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# Supplemental betaine and peroxide-treated feather meal for finishing cattle<sup>1</sup>

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**ABSTRACT:** These studies evaluated the effects of betaine, provided either as feed-grade betaine or as concentrated separator by-product (CSB; desugared beet molasses), on performance and carcass characteristics of finishing cattle. In Exp. 1, 175 steers (410 kg initial BW) were fed a finishing diet based on steam-flaked and dry-rolled corn, and treatments included 10.5 and 21 g/d feed-grade betaine and 250 and 500 g/d CSB (supplying 15.5 and 31 g/d of betaine, respectively). Steers fed feed-grade betaine had greater (linear and quadratic effects,  $P < 0.1$ ) DMI than control steers, but ADG and gain efficiencies were not affected by treatment. Dressing percent and backfat thickness was greater ( $P < 0.1$ ) for steers that received feed-grade betaine than for controls. Longissimus muscle area was lower ( $P < 0.1$ ) for steers supplemented with either feed-grade betaine or CSB than for control steers. Yield grades were higher for cattle receiving feed-grade betaine (quadratic effect,  $P < 0.1$ ) than for control steers. Marbling scores were not affected by supplemental betaine, but the percentage of carcasses grading USDA Select was lower (linear and quadratic effects,  $P < 0.1$ ) for steers fed feed-grade betaine than for control steers,

predominantly due to a greater percentage grading USDA Choice. In Exp. 2, 312 heifers (343 kg initial BW) were used in a finishing study to evaluate the effects of graded levels of feed-grade betaine and peroxide-treated feather meal on performance and carcass characteristics. Treatments included two finishing diets (containing peroxide-treated or untreated feather meal) and four levels (0, 4, 8, and 12 g/d) of feed-grade betaine arranged in a  $2 \times 4$  factorial. No significant interactions occurred between treatment of feather meal and betaine. Treatment of feather meal with hydrogen peroxide (5% wt/wt) increased in situ protein degradability but did not alter DMI, ADG, gain efficiencies, or carcass characteristics of heifers when it replaced untreated feather meal in the diet. Top-dressing feed-grade betaine to the diets had no effect on DMI, ADG, and gain efficiencies. Marbling scores were greater (cubic effect,  $P < 0.05$ ) for heifers fed diets top-dressed with 4 and 12 g/d of feed-grade betaine, but other carcass characteristics were not altered significantly. Overall, feed-grade betaine and CSB did not alter growth performance, but did have minor effects on carcass characteristics.

Key Words: Betaine, Cattle, Feather Meal, Feedlots, Performance

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## Introduction

Finishing cattle respond positively to supplementation of ruminally protected choline (Drouillard et al., 1998; Bindel et al., 2000). Because choline is degraded extensively by ruminal microbes (Sharma and Erdman, 1989), it needs to be protected from ruminal destruction for appreciable amounts to be absorbed by ruminants. One function of choline is methyl group donation via betaine. Therefore, cattle may respond to supplemental betaine when methyl groups are deficient. Mitchell et

al. (1979) and Löest et al. (2001) demonstrated that betaine was degraded by ruminal microbes. Therefore, betaine could alter ruminal fermentation by serving as a source of either ruminally available nitrogen or methyl groups. Concentrated separator by-product (CSB) is a by-product of the sugar industry that results when additional sugar is extracted from beet molasses. It contains high concentrations of betaine and could serve as a source of betaine for cattle diets.

The performance of finishing cattle often is improved when high-grain diets are supplemented with degradable, true protein (Braman et al., 1973; Thomas et al., 1984; Milton et al., 1997a), whereas addition of ruminal escape protein sources generally is ineffective in improving performance (Loerch and Berger, 1981; Sindt et al., 1993a,b). Milton et al. (1997b) suggested that the improved performance observed in response to soybean meal supplementation was due to improvements in di-

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etary energy utilization rather than metabolizable protein supply. Feather meal is high in ruminal escape protein (70%; NRC 1996); therefore, increasing the ruminal degradation of this protein may improve its value in finishing diets for cattle.

Our objectives were to 1) investigate the effects of betaine, provided either as feed-grade betaine or as CSB, on animal performance and carcass characteristics and 2) evaluate peroxide-treated feather meal in finishing diets.

## Materials and Methods

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

### Experiment 1

Large-framed yearling steers of various breed origins ( $n = 175$ ; 410 kg initial BW) were used in a randomized complete block design. All steers were implanted with Revalor-S (120 mg trenbolone acetate and 24 mg estradiol-17 $\beta$ ; Hoechst-Roussel Agri-Vet Company, Somerville, NJ) and treated for external parasites using permethrin (Boss Pour-On Insecticide; Schering Plough, Union, NJ) 8 d before the experiment started. Steers were weighed individually, allotted to one of five blocks based on weight, and stratified by breed and weight to one of five pens within each block. The three heaviest blocks were housed in open-front barns with five steers per pen ( $4.8 \times 6.1$  m), whereas the remaining two blocks were housed uncovered with 10 steers per pen ( $4.3 \times 13.4$  m). Steers were switched gradually over a period of 8 d from a corn-based diet containing 13% chopped alfalfa (DM basis) to a finishing diet based on a mix of steam-flaked and dry-rolled corn (Table 1). The basal diet was offered to steers once daily on an ad libitum basis. Initial pen weights were obtained after the adaptation period. Treatments were 1) control (no added betaine), 2) 10.5 g/d feed-grade betaine, 3) 21 g/d feed-grade betaine, 4) 250 g/d CSB, and 5) 500 g/d CSB. The 250 g/d CSB treatment supplied 15.5 g/d of betaine, whereas the 500 g/d CSB treatment supplied 31 g/d of betaine. Feed-grade betaine (Betafin-S6) was obtained from Finnsugar Bioproducts, Helsinki, Finland, and CSB (desugared beet molasses) from American Crystal Sugar, Moorhead, MN. The betaine and CSB were top-dressed to the basal diet at feeding. Four blocks containing the heaviest steers were fed 82 d, whereas the block containing the lightest steers was fed 113 d. At the end of the finishing period, final pen weights were obtained before steers were shipped to a commercial abattoir.

Hot carcass weights and the incidence of liver abscesses were recorded at slaughter. Kidney, pelvic, and heart fat, 12th-rib fat thickness, marbling score, longissimus muscle area, USDA yield grade, and USDA quality grade were measured after carcasses had been

**Table 1.** Ingredients and nutrient compositions of diets

Item	Exp. 1	Exp. 2
Ingredient	% of DM	
Steam-flaked corn	39.2	81.6
Dry-rolled corn	43.6	—
Chopped alfalfa hay	8.0	7.0
Cane molasses	2.0	4.0
Feather meal <sup>a</sup>	—	3.0
Bleachable tallow	2.0	2.0
Soybean meal, 47.5% CP	2.0	—
Limestone	1.3	1.3
Urea	1.1	0.55
Salt	0.30	0.30
Ammonium sulfate	0.22	—
Potassium chloride	0.16	0.15
Monocalcium phosphate	0.14	—
Trace mineral mix <sup>b</sup>	0.05	0.06
Rumensin-80 <sup>c</sup>	0.02	0.02
Tylan-40 <sup>d</sup>	0.01	0.01
Vitamin A premix <sup>e</sup>	0.01	0.01
Nutrient, calculated		
CP	13.2	13.0
Ca	0.68	0.65
P	0.30	0.28
K	0.63	0.65

<sup>a</sup>Untreated or treated with hydrogen peroxide.

<sup>b</sup>To provide (DM basis): 41 mg Zn, 41 mg Mn, 7 mg Cu, 0.43 mg I, 0.20 mg Se, and 0.03 mg Co per kg of diet (Exp. 1); 60 mg Zn, 60 mg Mn, 10 mg Cu, 0.63 mg I, 0.25 mg Se, and 0.05 mg Co per kg of diet (Exp. 2).

<sup>c</sup>To provide (DM basis): 33 mg monensin per kg of diet (Exp. 1 and 2); Elanco Animal Health, Indianapolis, IN.

<sup>d</sup>To provide (DM basis): 11 mg tylosin per kg of diet (Exp. 1 and 2); Elanco Animal Health.

<sup>e</sup>To provide (DM basis): 2,645 IU vitamin A per kg of diet (Exp. 1 and 2).

chilled for 24 h. USDA quality grades were determined by a USDA grader.

**Statistical Analysis.** The general linear models procedure of SAS (SAS System for Windows Release 6.12; SAS Inst. Inc., Cary, NC) was used to analyze animal performance and carcass characteristics as a randomized complete block design. Pen was the experimental unit, and the model included effects of block and treatment. Contrasts were used to evaluate the linear and quadratic effects of feed-grade betaine and CSB. Significance was declared at  $P < 0.1$ .

### Experiment 2

Medium-framed crossbred heifers of various breed origins ( $n = 312$ ; initial BW = 343 kg) were used in a randomized block design. Heifers were weighed individually and implanted with Revalor-H (140 mg trenbolone acetate and 14 mg estradiol-17 $\beta$ ; Hoechst-Roussel Agri-Vet Company). Then they were allotted to one of three blocks based on BW and previous nutritional treatment imposed during the growing phase and within each block were stratified by BW to one of eight pens ( $10 \times 27$  m; 12 to 13 heifers per pen). Initial pen weights were obtained on the following day before feeding. Heifers had been adapted previously to a common finishing

diet, so they received the dietary treatments immediately. Treatments were arranged in a  $2 \times 4$  factorial with two finishing diets (containing untreated or peroxide-treated feather meal) and four levels (0, 4, 8, and 12 g/d) of supplemental feed-grade betaine, which were top-dressed to the diets at feeding. The experimental diets were fed to heifers once daily to allow ad libitum consumption. The three blocks of heifers were fed for 117, 127, and 159 d, then final pen weights were obtained, and heifers were shipped to a commercial abattoir. Carcass data were collected as described for Exp. 1.

**Chemical Treatment of Feather Meal.** Treatment involved adding 14.3 kg of 35% (wt/vol) feed-grade hydrogen peroxide solution to 100 kg of feather meal (as is) as it was being mixed continuously in a feed truck. This supplied approximately 5% (wt/wt) of active hydrogen peroxide. After being mixed for 15 min, the treated feather meal was cooled by spreading to a depth of 30 cm on a clean concrete surface.

Untreated and peroxide-treated feather meals and other feed ingredients for the basal diet were sampled weekly, dried in a forced-air oven at 55°C, and allowed to air-equilibrate before being ground through a 1-mm screen and analyzed for DM by drying at 105°C for 24 h. Feather meal samples also were analyzed for Kjeldahl N (AOAC, 1990).

**Protein Degradation Assay.** The protein degradabilities of the chemically treated and untreated feather meal samples were measured using the in situ bag technique. Duplicate polyester bags (5 × 10 cm; pore size = 50 µm), containing either no sample (blank) or 1.25 g of soybean meal (standard), feather meal, or peroxide-treated feather meal were sealed using an impulse heat sealer and soaked in warm tap water before being suspended for 12 h in the rumen of a cannulated Holstein steer fed a 50% concentrate diet. Bags were removed, rinsed in a commercial washing machine as described by Coblenz et al. (1999), and then dried in a forced-air oven at 55°C; bags with or without samples were analyzed for Kjeldahl N.

**Statistical Analysis.** Animal performance and carcass characteristics were analyzed statistically as a randomized complete block design using the General Linear Models procedure of SAS. Pen was the experimental unit, and the model included effects of block, diet (treated vs untreated feather meal), level of betaine supplementation, and the interaction between diet and betaine. Contrasts were used to determine 1) the linear, quadratic, and cubic effects of betaine and 2) the interaction between diet (treated vs untreated feather meal) and the effects of betaine. Significance was declared at  $P < 0.1$ .

## Results and Discussion

### Experiment 1

Performance and carcass characteristics for steers supplemented with feed-grade betaine and CSB are

presented in Table 2. Daily DMI was greater (linear and quadratic effects,  $P < 0.1$ ) for steers supplemented with feed-grade betaine than for control steers. Reasons for the increase in DMI are unknown, but Mitchell et al. (1979) demonstrated that betaine is metabolized by ruminal microbes, so it may have an effect on ruminal fermentation. Although it is unlikely that top-dressing betaine to the basal diet increased palatability, this possibility cannot be ignored. In contrast to these results, Goodall and Brethour (1999) observed no differences in DMI when finishing steers were supplemented with 20 g/d of betaine. Supplemental feed-grade betaine and CSB did not affect ADG or gain efficiencies (Table 2). Goodall and Brethour (1999) similarly reported no differences in ADG and feed efficiencies when betaine was fed to steers. This lack of response may indicate that animal performance was not limited by availability of methyl groups or that little or no betaine escaped ruminal degradation to become available for the animals.

Although the supplementation of feed-grade betaine and CSB had little effect on steer performance, some carcass characteristics were altered by treatments (Table 2). Hot carcass weights were not different among treatments, but dressing percent was greater (linear effect,  $P < 0.1$ ) for steers receiving feed-grade betaine than for control steers. Steers fed 10.5 g/d of feed-grade betaine also had greater (quadratic effect,  $P < 0.1$ ) 12th rib backfat than control steers. Longissimus muscle areas were lower for steers receiving supplemental CSB (linear effect,  $P < 0.1$ ) and feed-grade betaine (quadratic effect,  $P < 0.1$ ) than for control steers. Yield grades were higher for cattle receiving supplemental feed-grade betaine (quadratic effect,  $P < 0.1$ ) than for control steers. The percentage of carcasses grading USDA Select were lower (linear and quadratic effects,  $P < 0.1$ ) for steers fed feed-grade betaine than for control steers, which was predominantly a result of numeric increases in the percentage of carcasses grading USDA Choice.

The exact mode of action for the improvements in carcass characteristics of finishing cattle is unclear, but it could be due to direct or indirect effects of betaine. An indirect effect might be the higher DMI of steers supplemented with betaine, which would increase total energy intake and allow for greater fat deposition. However, direct effects of betaine on ruminal or animal metabolism cannot be excluded.

In an in vitro experiment (Löest et al., 2001), 63 and 94% of the betaine from feed-grade betaine and CSB, respectively, disappeared after 24 h of incubation in ruminal contents of steers fed a high-grain diet. Mitchell et al. (1979) similarly reported degradation of betaine in vitro and in vivo. The ruminal degradation of betaine would suggest that the effects of supplemental feed-grade betaine and CSB on carcass characteristics of finishing cattle could be due to an effect on ruminal fermentation. Although Mitchell et al. (1979) identified the major metabolites of betaine, their effects in the rumen have not been established. These authors sug-

**Table 2.** Effects of feed-grade betaine and concentrated separator by-product (CSB) on the performance and carcass characteristics of finishing steers (Exp. 1)

Item	Control	Betaine, g/d		CSB, g/d		SEM
		10.5	21	250	500	
<i>Performance</i>						
Initial BW, kg	425	424	424	421	421	4.4
Final BW, kg	575	577	575	566	571	6.1
DMI, kg/d <sup>ab</sup>	9.53	10.02	9.86	9.64	9.84	0.13
ADG, kg	1.70	1.75	1.74	1.66	1.72	0.06
Gain:feed, g/g	0.179	0.174	0.175	0.172	0.175	0.006
Carcass adjusted ADG, kg <sup>c</sup>	1.43	1.47	1.52	1.44	1.46	0.05
Carcass adjusted gain:feed <sup>c</sup>	0.150	0.146	0.154	0.149	0.148	0.005
<i>Carcass</i>						
Hot carcass weight, kg	347	348	351	345	346	2.8
Dressing, % <sup>a</sup>	62.8	62.8	63.5	63.3	63.0	0.27
Kidney, pelvic, and heart fat, %	2.14	2.17	2.08	2.04	2.07	0.04
Backfat, cm <sup>b</sup>	1.04	1.22	1.04	1.03	1.09	0.074
Longissimus area, cm <sup>2</sup> <sup>bd</sup>	91.1	86.2	89.0	87.3	86.3	1.6
Yield grade <sup>b</sup>	2.34	2.78	2.45	2.48	2.59	0.10
Yield grade 1, %	14	6	6	10	6	4.6
Yield grade 2, % <sup>b</sup>	47	22	56	35	46	6.3
Yield grade 3, % <sup>bf</sup>	27	54	32	50	34	8.7
Yield grade 4 & 5, %	12	18	6	5	14	6.4
Marbling score <sup>e</sup>	3.92	4.19	4.17	4.06	4.17	0.12
USDA Prime, %	0	4	4	2	4	3.1
USDA Choice, %	49	72	66	60	62	7.6
USDA Select, % <sup>ab</sup>	51	20	30	38	34	7.2
USDA Standard, %	0	4	0	0	0	1.8
Liver abscesses, % <sup>f</sup>	2	4	8	17	4	5.0

<sup>a</sup>Linear effect of feed-grade betaine supplement ( $P < 0.1$ ).

<sup>b</sup>Quadratic effect of feed-grade betaine supplement ( $P < 0.1$ ).

<sup>c</sup>Computed using carcass weights and a common dressing percentage (63%).

<sup>d</sup>Linear effect of CSB supplement ( $P < 0.1$ ).

<sup>e</sup>3.00 = Slight<sup>00</sup>; 4.00 = Small<sup>00</sup>.

<sup>f</sup>Quadratic effect of CSB supplement ( $P < 0.1$ ).

gested that betaine could contribute to the nitrogen supply in feedlot diets. However, the amounts of metabolizable protein supplied by the basal diet in this study were estimated to be 1.03 and 1.01 kg/d for steers receiving supplemental feed-grade betaine and CSB, respectively, which satisfied the requirement (0.94 kg/d) of the steers (NRC, 1996). The amount of nitrogen supplied by betaine also was small relative to the supply from the basal diet. Thus, responses to betaine probably were not due to the additional supply of nitrogen.

The effects of feed-grade betaine and CSB supplementation on carcass characteristics also may have been due to postruminal absorption. Mitchell et al. (1979) concluded that some betaine may escape ruminal degradation and pass to the small intestine, where it can be absorbed. Betaine is the active methylating form of choline and plays an important role in the conservation of methionine by the transfer of methyl groups to homocysteine (Finkelstein, 1990). Choline also plays an important role in the synthesis of phosphatidylcholine (Mookerjea, 1971) and the transport of triglycerides from the liver (Haines and Mookerjea, 1965; Lombardi et al., 1968). One hypothesis is that absorbed betaine may decrease the need for methyl groups from choline, therefore increasing the availability of choline for lipid

metabolism. Another possibility is that betaine increases the remethylation of homocysteine to methionine, which, in turn, can be activated to S-adenosylmethionine, a major methyl group donor for many transmethylation reactions in the body (Eloranta, 1977; Finkelstein, 1990). One of these transmethylation reactions includes the synthesis of phosphatidylcholine (Barak et al., 1996; Chiang et al., 1996).

Addition of CSB to finishing diets in amounts up to 500 g/d did not alter steer performance and only had minor effects on carcass characteristics. Because CSB currently is relatively inexpensive, it could be an economical ingredient for use in finishing diets. Feed-grade betaine had only minor effects on performance, but tended to improve carcass quality grades.

### Experiment 2

Chemical treatment of feather meal with hydrogen peroxide increased in situ CP degradability by 56% (from 32% to 50%). Hydrogen peroxide oxidizes methionine residues to sulphoxide and sulphone residues and cyst(e)ine residues to cysteic acid (Anderson et al., 1975; Korycka-Dahl and Richardson, 1980). Because of the high cyst(e)ine content of feather meal (Goedeken et

**Table 3.** Effects of protein degradability of feather meal on the performance and carcass characteristics of finishing heifers (Exp. 2)

Item	Feather meal		SEM
	Untreated	Treated	
<i>Performance</i>			
Initial BW, kg	342	343	0.49
Final BW, kg <sup>a</sup>	490	494	2.5
DMI, kg/d	8.09	8.12	0.096
ADG, kg <sup>a</sup>	1.09	1.12	0.019
Gain:feed, g/g <sup>a</sup>	0.136	0.138	0.0023
Carcass adjusted ADG, kg <sup>b</sup>	1.09	1.13	0.019
Carcass adjusted Gain:feed <sup>b</sup>	0.136	0.139	0.0022
<i>Carcass</i>			
Hot carcass weight, kg	316.5	319.3	1.7
Dressing, %	64.6	64.7	0.12
Kidney, pelvic, and heart fat, %	2.19	2.25	0.047
Backfat, cm	1.03	1.01	0.037
Longissimus area, cm <sup>2</sup>	90.0	91.7	1.0
Yield grade	2.33	2.33	0.068
Yield grade 1, %	19	16	2.6
Yield grade 2, %	37	40	3.7
Yield grade 3, %	36	41	4.0
Yield grade 4 & 5, %	8	4	1.8
Marbling score <sup>c</sup>	3.66	3.47	0.089
USDA Prime, %	8	3	2.2
USDA Choice, % <sup>d</sup>	66	76	3.3
USDA Select, %	21	19	3.2
USDA Standard, %	4	2	1.1
Liver abscesses, %	5	6	1.9

<sup>a</sup>Computed by applying a 4% shrink to final BW.

<sup>b</sup>Computed using carcass weights and a common dressing percentage (64%).

<sup>c</sup>3.00 = Slight<sup>00</sup>; 4.00 = Small<sup>00</sup>.

<sup>d</sup>Treatment means differ ( $P < 0.1$ ).

al., 1990), treatment with hydrogen peroxide may have increased ruminal protein degradability by destroying disulfide bonds that can limit microbial breakdown (Mahadevan et al., 1980).

No significant interactions occurred between feather meal treatment and betaine; therefore, results for this experiment are presented separately as main effects of feather meal treatment (Table 3) and betaine supplementation (Table 4).

Replacement of untreated feather meal with peroxide-treated feather meal in the finishing diet of heifers did not alter DMI, ADG, or gain efficiencies (Table 3). Carcass characteristics were generally not influenced by the treatment of the feather meal, although the percentage of carcasses grading USDA Choice were greater ( $P < 0.1$ ) for heifers fed the diet containing peroxide-treated feather meal. However, the percentage of carcasses grading USDA Prime were numerically lower for heifers fed the peroxide-treated feather meal, such that there were no significant differences in carcasses grading USDA Choice or better.

Previous research has demonstrated that degradable, true protein sources supplemented to high-grain diets may improve performance of finishing cattle (Braman et al., 1973; Thomas et al., 1984; Milton et al., 1997a). However, adding sources of ruminal escape protein to these diets has been less effective (Loerch and Berger,

1981; Sindt et al., 1993a,b). Ruminal fermentation and microbial production may be enhanced by the supply of preformed peptides, amino acids, and other nutrients (Stern and Hoover, 1979; Russell et al., 1992; Wallace, 1996). Also, Milton et al. (1997b) suggested that the responses to degradable, true protein sources in high-grain diets likely were due to increased utilization of dietary energy rather than to the supply of metabolizable protein. Increasing the protein degradability of sources high in ruminal escape protein, such as feather meal, may improve their value in high-grain diets. However, in our experiment, the lack of change in performance and carcass characteristics for cattle fed the diet containing peroxide-treated feather meal suggests that a higher level of degradable, true protein from feather meal did not greatly enhance ruminal fermentation. Perhaps the chemical treatment of feather meal did not alter ruminal protein degradation enough to evoke a response under our experimental conditions or the cattle did not require additional ruminally available protein. Although not statistically different, during the first 28 d, heifers fed diets containing peroxide-treated feather meal had numerically lower DMI than heifers fed diets containing untreated feather meal (7.03 vs 7.23 kg/d), suggesting that peroxide-treatment of feather meal may decrease palatability.

**Table 4.** Effects of feed-grade betaine on the performance and carcass characteristics of finishing heifers (Exp. 2)

Item	Betaine, g/d				SEM
	0	4	8	12	
<i>Performance</i>					
Initial BW, kg	342	342	343	343	0.69
Final BW, kg <sup>a</sup>	491	488	492	496	3.5
DMI, kg/d	8.19	8.07	7.97	8.20	0.14
ADG, kg <sup>a</sup>	1.11	1.09	1.11	1.14	0.026
Gain:feed, g/g <sup>a</sup>	0.136	0.135	0.140	0.139	0.0032
Carcass adjusted ADG, kg <sup>b</sup>	1.10	1.08	1.13	1.14	0.027
Carcass adjusted gain:feed <sup>b</sup>	0.135	0.135	0.142	0.139	0.0031
<i>Carcass</i>					
Hot carcass weight, kg	316.9	314.5	319.7	320.4	2.3
Dressing, %	64.5	64.5	65.0	64.6	0.17
Kidney, pelvic, and heart fat, %	2.21	2.20	2.30	2.17	0.066
Backfat, cm	1.02	1.03	1.00	1.03	0.052
Longissimus area, cm <sup>2</sup>	91.4	89.7	92.0	90.2	1.4
Yield grade	2.29	2.30	2.31	2.41	0.097
Yield grade 1, %	18	22	19	10	3.7
Yield grade 2, %	38	34	37	44	5.2
Yield grade 3, %	40	36	37	41	5.7
Yield grade 4 & 5, %	4	8	6	5	2.6
Marbling score <sup>cd</sup>	3.44	3.81	3.42	3.60	0.13
USDA Prime, %	6	9	3	5	3.1
USDA Choice, %	71	69	71	73	4.7
USDA Select, %	19	18	24	20	4.5
USDA Standard, %	4	4	3	3	1.6
Liver abscesses, %	7	7	3	7	2.7

<sup>a</sup>Computed by applying a 4% shrink to final BW.

<sup>b</sup>Computed using carcass weights and a common dressing percentage (64%).

<sup>c</sup>3.00 = Slight<sup>00</sup>; 4.00 = Small<sup>00</sup>.

<sup>d</sup>Cubic effect of betaine ( $P < 0.1$ ).

Top-dressing feed-grade betaine to the finishing diets had no effect on DMI, ADG, or gain efficiencies (Table 4). Goodall and Brethour (1999) also reported no effects of supplemental betaine on DMI, ADG, and feed efficiencies of steers fed finishing diets. Carcass characteristics were generally not affected by addition of betaine to the diets, although marbling scores were greater (cubic effect,  $P < 0.1$ ) for heifers fed diets top-dressed with 4 and 12 g/d of betaine than for control heifers. However, percentages of carcasses grading USDA Choice or better were not affected by top-dressing betaine; carcasses grading USDA Choice or better averaged 77% for heifers receiving no betaine, leaving little room for improvement.

The results of this study demonstrate that supplementation of feed-grade betaine to diets for finishing heifers had only small effects on performance and carcass characteristics. This suggests that methyl group requirements of finishing cattle were satisfied by dietary and/or microbial supply or that little or no supplemented betaine escaped ruminal degradation to effectively supply methyl groups to the animal. If feed-grade betaine was metabolized extensively in the rumen, its effects on ruminal fermentation were not large enough to greatly alter performance and carcass characteristics in Exp. 2.

## Implications

Additions of feed-grade betaine and concentrated separator by-product to high-grain diets of finishing cattle had little impact on performance, but did tend to increase indicators of carcass fatness slightly. Because concentrated separator by-product is currently inexpensive, it may be an economic ingredient for use in finishing diets. Chemical treatment of feather meal with peroxide increased in situ protein degradability. However, responses to treatment of feather meal were not observed in our study, perhaps because the cattle did not require additional ruminally available protein.

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