Effects of glycerol supplementation on dry matter intake, rate and site of digestion, and ruminal fermentation in cannulated steers fed finishing diets

T.C. Gilbery, G.P. Lardy and M.L. Bauer
NDSU Department of Animal Sciences

Summary
Four Holstein steers (initial weight, 588 ± 98 lbs) fitted with ruminal and duodenal cannulae were utilized in a 4 x 4 Latin square study to assess the effects of glycerol inclusion in finishing diets on intake, ruminal fermentation, and site of digestion. Glycerol replaced an equivalent amount of corn on a dry matter (DM) basis as an energy source in the ration and cattle were fed unlimited amounts (ad libitum) as a total mixed ration (TMR).

Dry matter intake (DMI) as a percent of body weight averaged 19.1 pounds, (2.85% of body weight; P = 0.07) and organic matter (OM) intake tended to decrease (linear, P = 0.08) as the amount of glycerin increased in the diet.

As dietary glycerol replaced corn in the finishing diet we observed a decrease (P = 0.05) in apparent ruminal OM digestion. Total tract OM digestion, however, was not different as glycerol increased in the diet. Treatment tended to decrease crude protein (CP) intake (linear, P = 0.10) and microbial CP flow (quadratic, P = 0.09). Apparent ruminal (quadratic, P = 0.03) and total tract (linear, P = 0.05) CP digestion were different among treatments. Microbial efficiency changed (P = 0.05) in a quadratic manner as glycerol increased in the ration. Total tract acid detergent fiber (ADF) (linear, P = 0.04) and neutral detergent fiber (NDF) (linear, P = 0.03) digestion decreased as the level of glycerol increased in the diet. Ruminal pH was not different among treatments (P = 0.13) while ruminal ammonia was lower (P = 0.02) with increasing levels of dietary glycerol.

Introduction
Glycerin is produced from the catalyzed reactions between alcohol triacylglycerides in vegetable oils and animal fats yielding biodiesel and the coproduct crude glycerin (Van Gerpen, 2005). About 10 percent of the weight of the oil or fat used to produce biodiesel becomes glycerin (Dasari et al., 2005). The recent increase in demand for biodiesel from fats and oils has led to greater availability of glycerin as a feed constituent in ruminant diets. Historically the price of glycerol has been too high to be considered as a nutrient source for animal diets, but as the availability of glycerol increases, the feed industry may be able to utilize it as a dietary ingredient.

Wang et al. (2008) reported increased ruminal fermentation and feed digestion when feeding glycerol at 2.2 percent of dietary DM. German researchers (Schröder and Südekum, 1999) reported that glycerol can replace up to 10 percent of readily fermentable starches without negatively affecting intake and ruminal nutrient degradation; however its energy value in a starch-based diet was 85 percent of its value when fed in a forage-based diet. Crude glycerol as an energy component in animal diets could provide an alternative to partially replace corn for cattle feeders.

Our objective was to evaluate the use of glycerol in beef cattle finishing diets and its corresponding effects on site of digestion and ruminal fermentation in steers consuming high-concentrate diets. Utilization of glycerol in livestock feed would add value to the overall biodiesel industry thereby benefitting the soybean farmer.

Procedures
Four ruminally and duodenally cannulated Holstein steers (588 ± 98 lbs initial BW) were used in a 4 x 4 Latin square design to evaluate the effects of glycerol inclusion on ruminal fermentation and digestion in finishing diets. Treatments were control (no glycerol) and levels of glycerol replacing corn in the ration at 6, 12, and 18 percent of dietary DM.

Steers were housed in an enclosed barn in individual pens (10 x 12 ft.) during each 9-day adaptation period and stalled in individual tie-stalls (4 x 8 ft.) during each 5-day collection period. Steers were offered diets in the form of a totally-mixed ration at 7 a.m. and 7 p.m. in quantities to ensure ad libitum intakes and 10 percent feed refusal daily.

Feed ingredients were grass hay, field peas, corn, wheat midds, dried distillers grains, de-sugared molasses, glycerol, and a supplement (Table 1). Diets were formulated to provide 17 percent CP and a calcium-to-phosphorus ratio of 1.5-to-1 (DM basis).

Table 1. Formulation of dietary treatments (% of DM).

	Dietary Glycerol Concentration			
Item	0%	6%	12%	18%
Grass hay	8.00	8.00	8.00	8.00
Field peas	11.48	11.48	11.48	11.48
Corn	18.00	12.00	6.00	--
Wheat midds	28.00	28.00	28.00	28.00
Dried distillers grains	28.00	28.00	28.00	28.00
De-sugared molasses	4.00	4.00	4.00	4.00
Glycerol	--	6.00	12.00	18.00
Calcium carbonate	1.80	1.80	1.80	1.80
Monensin premix[1]	0.02	0.02	0.02	0.02
Trace mineral premix[2]	0.30	0.30	0.30	0.30
Vitamin A and D premix[3]	0.10	0.10	0.10	0.10
Chromic oxide	0.25	0.25	0.25	0.25
Sodium chloride	0.05	0.05	0.05	0.05

[1]Contained 176 g monensin/kg; formulated to provide 200 mg of monensin/kg of diet (Elanco Animal Health, Greenfield, IN).
[2]Contained (per kg) a minimum of 32.9 g Ca, 25.6 g Cu, 160 g Zn, 65.0 g Fe, 40.0 g Mn,1.05 g I, 0.250 g Co.
[3] Contained vitamin A and D concentrations of 22,000 and 2,100 IU/kg, respectively.

Each experimental period was 14 days in length, allowing nine days for adaption to diet and five days for sample collection. Feed refusal samples were measured to determine DMI.

Table 2. Analyzed nutrient composition of dietary components and dietary samples in finishing diets (% of DM).

Individual ingredients	OM	CP	NDF	ADF	Fat	Ca	Phos
Wheat midds	93.7	18.8	43.5	13.1	3.8	0.2	1.3
Dried distillers grains	94.7	28.1	31.2	8.1	10.0	0.1	1.0
Corn	98.3	8.6	14.0	3.4	3.0	0.1	0.3
Field peas	96.2	24.2	26.1	7.0	0.9	0.2	0.4
Grass hay	90.6	8.7	75.4	43.2	0.9	0.4	0.3
Premix supplement	8.9	0.2	--	--	0.1	27.4	0.2
De-sugared molasses	--	11.3	--	--	--	--	--
Glycerol[a]	92.2	2.4	--	< 0.5	0.8	--	--
Dietary treatments							
0% glycerol	90.9	18.8	36.2	12.6	5.0	0.9	0.8
6% glycerol	90.2	18.6	33.7	11.5	4.9	0.9	0.8
12% glycerol	89.6	18.7	33.2	11.3	4.7	0.9	0.8
18% glycerol	89.1	18.2	32.4	10.8	4.4	0.9	0.8

[a]Methanol concentration of glycerol was 0.02%.

Total fecal output was measured to determine total tract digestion. Intestinal samples were taken during a 3-day period to estimate nutrient flow. Ruminal fluid samples were collected and analyzed for ammonia (NH_3), volatile fatty acid (VFA) concentrations and pH.

Results

Dry matter intake was not different (P = 0.12; 19.1 lbs/day) among treatments; however, DM intake as a percentage of body weight tended to decrease (P = 0.07; 2.85% of BW) steers' consumption of finishing diets as the concentration of glycerol increased. Optimum DM intakes were observed for steers consuming the 6 percent (20.2 lbs/day) dietary glycerin treatment.

Feeding glycerol at 18 percent of dietary DM decreased NDF intake 24 percent (7.3 vs. 5.6 lbs/day) over the control treatment. In other research (Parsons et al., 2009) similar to ours, glycerin has shown to increase intake and gain when fed up to 8 percent of diet DM, however, feeding glycerin over 8 percent of diet DM resulted in reduced intake and performance of heifers on finishing diets.

True ruminal OM digestion decreased (P = 0.04) with increasing dietary glycerol while total tract OM digestion was not different among treatments. True ruminal CP and total tract CP digestion decreased (P ≤ 0.05) as the level of glycerol increased in the diet. Ruminal and post-ruminal flow of NDF decreased (P ≤ 0.04) with the increase in dietary glycerol. ADF digestion followed similar trends as ruminal and post ruminal decreases (P ≤ 0.05) were observed as dietary glycerol concentration increased. Microbial efficiency changed in a quadratic manner (P < 0.01), which followed a similar pattern as microbial CP. We theorize the rumen microflora may have selected glycerin as a more readily available nutrient source thereby inhibiting ruminal fermentation of other nutrient sources. This theory is supported by the decrease (P = 0.02) in ruminal ammonia (NH_3, a by-product of fermentation) observed with dietary supplementation of glycerin.

Ruminal data for pH, NH_3 and VFA are mean values reported for samples collected 24 hours post feeding. Ruminal pH did not differ with the inclusion of dietary glycerol; ruminal pH averaged 6.0 ± 0.11 for all treatments over the 24-hour sampling period. Glycerol inclusion in finishing diets for steers did not affect total VFA concentration. Ruminal proportion of acetate and proprionate production were not altered by the inclusion of glycerol in finishing diets for steers.

Table 3. Effect of glycerol inclusion on dry matter, OM, and CP digestion in steers consuming a finishing diet.

	Treatments					P value[a]		
Item	0%	6%	12%	18%	SEM[b]	Linear	Quad	Cubic
DMI, lb/d	19.9	20.2	19.2	17.2	1.28	0.12	0.35	0.91
% of BW	2.9	3.0	2.9	2.7	0.18	0.07	0.27	0.96
OMI, lb/d	18.1	18.3	17.2	15.3	1.15	0.08	0.32	0.02
Duodenal OM flow								
Microbial, lb/d	0.93	0.84	0.79	0.84	0.04	0.22	0.26	0.74
OM digestion, % of intake								
Apparent ruminal	82.9	84.3	83.4	79.8	1.2	0.05	0.04	0.95
True ruminal	88.2	89.1	87.9	85.4	8.7	0.04	0.08	0.82
Small intestine	4.6	4.3	4.5	7.8	1.0	0.06	0.11	0.57
Large intestine	2.6	1.9	2.3	1.2	0.7	0.31	0.79	0.50
Total tract	90.2	90.5	90.1	88.7	7.0	0.13	0.24	0.87
Duodenal CP flow								
Microbial, lb/d	0.51	0.46	0.46	0.51	0.03	0.53	0.09	0.90
CP digestion, % of intake								
Apparent ruminal	68.4	70.0	70.1	61.7	2.5	0.05	0.03	0.24
True ruminal	82.7	83.0	83.3	77.8	1.5	0.05	0.09	0.38
Small intestine	20.2	20.9	19.4	24.9	2.6	0.13	0.18	0.23
Large intestine	3.5	1.2	1.9	3.7	0.9	0.69	0.08	0.63
Total tract	92.2	92.7	91.1	90.6	0.6	0.05	0.55	0.30
Microbial	5.3	4.8	4.8	6.2	0.5	0.03	0.006	0.53

[a]probabilities for contrast F-test
[b]n = 4
[c]Grams duodenal microbial N per kg ruminal OM truly fermented.

Implications

Results from this study indicate the use of glycerol exceeding 6 percent of dietary DM may reduce DM and NDF intake of steers consuming high-concentrate diets. Ruminal digestion of CP and NDF were decreased as dietary glycerol increased in steers consuming finishing diets.

Increasing levels of glycerol replaced corn rations.

Literature Cited

Desari, M. A., P.P. Kiatsimkul, W.R. Sutterlin, and G.J. Suppes. 2005. Low-pressure hydrogenolysis of glycerol to propylene glycol. Appl. Catal. Gen. 281:225-231.

Parsons, G.L., M.K. Shelor and J.S. Drouillard. 2009. Performance and carcass traits of finishing heifers fed crude glycerin. J. Anim. Sci. 87:653-657.

Schröder, A., and K.H. Südekum. 1999. Glycerol as a by-product of biodiesel production in diets for ruminants. In: Wratten, N., Salisbury, P.A. (Eds.), New Horizons for an Old Crop. Proc. 10th Int. Rapeseed Congr., Canberra, Australia. Paper no. 241. The Regional Institute Ltd., Gosford, New South Wales, Australia.

Van Gerpen, J. 2005. Biodiesel processing and production. Fuel Process. Technol. 86:1097-1107.

Wang C., Q. Liu, W.J. Huo, W.Z. Yang, K.H. Kong, Y.X. Huang, and G. Guo. 2008. Effects of glycerol on rumen fermentation, urinary excretion of purine derivatives and feed digestibiliy of steers. Anim. Feed Sci. and Technol. 121; 15-20.