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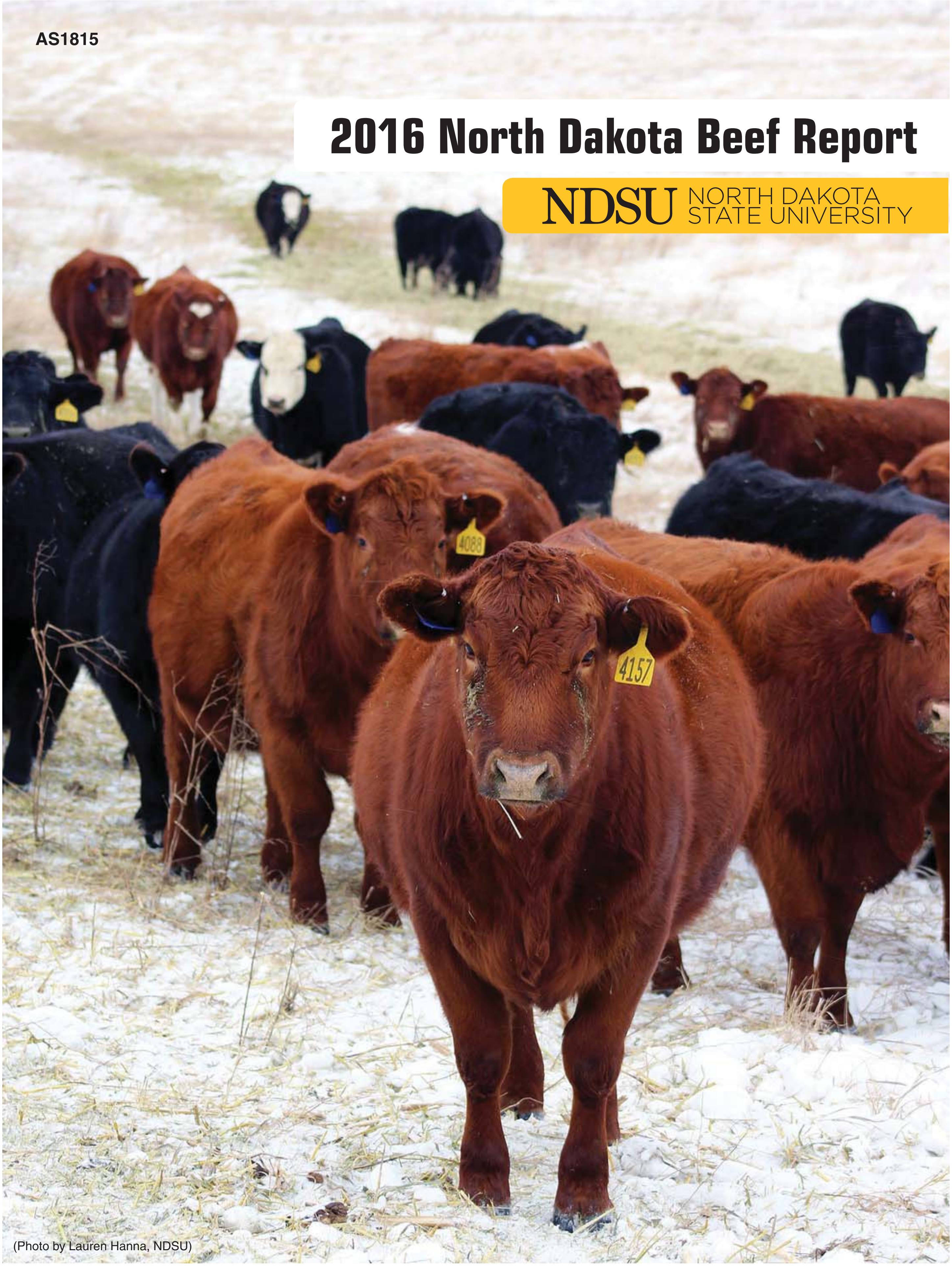

(Photo by Lauren Hanna, NDSU)

Growing and finishing feedlot performance of steers fed diets with rolled corn or rolled barley and medium- or low-fat dry distillers grains with solubles

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Feeding low- or medium-fat dried distillers grains with solubles (DDGS) at 26 percent of the diet dry matter to steers in growing and finishing diets appears to influence animal performance and carcass attributes similarly. When fed at similar diet dry-matter levels, rolled barley and rolled corn have similar effects on animal performance and carcass characteristics. Barley appears to result in similar feed efficiency with corn in the growing phase but showed improved feed efficiency in the finishing phase as a result of lower dry-matter intake and similar performance when compared with corn-based diets.

Summary

Crossbred steers (n = 154), with an initial body weight (BW) of 684 pounds, were used in a 189-day growing and finishing feedlot study evaluating the effects of corn or barley and two fat levels of dry distillers grains with solubles (DDGS). Steers were blocked by initial BW into four weight blocks and assigned randomly to one of 16 pens. Pens were assigned to one of four dietary treatments within weight blocks. Treatments were arranged as a 2 × 2 factorial with grain type (dry rolled corn or dry rolled barley) as one factor and fat content of DDGS (med-fat, 9.6 percent fat or low-fat, 5.8 percent fat) as the other factor. No grain type (corn or barley) by DDGS fat level (9.6 or 5.8 percent fat) interactions were detected ($P \geq 0.29$). Initial and final BW, average daily gain (ADG), dry-matter intake (DMI) and gain:feed (G:F; pounds BW gain/pound of feed consumed) were similar ($P \geq 0.11$) for low- and med-fat DDGS for the growing and finishing phases. Dressing percent, hot carcass weight (HCW), yield grade, longissimus muscle (LM) area, marbling score and back fat (BF) did not differ between DDGS treatments ($P \geq 0.18$). Steers fed corn- and barley-based diets had similar initial and final growing ($P \geq 0.16$) and finishing ($P \geq 0.17$) BW and ADG. Growing DMI was similar ($P = 0.37$) for corn and barley grain, resulting in similar G:F in the growing phase ($P = 0.26$). However, cattle on the corn finishing diets had greater ($P = 0.02$) DMI than barley, resulting in a tendency ($P = 0.08$) for barley to be more efficient than corn during the finishing phase. Overall, barley-fed steers had greater ($P = 0.002$) G:F than corn-fed steers. The carcass parameters dressing percent, HCW, yield grade, LM area, marbling score and BF were all similar ($P \geq 0.09$) for barley- and corn-fed cattle. Low-fat and medium-fat DDGS can be fed with corn and barley grain at similar levels without affecting animal performance. Additionally, rolled corn and rolled barley are comparable grain sources for growing and finishing feedlot steers.

Introduction

Corn distillers grain (DG) is produced at multiple ethanol plants in North Dakota. Primarily three moisture levels of corn distillers grain products are available: dry (about 90 to 95 percent dry matter, DDGS), modified (49 to 52 percent dry mater, MDGS) or wet (less than 48 percent dry matter, WDGS). The DDGS product is the most shelf stable and transportable due to the lower moisture content.

The current process for ethanol plants involves a step to remove corn oil (fat) from DG during ethanol production. Ethanol plants remove corn oil from DG for higher-value biodiesel and feed markets. Some plants remove a greater proportion of oil than others, resulting in fat levels of DG ranging from 4 to 10 percent, depending on the plant process.

Fat is high in energy, thus oil removal may alter the nutrient density of the resulting distillers grain feedstuff. While certain nutrients such as protein are slightly increased, the main concern is a reduction in energy value related to fat removal and its effect on animal performance.

A portion of the distillers grains produced in North Dakota is fed in the state, but the majority is exported to other locations in the U.S., Canada and other international locations. Typically, feedlot diets in the U.S. include corn grain as the primary grain source. However, in Canada and at times in North Dakota, barley

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is the primary grain source. Barley is higher in protein and fiber and lower in starch than corn; however, corn starch may be less digestible unless it is steam-flaked (Gibb and McAllister, 2003).

Concern has developed among nutritionists and feedlot managers that the variation in fat levels in the current distillers grains products on the market could affect animal performance when corn or barley is fed as the primary grain source. The objective of this study was to evaluate the effects on animal performance and carcass characteristics of feedlot cattle fed diets with moderate- or low-fat DDGS with rolled corn or rolled barley grain.

Experimental Procedures

All trial procedures were approved by the NDSU Animal Care and Use Committee. Crossbred steers (n = 154), with an initial BW of 684 pounds, were used in a 189-day feedlot study evaluating the effects of corn or barley and two fat levels of DDGS. The study, conducted at the NDSU Carrington Research Extension Center, included a 57-day growing phase (day 0 to day 57) and an approximately 132-day finishing phase (day 58 to end).

The heavy block (four pens) was marketed at day 180 and the remaining three blocks (12 pens) were marketed on day 194. Steers were consigned by North Dakota producers through the Dakota Feeder Calf Show producer feedout program.

Steers were implanted with 120 milligrams (mg) of trenbolone acetate and 24 mg of estradiol (Revalor S, Merck Animal Health) on day 0 and day 85. Upon arrival, steers were blocked by initial BW into four weight blocks and assigned randomly to one of 16 pens.

Pens were assigned to one of four dietary treatments within block in the 2 x 2 factorial design. Grain type (dry rolled corn or dry rolled barley), as one factor, was fed at 30 and 51 percent of the diet DM for the growing and finishing diets, respectively. Two fat levels of DDGS (med-fat, 9.6 percent fat or low-fat, 5.8 percent fat) were included as the other factor and fed at 26 percent diet DM in the growing and finishing diets.

Growing diets included 19 percent grass hay, 22 percent corn silage, and 3 percent vitamin and mineral supplement with an ionophore (DM basis). Finishing diets included 20 percent corn silage, and 3 percent supplement vitamin and mineral supplement with an ionophore (DM basis; Table 1 and 2).

Steers were weighed on day 0 and every 28 days until harvest. Steers were marketed at a commercial abattoir (Tyson Fresh Meats, Dakota City, Neb.). Hot carcass weights were obtained at harvest.

The following carcass attributes were evaluated by a trained grader after a 24-hour chill: 12th rib-fat depth; rib-eye area; kidney, pelvic and heart fat (KPH); marbling score; and U.S. Department of Agriculture

Table 1. Growing diets for steers fed two fat levels of dry distillers grains (DDGS) and corn or barley.

	Medium-fat DDGS		Low-fat DDGS	
Ingredient, % Dry Matter	Barley	Corn	Barley	Corn
Barley	30.2	–	30.3	–
Corn	–	30.8	–	30.7
DDGS, low-fat	–	–	25.6	25.5
DDGS, med-fat	25.7	25.6	–	–
Corn silage	22.1	21.9	22.0	21.8
Grass hay	18.6	18.4	18.5	18.4
Supplement	3.4	3.3	3.7	3.7
Diet dry matter, %	76.0	76.5	76.2	76.5
Crude protein, %	15.3	14.2	15.2	14.2
NEg, Mcal/lb.	49.1	51.8	47.5	50.1
Fat, %	4.1	4.6	3.1	3.6

Table 2. Finishing rations for steers fed two fat levels of dry distillers grains (DDGS) and corn or barley.

	Medium-fat DDGS		Low-fat DDGS	
Ingredient, % Dry Matter	Barley	Corn	Barley	Corn
Barley	50.9	–	51.1	–
Corn	–	51.4	–	51.5
DDGS, low-fat	–	–	25.9	25.8
DDGS, med-fat	26.1	25.9	–	–
Corn silage	19.5	19.4	19.4	19.3
Grass hay	0.7	0.8	0.7	0.6
Supplement	2.8	2.6	2.9	2.8
Diet dry matter, %	76.8	77.5	77.1	77.5
Crude protein, %	16.3	14.5	16.3	14.5
NEg, Mcal/lb.	56.5	60.9	55.0	59.3
Fat, %	4.2	5.0	3.2	4.0

yield grade. Performance and carcass characteristics were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.) and pen was the experimental unit.

Results and Discussion

No grain type (corn or barley) by DDGS fat level (9.6 or 5.8 percent fat) interactions were detected ($P \geq 0.29$); steers fed corn and barley responded to dietary treatments similarly across the two fat levels of DDGS fed at 26 percent of the diet dry matter, thus data is presented as main effects of DDGS fat level or grain type.

Initial and final body weight (BW) for the growing ($P \geq 0.18$) and finishing phases ($P \geq 0.11$) were similar for low- and med-fat DDGS (Table 3). Similarly, ADG, DMI and gain:feed (G:F; pounds BW gain/pound of feed consumed) were similar for growing ($P \geq 0.19$) and finishing ($P \geq 0.17$) phases for low- and med-fat DDGS. This is consistent with results observed in a previous feedlot study evaluating high- (12 percent fat), medium- (8 percent fat) and low- (4.5 percent fat) fat DDGS fed at 20 percent of the diet dry matter for finishing steers (Anderson and Engel, 2014).

In contrast, research conducted at Agriculture and Agri-food Canada, Lethbridge Research Centre, found that feeding growing feedlot diets to steers with 60 percent corn silage and 24.3 or 15 percent barley with 10 or 20 percent low- or medium-fat DDGS resulted in higher dry-matter intake and increased average daily gain for low-fat DDGS diets, compared with the medium-fat DDGS treatments (Ribeiro et al., 2016).

In the finishing phase of the Lethbridge study, barley replaced DDGS and levels were decreased to 5 and 10 percent for low- and medium-fat DDGS. The steers fed medium-fat DDGS in the finishing phase displayed improved feed efficiency conversion, compared with low-fat DDGS.

In a metabolism trial with diets similar to the current trial, Keomanivong et al. (2015) found that diets with low-fat DDGS had increased ruminal amylase activity. Additionally, this increased amylase activity was observed to be greater in diets with barley, compared with corn.

In a comparison of low-fat and traditional (high-fat) DDGS replacing corn in feedlot rations, Ceconi et al. (2012) observed lower rumen ammonia-nitrogen and greater volatile fatty acid concentrations in low-fat DDGS diets, compared with high-fat DDGS. The metabolism data from these studies (Keomanivong et. al., 2015 and Ceconi et. al., 2012) indicate that low-fat DDGS may enhance or higher-fat DDGS may suppress ruminal microorganism growth and activity.

In the current study, dressing percent, hot carcass weight, yield grade, longissimus muscle area,

Table 3. Growing and finishing performance of steers fed diets with two fat levels of dry distillers grains (DDGS) and corn or barley.

	DDGS		Grain			*P*-Value		Interaction
	Low-fat	Medium-fat	Barley	Corn	SEM	Grain	DDGs	Grain x DDGS
No. pens, n	8	8	8	8	–	–	–	–
Initial weight	683	690	690	682	3.38	0.16	0.18	0.70
Weight-d57[1]	860	870	873	857	7.96	0.17	0.43	0.37
Final weight[2]	1,398	1,419	1,413	1,393	12.86	0.30	0.11	0.40
ADG, d0-57	3.1	3.2	3.2	3.1	0.12	0.37	0.80	0.39
ADG, d58-end	4.0	4.1	4.1	4.1	0.07	0.80	0.33	0.42
ADG, d0-End	3.8	3.8	3.8	3.8	0.06	0.76	0.36	0.29
DMI, d 0-57	17.3	18.6	17.8	18.2	0.65	0.65	0.19	0.50
DMI, d58-end	22.1	23.0	21.7	23.4	0.42	0.02	0.17	0.35
DMI, d0-End	20.7	21.7	20.5	21.8	0.40	0.05	0.12	0.32
Feed:Gain, d0-57	5.6	5.9	5.5	5.9	0.18	0.15	0.29	0.69
Feed:Gain, d58-End	5.5	5.6	5.3	5.7	0.10	0.07	0.26	0.72
Feed:Gain, d0-End	5.5	5.7	5.4	5.8	0.08	0.002	0.20	0.85
Gain:Feed, d0-57	0.182	0.172	0.182	0.172	0.006	0.26	0.26	0.73
Gain:Feed, d58-End	0.184	0.180	0.187	0.177	0.003	0.08	0.25	0.73
Gain:Feed, d0-End	0.183	0.178	0.185	0.175	0.003	0.002	0.19	0.76

[1]The growing diet was fed from day 0 to day 57.
[2]Finishing ration was fed from day 58 to d 180 for four heavy pens and day 194 for 12 remaining pens.

marbling score and back fat did not differ among DDGS treatments ($P \geq 0.18$; Table 4). Anderson and Engel (2014) observed similar results for carcass characteristics in feedlot diets with three fat levels of distillers, with the exception of yield grade and marbling score.

Marbling score increased with increasing fat levels in DDGS and USDA yield grade was greater for high-fat but similar between medium- and low-fat DDGS diets. Similarly, Ribeiro et al. (2016) found carcass quality and liver abscesses were unaffected by type of DDGS and inclusion level.

In the current study, dietary fat levels ranged from 3.1 to 4.6 percent for the growing diets and 3.2 to 5 percent for the finishing diets (Table 1 and 2). Total dietary fat was 1 percent greater in the medium-fat DDGS diets, compared with the low-fat DDGS diets, when compared within the same grain type diets. Corn grain diets were slightly higher in total fat than the barley diets.

Steers fed corn- and barley-based diets had similar BW at trial initiation ($P = 0.16$), at the end of the growing phase ($P = 0.17$) and at trial completion ($P = 0.30$). Growing and finishing phase ADG was similar ($P \geq 0.37$) between grain sources. Growing DMI was similar ($P = 0.65$) for corn and barley grain (Table 3). However, cattle on the corn finishing diets had greater ($P = 0.02$) DMI than barley, resulting in similar ($P = 0.26$) growing phase G:F but had a tendency ($P = 0.08$) for barley to be more efficient than corn in the finishing phase.

Overall, barley-fed steers had greater ($P = 0.002$) G:F than corn-fed steers. Anderson and Ilse (2012) observed that as barley replaced corn at 0, 33, 67 and 100 percent of the diet for finishing steers, a linear decrease in feed intake, similar overall gains and a linear improvement in feed efficiency. Pritchard and Robbins (1991) substituted rolled barley for 0, 25, 50, 75 or 100 percent whole shelled corn in finishing diets. Increasing barley substitution resulted in decreased ADG and DMI but did not affect feed conversion.

We expected that as DMI decreased, ADG also would decrease. However, the lack of difference in feed conversion would support the idea that the energy value of barley may be underestimated (Owens et. al., 1997) and the energy value of corn may be overestimated (Zinn et al., 2002).

While corn is generally higher in starch than barley, differences in the kernel structure and starch matrix arrangement between these grains likely account for the differences in performance. The starch and protein fractions of barley are more digestible than they are in corn (Gibb and McAllister, 2003). The carcass parameters for dressing percent, HCW, yield grade, LM area, marbling score and BF were all similar ($P \geq 0.09$) for barley- and corn-fed cattle (Table 4).

Feeding low- or med-fat DDGS at 26 percent of the diet dry matter in the growing and finishing phases appears to influence animal performance and carcass attributes similarly. When fed at similar diet dry-matter levels, rolled barley and rolled corn have similar effects on animal performance and carcass characteristics. Additionally, barley appears to result in similar feed efficiency with corn in the growing phase but may improve feed efficiency, compared with corn in the finishing phase.

Table 4. Carcass performance for steers fed growing and finishing diets with two fat levels of dry distillers grains (DDGS) and corn or barley.

	DDGS		Grain			*P*-Value		Interaction
	Low-fat	Medium-fat	Barley	Corn	SEM	Grain	DDGs	Grain x DDGS
No. Pens, n	8	8	8	8	–	–	–	–
Shrunk dressing percent	63.6	63.2	63.0	63.9	0.004	0.09	0.46	0.88
Hot carcass weight, lb.	838	853	846	846	7.2	1.00	0.18	0.41
Yield grade[1]	3.1	3.1	3.1	3.2	0.12	0.47	0.85	0.73
Longissimus muscle area, sq in.	13.6	13.5	13.6	13.5	0.18	0.55	0.94	0.09
Marbling score[2]	455	475	451	478	10.15	0.10	0.19	0.29
Back fat, in.	0.54	0.53	0.52	0.55	0.02	0.38	0.84	0.50

[1]Yield grade is composite calculation of fat to lean yield in a carcass based on a relationship of hot carcass weight, rib-eye area, fat thickness and KPH; low values = lean carcasses.

[2]USDA Quality grades based on scores of 300-399 = select, 400-499 = low choice, 500-599 = average choice, 600-699 = high choice, 700+ = prime

Literature Cited

Anderson, V.L., and C.L. Engel. 2014. Effects of fat levels in distillers grain on feedlot finishing performance and carcass traits. Carringt. Res. Ext. Center, North Dakota State Univ. A Rep. Agric. Res. Ext. Cent. North Dakota 55:43-46.

Anderson, V.L., and B.R. Ilse. 2012. Effect of reciprocal levels of hull-less barley and corn in finishing diets on feedlot performance and carcass characteristics. North Dakota Beef Rep.:41–43.

Ceconi, I., A. Dicostanzo and G.I. Crawford. 2012. Effect of low-fat dried distillers grains inclusion in finishing diets on feedlot cattle total tract digestibility and ruminal fermentation parameters. Project AIC125. Available from: www.mncorn.org/sites/mncorn.org/files/research/final-reports/201306/MNCG AURI AIC 125 Effect of low fat DDGS on Rumen Fermenation Final Report.pdf

Gibb, D.J., and T.A. McAllister. 2003. Corn compared to barley in feedlot diets. In: Agriculture. Available from: www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/fcd5589/$FILE/proceedings_3rdcanbarsymp.pdf#page=53

Keomanivong, F.E., M.A. Rodenhuis, M.C. Ruch, M.S. Crouse, J.D. Kirsch, M.L. Bauer and K.C. Swanson. 2015. The impact of barley- vs. corn-based diets with variable distillers fat inclusion levels on rumen α-amylase activity. North Dakota Beef Rep.:11–13. Available from: www.ag.ndsu.edu/pubs/ansci/beef/as1775-03.pdf

Pritchard, R.H., and M.A. Robbins. 1991. Substitutlon of rolled barley for whole shelled corn in finishing diets for steers. South Dakota Beef Rep. 91:21–24. Available from: http://openprairie.sdstate.edu/cgi/viewcontent.cgi?article=1000&context=sd_beefreport_1991

Ribeiro, G.O., M. Hünerberg, D.J. Gibb and T.A. Mcallister. 2016. Effect of corn dried distillers' grains plus solubles (DDGS) with medium and low residual oil content on growth performance of growing and finishing steers fed diets containing corn silage. Lethbridge, AB.

Zinn, R.A., F.N. Owens and R.A. Ware. 2002. Flaking corn: Processing mechanics, quality standards, and impacts on energy availability and performance of feedlot cattle 1. J. Anim. Sci 80:1145–1156.

The influence of grain source and dried corn distillers grains plus solubles oil concentration on finishing cattle performance and feeding behavior

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The objective of this experiment was to determine the effect of grain type (corn vs. barley) and oil concentration of dried corn distillers grains plus solubles (DDGS; moderate = 7.9 percent vs. low = 4.5 percent) on finishing performance, feeding behavior and carcass characteristics. Our data indicate that including a lower-fat DDGS, as compared with a moderate-fat DDGS, in a finishing diet may not influence finishing performance, feeding behavior or carcass measurements and that feeding barley-based diets resulted in decreased dry-matter intake and improved gain efficiency.

Summary

Eighty-one steers (944 ± 7.7 pounds of body weight) were used to determine the effect of grain type (corn vs. barley) and oil concentration of dried corn distillers grains plus solubles (DDGS; moderate = 7.9 percent vs. low = 4.5 percent) on finishing performance, feeding behavior and carcass characteristics. Steers were allotted by body weight to three pens. Within each pen, steers were assigned randomly to one of four dietary treatments (n = six or seven steers per treatment): 1) corn and moderate-fat DDGS, 2) corn and low-fat DDGS, 3) barley and moderate-fat DDGS and 4) barley and low-fat DDGS. Intake and feeding behavior traits were calculated from data generated via the Insentec feeding system. Steers were slaughtered with an average body weight of 1,473 ± 9.7 pounds and were marketed in two groups at 119 (n = 40) and 155 (n = 41) days. Final body weight and average daily gain were not affected ($P \geq 0.68$) by grain type or DDGS oil concentration. Dry-matter intake decreased ($P = 0.002$) and gain:feed increased ($P = 0.01$) in steers fed barley-based diets. Daily visits to the feeder decreased ($P = 0.05$), but time eating per visit increased ($P = 0.03$) in steers fed barley-based diets,

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compared with those fed corn-based diets. We found no effect ($P \geq 0.26$) of treatment on carcass traits: hot carcass weight; marbling; rib-eye area; 12th rib fat; and kidney, pelvic and heart fat. These data indicate steers fed barley-based diets had improved gain efficiency, having a greater gain:feed than steers fed corn-based diets. Oil concentration of DDGS had no effect on finishing performance. Steers fed barley-based diets spent more time eating per visit but visited the bunk less per day than those steers fed corn-based diets, which could account for the lower dry-matter intake in steers fed barley diets. Carcass traits were not affected by either grain type or oil concentration of DDGS. Our data indicate that including a lower-fat DDGS, as compared with a moderate-fat DDGS, in a finishing diet may not influence finishing performance, feeding behavior or carcass measurements, and that feeding barley-based diets resulted in decreased dry-matter intake and improved gain efficiency.

Introduction

Feed costs represent the largest direct cost in beef production. Utilizing different grain types can influence feed efficiency. Corn dried distiller grains plus solubles (DDGS) is a valuable feed product utilized in finishing diets (Klopfenstein et al., 2008) and may influence growth performance differently, depending on grain source and processing.

The ethanol industry is evolving and changing its production practices. This has resulted in changes in the nutrient composition of the final coproduct available as a feedstuff.

Decreasing fat in the diet has been shown to decrease average daily gain in finishing steers (Zinn, 1989). However, increasing oil concentration in the diet also can have a negative effect on digestibility of nonlipid energy sources (Jenkins, 1993), so DDGS with a lower oil concentration actually could provide beneficial affects to ruminants.

Therefore, research is needed to determine what affect DDGS oil concentration has on finishing cattle performance, feeding behavior and carcass quality when commonly fed feed grains are fed. We hypothesize that grain type and DDGS oil concentration will influence finishing performance and feeding behavior.

Our objectives were to determine the effects of grain source (corn vs. barley) and DDGS oil concentration (4.5 vs. 7.9 percent DM) on finishing performance, feeding behavior and carcass quality.

Experimental Procedures

All procedures with animals were approved by the North Dakota State University (NDSU) Animal Care and Use Committee. Eighty-one steers (944 ± 7.7 pounds of body weight) predominately of Angus, Simmental and Shorthorn breeding were used in a 2 x 2 factorial arrangement of treatments (grain type [rolled corn vs. barley] and DDGS oil concentration [moderate = 7.9 percent vs. low = 4.5 percent]; Tables 1 and 2).

The steers were allotted into three pens (light, medium and heavy pens; n = 27 per pen) and housed at the NDSU Beef Cattle Research Complex. Within each pen, steers were assigned randomly to one of four experimental treatment diets (n = six or seven steers per treatment within pen; n = 20 or 21 per treatment): 1) corn with moderate-fat DDGS, 2) corn with low-fat DDGS, 3) barley with moderate-fat DDGS, and 4) barley with low-fat DDGS.

Diets were formulated to meet or exceed recommendations for dietary intake protein (DIP), metabolizable protein (MP), vitamins and minerals (NRC, 1996). Diets were offered for ad libitum intake. Steers were adapted to experimental diets by transitioning to the final diet during a 21-day period. Intake

Table 1. Diet composition.

	Treatment			
	Rolled Corn		Rolled Barley	
Dietary Component, % of DM	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS
Rolled corn	50	50	-	-
Barley	-	-	50	50
DDGS	25	25	25	25
Corn silage	20	20	20	20
Limestone	2	2	2	2
Urea	0.15	0.15	-	-
Salt	0.05	0.05	0.05	0.05
Vitamin premix[1]	0.01	0.01	0.01	0.01
Mineral premix[2]	0.05	0.05	0.05	0.05
Rumensin[3]	0.02	0.02	0.02	0.02
Tylan[4]	0.01	0.01	0.01	0.01
Fine-ground corn	2.71	2.71	2.86	2.86

[1]Contained 48,510 kilo International Units per kilogram (kIU/kg) vitamin A and 4,630.5 kIU/kg vitamin D.
[2]Contained 3.62 percent calcium, 2.56 percent copper,16 percent zinc, 6.5 percent iron, 4 percent manganese, 1.050 milligrams per kilogram (mg/kg) iodine and 250 mg/kg cobalt.
[3]Contained 176.4 grams (g) monensin/kg premix.
[4]Contained 88.2 g tylosin/kg premix.

Table 2. Analyzed nutrient concentration of diets (DM basis).

	Treatment			
	Rolled Corn		Rolled Barley	
Dietary Component, % of DM	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS
Crude protein	13.7	14.0	14.8	14.8
Neutral detergent fiber	29.8	31.8	32.6	34.7
Acid detergent fiber	11.9	12.5	13.3	14.1
Ether extract	3.49	4.18	2.40	3.11
Calcium	1.09	1.16	1.15	1.07
Phosphorus	0.46	0.46	0.50	0.48
Starch	43.6	42.1	37.1	37.5

and feeding behavior traits were calculated from data generated via the Insentec feeding system.

Steers were slaughtered with an average body weight of 1,473 ± 9.7 pounds and were marketed in two groups at 119 (n = 40) and 155 (n = 41) days. Data were analyzed as a completely randomized block (days to slaughter) design using the generalized linear means mixed procedure of SAS with a 2 x 2 factorial arrangement of treatments. Data were considered significant when $P \leq 0.05$ and a tendency was considered when $0.05 < P \leq 0.10$.

Results and Discussion

Initial and final body weight did not differ between grain types or DDGS oil concentration (Table 3). We found no difference in average daily gain between grain types or DDGS oil concentration. Dry-matter intake decreased ($P = 0.002$) in steers fed barley, as compared with corn; however, we found no differences in dry-matter intake between DDGS oil concentrations. Barley-fed steers had increased ($P = 0.01$) gain:feed, compared with corn-fed steers, and we found no differences between DDGS oil concentrations.

No differences were observed in hot carcass weight; marbling score; rib-eye area; 12th rib fat; or kidney, pelvic and heart fat among steers fed different grain types or oil concentration of DDGS. We found a decrease ($P = 0.05$) in visits to the bunk per day in steers fed barley, compared with those fed corn, but no differences were found between DDGS oil concentrations (Table 4).

Time eating per visit increased ($P = 0.03$) in barley-fed steers. We observed a tendency ($P = 0.06$) for time eating per visit with DDGS oil concentrations to increase in low-oil-concentration DDGS. We found a tendency ($P = 0.09$) for a decrease in eating rate per visit for steers fed moderate-oil-concentration DDGS. We also observed a tendency ($P = 0.06$) for a decrease in eating rate per meal in barley-fed steers. No differences were found in eating rate per meal between oil concentrations of DDGS.

Research conflicts in regard to the effects on gain efficiency when different grain types are fed in finishing diets. These differences could be due to a number of variables, such as diet composition, grain source (field by field, state and region variety) or grain variety. Differences in dry-matter intake appear to be the driving influence behind the improved efficiency observed in this study.

Intake can be affected by roughage source and inclusion level in the diet and grain processing and, therefore, differences in each experiment's diets could affect intake. Our results were in agreement with the data suggesting that feeding barley improves gain efficiency, as compared with feeding corn.

Bremer et al. (2015) studied the effect of increasing distillers products with a reduced oil concentration on cattle performance to determine if the oil concentration affects average daily gain. Their results indicated an increase in average daily gain with increasing reduced-oil wet distillers grains plus solubles (7.9 percent fat) similar to normal-oil wet distillers grains plus solubles. Similar to our results, they also reported no differences in growth performance when feeding reduced-oil-concentration (7.9 percent fat) wet distillers grains plus solubles, compared with a normal wet distillers grains plus solubles (11.3 percent fat).

Steers fed barley-based diets spent more time eating per visit but visited the bunk less per day than those steers fed corn-based diets, which could account for the lower dry-matter intake in steers fed barley diets.

Steers fed moderate-oil-concentration DDGS tended to spend less time at the bunk per visit, which could be associated with changes in ruminal fermentation and digestion. More research is needed to better understand the effects that changes in feeding behavior induced by feeding different feeds have on growth performance.

In conclusion, utilizing barley, in comparison with corn, in finishing cattle diets decreased dry-matter intake, increased gain:feed and altered feeding behavior in cattle consuming a 90 percent concentrate diet without affecting carcass mass or quality. Utilizing a lower-oil-concentration DDGS did not significantly impact performance or carcass quality.

We found a tendency for oil concentration of DDGS to alter feeding behavior; however, this did not seem to influence performance. Therefore, utilizing DDGS with a lower oil concentration in finishing diets likely will not greatly affect performance or carcass quality of finishing cattle.

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Literature Cited

Bremer, M.L., M.E. Harris, J.A. Hansen, K.H. Jenkins, M.K. Luebbe and G.E. Erickson. Feeding value of de-oiled wet distillers grains plus solubles relative to normal when fed with either dry-rolled corn or steam-flaked corn in beef finishing diets. Nebraska Beef Report 852, 77-79. 2015.

Jenkins, T.C. 1993. Lipid metabolism in the rumen. J. Dairy Sci. 76:3851-3863.

Klopfenstein, T.J., G.E. Erickson and V.R. Bremer. 2008. Board-invited review: Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86:1223-1231.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th Ed. ed. National Academy Press, Washington, D.C.

Zinn, R.A. 1989. Influence of level and source of dietary fat on its comparative feeding value in finishing diets for steers: feedlot cattle growth and performance. J. Anim Sci. 67:1029-1037.

Table 3. Effects of grain source and oil level of dried distillers grains plus solubles on feeding behavior in finishing cattle.

	Treatment							
	Rolled Corn		Rolled Barley					
Item	Low-fat DDGS	Mod-fat DDGS	Low-fat DDGS	Mod-fat DDGS	SEM[a]	Grain	DDGS	Grain*DDGS
Initial weight, lb.	937	939	952	937	15.6	0.74	0.66	0.57
Final weight, lb.	1,464	1,482	1,479	1,462	19.4	0.89	0.94	0.34
Average daily gain, lb./day	3.95	4.06	4.01	3.97	0.088	0.79	0.68	0.41
Dry matter intake, lb.	26.7	26.2	24.9	24.9	0.49	0.002	0.85	0.75
Gain:feed	0.149	0.154	0.161	0.159	0.0034	0.01	0.62	0.24
Hot carcass weight, lb.	904	908	897	897	13.9	0.52	0.82	0.85
Marbling score[b]	508	477	475	483	26.8	0.62	0.67	0.46
Rib-eye area, in.^{2}	13.7	14.2	13.8	13.6	0.05	0.55	0.59	0.26
12th rib fat, in.	0.539	0.500	0.504	0.528	0.0164	0.96	0.86	0.45
Kidney, pelvic, and heart fat, %	1.84	1.82	1.83	1.79	0.042	0.56	0.53	0.84

[a]Standard error of the mean (n = 20).
[b]400 to 499 = small, 500 – 599 = modest.

Table4. Effects of grain source and oil level of dried distillers grains plus solubles on feeding behavior in finishing cattle.

	Treatment							
	Rolled Corn		Rolled Barley					
Item	Low-fat DDGS	Mod-fat DDGS	Low-fat DDGS	Mod-fat DDGS	SEM[a]	Grain	DDGS	Grain*DDGS
Events, per day								
Visits	27.1	28.6	23.1	26.2	1.6	0.05	0.16	0.60
Meals	7.35	7.62	7.61	7.55	0.257	0.71	0.68	0.53
Time eating, min.								
Per visit	3.46	3.18	4.21	3.55	0.248	0.03	0.06	0.44
Per meal	12.67	11.30	11.68	11.88	0.561	0.71	0.29	0.17
Eating rate, lb.								
Per visit	1.03	0.99	0.20	1.00	0.069	0.17	0.09	0.20
Per meal	3.73	3.53	3.37	3.35	0.146	0.06	0.42	0.53
Per min	0.300	0.313	0.298	0.287	0.0104	0.17	0.95	0.25

[a]Standard error of the mean (n = 20).

Effect of grain type and dried distillers grain with solubles oil concentration on site of digestion

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The objective of this experiment was to determine the effects of grain type (corn vs. barley) and oil concentration of dried distillers grains plus solubles (DDGS; moderate = 7.9 percent vs. low = 4.5 percent ether extract) on site of digestion. Our data indicate that including a lower-fat DDGS, as compared with a moderate-fat DDGS, in a finishing diet may not have an influence on site of digestion of nonlipid nutrients in finishing cattle.

Summary

Eight Holstein steers (1,579 ± 137 pounds) were used in a 4 x 4 Latin Square design consisting of four periods and four dietary treatments, with two steers assigned per treatment per period to determine the impact of grain type (corn vs. barley) and DDGS oil concentration (DDGS; moderate = 7.9 percent vs. low = 4.5 percent) on intake and total-tract digestibility. Apparent ruminal dry-matter and intestinal digestibility as a percentage of intake decreased ($P \leq 0.03$) in steers fed corn-based diets. We found no difference in total-tract dry-matter digestibility between grain types. No effects on dry-matter intake or digestibility were observed between steers fed low- and moderate-oil concentrations of DDGS. Starch intake was greater ($P = 0.01$) in steers fed corn-based diets, and total-tract starch digestibility was greater ($P = 0.01$) in steers fed barley-based diets. We found no effects on intake or digestibility of starch between low- and moderate-oil concentrations of DDGS. Intake of total lipids increased ($P < 0.001$) in steers fed corn diets as well as in steers fed diets with moderate oil of DDGS. Apparent ruminal lipid digestibility increased ($P = 0.02$) in steers fed moderate-oil DDGS, while intestinal lipid digestibility as a percent of intake was increased ($P = 0.04$) in steers fed low-oil DDGS. No differences were found in lipid apparent ruminal digestibility or lipid intestinal digestibility between grain types. Total-tract lipid digestibility was increased ($P < 0.001$) in steers fed moderate-oil DDGS. In summary, utilizing barley, as compared with corn, in finishing diets increases total-tract starch digestion, and decreasing the oil concentration of DDGS had no effect on site of digestion or total-tract digestibility of dry matter, crude protein and starch of the diets, although lipid digestibility was greater in steers fed moderate-fat DDGS. Therefore, utilizing low-oil DDGS in finishing diets may not affect digestibility of nonlipid nutrients in finishing cattle.

Introduction

Feed costs represent the largest expense in beef production. Grain type, specifically feeding barley vs. corn, can result in differences in digestibility and performance (Gozho and Mutsvangwa, 2008). Corn dried distiller grains plus solubles (DDGS) is a valuable feed product utilized in finishing diets (Klopfenstein et al., 2008) and may influence growth performance differently, depending on grain source and processing.

The beef cattle National Research Council (NRC, 1996) reports DDGS having 11 percent ether extract on a dry-matter basis. This concentration has changed, however, as the ethanol industry has evolved and extracts more oil from the corn, resulting in DDGS with a lower oil content of approximately 4 to 5 percent. This raises the question of what happens to the digestibility of this low-oil DDGS product.

We hypothesized that grain type and DDGS oil concentration would have an effect on site of digestion. Our objectives were to determine the effect of grain type and DDGS oil concentration on ruminal, intestinal and total-tract digestibility.

Experimental Procedures

All animal care and handling procedures were approved by the NDSU Animal Care and Use Committee. Eight Holstein steers (1,579 ± 137 pounds) were used in a 4 x 4 Latin Square design consisting of four periods and four dietary treatments, with two steers assigned per treatment per period to determine the impact of grain type (corn vs. barley) and DDGS oil concentration (DDGS; moderate = 7.9 percent vs. low = 4.5 percent; Tables 1 and 2) on intake and total tract digestibility.

Steers were housed in individual tie stalls in a temperature-controlled environment at the North Dakota State University Animal

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Nutrition and Physiology Center. Dietary treatments were offered to ensure ad libitum intake and 6 percent feed refusal daily. Treatments were 1) corn with moderate-fat DDGS, 2) corn with low-fat DDGS, 3) barley with moderate-fat DDGS and 4) barley with low-fat DDGS.

Steers were adapted from a high-forage diet to a high-concentrate diet during a 21-day period. Then steers were adapted to their respective treatments during a seven-day period followed by a seven-day sample (feed, feed refusals, feces, and duodenal and ileal digesta) collection period. Finally, a 10-day transition period occurred in which steers were transitioned to their next treatment diet.

Data were analyzed as a replicated 4 x 4 Latin Square, with a 2 x 2 factorial arrangement of treatments using generalized least square means mixed procedure in SAS. A *P*-value of less than or equal to 0.05 was considered a significant difference, while a *P*-value of greater than 0.05 but less than 0.10 was considered a tendency.

Results and Discussion

We found no differences in dry-matter intake between grain types (Table 3). Apparent ruminal dry-matter digestibility decreased (P = 0.02) in steers fed corn-based diets. Intestinal dry-matter digestibility as a percent of intake decreased (P < 0.03) in steers fed barley-based diets.

We observed no difference in total-tract dry-matter digestibility between grain types. No effects on dry-matter intake or digestibility were observed between steers fed low- or moderate-oil concentrations of DDGS. We also found no differences in crude protein intake between grain types.

We observed a tendency for apparent ruminal crude protein digestibility (percent of intake) to decrease (P = 0.06) in steers fed corn-based diets. We found a tendency (P = 0.09) for intestinal crude protein digestibility as a percent of intake to decrease in steers fed barley-based diets.

No differences were found in total-tract crude protein digestibility between grain types. No effects were found on crude protein intake or digestibility between steers fed low- or moderate-oil concentrations of DDGS.

Starch intake was greater (P = 0.01) in steers fed corn-based diets than in steers fed barley-based diets. Apparent ruminal starch digestibility and intestinal digestibility as a percent of intake did not differ between grain types. Total-tract starch digestibility decreased (P = 0.01) in corn-based diets.

We found no effects on intake or digestibility of starch between low- and moderate-oil concentrations of DDGS. Intake of total lipids increased (P < 0.001) in steers fed

Table 1. Dietary composition.

	Corn		Barley	
Dietary Component, % of dry matter	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS
Rolled corn	50	50	–	–
Rolled barley	–	–	50	50
DDGS	25	25	25	25
Corn silage	20	20	20	20
Limestone	2	2	2	2
Urea	0.15	0.15	–	–
Salt	0.05	0.05	0.05	0.05
Vitamin premix[1]	0.01	0.01	0.01	0.01
Mineral premix[2]	0.05	0.05	0.05	0.05
Rumensin[3]	0.02	0.02	0.02	0.02
Tylan[4]	0.01	0.01	0.01	0.01
Fine-ground corn	2.46	2.46	2.61	2.61
Chromium oxide	0.25	0.25	0.25	0.25

[1]Contained 48,510 kilo International Units per kilogram (kIIU/kg) vitamin A and 4,630.5 kIU/kg vitamin D.

[2]Contained 3.62 percent calcium, 2.56 percent copper,16 percent zinc, 6.5 percent iron, 4 percent manganese, 1.050 milligrams per kilogram (mg/kg) iodine and 250 mg/kg cobalt.

[3]Contained 176.4 grams (g) monensin/kg premix.

[4]Contained 88.2 g tylosin/kg premix.

Table 2. Analyzed nutrient concentration of diets.

	Rolled Corn		Rolled Barley	
Dietary Component, % of dry matter	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS
Crude protein	13.7	14.0	14.8	14.8
Neutral detergent fiber	29.8	31.8	32.6	34.7
Acid detergent fiber	11.9	12.5	13.3	14.1
Ether extract	3.49	4.18	2.40	3.11
Calcium	1.09	1.16	1.15	1.07
Phosphorus	0.46	0.46	0.50	0.48
Starch	43.6	42.1	37.1	37.5

Table 3. Effects of grain source and oil level of dried distillers grains plus solubles on nutrient intake and site of digestion.

	Treatment							
	Rolled Corn		Rolled Barley					
Items	Low-fat DDGS	Mod-fat DDGS	Low-fat DDGS	Mod-Fat DDGS	*P*-value SEM	Grain	DDGS	Grain*DDGS
Intake, lb.								
Dry matter	33.3	31.5	32.4	32.6	1.34	0.99	0.46	0.37
Crude protein	4.94	4.83	4.87	4.85	0.218	0.89	0.64	0.76
Starch	17.9	16.1	14.9	15.0	0.767	0.01	0.28	0.21
Lipid	1.35	1.69	0.96	1.47	0.050	<0.001	<0.001	0.03
Digestiblity, % of intake								
Apparent ruminal								
Dry matter	46.2	43.1	51.7	53.7	3.22	0.02	0.85	0.37
Crude protein	-18.6	-19.4	-1.15	-7.2	9.32	0.06	0.60	0.67
Starch	88.3	93.3	90.9	91.8	1.8	0.78	0.11	0.26
Lipid	-58.8	-45.3	-75.1	-22.5	14.24	0.82	0.02	0.13
Intestinal								
Dry matter	33.2	35.6	26.7	25.8	3.16	0.01	0.78	0.53
Crude protein	96.6	96.8	80	87.4	9.32	0.09	0.55	0.55
Starch	7.99	3.21	7.58	7.01	1.803	0.36	0.14	0.24
Lipid	140	130	152	107	13.7	0.68	0.04	0.15
Total Tract								
Dry matter	79.5	78.7	78.6	79.1	0.94	0.78	0.86	0.45
Crude protein	78.7	77.6	78.8	79.8	1.08	0.3	0.94	0.33
Starch	96.6	96.9	98.3	98.8	0.7	0.01	0.49	0.93
Lipid	81.1	85.5	77.5	84.4	1.32	0.07	<0.001	0.25

[a]Standard error of the mean (n = 8).

corn diets as well as in steers fed diets with moderate oil of DDGS. Apparent ruminal lipid digestibility increased ($P = 0.02$) in steers fed moderate oil DDGS, while intestinal lipid digestibility as a percent of intake was increased ($P = 0.04$) in steers fed low-oil DDGS.

No differences were found in lipid apparent ruminal digestibility or lipid intestinal digestibility between grain types. Total-tract lipid digestibility was increased ($P < 0.001$) in steers fed moderate-oil DDGS and tended ($P = 0.07$) to increase in steers fed corn-based diets.

Little is known about how the oil concentrations of DDGS affect the site of digestion in finishing cattle. Jolly-Breithaupt et al. (2015) reported a decrease in total-tract digestibility of fat in de-oiled condensed distillers solubles vs. normal condensed distillers solubles, similar to what we observed in our study.

This might indicate that the animal utilizes more of the lipid from the moderate-oil DDGS than the low-oil DDGS, which supports the theory that the lipids in the lower-oil-concentration products may not be as digestible. This theory needs to be studied further to know the full effects and implications that can be associated with feeding ethanol coproducts with lower-oil concentrations.

In conclusion, utilizing barley, as compared with corn, in finishing diets increases total tract starch digestion, which may increase the amount of volatile fatty acids and glucose available to the animal and potentially provide more energy to the animal, resulting in improved growth performance.

Also, decreasing the oil concentration of DDGS had no effect on the site of digestion or total-tract digestibility of dry matter, crude protein or starch of the diets. Therefore, utilizing low-oil DDGS in finishing diets may not affect digestibility of nonlipid nutrients in finishing cattle.

Literature Cited

Gozho, G.N., and T. Mutsvangwa. 2008. Influence of carbohydrate source on ruminal fermentation characteristics, performance, and microbial protein synthesis in dairy cows. J. Dairy Sci. 91:2726-2735.

Jolly-Breithaupt, M.L., A.L. Schreck, J.L. Harding, J.C. MacDonald, T.J. Klopfenstein and G.E. Erickson. Nutrient digestibility and ruminal pH of finishing diets containing dry milling byproducts with and without oil extraction. Nebraska Beef Report 832, 80-82. 2015.

Klopfenstein, T.J., G.E. Erickson and V.R. Bremer. 2008. Board-invited review: Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86:1223-1231.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th Ed. ed. National Academy Press, Washington, D.C.

The influence of dry-rolled corn particle size and dried corn distillers grains plus solubles inclusion levels on rumen pH, ammonia and VFA concentration, total in vitro ruminal gas production and enteric methane emission

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The objectives of this study were to determine the influence of dry-rolled corn particle size and dried distillers grains with solubles (DDGS) inclusion level on ruminal pH, ammonia (NH3) and volatile fatty acid (VFA) concentrations and in vitro ruminal gas production and methane (CH4) emission. No differences in rumen pH were seen among treatments. Rumen ammonia was greater in steers receiving 20 percent DDGS, while steers fed fine-rolled corn had greater concentrations of butyric acid than steers fed coarse-rolled treatments. Total gas production and methane concentration were unaffected by treatment.

Summary

Eight cannulated Holstein steers (1,159 ± 8 pounds) were used in a 4 x 4 Latin square design to examine the impact of coarse (2.5 millimeter [mm]) vs. fine-rolled corn (1.7 mm) and 20 vs. 40 percent DDGS inclusion on ruminal pH, ammonia and VFA concentrations, in vitro ruminal gas production and enteric methane emission. Steers were housed in individual tie stalls (3.3 by 7.2 feet) in a temperature-controlled environment at the NDSU Animal Nutrition and Physiology Center. Dietary treatments (Table 1) were offered for ad libitum intake and consisted of 1) 65 percent coarse-rolled corn and 20 percent DDGS, 2) 45 percent coarse-rolled corn and 40 percent DDGS, 3) 65 percent fine-rolled corn and 20 percent DDGS and 4) 45 percent fine-rolled corn and 40 percent DDGS. Steers were provided experimental diets for 14 days (seven days of diet adaptation and seven days of data collection). Results indicate no differences among dietary treatments in overall rumen pH. The concentration of NH_3 was greater ($P = 0.02$) in cattle consuming 20 percent DDGS. Butyric acid concentration was greater ($P = 0.02$) in cattle fed fine-rolled corn, while no other VFAs differed among treatments. No differences were observed in the amount and rate of total gas produced or concentration of methane emitted.

Introduction

Ethanol is a commonly produced alternative fuel that largely is manufactured using corn grown in the Midwestern U.S. The production of ethanol also supplies a byproduct known as dried corn distillers grains plus solubles (DDGS), which provides a valuable feed source for ruminants. Ensuring the amount of corn grown to produce ethanol also allows much of the crop to be fed to cattle, which has proven to be extremely beneficial in regards to animal efficiency and environmental sustainability.

Methane is a greenhouse gas produced during enteric fermentation of feed in ruminants and can be influenced by feed intake, type of carbohydrate in the diet, feed processing methods and changes in ruminal microflora. The high levels of starch found in corn-based rations have been shown to be beneficial to the environment because cattle fed these diets produce less methane due to reduced hydrogen production in the rumen. In addition, a greater feed efficiency provides a shorter time to market, allowing less opportunity of methane emission to occur (Swanson et al., 2014).

Unfortunately, in regard to distillers grains and methane production, variable results have been observed. For example, distillers grains contain greater concentrations of fat and fiber. The fat found in these byproducts may reduce or eliminate protozoa as well as methanogenic bacteria in the rumen, helping mitigate CH4 emissions by altering the hydrogen sink through bio-hydrogenation via propionate production (Massé et al., 2014). Fiber, however, is concentrated nearly three-fold during ethanol production and possesses greater methanogenic potential than that of starch (Behlke et al., 2008).

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While a diet containing corn and DDGS offers a desirable nutrient profile, careful consideration must be taken when formulating such rations. Corn distillers grains commonly are mixed with cattle rations in ranges from 10 to 50 percent (dry-matter [DM] basis), depending on the goal of supplementation. When used as a protein source, 10 to 15 percent inclusion usually is the most desirable, while an addition of 20 to 30 percent is more common when used as an energy source, with approximately 40 to 50 percent generally the upper limit (Klopfenstein et al., 2008).

The available information on particle size reduction of rolled corn is limited, but Loe et al. (2006) reported an increase in intake when offering finely vs. coarsely rolled corn. Grain particle size, level of rumen carbohydrate fermentation and level of neutral detergent fiber (NDF) also will impact rumen pH and may cause acidosis. With this in mind, developing feeding strategies is important to determine the optimum corn processing method and DDGS inclusion rates to obtain the greatest benefit from each ration.

Experimental Procedures

All procedures involving animals were approved by the NDSU Animal Care and Use Committee. Eight cannulated Holstein steers (1,159 ± 8 pounds) were used in a 4 x 4 Latin square-designed experiment to examine the impact of dry-rolled corn processing and DDGS inclusion rate on ruminal pH, ammonia concentration, VFA profile, ruminal gas production and in vitro enteric methane emission in cattle.

Steers were housed in individual stalls in a temperature-controlled environment at the NDSU Animal Nutrition and Physiology Center. Dietary treatments (Table 1) were offered to ensure ad libitum intake and approximately 6 percent feed refusal daily. Treatments consisted of 1) coarse-rolled (2.5 millimeters [mm]) and 20 percent DDGS, 2) coarse-rolled corn and 40 percent DDGS, 3) fine-rolled corn (1.7 mm) and 20 percent DDGS and 4) fine-rolled corn and 40 percent DDGS.

Diets were formulated to meet or exceed National Research Council (NRC) recommendations for degradable intake protein (DIP), metabolizable protein (MP), vitamins and minerals (NRC, 1996). Before the initiation of the experiment, steers were adapted to a high-grain diet during a period of 21 days. A preliminary period of seven days on the animals' respective treatment preceded seven days of sample collection for each period. This was followed by a three-day rest period in which steers were offered an intermediate diet to allow all animals to return to a basal level.

Ruminal pH was determined using a wireless pH sensor (Kahne Ltd., Auckland, New Zealand), with measurements taken every five minutes from days 3 to 5 of the collection period. Sensors were calibrated with 7 and 4 pH solutions before each period and were inserted manually into the rumen and placed in the liquid phase of the ventral sac.

Ammonia and VFA concentrations were quantified using a subsample of approximately 200 milliliters (mL) of rumen fluid collected from days 3 to 5 (at 2 a.m., 8 a.m., 2 p.m. and 8 p.m. on day 3; 4 a.m., 10 a.m., 4 p.m. and 10 p.m.

Table 1. Dietary composition and analyzed nutrient concentration of diets (DM basis).

	Coarse-rolled corn		Fine-rolled corn	
Dietary component, % of DM	20% DDGS	40% DDGS	20% DDGS	40% DDGS
Coarse-rolled corn	65.0	45.0	–	–
Fine-rolled corn	–	–	65.0	45.0
Dried corn distillers grains with solubles	20.0	40.0	20.0	40.0
Grass-legume hay	5.0	5.0	5.0	5.0
Corn silage	5.0	5.0	5.0	5.0
Limestone	1.56	1.90	1.56	1.90
Urea	0.85	–	0.85	–
Salt	0.20	0.20	0.20	0.20
Vitamin premix	0.01	0.01	0.01	0.01
Trace mineral premix	0.05	0.05	0.05	0.05
Rumensin/Tylan premix	0.03	0.03	0.03	0.03
Fine-ground corn	2.05	2.56	2.05	2.56
Chromium oxide	0.25	0.25	0.25	0.25
Feed Analysis				
Dry matter, % of as fed	82.2	82.9	82.4	83.6
Organic matter, % of DM	94.9	93.7	95.1	93.8
Crude protein, % of DM	16.3	17.9	15.9	17.4
Neutral detergent fiber, % of DM	27.1	30.2	24.5	30.5
Acid detergent fiber, % of DM	9.02	11.1	8.47	11.0
Fat, % of DM	4.45	4.92	3.77	4.86
Calcium, % of DM	0.794	0.929	0.757	1.00
Phosphorus, % of DM	0.408	0.537	0.409	0.538

on day 4; and 6 a.m., noon, 6 p.m. and midnight on day 5 to represent every other hour in a 24-hour cycle.

After collection, subsamples were taken to the lab and stored frozen (minus 20 C) until the end of the collection period, at which point they were thawed, equally composited and used for ammonia and VFA analysis.

Gas production was determined using Ankom's gas pressure flasks, wireless system and analysis software (Gas Pressure Monitor, Ankom Technology Corp., Macedon, N.Y.). After the addition of ruminal fluid and buffer, the vials were flushed with carbon dioxide. The flasks then were screwed tightly to the pressure monitor caps and placed in an oscillating water bath (Northwest Scientific Incorporated) at 39 C for 24 hours, with the oscillation set at 125 revolutions per minute.

Data obtained from this system were converted from pressure units to volume units (mL) using the formula reported by López et al. (2007). Gas production was examined on days 1 and 7 of the collection period for approximately 24 hours.

Data were analyzed as a 2 × 2 factorial using the Mixed procedure of SAS (SAS Inst. Inc., Cary, N.C.). The model included the effects of animal, period, degree of dry-roll processing (coarse vs. fine), DDGS inclusion (20 vs. 40 percent DDGS) and the interaction between the degree of dry-roll processing × DDGS inclusion rate. Statistical significance was declared at $P \leq 0.05$.

Results and Discussion

No differences were observed in ruminal pH among dietary treatments ($P > 0.05$). Rumen NH3 was increased ($P = 0.02$) in diets containing 20 percent DDGS. Urea was added to rations with 20 percent DDGS to meet the NRC's DIP requirement. This urea likely was rapidly hydrolyzed to ammonia by bacterial urease. Volatile fatty acids were generally unaffected by dietary treatment; however, the level of butyric acid was greater ($P = 0.02$) in cattle consuming fine-rolled corn (Table 2).

In vitro gas production and enteric methane emission were not different among treatments ($P \geq 0.44$; Table 3). Acetate has been shown to increase methane production, while propionate has the opposite effect (Moss et al., 2000). As no changes to the acetate:propionate ratio were found in the current study, we were not surprised that methane concentrations did not differ between the variable rations.

Dietary treatments did not affect rumen pH or VFA concentration in a way that would affect gas production or enteric methane emission significantly. This would indicate that the digestive tracts of the cattle tested were not strongly influenced by the degree of corn processing or inclusion rate of DDGS.

Table 2. Ruminal pH and VFA profiles of steers fed coarse- vs. fine-rolled corn with 20 vs. 40 percent dried distillers grains with solubles.

	Coarse-rolled corn		Fine-rolled corn			*P*-Values			
	20% DDGS	40% DDGS	20% DDGS	40% DDGS	SEM[a]	Corn	Distiller's	Corn * Distiller's	Hour
Rumen pH	5.96	5.68	5.88	5.70	0.134	0.85	0.12	0.72	<0.001
Minimum	5.31	5.04	5.22	5.10	0.197	0.94	0.32	0.68	-
Maximum	6.69	6.77	7.04	6.78	0.214	0.44	0.69	0.49	-
Time < 5.5, h/d	3.02	11.1	4.66	5.82	2.125	0.40	0.07	0.14	-
Rumen NH_3, mM	13.3	10.4	13.4	9.8	13.31	0.87	0.02	0.80	<0.001
Total VFA, mM	184	183	197	198	9.7	0.14	0.99	0.91	<0.001
				VFA, mol/100 mol					
Acetic	33.1	34.1	32.0	32.7	1.44	0.41	0.56	0.92	0.18
Propionic	22.0	24.7	25.2	22.2	2.19	0.87	0.96	0.20	<0.001
Isobutyric	2.79	2.77	2.48	2.58	0.159	0.12	0.82	0.73	<0.001
Butyric	17.4	15.3	19.6	21.4	1.68	0.02	0.93	0.24	0.45
Isovaleric	16.5	14.7	11.9	10.9	2.07	0.06	0.50	0.84	<0.001
Valeric	8.24	8.51	8.83	10.2	0.642	0.10	0.23	0.42	0.05
Acetate:Propionate	1.65	1.52	1.39	1.70	3.4	0.84	0.66	0.28	0.001

[a]Data are presented as least square means per treatment ± SEM, n = 8

Table 3. Gas production and methane emission of steers fed coarse- vs. fine-rolled corn with 20 vs. 40 percent dried distillers grains with solubles.

	Coarse-rolled corn		Fine-rolled corn			*P*-Values		
	20% DDGS	40% DDGS	20% DDGS	40% DDGS	SEM[a]	Corn	Corn * Distiller's	Distiller's
Gas production, mLs								
A	195	176	183	198	30.5	0.86	0.96	0.56
C	0.075	0.063	0.082	0.094	0.0234	0.38	0.10	0.55
d	0.019	0.128	-0.068	-0.132	0.1013	0.09	0.82	0.38
L	1.19	1.07	1.65	0.804	0.2890	0.71	0.08	0.17
Methane, % of gas	10.8	12.1	11.5	12.6	12.64	0.68	0.44	0.94

[a]Data are presented as least square means per treatment ± SEM, n = 4 per treatment. A = asymptote, C = rate, d = degradation rate, L = Lag

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Literature Cited

Behlke, E.J., T.G. Sanderson, T.J. Klopfenstein and J.L. Miner. 2008. Ruminal methane production following the replacement of dietary corn with dried distiller's grains. Nebraska Beef Rep. 50

Klopfenstein, T.J., G.E. Erickson and V.R. Bremer. 2008. Board-invited review: Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86:1223-1231.

Loe, E.R., M.L. Bauer and G.P. Lardy. 2006. Grain source and processing in diets containing varying concentrations of wet corn gluten feed for finishing cattle. J. Anim Sci. 84:986-996.

López, S., M.S. Dhano, J. Dijkstra, A. Bannink, E. Kebreab and J. France. 2007. Some methodological and analytical considerations regarding application of the gas production technique. Anim. Feed Sci. Technol. 135:139–156

Massé, D.I., G. Jarret, C. Benchaar and N.M. Cata Saady. 2014. Effect of corn dried distillers grains with solubles (DDGS) in dairy cow diets on manure bioenergy production potential. Animal. 4, 82-92

Moss, A.R., J.P. Jouany and J. Newbold. 2000. Methane production by ruminants: Its contribution to global warming. Ann. Zootech. 49:231–253.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th Ed. National Academy Press, Washington, D.C.

Swanson, K.C., A. Islas, Z.E. Carlson, R.S. Goulart, T.C. Gilbery and M.L. Bauer. 2014. Influence of dry-rolled corn processing and increasing dried corn distillers grains plus solubles inclusion for finishing cattle on growth performance and feeding behavior. J. Anim. Sci. 72:1477-1483.