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Performance and carcass traits of finishing heifers fed crude glycerin[1,2]

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ABSTRACT: Crossbred heifers (n = 373; 421.6 kg ± 28.9) were fed finishing diets containing 0, 2, 4, 8, 12, or 16% crude glycerin (DM basis). Diets consisted of steam-flaked corn with 6% alfalfa hay and 1.2% urea and provided 300 mg of monensin, 90 mg of tylosin, and 0.5 mg of melengestrol acetate per animal daily. Cattle were stratified by BW and allocated randomly, within strata, to concrete-surfaced feedlot pens each containing 6 to 7 heifers, with 9 pens per dietary treatment. Cattle were transitioned from the control diet to diets containing increasing proportions of glycerin over a period of 10 d. Cattle had ad libitum access to feed, and diets were delivered once daily throughout the 85-d trial period. As the concentration of glycerin increased, DMI decreased linearly ($P < 0.001$). Heifers fed 0, 2, 4, 8, 12, and 16% glycerin had ADG of 1.19, 1.34, 1.29, 1.25, 1.17, and 1.03 kg, respectively (linear, $P = 0.013$; quadratic, $P = 0.010$). Feeding glycerin had a quadratic effect on G:F, and G:F was optimal when glycerin was fed at 2% of the diet (quadratic, $P = 0.046$). Glycerin increased the final BW by 12.7, 8.1, and 5.3 kg when fed at 2, 4, and 8% of the diet, respectively, but reduced the final BW by 1.9 and 14.3 kg when included at 12 and 16% of the diet (linear, $P = 0.009$; quadratic, $P = 0.006$). Similarly, HCW increased by 8.1, 5.1, and 3.3 kg when glycerin was fed at 2, 4, and 8% of the diet, respectively, but were 1.2 and 9.1 kg less than controls when glycerin was fed at 12 and 16%, respectively (linear, $P = 0.009$; quadratic, $P = 0.006$). Longissimus muscle area decreased linearly as glycerin concentrations increased ($P < 0.013$). Feeding glycerin resulted in linear decreases in subcutaneous fat over the 12th rib and marbling scores ($P = 0.045$). Glycerin tended to decrease the percentage of cattle grading USDA Choice ($P = 0.084$) and increase the percentage of cattle grading USDA Select. Adding glycerin to cattle-finishing diets improved BW gain and feed efficiency, particularly when added at concentrations of 8% or less on a DM basis.

Key words: glycerin, heifer, steam-flaked corn

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INTRODUCTION

Because of rising corn costs, alternative feed sources, such as glycerin, have become a major focus for the livestock industry. Rapid expansion of the biodiesel industry has created affordable supplies of crude glycerin. Catalyzed reactions between alcohol and triacylglycerides in vegetable oils and animal fats yield biodiesel and the coproduct, crude glycerin (Van Gerpen, 2005). Approximately 10% of the weight of oil or fat used to produce biodiesel becomes glycerin (Dasari et al., 2005), and the US biodiesel industry anticipates that glycerin output will be 635 million kg between 2006 and 2015.

Several studies have evaluated the use of glycerin in diets for poultry (Simon et al., 1996; Cerrate et al., 2006), swine (Kijora et al., 1995; Lammers et al., 2007a,b), and cattle (Fisher et al., 1973; DeFrain et al., 2004). In nonruminants, limited work has been conducted to understand the metabolism of glycerin. After ingestion, glycerol is converted to glucose via phosphorylation to glycerol-3-phosphate, which is catalyzed by glycerol kinase and enters gluconeogenesis in the liver (Mourot et al., 1994). Trabue et al. (2007) suggest that ruminal metabolism of glycerol is approximately 80% after 24 h, resulting in a decreased acetate:propionate ratio ($P < 0.05$; Schröder and Südekum, 2007). Researchers in our laboratory estimate that glycerin is almost entirely converted to propionate, which would support a reduction in the acetate:propionate ratio [J. S. Drouillard and J. Heidenreich (Kansas State University, Manhattan), unpublished data]. Previous research suggests glycerin is an effective feed source in multiple species, but limited data show the effect of glycerin on beef cattle performance and carcass characteristics.

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Table 1. Experimental diets (DM basis) and calculated dietary nutrients for crossbred heifers fed diets containing 0, 2, 4, 8, 12, or 16% crude glycerin on a DM basis

	Crude glycerin, %					
Item	0	2	4	8	12	16
Ingredient, %						
Steam-flaked corn	82.6	80.2	77.8	73.0	68.2	63.4
Corn steep liquor	5.7	5.7	5.7	5.7	5.7	5.7
Alfalfa hay	5.9	5.9	5.9	5.9	5.9	5.9
Crude soy-based glycerin[1]	0.0	2.0	4.0	8.0	12.0	16.0
Soybean meal	0.37	0.80	1.20	2.03	2.87	3.69
Limestone	1.45	1.46	1.44	1.42	1.41	1.40
Urea	1.15	1.14	1.14	1.13	1.13	1.11
Salt	0.28	0.29	0.28	0.28	0.28	0.27
Mineral premix[2]	0.35	0.34	0.34	0.34	0.31	0.33
Feed additive premix[3]	2.2	2.2	2.2	2.2	2.2	2.2
Calculated composition, %						
DM	81.0	81.2	81.3	81.5	81.7	81.9
CP	14.9	14.9	14.8	14.7	14.6	14.5
Ca	0.66	0.67	0.67	0.67	0.67	0.67
P	0.32	0.32	0.31	0.30	0.28	0.27

[1]Methanol content of glycerin <0.01%.

[2]Formulated to contain 0.1 mg/kg of Co; 10 mg/kg of Cu; 0.6 mg/kg of I; 60 mg/kg of Mn; 0.25 mg/kg of Se; 60 mg/kg of Zn; 1.0% K; 2,640 IU/kg of vitamin A; and 220 IU/kg of vitamin E.

[3]Feed additive premix was formulated to provide 300 mg of monensin (Elanco Animal Health, Greenfield, IN), 90 mg of tylosin (Elanco Animal Health), and 0.5 mg of melengestrol acetate (Pfizer Animal Health, Exton, PA) per heifer daily in a ground corn carrier. Additionally, ractopamine-HCl (Elanco Animal Health) was included at 200 mg/d in the final 42 d before slaughter.

Our objective was to evaluate the effects of glycerin on feedlot performance and carcass characteristics while establishing an optimal feeding amount in finishing heifers fed diets containing steam-flaked corn.

MATERIALS AND METHODS

Procedures for this experiment were approved by the Kansas State University Institutional Animal Care and Use Committee.

Crossbred heifers (n = 373; 421.6 kg ± 28.9 of initial BW) were used in a randomized complete block design to determine the effects of crude glycerin in finishing diets. On arrival, all cattle were offered ad libitum access to alfalfa hay and water before processing. Within 24 h of arrival, cattle received injections of Bovishield 4 and Ultrabac 7 vaccines (Pfizer Animal Health, Exton, PA) and were treated with Phoenectin parasiticide (IVX Animal Health, St. Joseph, MO). Cattle were implanted with Revalor-200 (Intervet, Millsboro, DE) and were gradually adapted to a 94% concentrate diet with 6% alfalfa hay (Table 1). Cattle were blocked by initial BW and randomly assigned, within block, to each of the 6 treatments. Three BW blocks were used, with 6 to 7 animals per pen and 9 pens per treatment, for a total of 54 pens. Cattle were housed on concrete-surfaced pens (36.5 m^2) with roofs covering half the pen and the entire feed bunk. All diets contained 30 mg of monensin/kg (Elanco Animal Health, Greenfield, IN), 9 mg of tylosin/kg (Elanco Animal Health), and 0.5 mg of melengesterol acetate (Pfizer Animal Health, Exton, PA) per heifer daily. Dietary treatments consisted of 0, 2, 4, 8, 12, or 16% soy-based crude glycerin (DM basis) in steam-flaked corn diets. Cattle were transitioned from the control diet to diets containing increasing proportions of glycerin over a period of 10 d. Cattle were fed once daily (afternoon) ad libitum. Heifers were fed for 85 d and then transported to a commercial abattoir, where carcass data were collected. Hot carcass weights and liver scores were obtained at the time of slaughter. Longissimus muscle area, 12th-rib fat thickness, marbling score, KPH, incidences of dark cutters, and USDA quality and yield grades were collected after a 24-h chill. Carcass-adjusted final BW was calculated by dividing HCW by a common dressing percentage of 63.5%.

Statistical Analysis

Data were analyzed as a randomized complete block design by using the MIXED procedure (SAS Inst. Inc., Cary, NC). Pen was the experimental unit, and model effects included block and treatment. Orthogonal contrasts were used to determine the linear, cubic, and quadratic effects of glycerin and 0% glycerin vs. glycerin treatment. Treatment means were computed with the LSMEANS option.

RESULTS AND DISCUSSION

Feedlot Performance

Average daily gains increased by 12.6, 8.4, and 5.0% for cattle fed 2, 4, and 8% glycerin, respectively, but

Table 2. Feedlot performance of heifers fed 0, 2, 4, 8, 12, or 16% crude glycerin for the final 85 d before slaughter

	Crude glycerin, %							Contrast, P-value		
Item	0	2	4	8	12	16	SEM	Linear	Quadratic	0 vs. glycerin[1]
No. of heifers	62	62	61	63	63	62	—	—	—	—
Days on feed	85	85	85	85	85	85	—	—	—	—
Initial BW, kg	421.7	421.6	421.4	421.7	421.8	421.6	5.74	0.990	0.992	0.991
Shrunk final BW,[2] kg	528.0	531.2	526.2	530.3	522.1	508.0	4.303	0.001	0.017	0.342
Final BW,[3] kg	523.0	535.7	531.1	528.3	521.1	508.71	7.31	0.009	0.006	0.732
DMI, kg/d	8.84	8.88	8.66	8.61	8.40	7.80	0.13	0.001	0.014	0.015
ADG, kg	1.19	1.34	1.29	1.25	1.17	1.03	0.09	0.013	0.010	0.741
G:F, kg/kg	0.136	0.152	0.150	0.146	0.140	0.132	0.007	0.319	0.046	0.320

[1]Compares the effects of 0% glycerin with the combined glycerin treatment.
[2]Calculated by multiplying the final BW by 96%.
[3]Calculated by dividing HCW by a common dressing percentage of 63.5%.

at 12 and 16% glycerin, ADG were reduced by 1.7 and 13.4%, respectively (Table 2; linear, 0.013; quadratic, P = 0.010). The first reports of glycerin fed in finishing steer diets resulted in improving ADG by 11.4% when glycerin replaced 10% of the dry-rolled corn, but improved ADG by only 2.5% when glycerin replaced 10% of the dry-rolled corn in diets that also contained 30% distillers dried grains with solubles and 15% soyhulls (Pyatt et al. (2007). Similarly, feeding glycerin to finishing pigs at 5 and 10% of the diet increased ADG by 5.3 and 12%, respectively, but replacing barley with 20 and 30% glycerin decreased ADG by 3.7 and 18.2%, respectively (Kijora et al., 1995). In lactating dairy cows fed diets consisting of corn silage, legume forage, and corn grain, replacing corn with 10 and 15% glycerin increased BW gains (Donkin et al., 2007). Low to moderate concentrations of glycerin, particularly less than 8% in feedlot diets, effectively increased daily BW gains.

No changes in DMI occurred when glycerin was fed at either 0 or 2% of the diet (8.84 vs. 8.88 kg), but increasing glycerin to 4, 8, 12, and 16% reduced DMI to 8.66, 8.61, 8.40, and 7.80 kg, respectively (linear, P < 0.001; quadratic, P = 0.014). Similarly, Pyatt et al. (2007) reported a 10.1% reduction in DMI when glycerin was added at 10% to a dry-rolled corn diet fed to steers. Kijora et al. (1995) reported that DMI of finishing pigs increased by 9.6 and 12.6% when glycerin replaced 5 and 10% barley. Schröder and Südekum (2007) reported a 0.7 kg/d reduction in starch intake in ruminally cannulated steers fed 15% glycerol. Changes in DMI and the replacement of rapidly fermentable starch sources with glycerin could explain the reductions in total ingested starch. Trabue et al. (2007) reported that increased lactate accumulation might slow glycerol fermentation in the rumen, altering intake. In addition, Roger et al. (1992) reported that adding glycerin at 5% of the in vitro media greatly inhibited the growth and cellulolytic activity of rumen bacteria and fungi. Small inclusion amounts of glycerin could be beneficial to livestock growth, but concentrations greater than 5% might create an unhealthy rumen, resulting in reduced DMI.

Feed efficiency improved by 10.8, 10.0, 7.2, and 3.1% when glycerin was included at 2, 4, 8, and 12% of the diet, respectively, but adding glycerin at 16% reduced efficiency by 2.8% (quadratic, P = 0.046). Pyatt et al. (2007) reported a 21.9% improvement in efficiency when glycerin replaced 10% of the dry-rolled corn in the diet and a 16.4% improvement when glycerin replaced 10% of the dry-rolled corn in diets also containing 30% distillers grains. In broilers, glycerin improved G:F by 1.3% compared with control broilers when fed at 5% inclusion, but reduced feed conversion by 3.1% when added at 10% of the diet and fed for 42 d (Cerrate et al., 2006). The researchers who conducted that study commented that the decreased efficiency and growth at the 10% amount was the result of diets with poor flowability, which lodged in feeders. Another experiment (Cerrate et al., 2006) compared concentrations of 0, 2.5, and 5% glycerin in male broiler diets fed for 42 d; efficiency improved by 1.1 and 0.9% compared with controls when glycerin was added at 2.5 and 5%, respectively.

Feeding crude glycerin at 2 or 8% of the diet DM increased shrunk final BW, but decreases were observed when glycerin concentration was increased to 12 or 16% of the diet (linear, P = 0.001; quadratic, P = 0.017). Cerrate et al. (2006) reported no differences in BW when glycerin was fed at 5% to male broilers, but a significant reduction in BW occurred when glycerin was fed at 10% of the diet. Their second experiment resulted in the final BW increasing by 3.59 and 3.48% compared with BW of control broilers when glycerin was fed at 2.5 and 5%, respectively (Cerrate et al., 2006). Glycerin can have positive effects on ADG, feed efficiency, and final BW when included at less than 10% of livestock diets.

Carcass Characteristics

Carcass-adjusted final BW increased by 12.7, 8.1, and 5.3 kg when glycerin was fed at 2, 4, and 8%, respectively, but glycerin decreased carcass-adjusted final

Table 3. Carcass characteristics of heifers fed 0, 2, 4, 8, 12, or 16% crude glycerin

	Crude glycerin,%							Contrast, P-value			
Item	0	2	4	8	12	16	SEM	Linear	Quadratic	Cubic	0 vs. glycerin[1]
HCW, kg	332.12	340.2	337.3	335.4	330.9	323.0	4.6	0.009	0.006	0.547	0.732
Dressed yield, %	62.96	64.1	64.2	63.3	63.4	63.6	0.005	0.924	0.328	0.085	0.161
LM area, cm^2	83.08	86.3	84.0	82.7	81.7	81.4	1.5	0.013	0.217	0.052	0.903
USDA yield grade											
Yield grade 1, %	11.38	16.1	13.2	11.1	12.7	15.9	4.03	0.767	0.787	0.314	0.584
Yield grade 2, %	32.01	32.8	31.2	33.3	28.6	40.5	6.5	0.563	0.476	0.471	0.859
Yield grade 3, %	51.85	51.1	47.6	44.5	50.8	42.1	6.6	0.343	0.994	0.700	0.523
Yield grade 4, %	4.8	0	6.4	11.1	6.4	1.6	2.6	0.718	0.070	0.028	0.912
Yield grade 5, %	0.0	0.0	1.6	0.0	0.0	0.0	0.7	0.771	0.291	0.469	0.657
Average yield grade	2.5	2.4	2.5	2.6	2.5	2.3	0.09	0.589	0.160	0.050	0.636
USDA quality grade											
Prime, %	3.2	0.0	1.6	0.0	0.0	1.6	1.3	0.377	0.142	0.927	0.076
Choice, %	53.7	50.3	57.4	42.9	52.4	37.3	6.1	0.084	0.389	0.640	0.402
Select, %	43.1	46.5	37.8	53.9	46.0	57.9	5.6	0.064	0.378	0.861	0.386
Standard, %	0.0	3.2	3.2	3.2	1.6	3.2	1.7	0.771	0.291	0.469	0.657
Marbling[2]	435	405	416	398	410	397	9.7	0.022	0.343	0.234	0.008
KPH, %	2.24	2.21	2.19	2.24	2.20	2.19	0.04	0.422	0.889	0.421	0.341
Subcutaneous fat, cm	1.21	1.10	1.18	1.18	1.18	1.02	0.06	0.045	0.125	0.009	0.096
Liver abscess, %	11.11	6.611	17.72	9.52	4.76	17.72	4.10	0.577	0.530	0.159	0.972

[1]Compares the effects of 0% glycerin with the combined glycerin treatment.

[2]Marbling scores were obtained by USDA graders at a commercial abattoir: Slight = 300 to 399; Small = 400 to 499; Modest = 500 to 599.

BW by 1.9 and 14.3 kg when fed at 12 and 16%, respectively. Likewise, HCW increased by 8.1, 5.1, and 3.2 kg when glycerin was fed at 2, 4, and 8%, respectively, but HCW decreased by 1.2 and 9.1 kg when glycerin was fed at 12 and 16%, respectively (Table 3; linear, $P = 0.009$; quadratic, $P = 0.006$). Including glycerin at up to 8% of the diet could effectively increase HCW in finishing cattle. Longissimus muscle area significantly increased when glycerin was fed at 2% of the diet, but a linear ($P = 0.013$) reduction in LM area occurred with increasing amounts of glycerin. Similarly, chickens fed 2.5 and 5% glycerin showed significant increases of 0.64 and 0.80% in breast meat yield, respectively (Cerrate et al., 2006).

Heifers fed glycerin at 2 and 16% were leaner and had decreased numerical USDA yield grades, but feeding glycerin at intermediate concentrations had no effect on yield grades (cubic, $P = 0.050$). Feeding glycerin caused linear ($P = 0.022$) reductions in marbling scores compared with control heifers. Previous research suggests that increasing the glucogenic substrates (e.g., glycerin) fed to cattle results in increased marbling scores. However, glycerin showed no positive effects on marbling when various concentrations were fed to feedlot heifers. Glycerin tended (linear, $P = 0.084$) to decrease the percentage of cattle grading USDA Choice while simultaneously increasing the percentage of cattle grading USDA Select. Reductions in USDA quality grades might be associated with the decline in subcutaneous fat caused by feeding diets containing glycerin ($P = 0.096$). Cattle consuming diets containing glycerin were leaner, and the most notable reductions in subcutaneous fat occurred when glycerin was fed at 2 and 16% of the diet (linear, $P = 0.045$; cubic $P = 0.009$). The reductions in subcutaneous fat for the 2 aforementioned treatments might explain the decreased numerical yield grades, but other dietary concentrations of glycerin elicited no effect on yield grade despite cattle having leaner carcasses. Because glycerin reduced subcutaneous fat, it is conceivable that glycerin may alter fat deposition, which might explain the observed reductions in marbling scores. Because most glycerin is converted to propionate, we speculated that improvements in quality grades would be observed, but this was not supported because glycerin-fed cattle were leaner and had decreased marbling scores. No treatment differences occurred for KPH percentages and liver abscesses. Our data indicate that in finishing diets, glycerin concentrations up to 8% were optimal and greater inclusion could have deleterious effects. Supporting this, Schröder and Südekum (2007) suggested that glycerin concentrations greater than 10% of dietary DM would affect feed intake, water intake, and digestibility of the diet and nutrients. This might explain the reduction in growth performance and carcass characteristics observed in our study when glycerin was fed at 12 and 16%. Feeding less than 8% crude glycerin in steam-flaked corn diets can improve the gain and efficiency of finishing heifers, with the maximum benefits observed at the 2% concentration. Understanding the effects of glycerin on meat characteristics, VFA, ruminal changes, and digestibility in ruminants will be necessary to determine the relative feed value of glycerin. In addition, this will help answer questions pertaining to differences in performance and carcass characteristics as inclusion concentrations are increased.

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