BURNETT CENTER INTERNET PROGRESS REPORT

No. 1 - January, 1999

Effects of Source and Level of Ruminally Protected Choline on Performance and Carcass Characteristics of Finishing Beef Steers

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Introduction

Previous research (Galyean et al., 1997) indicated that daily gain and feed efficiency were improved when finishing beef steers were fed graded levels of ruminally protected choline (**RPC**; .25, .5, and 1% of dietary DM). Responses were cubic ($P < .10$) in nature, with an 11% increase in daily gain and a 6.8% improvement in feed efficiency for .25% RPC vs the control diet, but no effect on gain or efficiency with the 1% RPC diet vs the control diet. Subsequent research at Kansas State University (Bindel et al., 1998) confirmed the findings of Galyean et al. (1997) and suggest the need for further research to evaluate the efficacy of dietary levels of RPC at less than .25% of the dietary DM and to evaluate additional sources of RPC. This research is needed to allow beef cattle feedlot managers and nutritionists to make informed decisions on the use of RPC in feedlot cattle diets.

Experimental Procedures

Three hundred five (305) medium- to large-framed beef steers (British x Continental) were purchased for use in the experiment. The steers had previously grazed annual winter wheat pasture before shipment to the Texas Tech University (TTU) Burnett Center on March 30, 1998.

On arrival at the Burnett Center, each steer was weighed, given a numbered ear tag, vaccinated with Bovishield 4 + Lepto and Fortress 7 or Vision 7 clostridial preparations, and treated for internal and external parasites with Dectomax. Following processing, steers were housed in the partially slotted floor pens at the Burnett Center (seven steers per pen) and offered a 60% concentrate starter diet.

The 25 lightest and heaviest steers of the group of 305 steers were designated as extra cattle that would not be used in the experiment. The remaining 280 steers were split into Light and Heavy BW blocks (140 steers in each block). Within each weight block, steers were stratified by BW and assigned randomly within BW strata to one of the seven dietary treatments. After assignment of steers to treatment within weight blocks, pens (four pens of five steers each per treatment within weight block) were assigned randomly to the seven dietary treatments. Steers were sorted to their assigned pens on April 3, 1998.

Cattle in all pens were adapted to approximately ad libitum consumption of the 60% concentrate starter diet, thereafter stepped through 70% and 80% concentrate diets, and finally stepped to the 90% concentrate Control diet. The 90% concentrate Control diet was fed for approximately 4 d before the experiment

was initiated on April 22, 1998. On this date, each steer was weighed and implanted with Ralgro.

Experimental Design. The seven dietary treatments were arranged in a randomized block design. Pen was the experimental unit (four pens per treatment with five steers per pen in each of two weight blocks for a total of eight pens per treatment). The treatments were six different 90% concentrate diets with two levels (approximately 2.5 or 5 g per animal daily, designated as Low or High, respectively) and three sources (Source A, B, or C) of RPC plus the 90% concentrate Control diet that did not contain RPC. Source A was Balchem Capshure encapsulated choline, Source B was an experimental source of encapsulated choline supplied by DuCoa, and Source C was Sintofarm encapsulated choline.

Experimental Diets. Ingredient composition of the seven diets is shown in Table 1. These data reflect adjustments for the average DM content of feed ingredients for the overall experimental period. Each diet contained the same intermediate premix (Table 2) to supply protein, various minerals and vitamins, Rumensin (30 g/ton, DM basis), and Tylan (8 g/ton, DM basis). Each RPC source, at the specified level, was added to the diet directly at the time of mixing via a premix (50:50 mixture of each RPC source and ground milo, DM basis). The percentage of each RPC premix added to the diets was determined by assuming an average DM intake per animal daily of 8.5 kg. Assayed values of choline chloride were available for each RPC source (Source A = 33.03%, Source B = 32.08%, and Source C = 23.92%). Based on these assayed values and an assumed content of 87% choline in choline chloride, the ground milo:RPC source premixes contained 14.35, 13.98, and 10.41% choline, for Source A, B, and C, respectively. The desired intake of ruminal escape choline (2.5 or 5 g/animal daily; 2.87 and 5.75 g/animal daily, respectively, of choline chloride) was divided by the percentage of choline in each premix, with the result divided by an assumed DM intake of 8,500 g/d to calculate the percentage of each RPC premix needed for each of the RPC-containing diets shown in Table 1.

Management, Feeding, and Weighing Procedures. Standard procedures at the Burnett Center were used throughout the experiment. All diets were mixed in a 45-cubic foot capacity Marion paddle mixer. The Burnett Center feed milling system is operated by a computer-controlled WEM batching system. Once the total amount of feed for a given treatment was mixed, the amount of feed allotted to each pen within a given treatment was delivered using a Rotomix 84-8 self-propelled mixer/delivery wagon. During the first 24 d of the experiment, a computer-controlled belt-feeding system was used to feed the experimental diets because the Rotomix 84-8 unit was not ready for use.

Mixing and feeding order of treatment diets throughout the experiment was Control, Low A, High A, Low B, High B, Low C, and High C. Dry matter of ingredients used in the experimental diets was measured every 2 wk during the experiment. These ingredient DM values were used to calculate the DM percentage of each dietary ingredient for the overall experiment. In addition, samples of mixed feed delivered to feed bunks were taken weekly throughout the experiment. Samples of feed taken from the bunk were composited for each 28-d period of the experiment and further composited across the entire experimental period. Samples were ground to pass a 2-

mm screen in a Wiley mill, and overall composites were analyzed for DM, ash, CP, ADF, Ca, and P (AOAC, 1990; Table 3).

Each feed bunk was evaluated visually at approximately 0700 to 0730 daily. The quantity of feed remaining in each bunk was estimated, and the daily allotment of feed for each pen was recorded. This bunk-reading process was designed to allow for little or no accumulation of unconsumed feed (0 to 1 lb per pen). Feed bunks were cleaned and unconsumed feed was weighed at 28-d intervals throughout the trial. Dry matter content of bunk weighback samples was determined in a forced-air oven by drying overnight at 100°C. Bunk weighbacks and DM determinations of weekly feed bunk samples were used to calculate DM intake for each pen.

After 28, 56, and 84 d on feed, steers in all pens were weighed before the morning feeding. These BW measurements were taken to assess performance of the cattle on a regular basis. On d 56, at the time of a regularly scheduled BW measurement, each steer was reimplanted. Heavy block steers were implanted with Synovex S, whereas Light block steers were implanted with Revalor S. Steers in the Heavy block were weighed on d 105 and shipped to a commercial slaughter facility to obtain carcass data. Steers in the Light block were fed 140 d before shipment to a commercial slaughter facility. All BW measurements taken during the experiment were obtained using a single-animal scale that was calibrated with 1,000 lb of certified weights on the day before each scheduled weigh day. One steer died during the experiment, and one steer was removed from the experiment because of a leg injury.

Carcass Evaluation. All carcass measurements were obtained by the Beef Carcass Research Center of West Texas A & M University, Canyon, TX. Steers in the Heavy block were shipped to the Excel Corporation facility at Plainview, TX, whereas the Light block steers were shipped to the IBP facility in Amarillo, TX for slaughter and collection of carcass data. Measurements included hot carcass weight, longissimus muscle area, marbling score, percentage kidney, heart, and pelvic fat, fat thickness measured between the 12th and 13th ribs, yield grade, and liver abscess score. Liver abscess scores were recorded on a scale of 1 to 4, with 0 = no abscesses, 1 = A-, 2 = A, 3 = A+, and 4 = liver condemned for reasons other than abscesses.

Statistical Analyses. All data were analyzed with pen as the experimental unit. A randomized block design was used, and computations were made with the General Linear Models procedure of SAS (1987). Effects of block, treatment, and block x treatment were considered, with the residual (pen within block x treatment) used as the error term for testing treatment effects. Carcass data were entered on an individual animal basis, and analyzed with a model that included effects for block, treatment, block x treatment, and pen within block x treatment. Pen within block x treatment was specified as the error term for testing treatment effects. Residual mean square in this model for carcass data (not used for testing) would include individual animal variation. The following orthogonal contrasts were used to test treatment effects: 1) Control vs the average of all RPC treatments; 2) High vs Low RPC level; 3) Source A vs the average of Sources B and C; 4) Source B vs Source C; 5) Level x Source A vs the average of Sources B and C; and 6) Level x Source B vs Source C.

Results and Discussion

Performance Data. Daily gain, DM intake, and feed:gain ratio data are shown in Table 4. Cumulative performance data are shown only for d 0 to 28, d 0 to 56, and d 0 to 84 because of different days on feed for the two blocks of steers after d 84. Data labeled "d 0 to end" in Table 4 represent the average from the beginning to the end of the experiment for both blocks of steers (Heavy block = 105 days on feed and Light block = 140 days on feed).

No differences ($P > .10$) were noted in either initial or final BW among treatments. For d 0 to 28, daily gain by steers fed either level of Sources B and C tended to greater ($P < .09$) than gain by steers fed either level of Source A; however, this effect was not evident during d 0 to 56, d 0 to 84, or the overall trial. No differences ($P < .10$) were noted for DM intake among the seven treatments at any time during the experiment. Feed:gain ratio did not differ among treatments during d 0 to 28, d 0 to 56, or for the overall trial; however, during d 0 to 84, the feed:gain ratio tended to be less ($P < .09$) for cattle fed RPC Source C than for those fed RPC Source B.

Dietary NEm and NEg values were calculated from NRC (1996) equations using the overall trial data for BW, daily gain, and DM intake for each treatment. Calculated NEm and NEg values, respectively, were 2.12 and 1.45, 2.08 and 1.41, 2.13 and 1.46, 2.13 and 1.45, 2.14 and 1.46, 2.14 and 1.47, and 2.12 and 1.45 Mcal/kg of dietary DM for the Control, Low A, High A, Low B, High B, Low C, and High C treatments, respectively. The small differences among the treatments for these calculated energy values reflect the generally similar performance data among treatments.

The DM intake data for the overall experiment and the percentages of RPC premix added to the diets (Table 1) were used to calculate intakes of each RPC source. Based on these calculations, the intake of choline chloride (assumed 100% ruminal escape value) for the Low A, High A, Low B, High B, Low C and High C diets was 3.21, 6.06, 3.04, 6.14, 3.01, and 6.12 g/steer daily, respectively. These values are slightly greater than the target intakes of ruminal escape choline chloride of 2.87 and 5.75 g/steer daily for each source. The greater RPC intakes than targeted were a result of the slightly greater DM intake by the steers for the overall experiment than the value of 8.5 kg/d on which calculations for RPC inclusion in the diets were based.

Present performance data differ from the findings of Galyean et al. (1997) and Bindel et al. (1998). Galyean et al. (1997) reported that daily gain increased 11% and feed efficiency was improved by 6.8% when finishing cattle were fed 5 g per animal daily of RPC (from Source A) compared with controls. Similarly, Bindel et al. (1998) reported an 8.6% increase in daily gain and a 7.6% improvement in feed efficiency when finishing heifers were fed 5 g of RPC per animal daily vs unsupplemented controls. Reasons for differing results are not clear; however, performance by cattle in the present study was considerably greater than in these two previous experiments. For example, Control steers in the study reported by Galyean et al. (1997) gained 3.05 lb/d, and Control heifers in the study reported by Bindel et al. (1998) gained only 2.2 lb/d. In contrast, Control steers in the present experiment gained 3.76 lb/d for the overall experiment. Given the high level of performance by cattle in the present experiment, perhaps little or no improvement in daily gain would have been

expected by feeding RPC.

Carcass Data. Carcass measurements are shown in Table 5. Hot carcass weight and dressing percent did not differ among the seven treatments. There was a consistent trend for cattle fed any of the RPC sources and levels to have larger longissimus muscle areas (Control vs the average of all RPC treatments, $P < .11$). Moreover, carcass fat thickness was less for the cattle fed RPC vs control cattle (Control vs the average of all RPC treatments, $P < .01$). This trend for larger longissimus muscle area coupled with lower fat thickness resulted in lower USDA yield grades for cattle fed RPC (Control vs the average of all RPC treatments, $P < .01$). Percentage of kidney, pelvic, and heart fat was affected by a RPC level x Source B vs Source C interaction ($P < .10$). Marbling score was affected by an interaction of RPC level x Source A vs the average of Sources B and C ($P < .09$); however, little difference in marbling score was evident for Control steers vs those fed RPC. Percentage of carcasses grading USDA Choice was less than 50% for all treatments, but as would be expected from marbling score data, not markedly affected by feeding RPC.

Present results seem to contradict those of Galyean et al. (1997), who reported a linear increase in carcass yield grade as RPC (from Source A) level increased from 5 to 10 and 20 g/animal daily. However, examination of the Galyean et al. (1997) data for the 5 g/d RPC level indicated very similar, although non-significant responses, to those observed in the present experiment (i.e., slightly larger longissimus muscle area and slightly lower carcass fat thickness and yield grade with 5 g of RPC daily vs control). Bindel et al. (1998) reported no effect of RPC level on carcass characteristics of finishing heifers.

Liver score data are shown in Table 6. Because of small numbers per subclass, these data were not analyzed statistically. Overall, percentage of livers that were not condemned varied little among treatments. Reasons for condemnation varied somewhat with treatment, particularly condemnations caused by the presence of liver flukes.

Summary and Conclusions

Results of this experiment suggest that neither level (approximately 2.5 or 5 g/animal daily) nor source of RPC had marked effects on performance of finishing beef steers. Level of performance in the present experiment was much greater than in previous experiments with RPC, which may have affected our results. Carcass data from the present experiment indicate that both levels of RPC, across all three sources, increased carcass leanness as evidenced by decreased fat thickness and yield grade. Moreover, carcass muscling may have been increased as evidenced by a trend for greater longissimus muscle area in steers fed RPC. Because all cattle in the present and previous RPC experiments were implanted with growth-promoting implants, it may desirable to determine the effects of RPC on growth and carcass characteristics of non-implanted cattle.

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Acknowledgements

This research was supported by a grant from DuCoa, a DVC Company, and funds from the Thornton Endowment, Texas Tech University.

Table 1. Ingredient composition (%, DM basis) of the experimental diets[a]

		RPC Source A		RPC Source B		RPC Source C	
Ingredient	Control	Low	High	Low	High	Low	High
Cottonseed hulls	5.18	5.17	5.17	5.17	5.17	5.17	5.17
Ground alfalfa hay	5.37	5.37	5.37	5.37	5.37	5.37	5.37
Whole shelled corn	10.19	10.20	10.22	10.20	10.21	10.24	10.17
Steam-flaked corn	64.01	63.80	63.58	63.80	63.59	63.69	63.48
Molasses	3.68	3.68	3.67	3.68	3.67	3.68	3.67
Fat (yellow grease)	3.05	3.05	3.05	3.05	3.05	3.05	3.05
Urea	.90	.90	.90	.90	.90	.90	.90
TTU premix[b]	7.62	7.62	7.61	7.62	7.61	7.62	7.61
RPC premix[c]	-	.21	.41	.21	.42	.28	.56

[a]Control = no ruminally protected choline (RPC). Sources A, B, and C are described in the text. Low and High levels of each source supplied an estimated intake of 2.5 and 5 g/animal daily of RPC.

[b]Premix composition is shown in Table 2.

[c]Separate premixes were used for each RPC source. Each RPC premix was 50% ground milo and 50% of the RPC source (DM basis).

Table 2. Composition of the TTU premix used in experimental diets

Ingredient	%, DM basis
Ground milo	14.6236
Cottonseed meal	60.0000
High-calcium limestone	14.0351
Dicalcium phosphate	.3454
Potassium chloride	2.6667
Magnesium oxide	1.1862
Ammonium sulfate	2.2222
Salt	4.0000
Cobalt carbonate	.0006
Copper sulfate	.0524
Iron sulfate	.0444
EDDI	.0008
Manganese oxide	.0889
Selenium premix, .2%	.0333
Zinc sulfate	.2750
Vitamin A, 650,000 IU/g[a]	.0041
Vitamin E, 275 IU/g[a]	.0762
Rumensin, 80 mg/lb[a]	.2250
Tylan, 40 mg/lb[a]	.1200

[a]Stated concentrations are on a 90% DM basis.

Table 3. Chemical composition of the experimental diets[a,b]

		RPC Source A		RPC Source B		RPC Source C	
Ingredient	Control	Low	High	Low	High	Low	High
Dry matter, %	85.03	84.85	84.62	84.78	84.71	84.49	84.66
Ash, %	4.85	4.98	4.77	4.50	4.13	4.46	4.35
Acid detergent fiber, %	6.78	6.06	7.14	8.84	7.37	8.31	6.15
Crude protein, %	14.54	14.50	14.57	14.71	13.62	14.13	13.89
Calcium, %	.52	.58	.55	.54	.53	.47	.49
Phosphorus, %	.36	.32	.33	.33	.29	.33	.32

[a]All values except Dry matter, % are expressed on a DM basis. Values represent analyses conducted on a sample of each diet composited across Weeks 7 through 20 of the experiment.

[b]Control = no ruminally protected choline (RPC). Sources A, B, and C are described in the text. Low and High levels of each source supplied an estimated intake of 2.5 and 5 g/animal daily of RPC.

Table 4. Effects of source and level of ruminally protected choline (RPC) on performance by finishing beef steers[a]

		RPC Source A		RPC Source B		RPC Source C				
Item	Control	Low	High	Low	High	Low	High	SE[b]	Contrast[c]	OSL[d]
Initial BW, lb	798.6	800.6	791.3	800.7	800.7	796.3	800.8	6.56	-	NS
Final BW, lb	1,257.2	1,239.6	1,231.2	1,239.6	1,251.4	1,241.1	1,247.5	13.81	-	NS
Daily gain, lb										
d 0 to 28	4.28	4.18	4.21	4.42	4.54	4.50	4.52	.196	3	.09
d 0 to 56	4.01	3.98	3.99	3.97	4.21	4.09	4.08	.122	-	NS
d 0 to 84	3.98	3.96	3.88	3.82	3.98	3.98	3.97	.100	-	NS
d 0 to end	3.76	3.60	3.62	3.61	3.70	3.65	3.66	.088	-	NS
Daily DMI, lb/steer										
d 0 to 28	18.71	18.86	18.29	19.08	19.31	18.31	19.27	.521	-	NS
d 0 to 56	19.43	19.77	19.08	19.22	19.90	18.97	19.51	.480	-	NS
d 0 to 84	20.28	20.44	19.70	19.82	20.23	19.76	20.10	.436	-	NS
d 0 to end	20.47	20.39	19.75	19.87	20.11	19.82	20.15	.413	-	NS
Feed:gain										
d 0 to 28	4.44	4.55	4.39	4.33	4.31	4.10	4.26	.176	-	NS
d 0 to 56	4.86	4.97	4.79	4.87	4.76	4.64	4.78	.117	-	NS
d 0 to 84	5.11	5.17	5.08	5.20	5.09	4.96	5.07	.075	4	.09
d 0 to end	5.45	5.67	5.46	5.52	5.44	5.42	5.51	.075	-	NS

[a]Control = no ruminally protected choline (RPC). Sources A, B, and C are described in the text. Low and High levels of each source supplied an estimated intake of 2.5 and 5 g/animal daily of RPC.

[b]Pooled standard error of treatment means, n = eight pens/treatment.

[c]Orthogonal contrasts: 1) Control vs the average of all RPC treatments; 2) High vs Low RPC level; 3) Source A vs the average of Sources B and C; 4) Source B vs Source C; 5) Level x Source A vs the average of Sources B and C; and 6) Level x Source B vs Source C.

[d]OSL = observed significance level of orthogonal contrasts. . NS = non-significant, P > 10.

Table 5. Effects of source and level of ruminally protected choline (RPC) on carcass characteristics of finishing beef steers[a]

		RPC Source A		RPC Source B		RPC Source C				
Item	Control	Low	High	Low	High	Low	High	SE[b]	Contrast[c]	OSL[d]
Hot carcass wt, lb	775.5	765.2	757.4	764.9	772.0	763.4	765.6	9.549	-	NS
Dressing percent	61.67	61.75	61.54	61.70	61.59	61.67	61.59	.400	-	NS
LM area[e], sq. in.	12.83	13.09	12.95	13.26	13.35	13.25	13.34	.216	1	.11
Fat thickness, in.	.52	.46	.45	.42	.43	.43	.42	.027	1	.01
KPH[f], %	2.45	2.68	2.70	2.40	2.69	2.66	2.49	.141	6	.10
Yield grade	3.10	2.79	2.80	2.68	2.66	2.68	2.65	.128	1	.01
Marbling score[g]	388.5	367.9	389.5	387.8	364.0	398.0	389.5	12.39	5	.09
Choice, %[h]	42.50	30.77	40.00	37.50	23.69	46.15	33.33	-	-	-
Select, %	47.50	64.10	57.50	52.50	68.42	53.85	61.54	-	-	-
Standard, %	10.00	5.13	2.50	10.00	7.89	0.00	5.13	-	-	-

[a]Control = no ruminally protected choline (RPC). Sources A, B, and C are described in the text. Low and High levels of each source supplied an estimated intake of 2.5 and 5 g/animal daily of RPC.

[b]Pooled standard error of treatment means, n = eight pens/treatment.

[c]Orthogonal contrasts: 1) Control vs the average of all RPC treatments; 2) High vs Low RPC level; 3) Source A vs the average of Sources B and C; 4) Source B vs Source C; 5) Level x Source A vs the average of Sources B and C; and 6) Level x Source B vs Source C.

[d]OSL = observed significance level of orthogonal contrasts. NS = non-significant, P > .12.

[e]LM = longissimus muscle.

[f]KPH = kidney, pelvic, and heart fat.

[g]300 = Slight^0; 400 = Small^0; 500 = Modest^0.

[h]Choice, % includes cattle that graded Prime.

Table 6. Distribution of liver scores (% of total) in finishing beef steers fed different sources and levels of ruminally protected choline (RPC)[a]

		RPC Source A		RPC Source B		RPC Source C	
Liver score	Control	Low	High	Low	High	Low	High
Not condemned	77.50	71.80	77.50	87.50	71.05	76.92	76.92
A-	10.00	0.00	2.50	2.50	0.00	0.00	0.00
A	5.00	5.13	2.50	0.00	5.26	5.13	7.69
A+	0.00	2.56	2.50	2.50	7.90	2.56	0.00
Fluke	5.00	20.51	10.00	5.00	5.26	10.26	12.82
Other[b]	2.50	0.00	5.00	2.50	10.53	5.13	2.57

[a]Control = no ruminally protected choline (RPC). Sources A, B, and C are described in the text. Low and High levels of each source supplied an estimated intake of 2.5 and 5 g/animal daily of RPC.

[b]Liver condemned for reasons other than an abscess or flukes (e.g., adhesions).