared to OIL and NO OIL. Differences in ADF and NDF intakes may be explained by differences in ADF and NDF concentrations of the dietary ingredients. The same components (corn bran and high protein dried distillers grains with solubles) comprised the OIL and NO OIL ration; these two feedstuffs were not used in the DG treatment. The ADF and NDF analyses indicated higher concentrations for OIL and NO OIL than that of DG. Apparent total tract digestibility of EE did not differ between DG and OIL; however, both values were greater than the apparent digestibility of NO OIL. Perhaps a difference of more than the 2% additional fat in the current experiment would have produced differences in EE digestibility. Apparent total tract N digestibility was not affected by treatment.

Fatty Acid Profiles

While differences in FA profiles can be calculated, results cannot truly be considered a measure of digestibility. Biohydrogenation processes in the rumen can alter FA concentrations such that certain FA leave the rumen in higher concentrations than what entered the rumen. Fatty acid retention was calculated as the difference between intake and fecal FA concentrations. If fecal FA concentrations were greater than that of the intake, calculations of apparent total tract FA digestibility were not performed or considered in statistical analysis. Fatty acid retention and apparent total tract digestibility estimates may not be accurate, and should be considered comparative estimates between treatments only, not as absolute values of FA concentrations.

Table 5. Apparent digestibility of fatty acids.

	Treatment[1]				
Fatty acid[2]	DG	OIL	NO OIL	SEM[3]	*P*- value
C17:0	37.44^{x}	1.32^{y}	15.56^{z}	4.76	0.002
C18:0	97.83^{x}	-5.18^{y}	43.69^{x,y}	26.77	0.073
C18:1*c*9	96.42^{x}	95.68^{x,y}	95.00^{y}	0.29	0.026
OCLA[4]	91.14^{x}	86.08^{x}	77.55^{y}	2.27	0.009
C20:3	70.01^{x}	68.08^{x}	56.94^{y}	1.94	0.003
C20:5	62.86^{x}	56.59^{x}	5.16^{y}	8.95	0.003
C22:2	61.92^{x}	59.51^{x}	47.75^{y}	2.18	0.004
Total *cis* C18:1	96.07^{x}	95.47^{y}	94.87^{z}	0.22	0.016
Total C20	74.06^{x}	77.80^{x}	54.79^{y}	5.16	0.029
Total CLA[5]	87.72^{x}	85.84^{x}	77.63^{y}	2.04	0.018

[1]DG = supplement comprised of dried distillers grains with solubles; OIL = supplement comprised of high-protein dried distillers grains with solubles, corn bran, and corn oil; NO OIL = supplement comprised of high protein dried distillers grains with solubles and corn bran.
[2]Fatty acids reported in µg fatty acid/mL plasma; expressed as number of carbons:number of double bonds.
[3]SEM = standard error of the mean.
[4]OCLA = other, unidentified conjugated linoleic acid.
[5]Total CLA = sum of OCLA and CLA*c*9*t*11.

Apparent digestibility of C17:0 was the lowest for OIL and greatest for DG; NO OIL was intermediate but different from both DG and OIL. C17:0 and other odd-carbon FA are typically considered *de novo* products of microbial fatty acid synthesis. Long chain FA may be fermented to form C17:0, which is most likely the case in the current experiment. C18:0 apparent digestibility was greatest for DG, lowest for OIL; NO OIL was intermediate but not different from either DG and OIL. The FA profiles of all dietary

ingredients included large quantities of various C18 FA; however, the form of the fat may account for the disparity in C18:0 digestibility between DG and OIL. C18:1*c*9 digestibility was greatest for DG, intermediate for OIL and least for NO OIL. Furthermore, total *cis*-C18:1 digestibility was greatest in DG, intermediate for OIL and least for NO OIL. The final groups of FA to display significance were C20:3, C20:5, C22:2, an unidentified CLA isomer (OCLA), total C20, and total CLA. In each instance, apparent digestibility was greatest in DG and OIL (Table 11). C18 and C20 isomers were present in the dietary treatments, and were greatest in the 2 fat supplemented groups. Differences in the apparent digestibility may simply be due to the dietary inclusion of these FA.

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