The impact of fine- vs. coarse-rolled corn-based diets with variable levels of distillers grain inclusion on starch digestibility, rumen α-amylase activity and rumen pH

F.E. Keomanivong[1], M.C. Ruch[1], J.D. Kirsch[1], M.L. Bauer[1], C.R. Dahlen[1], and K.C. Swanson[1]

The objectives of this study were to determine the impact of dry-rolled corn particle size and the inclusion level of dried corn distillers grains plus solubles (DDGS) on ruminal starch digestibility, α-amylase activity and ruminal pH. Results indicate diets containing coarse-rolled corn had greater amylase concentration per kilogram (kg) starch disappearance. Diets composed of 65 percent rolled corn and 20 percent DDGS had greater starch intake and disappearance, along with greater α-amylase activity and higher ruminal pH readings. These differences are likely the result of the final nutrient profile of each treatment rather than the direct effect of the DDGS inclusion level alone.

Summary

Eight cannulated Holstein steers (1,159 ± 8 pounds) were assigned randomly to four dietary treatments consisting 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, 4) 45 percent fine-rolled corn and 40 percent DDGS. Diets were formulated to meet NRC recommendations and were offered for ad libitum intake. Steers were provided the experimental diets for a period of 14 days, with sample collection occurring during the final seven days. Daily feed consumption was recorded, and samples of feed remaining in bunks were composited for each collection period. Feed was tested for starch content, and rumen fluid measurements included α-amylase activity and pH. Steers fed diets containing 65 percent rolled-corn and 20 percent DDGS had increased ($P < 0.001$) starch intake and disappearance (pounds per /day). The amylase/pound starch intake was greater in coarse-rolled corn treatments ($P = 0.02$), while the activity of α-amylase (U/L rumen fluid) and ruminal pH were increased ($P \leq 0.01$) in diets containing 65 percent rolled-corn and 20 percent DDGS.

Introduction

Amylase is an enzyme that works to break down starch. Unlike monogastrics, cattle do not produce significant quantities of amylase in their saliva. Instead, it first is generated by several species of bacteria found in the rumen, such as *Bacteroides amylophilus, Bacteroides ruminocola, Ruminobacteramylophilus, Succinimonas amylolytica* and *Lactobacillus* sp (Cerrilla and Martínez, 2003). When cattle are fed diets high in starch, these amylolytic organisms become more prevalent.

Starch (in relation to fiber) is responsible for increasing the energetic value in cattle diets and, as such, several grain-processing techniques have been developed to improve starch digestibility. One common practice includes reducing the particle size of corn grain, allowing for greater surface area to come into contact with the rumen microbes and release greater quantities of energy. However, producers need to take care to ensure that starch will not be digested too rapidly, resulting in increased incidence of ruminal acidosis and decreased intake and production.

Although starch is lost due to fermentation during the production of ethanol, the coproduct DDGS is still a valuable feed source in cattle diets. The concentrated fat and protein supplied by the distillers grain create a desirable ingredient that commonly is fed in combination with ground corn.

The amount of DDGS provided to cattle varies considerably among feedlots. Swanson et al. (2014) found that feeding cattle diets with increasing levels of DDGS allowed for improved gain-to-feed ratios. However, producers need to be aware of the risk of decreased ruminal pH, which could affect intake and digestibility (Felix et al., 2012).

Understanding how corn processing and the level of DDGS inclusion impact the rumen environment will have large implications for the effectiveness of rumen microbes on the breakdown of starch and utilization of energy.

[1]Department of Animal Sciences, NDSU

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 assigned randomly to four dietary treatments consisting of 1) 65 percent coarse-rolled corn (2.5 millimeters) and 20 percent DDGS, 2) 45 percent coarse-rolled corn and 40 percent DDGS, 3) 65 percent fine-rolled corn (1.7 millimeters) and 20 percent DDGS and 4) 45 percent fine-rolled corn and 40 percent DDGS. (Table 1).

Diets were formulated to meet National Research Council (NRC) recommendations and were offered for ad libitum intake. The experiment was designed as a 4 x 4 Latin square with 14-day periods allowing for seven days of diet adaptation and seven days of sample collection. Daily feed consumption was recorded, and samples of feed remaining in bunks was composited for each collection period.

Approximately 200 milliliters (mL) of rumen fluid was collected from days 3 to 5 in a manner to represent every other hour in a 24-hour cycle. Rumen pH was measured at the time of collection and remaining samples were frozen immediately.

The ruminal activity of α-amylase was determined using the procedure of Wallenfels et al. (1978) utilizing a kit from Teco Diagnostics (Anaheim, Calif.). Results were analyzed using the Mixed procedure of SAS. 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 degree of dry-roll processing × DDGS inclusion rate.

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
DDGS	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				
DM, % of as fed	82.2	82.9	82.4	83.6
OM, % of DM	94.9	93.7	95.1	93.8
CP, % of DM	16.3	17.9	15.9	17.4
NDF, % of DM	27.1	30.2	24.5	30.5
ADF, % of DM	9.02	11.1	8.47	11.0
EE, % of DM	4.45	4.92	3.77	4.86
Ca, % of DM	0.794	0.929	0.757	1.00
P, % of DM	0.408	0.537	0.409	0.538
Starch, % of DM	46.9	45.5	41.9	42.1
Degradable Intake Protein, % of Ration[a]	5.80	7.20	5.80	7.20

[a]Calculated NRC, 1996

Results and Discussion

The dry-matter intake of steers was not different (results not shown) among treatments. Starch intake and disappearance (pounds/day) was greater ($P < 0.001$) in diets containing 20 percent DDGS (Table 2). This was not surprising because the majority of starch is found in the grain and these treatments contained 65 percent rolled corn, rather than diets with 40 percent DDGS and 45 percent rolled corn.

The amylase/pound starch intake was greater ($P \leq 0.02$) in coarse-rolled corn treatments, indicating that microbes produced greater amounts of amylase in the presence of larger corn particles than that found in the fine-rolled corn treatments. Rumen amylase activity (U/L rumen fluid) was greater ($P < 0.0001$) in diets containing 65 percent rolled corn and 20 percent DDGS (Table 3). This indicates that greater levels of starch found within grain stimulates the rumen microbes to increase amylase production for starch breakdown.

Decreasing the particle size of corn grain typically decreases rumen pH (Krause and Combs, 2003). However, no differences were observed in ruminal pH among fine- vs. coarse-rolled corn treatments ($P > 0.05$). Inclusion of 20 percent vs. 40 percent DDGS resulted in higher pH ($P = 0.01$; Figure 1). The amount of

Table 2. Starch intake and disappearance for steers consuming fine-rolled or coarse-rolled corn supplemented with 20 or 40 percent DDGS.

	Coarse-rolled Corn		Fine-rolled Corn			*P*-values		
	20% DDGS	40% DDGS	20% DDGS	40% DDGS	SEM[a]	Corn	DDGS	Corn × DDGS
Intake, lb/d	13.0	10.9	13.3	10.9	0.172	0.64	<0.001	0.65
Disappearance, lb/d	12.2	10.4	12.6	10.4	0.155	0.57	<0.001	0.55
Apparent ruminal, % intake	85.8	88.5	87.3	88.0	0.13	0.70	0.23	0.45
Small intestinal, % duodenal flow	62.3	67.5	76.4	60.2	0.08	0.65	0.51	0.19
Total tract, % intake	94.8	95.8	95.4	95.7	0.01	0.66	0.26	0.53

Table 3. Ruminal amylase activity for steers consuming fine-rolled or coarse-rolled corn supplemented with 20 or 40 percent DDGS.

	Coarse-rolled Corn		Fine-rolled Corn			*P*-values		
	20% DDGS	40% DDGS	20% DDGS	40% DDGS	SEM[a]	Corn	DDGS	Corn × DDGS
Amylase, U/L rumen fluid	1520	1284	1487	1083	110.0	0.08	<0.001	22
Amylase/lb. starch intake	101	107	98.8	89.8	9.32	0.02	0.77	08
Amylase/lb. starch disappearance	120	116	121	105	12.0	0.32	0.06	21

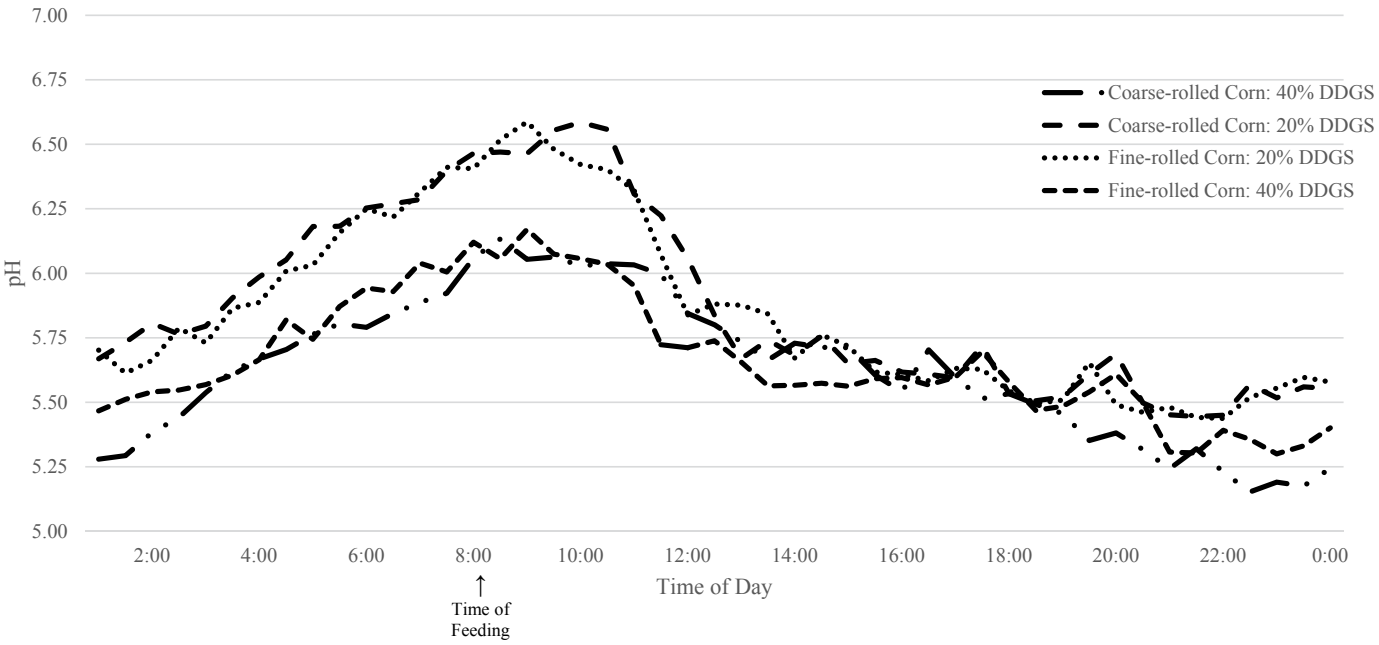

Figure 1. Ruminal pH for steers consuming fine-rolled or coarse-rolled corn supplemented with 20 or 40 percent DDGS.

Data are represented as ruminal pH during a 24-hour period. Effects of dry-rolled corn processing method ($P = 0.73$), DDGS inclusion level ($P = 0.01$), dry-rolled corn processing method, DDGS inclusion level ($P = 0.65$) and hour of the day ($P < 0.001$). The number of hours below a pH reading of 5.5 tended to be greater in cattle consuming 40 vs. 20 percent DDGS ($P = 0.07$).

time the rumen was below a pH 5.5 reading tended ($P = 0.07$) to be longer in cattle fed diets supplemented with 40 percent DDGS.

Similar results were found in a study by Laarman et al., (2012) who investigated the effects of feeding dry rolled corn vs. DDGS to Holstein calves during the weaning transition. Laarman reported calves consuming DDGS had pH readings below 5.2 for a greater period of time than those consuming corn alone.

In conclusion, the amount of starch digested is greater in cattle fed 20 percent DDGS than 40 percent DDGS. Rumen pH also decreased with increasing distillers. Lastly, rumen microbes are able to adapt to higher levels of starch intake by producing greater concentrations of amylase activity.

Acknowledgments

The authors thank the North Dakota Corn Council for partial funding for the project. Recognition also is owed to Terry Skunberg, Justin Gilbertson and the staff at the North Dakota State University Animal Nutrition and Physiology Center for assistance in animal care and management. Thank you to Kim Koch and Kurt Johnsen at Northern Crops Institute for the preparation and delivery of ration components, and Marsha Kapphahn and the Animal Science Nutrition Laboratory staff for aid in sample analyses.

Literature Cited

Cerrilla, M.E.O., and G.M. Martínez. 2003. Starch digestion and glucose metabolism in the ruminant: a review. Interciencia 28(7).

Erdman, R.A. 1988. Dietary buffering requirements of the lactating dairy cow: A review. J. Dairy Sci. 71(12): 3246–3266.

Felix, T.L., T.A. Murphy and S.C. Loerch. 2012. Effects of dietary inclusion and NaOH treatment of dried distillers grains with solubles on ruminal metabolism of feedlot cattle. J Anim Sci. 90(13):4951-61.

Gonzalez, L.A., X. Manteca, S. Calsamiglia, K.S. Schwartzkopf-Genswein and A. Ferret. 2012. Ruminal acidosis in feedlot cattle: Interplay between feed ingredients, rumen function and feeding behavior (a review). Anim. Feed Sci. Technol. 172:66-79.

Krause, K.M., and D.K. Combs. 2003. Effects of forage particle size, forage source, and grain fermentability on performance and ruminal pH in midlactation cows. J. Dairy Sci. 86(4):1382-97.

Laarman, A.H., T. Sugino and M. Oba. 2012. Effects of starch content of calf starter on growth and rumen pH in Holstein calves during the weaning transition. J. Dairy Sci. 95(8):4478-87.

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 distiller's grains plus solubles inclusion for finishing cattle on growth performance and feeding behavior. J. Anim. Sci. 92(6):2531-7.