

Effects of crude protein concentration and degradability on performance, carcass characteristics, and serum urea nitrogen concentrations in finishing beef steers

J. F. Gleghorn^{*1}, N. A. Elam², M. L. Galyean[†], G. C. Duff³, N. A. Cole⁴, and J. D. Rivera[†]

^{*}New Mexico State University Clayton Livestock Research Center, Clayton 88415; and

[†]Department of Animal and Food Sciences, Texas Tech University, Lubbock 79409

ABSTRACT: Two experiments were conducted at two locations to determine the effects of dietary CP concentration and source on performance, carcass characteristics, and serum urea nitrogen (SUN) concentrations of finishing beef steers. British × Continental steers were blocked by BW (357 ± 28 and 305 ± 25 kg initial BW; n = 360 and 225; four and five pens per treatment in Exp. 1 and 2, respectively). Steam-flaked corn-based diets were arranged in a 3 × 3 factorial with three CP concentrations (11.5, 13, or 14.5% of DM) and three sources of supplemental CP (N basis): 100% urea; 50:50 blend of urea and cottonseed meal; or 100% cottonseed meal. Steers in both experiments were initially implanted with Ralgro and reimplanted with Revalor-S on d 56. Performance and carcass data were pooled across locations. Crude protein concentration × source interactions were not observed ($P = 0.22$ to 0.93) for performance and carcass data. Crude protein concentration affected ADG ($P = 0.02$) and carcass-adjusted (to a common dressing percent within location) ADG quadratically ($P = 0.06$). Increasing the concentration of supplemental urea linearly increased carcass-adjusted ADG and G:F ($P < 0.05$) and carcass-adjusted G:F ($P <$

0.001). Dry matter intake was not affected ($P = 0.93$) by either CP concentration or source. Hot carcass weight (HCW; $P = 0.02$), LM area ($P = 0.05$), and dressing percent ($P = 0.03$) increased linearly with increasing urea concentration, whereas increasing CP concentration quadratically affected HCW ($P = 0.02$), with a maximum at 13% CP. Differences in backfat thickness and yield grade were negligible across treatments. Neither marbling score nor percentage of carcasses grading USDA Choice was affected by CP concentration or source. At all times measured, SUN concentrations increased ($P < 0.05$) with increasing CP concentration, but effects of CP source were small and variable across time. Results indicate that increasing CP concentrations from 11.5 to 13% slightly increased ADG and carcass-adjusted ADG, whereas increasing the proportion of supplemental urea increased carcass-adjusted ADG, G:F, and carcass-adjusted G:F and increased HCW, LM area, and dressing percent. A CP concentration above 13% seemed detrimental to ADG and HCW. Serum urea N increased over time, with CP concentration having a greater effect than CP source.

Key Words: Beef Cattle, Crude Protein Concentration, Feedlot, Protein Source, Serum Urea Nitrogen

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J. Anim. Sci. 2004. 82:2705–2717

Introduction

Current (NRC, 1996) estimates of protein requirements consider changes in feed processing, application

of various implant practices, and a host of other management factors to determine the CP concentrations needed in beef cattle diets. Thomson et al. (1995) estimated the optimal CP concentration in feedlot diets to be between 12 and 13% (DM basis), a concentration at which feedlot performance was maximized and protein wastage minimized. This range in dietary CP concentration agrees with recommendations by consulting nutritionists (Galyean and Gleghorn, 2001). Although providing supplemental CP increases performance by growing/finishing beef cattle, responses to CP concentration can vary with CP source (Huntington et al., 2001). Before the metabolizable protein (MP) system (NRC, 1996), CP requirements were based on the incorrect assumption that ruminal degradation of CP is con-

¹Correspondence: 15 NMSU Lane (phone: 505-374-2566; fax: 505-374-2568; e-mail: gleghorn@nmsu.edu).

²Dept. of Anim. Sci., Univ. of Kentucky, Lexington 40546.

³Dept. of Anim. Sci., Univ. of Arizona, Tuscon 85721.

⁴USDA-ARS Conservation and Production Research Laboratory, P.O. Drawer 10, Bushland, TX 79012. The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-ARS.

Received February 2, 2004.

Accepted May 20, 2004.

stant across all feed sources. Natural feed sources vary in their level of ruminal degradability, whereas most nonprotein N sources are essentially 100% degraded. Animal performance data suggest that the proper ratio of degraded:undegraded CP (DIP:UIP) should be fed to maximize performance (Stock et al., 1981; Milton et al., 1997a,b). Providing adequate DIP is necessary for maximum microbial CP synthesis, which depends largely on carbohydrate digestion in the rumen (Russell et al., 1992). Thus, requirements for DIP should be greatest with high-grain diets that are based on extensively processed starch (e.g., steam-flaked grains). Inclusion of DIP in such diets may alleviate ruminal ammonia shortages so that a loss of microbial yield does not occur. Our objective was to determine the effects of CP concentration and source of supplemental CP on feedlot performance, carcass characteristics, and serum urea N concentrations over the course of the feeding period of finishing beef steers fed steam-flaked corn-based diets.

Materials and Methods

Experiment 1, Clayton, NM

Cattle. Three-hundred crossbred medium- to large-framed (British \times Continental; average initial BW 357 ± 28 kg) beef steers were purchased from an order buyer (Prairie Livestock, West Point, MS) and shipped to the Clayton Livestock Research Center (CLRC), in Clayton, NM, on February 7, 2001. Steers were processed after arrival, including 1) individual identification, branding, and horn tipping as needed; 2) vaccination with a clostridial antigen (Ultrabac-7; Pfizer Animal Health, Exton, PA); 3) vaccination with an IBR-PI₃-BVD-BRSV vaccine (Pyramid 4; Ft. Dodge Animal Health, Overland Park, KS); 4) treatment for internal and external parasites (Cydectin; Ft. Dodge Animal Health); and 5) injection with 2 mL of a vitamin A/D₃ preparation (250,000 IU of vitamin A and 37,500 IU of vitamin D₃; AgriLabs, St Joseph, MO). After arrival, steers were sorted into 24 feedlot pens, with 12 to 13 steers per pen, and fed a 70% concentrate diet. Steers were fed approximately 2.26 kg of wheat hay in addition to the 70% concentrate diet during the first 3 d after arrival and were adapted to a 90% concentrate diet by decreasing the proportion of roughage over the subsequent 19-d period. Specifically, the 70% concentrate diet was fed for 5 d, a 75% concentrate diet was fed for 5 d, an 80% concentrate diet was fed for 5 d, and an 85% concentrate diet was fed for 4 d before starting the study. Seventy-five steers (average initial BW = 357 ± 28 kg) that have previously been used in receiving programs at the CLRC also were used in the study. Steers from the CLRC had been limit-fed a 90% concentrate diet (approximately 5.90 kg per animal) daily for approximately 14 wk before the study began. Steers were processed similarly to Prairie Livestock steers, including vaccination and treatment for external and

internal parasites. At the same time that Prairie Livestock steers were switched to an 85% concentrate diet, the CLRC steers were fed the same diet to decrease any differences in fill between the two sources of cattle. All steers received a zeranol implant (Ralgro; Schering-Plough Animal Health, Union, NJ) 1 d before the experiment started. Steers were reimplanted with Revalor-S (Intervet, Millsboro, DE) on d 56 of the experiment.

Treatment Assignment. All steers were weighed (unshrunk) 1 d before initiation of the study. Steer BW was stratified from heaviest to lightest to allow assignment to weight blocks, after which they were assigned to nine separate pens (10 steers per pen) within each of four weight blocks. Source of cattle (Prairie Livestock and CLRC steers) was equalized across pens. Thus, a total of 36 pens were used, with four weight blocks and nine treatments. Each soil-surfaced pen measured 12.2 m \times 34.8 m and had a 10.7-m fence-line bunk and individual water trough. The nine treatments consisted of three formulated CP concentrations (11.5, 13.0, and 14.5% of DM) and three sources (% N basis) of supplemental CP (all urea = U; a 50:50 blend of urea and cottonseed meal = B; or all cottonseed meal = C) arranged factorially.

Experimental Diets. The composition of the 90% concentrate diets used in Exp. 1 is presented in Table 1, and the composition of the intermediate premix used in this diet is presented in Table 3. Bunk samples were obtained weekly for DM analyses (100°C overnight in a forced-air oven). In addition, ingredient samples were obtained every 2 wk for determination of DM. Bunk samples were composited within each 28-d period for determination of CP (Kjeldahl N), ADF, ash, and P (AOAC, 1990), and results are summarized in Table 4.

Weighing and Feeding Procedures. Each steer was weighed on d 0 before feeding, and weights were obtained at 28-d intervals throughout the study. Scales were calibrated before use with 453.5 kg of certified weights (Silencer Single-Animal Squeeze Chute set on four load cells; Moly Mfg. Inc., Lorraine, KS). On weigh days, feed bunks for each pen were swept, and unconsumed feed was weighed and analyzed for DM content to allow for calculation of DMI for the period. Feed bunks were visually examined each day at approximately 0730. The estimated quantity of feed remaining in the bunk was used to determine a suggested feed call. The bunk-reading process was designed to allow for little or no accumulation of feed within the bunk from day to day; however, cattle were challenged regularly (typically at 3-d intervals) to ensure that consumption was ad libitum. When feed was left in the bunk, the pen was held at the previous level of feeding or slightly restricted until the total amount of feed delivered was consumed. Fresh feed was milled and delivered once daily in the morning. The quantity to be delivered to each pen was weighed to the nearest 0.45 kg and delivered to the pens by a feed truck fitted with six individual bins, each with an auger for dispensing feed.

Table 1. Ingredient composition (% DM basis) of concentrate diets for Exp. 1

Ingredient	CP concentration and source ^a								
	11.5%			13.0%			14.5%		
	U	B	C	U	B	C	U	B	C
Steam-flaked corn	80.56	79.26	77.46	79.84	76.90	73.28	79.11	74.67	69.13
Alfalfa hay	9.73	9.73	9.74	9.73	9.74	9.75	9.73	9.74	9.76
Cottonseed meal	—	1.67	3.71	—	3.52	7.78	—	5.35	11.87
Urea	0.49	0.26	—	1.02	0.56	—	1.55	0.85	—
Molasses	3.74	3.74	3.74	3.74	3.74	3.74	3.73	3.74	3.75
Fat (yellow grease)	2.90	2.91	2.91	2.90	2.90	2.91	2.90	2.91	2.91
Limestone	—	—	—	—	—	0.10	—	—	0.14
Dicalcium phosphate	0.15	—	—	0.34	0.20	—	0.54	0.30	—
Premix ^b	2.43	2.43	2.44	2.43	2.44	2.44	2.44	2.44	2.44

^aU = 100% urea:0% CSM; B = 50% urea:50% CSM; C = 0% urea:100% CSM (% N basis).

^bPremix composition is presented in Table 3.

Carcass Evaluation. Steers were scheduled for slaughter when backfat thickness was estimated by ultrasound to be 10 mm. This estimation was accomplished first by visually evaluating the animals, and, when it was determined that approximately 50% of the steers within a weight block had adequate finish to grade USDA Choice, an ultrasound measurement (500-V, 17-cm linear probe; Aloka, Wallingford, CT) of the cattle was obtained at the next scheduled weigh period for verification of backfat thickness. Cattle were shipped to the Tyson Fresh Meats facility in Amarillo, TX, for slaughter, and carcass data were collected by the Beef Carcass Research Center at West Texas A&M University, Canyon. Cattle in Block 1 were fed for 126 d, those in Blocks 2 and 3 were fed 140 d, and cattle in Block 4 were fed for 154 d. Individual carcass measurements included hot carcass weight (HCW); backfat thickness; LM area; percentage of kidney, pelvic, and heart fat (KPH); and marbling score. These measurements were used to calculate USDA yield grade. Dressing percent was calculated by dividing HCW by final live weight. In addition, a liver condition was recorded on a scale of 0 to 6, with 0 = no abscesses, 1 = A-, 2 = A, 3 = A+, 4 = telangiectasis, 5 = fluke damage, and 6 = fecal contamination. As a result of health problems and/or death of 4 animals, only 356 animals were slaughtered and included in the data analyses.

Experiment 2, Lubbock, TX

Cattle. Two hundred and thirty-six steers (medium-to large-framed; British × Continental; average initial BW 305 ± 25 kg) were delivered to the Texas Tech University Burnett Center on April 24, 2001. Cattle were purchased through Prairie Livestock and originated in Perryville, MO. Steers were processed at the time of arrival, including 1) vaccination with Ultra Choice clostridial vaccine (Pfizer Animal Health) and Bovishield 4 + Lepto (Pfizer Animal Health); 2) treatment for parasites (Dectomax; Pfizer Animal Health); 3) measurement of individual BW; and 4) individual identification with an ear tag. Steers were placed in 12

soil-surfaced pens (19 to 20 steers per pen) and offered approximately 4 kg of a 65% concentrate diet. Two days after arrival, cattle were started on a 70% concentrate diet, which was fed for the next 12 d until the study began. Individual BW and health status were used to determine the cattle that would be included in the study. Three steers were eliminated because of heavy BW, and eight steers were eliminated because of previous health problems detected on or shortly after arrival. Cattle were assigned to blocks and pens (as described in a subsequent section) on May 9, 2001, and switched to an 80% concentrate diet on May 16 (d 0 = start of the experiment). This diet was fed for 1 wk, followed by the final 90% concentrate diet, which was fed for the remainder of the study. The ingredient composition of the 80% concentrate diet (data not shown) was similar to that of the 90% concentrate diet, except that alfalfa hay replaced portions of the steam-flaked corn, cottonseed meal, and urea, resulting in slighter higher contents of ADF and Ca than in the 90% concentrate diet.

Cattle were initially implanted with a Ralgro on May 9 (d -7) when they were assigned to treatments and placed in their pens. As in Exp. 1, steers were reimplanted with Revalor-S on d 56.

Treatment Assignment. The ear tag number, BW, and coat color data for the 225 selected steers were sorted in ascending order by BW. The first 45 steers of lightest BW were designated as Block 1, continuing through blocking groups of 45 steers each to the 45 steers of heaviest BW (Block 5). Within each block, steers were stratified by BW and assigned randomly to the nine treatments (nine pens of five steers each per block). As in Exp. 1, the nine treatments consisted of three formulated CP concentrations (formulated values of 11.5, 13.0, and 14.5% of dietary DM) and three sources of supplemental CP (U, B, and C) arranged factorially. Blocks were assigned to nine contiguous pens in the Burnett Center, and treatments were then assigned randomly to pens within blocks. The partially slotted-floor pens measured 2.9 m × 5.6 m, with a feed bunk 2.44 m in length on one end of the pen. Water troughs were shared between adjacent pens. The proportion of

Table 2. Ingredient composition (% DM basis) of the 90% concentrate diets for Exp. 2

Ingredient	CP concentration and source ^a								
	11.5%			13.0%			14.5%		
	U	B	C	U	B	C	U	B	C
Steam-flaked corn	79.80	78.56	76.66	79.11	76.19	72.43	78.43	73.94	68.25
Alfalfa hay	9.96	9.95	10.04	9.95	9.92	9.90	9.94	9.90	9.97
Cottonseed meal	—	1.72	3.81	—	3.60	7.97	—	5.46	12.11
Urea	0.50	0.27	—	1.03	0.57	—	1.57	0.86	—
Molasses	4.13	4.13	4.12	4.13	4.12	4.19	4.12	4.11	4.18
Fat (yellow grease)	2.96	2.96	2.96	2.96	2.95	2.95	2.96	2.95	2.93
Limestone	—	—	—	—	—	0.10	—	—	0.14
Dicalcium phosphate	0.16	—	—	0.35	0.20	—	0.55	0.30	—
Premix ^b	2.49	2.41	2.41	2.47	2.45	2.46	2.43	2.48	2.42

^aU = 100% urea:0% CSM; B = 50% urea:50% CSM; C = 0% urea:100% CSM (% N basis).

^bPremix composition is presented in Table 3.

steers with different coat colors was checked by a χ^2 analysis, and no difference was detected in the distribution of coat colors among treatments or blocks ($P = 0.28$ and $P = 0.32$, respectively).

Diet Analyses. Ingredient composition of the 90% concentrate diet used in Exp. 2 is presented in Table 2, and the composition of the premix used in this diet is given in Table 3. Diet samples were collected weekly for DM analysis and composited within each 28-d period for determination of N (FP-2000 Nitrogen/Protein Analyzer; Leco, St. Joseph, MI). An overall compiled trial sample also was obtained from weekly samples of the

90% concentrate diets and ground to pass a 2-mm screen in a Wiley mill. Ash, ADF, Ca, and P (AOAC, 1990) were analyzed on this overall composite, and data are summarized in Table 4.

Weighting and Feeding Procedures. Individual weights were obtained on d 0 before feeding (C & S Single-Animal Squeeze Chute, set on four load cells; Cummings and Sons, Garden City, KS) and subsequently at 28-d intervals throughout the study. Before each weigh day, the scale was calibrated with 453.6 kg of certified (Texas Dept. of Agric.) weights.

Feed bunks were visually examined on a daily basis at approximately 0700 to 0730. Procedures were similar to those in Exp. 1, except that feed delivery was managed so that cattle were offered increasing amounts of feed (0.2 kg per steer daily) when the feed bunk was empty at the time of visual appraisal. As in Exp. 1, when feed was left in the bunk, the pen was held to the previous level of feeding or slightly restricted until the total amount of feed delivered was consumed. Daily feed delivery (at approximately 0800) was accomplished using a Rotomix 84-8 self-propelled mixing unit (Rotomix, Garden City, KS) fitted with load cells and a digital scale readout (readability ± 0.45 kg). As in Exp. 1, DM was determined on weekly feed samples and used in conjunction with the DM of fords collected at each 28-d period to determine DMI for each 28-d period.

Carcass Evaluation. Cattle within each block were ultrasonically evaluated (500-V, 17-cm linear probe; Aloka) approximately 40 d before their projected slaughter date to ensure that all cattle averaged an estimated backfat thickness of 11.4 to 12.7 mm at slaughter. Cattle were slaughtered at the Excel Corp. facility in Plainview, TX, in blocked groups. Total days on feed for each block were as follows: Block 5 = 154 d, Blocks 4 and 3 = 173 d, Block 2 = 203 d, and Block 1 = 210 d. Carcass measurements were the same as described for Exp. 1. As a result of health problems and/or death of 3 animals, only 222 animals were slaughtered and included in the data analyses.

All procedures and activities involving live animals in Exp. 1 and 2 were reviewed and approved by the

Table 3. Ingredient composition of the premixes used in Exp. 1 and 2

Ingredient	%, DM basis	
	Exp. 1	Exp. 2
Ground sorghum grain	18.191	—
Ground corn	—	23.363
Antioxidant ^a	—	0.500
Limestone	47.059	42.105
Dicalcium phosphate	1.036	—
Potassium chloride	8.000	8.000
Magnesium oxide	3.559	3.559
Ammonium sulfate	6.667	6.667
Salt	12.000	12.000
Cobalt carbonate	0.002	0.002
Copper sulfate	0.157	0.157
Iron sulfate	0.133	0.133
Calcium iodate	0.003	—
Ethylenediamine dihydroiodide	—	0.003
Manganous sulfate	0.500	—
Manganous oxide	—	0.267
Selenium premix, 0.06% Se	0.333	—
Selenium premix, 0.2% Se	—	0.100
Zinc sulfate	0.845	0.845
Vitamin A, 30,000 IU/g ^b	0.264	—
Vitamin A, 650,000 IU/g ^b	—	0.012
Vitamin E, 500 IU/g ^b	0.126	0.126
Rumensin-80, 176.4 g/kg ^b	0.675	0.675
Tylan, 88.2 g/kg ^b	0.450	0.450

^aEndox; Kemin Industries, Des Moines, IA.

^bConcentrations noted by the ingredient are on a 90% DM basis.

Table 4. Chemical composition of the 90% concentrate diets fed in Exp. 1 and 2^a

Ingredient	CP concentration and source ^b								
	11.5%			13.0%			14.5%		
	U	B	C	U	B	C	U	B	C
Exp. 1									
DM, %	85.5	84.8	85.1	84.8	84.7	85.2	84.8	85.0	85.2
CP, %	12.35	12.35	12.17	13.45	14.01	13.82	14.72	14.93	15.22
ADF, %	6.82	6.72	7.25	7.00	7.47	8.23	7.23	7.85	8.39
Ash, %	6.71	5.69	5.66	6.31	6.29	6.08	5.80	5.95	6.36
Ca, % ^c	0.66	0.63	0.64	0.71	0.68	0.68	0.75	0.70	0.70
P, %	0.29	0.23	0.25	0.32	0.32	0.29	0.32	0.33	0.32

Animal Care and Use Committees of New Mexico State University and Texas Tech University, respectively.

Pooled Analyses

Descriptions of experimental methods indicated hereafter apply to measurements and statistical analyses common to both experiments.

Blood Collection and Serum Urea Nitrogen Analyses. Blood was collected (before feeding) from randomly selected steers in each pen at 28-d intervals (to coincide with regularly scheduled BW measurements). Three steers per pen were sampled via jugular venipuncture in Exp. 1 (10-mL Corvac tubes; Sherwood Medical Co., St. Louis, MO), whereas two steers per pen were sampled in Exp. 2 (13-mL Vacutainer, SST Gel and Clot Activator; Becton Dickinson, Franklin Lakes, NJ). Samples from the majority of the cattle were collected via jugular venipuncture (>98%); however, in cases where a jugular sample could not be obtained, samples were collected via coccygeal venipuncture. The same steers within the pen were used for blood collection throughout the study (i.e., repeated measures). Blood was centrifuged at $1,000 \times g$ for 20 min (Model J2-21; Beckman, Irvine, CA), and separated serum was frozen in individual storage vials at -20°C . Serum urea nitrogen (SUN) was analyzed with a commercial kit (535-B; Sigma Chemical Co., St. Louis, MO) using a spectrophotometer (DU-50, $\lambda = 540$ nm; Beckman). Pen averages were calculated from individual concentrations and used to quantify changes in SUN during the growing and finishing phases of both trials. Four steers in Exp. 1 were excluded from the SUN analysis because these subjects did not have complete SUN profiles across the feeding period.

Data and Statistical Analyses

Feedlot performance and carcass characteristics were pooled across location. Performance data were evaluated using ADG; carcass-adjusted ADG, DMI, G:F, and carcass-adjusted G:F. Carcass-adjusted ADG and G:F were determined by using a final BW calculated from HCW divided by the average dressing percent for the cattle in each experiment (62.3 and 62.4%, for Exp. 1 and 2, respectively) rather than final measured live weight. Because live weight data for both experiments were obtained in the morning before feeding and gut fill was assumed to be equal among treatment groups, no adjustment (i.e., pencil shrink) was applied to live weight data. We made a decision *a priori* to pool the data from the two locations, considering location as a random effect. Nonetheless, preliminary analyses were conducted with a fixed-effects model, and tests for location \times CP concentration \times CP source interactions were nonsignificant for ADG, DMI, G:F, and carcass-adjusted G:F ($P = 0.93, 0.53, 0.50,$ and $0.38,$ respectively). Thereafter, performance and carcass data were analyzed with pen as the experimental unit using the MIXED procedure (SAS Inst. Inc., Cary, NC). The model statement for performance data included CP concentration, CP source, and the CP concentration \times CP source interaction. Location, block nested within location, and the location \times CP concentration \times CP source interaction were included in the random statement. Individually measured carcass characteristics (HCW, yield grade, dressing percent, marbling score, backfat thickness, and LM area) were analyzed, but the model was structured so pen would be the experimental unit. Thus, the mixed model for individual carcass data included fixed effects of CP concentration, CP source, and CP concentration \times CP source interaction. The random

Table 5. Effects of crude protein concentration and source on average daily gain (kg/d) for pooled data from Exp. 1 and 2^a

Period	CP concentration, %			Contrast ^b		CP source ^c			Contrast ^b		SEM ^d
	11.5	13.0	14.5	L	Q	U	B	C	L	Q	
d 0 to 28	1.90	2.10	2.15	0.02	0.34	2.07	2.07	2.00	0.44	0.68	0.168
d 0 to 56	1.86	2.00	2.01	0.03	0.25	1.98	1.96	1.93	0.38	0.89	0.070
d 0 to 84	1.83	1.94	1.92	0.03	0.05	1.93	1.89	1.87	0.15	0.78	0.124
d 0 to 112	1.78	1.85	1.84	0.04	0.07	1.85	1.82	1.80	0.11	0.97	0.112
d 0 to end ^e	1.65	1.71	1.67	0.30	0.02	1.69	1.67	1.66	0.17	0.94	0.127
Carcass-adjusted ADG ^f	1.63	1.71	1.68	0.12	0.06	1.71	1.67	1.64	0.04	0.71	0.126

^aNo CP concentration × CP source interactions ($P = 0.64$ to 0.95) were observed.

^bL = linear and Q = quadratic effects of either CP concentration or CP source (100 to 0% urea).

^cU = 100% urea:0% CSM; B = 50% urea:50% CSM; C = 0% urea:100% CSM (% N basis).

^dPooled standard error of the means; $n = 9$ pens per treatment.

^eAverage days on feed from d 0 to end (slaughter) were 140 and 185 for Exp. 1 and 2, respectively.

^fAdjusted final BW was calculated from hot carcass weight and the average dress of 62.3 and 62.4% for Exp. 1 and 2, respectively.

statement included location, block nested within location, the location × CP concentration × CP source interaction, and block nested within location × CP concentration × CP source. The distribution of carcasses grading USDA Choice and Select was analyzed using the GENMOD procedure (SAS Inst. Inc., Cary, NC), for which the model statement included block nested within location and treatment. Furthermore, orthogonal contrasts were used to analyze the response surfaces for CP level and source (level of supplemental urea). Liver abscess data were analyzed using χ^2 analysis, but, because of the very low rate of abscesses in both experiments (7.02 and 11.26% of all livers in Exp. 1 and 2, respectively), data are not shown.

Pooled SUN data were analyzed as repeated measures in a randomized complete block design using the MIXED procedure. Fixed effects tested were CP concentration, CP source, sampling day, and all interactions. The random statement included location, block nested within location, and all subsequent interactions with CP concentration and CP source. The repeated measure was defined as the individual steer nested within block × CP concentration × CP source × location. A compound symmetry covariance structure was used.

Results and Discussion

Average Daily Gain

No interaction was detected ($P = 0.22$ to 0.93) between CP concentration and CP source; therefore, the main effects of CP concentration and CP source are reported for performance and carcass data. Pooled ADG data from Exp. 1 and Exp. 2 are presented in Table 5. For the overall feeding period, CP concentration affected ADG quadratically ($P = 0.02$). The maximum ADG for the entire feeding period occurred with a CP concentration of 13% (1.71 kg/d), compared with 11.5 (1.65 kg/d) and 14.5% CP (1.67 kg/d). More pronounced differences among treatments in ADG were observed during the

initial part of the feeding period. During the first 28 d, ADG increased linearly ($P = 0.02$) with increasing CP concentration. Similarly, ADG through d 56 increased linearly ($P = 0.03$) with increasing CP concentration. By d 84 ($P = 0.05$) and 112 ($P = 0.07$), the response to CP concentration became quadratic, and, as with the overall trial results, maximal values were observed with 13% CP.

No differences in ADG were observed among CP sources ($P = 0.39$) for the overall feeding period (Table 5). For the interim periods and the overall trial results, ADG was numerically greatest for cattle receiving all supplemental protein in the form of urea, intermediate for the blend of urea and cottonseed meal, and least for all cottonseed meal.

Carcass-adjusted ADG tended ($P = 0.06$) to be affected by CP concentration. As with ADG based on live weight, carcass-adjusted ADG responded quadratically to increasing CP concentrations, with a maximal value at 13% CP. Carcass-adjusted ADG increased linearly ($P = 0.04$) as the percentage of supplemental CP supplied by urea increased, which agrees with the numerical trends noted for ADG based on live weight.

Dry Matter Intake

Neither CP concentration nor CP source affected DMI for the overall feeding period (Table 6); however, differences among periods existed for CP concentration. During the first 56 and 84 d on feed, DMI intake increased linearly with increasing CP concentration ($P = 0.04$), and this trend continued through d 112 ($P = 0.06$).

Gain Efficiency

Gain efficiency was not affected ($P = 0.52$) by CP concentration for the overall feeding period (Table 7); however, during the first 28 d on feed, G:F increased linearly ($P = 0.01$) with increasing CP concentration. Moreover, increasing the supplemental CP supplied by

Table 6. Effects of crude protein concentration and source on dry matter intake (kg/d) for pooled data from Exp. 1 and 2^a

Period	CP concentration, %			Contrast ^b		CP source ^c			Contrast ^b		SEM ^d
	11.5	13.0	14.5	L	Q	U	B	C	L	Q	
d 0 to 28	7.78	8.02	8.08	0.07	0.47	8.00	8.00	7.88	0.41	0.62	0.259
d 0 to 56	8.33	8.68	8.70	0.03	0.20	8.64	8.60	8.47	0.24	0.70	0.283
d 0 to 84	8.58	8.91	8.92	0.04	0.21	8.87	8.82	8.72	0.30	0.87	0.500
d 0 to 112	8.71	9.02	8.97	0.06	0.12	8.92	8.92	8.86	0.59	0.82	0.608
d 0 to end ^e	9.07	9.30	9.17	0.40	0.11	9.16	9.21	9.17	0.94	0.64	0.861

^aNo CP concentration × CP source interactions ($P = 0.88$ to 0.98) were observed.

^bL = linear and Q = quadratic effects of either CP concentration or CP source (100 to 0% urea).

^cU = 100% urea:0% CSM; B = 50% urea:50% CSM; C = 0% urea:100% CSM (% N basis).

^dPooled standard error of the means; $n = 9$ pens per treatment.

^eAverage days on feed from d 0 to end (slaughter) were 140 and 185 for Exp. 1 and 2, respectively.

urea linearly increased G:F ($P = 0.03$) for the overall feeding period, with the greatest efficiency observed with U. Carcass-adjusted G:F also increased linearly ($P = 0.001$) with increasing concentrations of supplemental CP in the form of urea (Table 7). As with actual G:F, no differences in carcass-adjusted G:F were noted among CP concentrations.

Cole and Hutcheson (1990) demonstrated the benefits of higher CP diets during the initial feeding period (first 14 d), when intakes are usually lower and rates of protein deposition are potentially high. In addition, diets containing greater concentrations of CP may be beneficial when feed intakes are relatively low (Fluharty and Loerch, 1995). These results could explain the increase in ADG to increasing CP concentration during the early part of the feeding period in the present study. Average daily gain responded linearly to CP concentration during the first 56 d on feed and then tended to become more quadratic in nature. This change in the nature of the response likely reflects a greater rate of protein deposition early in the feeding period, whereas, after d 56, the combination of increased DMI and a lower proportional rate of protein deposition resulted in an

oversupply of protein to the animal, such that excessive amounts of protein negatively affected ADG. In a recent study, Trenkle (2002) decreased the concentration of CP over the feeding period in diets of steers (initial BW = 274 kg) fed dry-rolled corn-based diets. Initial dietary CP (13%) was decreased after 84 d on feed to 11.85% and then to either 11.25 or 10.00% at 112 d, depending on treatment. Results for the overall feeding period indicated no difference among treatments for ADG and DMI; however, cattle receiving higher dietary CP after d 112 were more efficient ($P < 0.05$) than those fed lower CP concentrations after d 112. Furthermore, Klopfenstein and Erickson (2002) noted increased ADG and gain efficiency in yearling steers fed diets formulated to match MP requirements with BW throughout the feeding period. In the present study, increasing dietary CP linearly increased ADG ($P = 0.03$), DMI ($P = 0.07$), and G:F ($P = 0.06$) through the first 56 d of the feeding period. The linear response was not evident after 56 d of the feeding period for G:F, but ADG and DMI responded to increased CP concentrations through d 112 of the feeding period (Tables 5, 6, and 7, respectively). Indeed, performance responded quadratically

Table 7. Effects of crude protein concentrations and source on gain:feed ratio for pooled data from Exp. 1 and 2^a

Period	CP concentration, %			Contrast ^b		CP source ^c			Contrast ^b		SEM ^d
	11.5	13.0	14.5	L	Q	U	B	C	L	Q	
d 0 to 28	0.244	0.260	0.265	0.01	0.33	0.258	0.258	0.254	0.56	0.80	0.013
d 0 to 56	0.225	0.230	0.232	0.06	0.55	0.230	0.229	0.228	0.68	0.95	0.004
d 0 to 84	0.213	0.218	0.216	0.37	0.17	0.217	0.215	0.215	0.30	0.61	0.003
d 0 to 112	0.205	0.206	0.206	0.75	0.73	0.207	0.205	0.204	0.10	0.91	0.004
d 0 to end ^e	0.182	0.184	0.183	0.67	0.29	0.185	0.183	0.182	0.03	0.53	0.003
Carcass-adjusted G:F ^f	0.181	0.185	0.184	0.12	0.25	0.188	0.182	0.180	0.001	0.35	0.003

^aNo CP concentration × CP source interactions ($P = 0.31$ to 0.80) were observed.

^bL = linear and Q = quadratic effects of either CP concentration or CP source (100 to 0% urea).

^cU = 100% urea:0% CSM; B = 50% urea:50% CSM; C = 0% urea:100% CSM (% N basis).

^dPooled standard error of the means; $n = 9$ pens per treatment.

^eAverage days on feed from d 0 to end (slaughter) were 140 and 185 for Exp. 1 and 2, respectively.

^fAdjusted final BW was calculated from hot carcass weight and the average dress of 62.3 and 62.4% for Exp. 1 and 2, respectively.

to increasing dietary CP from 84 through the completion of the trial. Results from the present study and those of Trenkle (2002) and Klopfenstein and Erickson (2002) provide insight into the management of dietary CP levels relative to protein requirements of beef cattle as they reach maturity. Decreasing dietary CP as cattle reach heavier weights decreases N excretion (Klopfenstein and Erickson, 2002), which could have favorable environmental effects through decreased ammonia volatilization or runoff and percolation into surface or groundwater.

A concentration of 13% CP is approximately the value typically targeted for use in commercial settings (Galyean and Gleghorn, 2001). Increasing dietary CP concentration has increased ADG by finishing cattle (Trenkle, 1993; Thomson et al., 1995). Thomson et al. (1995) reported that increasing dietary CP from 10 to 13% CP increased DMI, ADG, and feed efficiency in cattle fed high-concentrate diets. The optimal concentration for CP in their steam-flaked sorghum-based finishing diets was determined to be between 12 and 13%, which was the point at which performance was maximized and protein wastage was minimized, as determined from plasma urea N concentrations (Thomson et al., 1995). Present data support these previous findings, in that ADG was greatest at 13% CP for the entire feeding period, with slightly lower ADG for 11.5 and 14.5% CP diets. In contrast to our results, Thomson et al. (1995) reported increased DMI and feed efficiency with increasing dietary CP concentration. This difference from our results might reflect the fact that Thomson et al. (1995) fed steam-flaked sorghum-based diets, whereas diets used in the present study were steam-flaked corn-based.

Our results suggest that effects of CP source on performance were somewhat less pronounced than effects of CP concentration. It is noteworthy, however, that G:F was consistently greatest over the feeding period for cattle receiving all supplemental CP from urea. In addition, carcass-adjusted ADG and G:F increased linearly with increasing supplemental CP from urea. Previous research has suggested that a proper blend of DIP and UIP is necessary to maximize performance (Stock et al., 1981), especially during the early part of the feeding period (Sindt et al., 1993). Supplementation of dry-rolled corn-based diets with CP sources that have a higher percentage of UIP increased ADG compared with equivalent concentrations of CP provided by urea alone (Milton et al., 1997b). In contrast, our findings do not support the hypothesis that a blend of DIP and UIP is necessary in supplemental CP because ADG and G:F were consistently higher for cattle supplemented with 100% urea. Even during the initial part of the feeding period, when MP supply may be short (Sindt et al., 1993; Milton et al., 1997b), no differences were noted in ADG, DMI, or G:F among supplemental CP sources. Perhaps differences in results between previous research and the present study are attributable to differences in corn-processing methods or BW of the

cattle used in the studies. Steers used by Sindt et al. (1993) were approximately 60 kg lighter than steers used in the present study; however, steers used by Milton et al. (1997b) were similar in BW to those used in the present study. Possible differences in pretrial management could affect initial performance through compensatory growth (Rossi et al., 2001), and differences in the ruminal digestibility of the diet fed (e.g., steam-flaked corn in the present study vs. dry-rolled corn in the diets fed in the other two studies) likely influenced results.

Inclusion of urea has been estimated to be most beneficial when limited to (0.9% of DM with dry-rolled corn diets (Milton et al., 1997a; Shain et al., 1998). In the current study, urea was included at approximately 0.50, 1.03, and 1.57% of DM for 11.5U, 13U, and 14.5U diets, respectively. If performance was maximized at 13% CP, and if performance was superior with all supplemental protein derived from urea, the concentration of urea inclusion for maximum performance was approximately 14% greater in the present study than in the previous studies. Cooper et al. (2002) demonstrated that corn processing (e.g., steam flaking) increases the dietary DIP requirement because of increased starch digestion within the rumen.

Optimal DIP concentrations (% of DM) in steam-flaked corn-based diets have been estimated at 8.3% (Cooper et al., 2002). In the present study, DIP (% of DM) ranged from 6.07 (11.5C) to 9.7% (14.5U). Again, with peak performance obtained at 13% CP and 100% urea inclusion, the corresponding DIP (% of DM) was 8.2%, a value that is in close agreement with the value of 8.3% proposed by Cooper et al. (2002).

Cecava et al. (1988) demonstrated an increased flow of nonessential amino acids to the small intestine when protein sources high in UIP were used as supplemental protein. Organic matter and starch digestion in the rumen were increased with as little as 0.5% urea inclusion, but total-tract digestion of starch and OM were not affected by urea concentration (Milton et al., 1997a). These factors combined with maximal microbial CP synthesis (MCP) with urea in high-concentrate diets (Devant et al., 2001) could provide support for the hypothesis that, when MCP is maximized, a more suitable array of amino acids and peptides will be presented to the small intestine for absorption with urea as the source of supplemental CP than with sources that provide more UIP. However, the validity of this hypothesis cannot be determined from present data.

Using the average pooled DMI (9.18 kg) data in Table 6, the average NE_m and NE_g concentrations for all diets based on tabular values (2.19 and 1.51 Mcal/kg of DM, respectively), the average (unshrunk) initial and final BW of the cattle in the two experiments (331 and 598 kg, respectively), and the overall average effective NDF of 8.19% (based on tabular values of NRC, 1996), the NRC (1996) MP system would predict MP requirements of 369 and 433 g/d for maintenance and gain, respectively. Predicted MCP synthesis would be 779 g/d, yield-

Table 8. Dietary net energy concentrations (Mcal/kg of DM) for 90% concentrate diets predicted from tabular values (formulation) or performance data^a

Item	CP concentration and source ^b									SEM ^c
	11.5%			13.0%			14.5%			
	U	B	C	U	B	C	U	B	C	
Formulation ^d										
NE _m	2.21	2.21	2.21	2.20	2.19	2.18	2.18	2.17	2.16	—
NE _g	1.52	1.52	1.52	1.51	1.51	1.50	1.50	1.49	1.48	—
Performance ^e										
NE _m	2.12	2.09	2.09	2.09	2.10	2.09	2.11	2.10	2.06	0.042
NE _g	1.45	1.43	1.42	1.43	1.43	1.42	1.44	1.43	1.40	0.036

^aEnergy concentrations apply to pooled data from Exp. 1 and 2.

^bU = 100% urea:0% CSM; B = 50% urea:50% CSM; C = 0% urea:100% CSM (% N basis).

^cPooled standard error of the means; n = 9 pens per treatment.

^dDetermined from diet formulation using tabular NE_m and NE_g values from the NRC (1996) for each feedstuff included in the diet.

^eDetermined from a quadratic equation (Zinn and Shen, 1998) using animal performance data to predict dietary energy values.

ing 499 g/d of MP from MCP. To meet this MP deficiency of 303 g, 379 g of UIP would be needed in the diet. Thus, the CP requirement, assuming the diet could be perfectly balanced for DIP (8.49% of DM) and UIP (4.13% of DM) would be 1,159 g/d, or 12.62%, of the diet. Among the nine experimental diets, tabular DIP values (sources U, B, and C, respectively) were 6.7, 6.4, and 6.1%; 8.2, 7.7, and 7.0%; and 9.7, 8.9, and 7.9% of DM for the for 11.5, 13, and 14.5% CP diets, respectively. Thus, the 13%, all-urea diet (8.2% DIP and 4.8% UIP) would have provided the best match to the NRC (1996) requirements, providing further support for the performance responses we observed with changes in CP concentration and source.

Net Energy Calculations

Calculations of dietary NE_m and NE_g concentrations were made by two methods (Table 8). For the first method (formulation in Table 8), tabular energetic values for individual feedstuffs, as defined by NRC (1996), were used to calculate total energy concentrations of the respective diets. The second method used animal performance to determine the energy content of each diet using the equation described by Zinn and Shen (1998), which calculates dietary NE_m concentration from energy expended for maintenance, daily energy deposited, and DMI. Dietary NE_g values were then calculated using the equation $NE_g = (0.877 \times NE_m) - 0.41$.

Formulated energy concentrations were higher than those calculated from animal performance (Table 8). No differences among CP concentrations were noted for NE_m ($P = 0.77$) and NE_g ($P = 0.73$) concentrations using the method described by Zinn and Shen (1998). Likewise, no differences among CP sources were detected for NE_m ($P = 0.13$) and NE_g ($P = 0.20$) concentrations. These results indicate that although supplemental protein sources were included at the expense of steam-flaked corn, little dilution of dietary energy occurred because of the inclusion of supplemental protein.

Carcass Characteristics

Results for pooled carcass data of cattle in Exp. 1 and 2 are presented in Table 9. Neither marbling score ($P = 0.56$ to 0.48) nor percentage of carcasses grading Choice ($P = 0.14$ to 0.40) was affected by CP concentration or source. Although small numerical differences in backfat thickness were noted among treatments, no differences were observed among CP concentrations ($P = 0.51$) and sources ($P = 0.21$).

Hot carcass weight responded quadratically ($P = 0.02$) to increasing CP concentration, with heaviest HCW observed with 13% CP, and slightly lower HCW noted for 11.5 and 14.5% CP; this result reflects the greater ADG and carcass-adjusted ADG with increasing CP concentration noted previously. Although absolute differences were small, USDA yield grade tended ($P = 0.07$) to increase with increasing CP concentration.

Increasing supplemental CP from urea linearly increased ($P = 0.02$) HCW. Furthermore, LM area ($P = 0.05$) and DP ($P = 0.03$) increased linearly as concentration of supplemental CP supplied by urea increased. Increased DP with increasing dietary urea concentration might be explained by the urea space concept for calculating body composition (Bartle et al., 1987). As infused urea is readily distributed among skeletal muscle shortly after infusion (Bartle et al., 1987), the hydrophilic characteristics of systemic ammonium ions may lead to increased water concentrations in tissues, thereby increasing the calculated DP of the live animal. Alternatively, an increased concentration of intact protein (UIP) in the gut of animals fed increasing concentrations of CP in the form of cottonseed meal might induce an osmotic drag, pulling water into the intestines, increasing gut fill, and decreasing DP.

The effects of supplemental CP source on carcass effects have varied in literature reports. Milton et al. (1997a) noted a quadratic effect of increasing urea concentration on HCW and DP. In the same study, yield grade and backfat thickness increased linearly with

Table 9. Effects of crude protein concentration and source on carcass characteristics for pooled data from Exp. 1 and 2^a

Item	CP concentration, %			Contrast ^b		CP source ^c			Contrast ^b		SEM ^d
	11.5	13.0	14.5	L	Q	U	B	C	L	Q	
HCW, kg ^e	369	376	373	0.09	0.02	376	373	370	0.02	0.74	6.63
Marbling score ^f	420	415	423	0.70	0.32	425	417	416	0.28	0.57	36.62
Choice, % ^g	55.15	54.74	48.97	—	—	53.40	57.73	47.67	—	—	—
Select, %	44.85	45.26	51.03	—	—	46.60	42.27	52.33	—	—	—
Yield grade	2.74	2.82	2.95	0.07	0.82	2.88	2.82	2.81	0.48	0.82	0.205
DP ^h	62.14	62.42	62.54	0.09	0.68	62.66	62.30	62.15	0.03	0.60	0.234
LM area, cm ²	87.37	88.33	85.99	0.23	0.11	87.97	88.26	85.45	0.05	0.13	2.49
Backfat, cm	1.10	1.15	1.19	0.27	0.87	1.20	1.18	1.07	0.11	0.45	0.10

^aNo CP concentration × CP source interactions ($P = 0.22$ to 0.80) were observed.

^bL = linear and Q = quadratic effects of either CP concentration or CP source (100 to 0% urea).

^cU = 100% urea:0% CSM; B = 50% urea:50% CSM; C = 0% urea:100% CSM (% N basis).

^dPooled standard error of the means; $n = 9$ pens per treatment.

^eHot carcass weight.

^fMarbling score: 300 = Slight 00; 400 = Small 00; 500 = Modest 00.

^gDistribution of Choice + Prime vs. Select + Standard carcasses did not differ among treatments ($P = 0.06$ to 0.82).

^hDressing percent = HCW/final live weight × 100.

increasing inclusion of urea. In contrast, Sindt et al. (1993) reported no differences in HCW or backfat thickness among protein (urea vs. urea-blood meal/feather meal) or grain (dry-rolled corn vs. dry-rolled grain sorghum) sources; however, quality grade was lower for cattle consuming a dry-rolled grain sorghum-based diet supplemented with urea than for cattle fed a dry-rolled corn-based diet supplemented with urea. In a recent study using urea and feather meal as supplemental protein sources, DP increased with increasing urea concentrations (Rivera et al., 2003). Diets containing supplemental protein in the combinations of urea:feather meal (100:0, 75:25, 50:50, and 25:75, % N basis) resulted in a linear decrease ($P = 0.004$) in DP (62.62, 62.23, 61.94, and 61.52%, respectively).

Effects of Crude Protein Concentration and Source on Serum Urea Nitrogen Concentrations

The effects of CP concentration and source on SUN for the pooled data are presented in Figures 1 and 2, respectively. Although blood was collected throughout the duration of the study (through d 196), SUN data were only analyzed through d 112 because this was the last date at which a complete profile for all steers on feed was available (i.e., after d 112, some blocks of cattle were removed for slaughter).

There was a sampling day × CP concentration ($P = 0.005$) interaction for pooled SUN data. As expected, the effect of CP concentration was not significant ($P = 0.97$) before treatments were applied on d 0; however, there were CP concentration effects on subsequent sampling days. On d 28, cattle fed 11.5 and 13% CP had lower SUN ($P < 0.03$) than those fed 14.5% CP. On d 56, SUN was lower in cattle fed 11.5% CP ($P < 0.02$) than in those fed either 13 or 14.5% CP, and SUN with 13% CP was lower ($P = 0.05$) than 14.5% CP. On d 84, cattle fed 11.5 and 13% CP had lower ($P < 0.05$) SUN

than those fed 14.5% CP. On d 112, SUN was less ($P < 0.01$) for cattle fed 11.5 vs. 14.5% CP, with value for cattle fed 13% CP being intermediate and not different from that of cattle fed the other two CP concentrations.

Similar to CP concentration, a sampling day × CP source interaction was noted ($P = 0.04$) for SUN; therefore, the effect of CP source was evaluated within sampling days. The only significant difference in SUN was noted on d 56. Cattle receiving all supplemental CP from either U or C did not differ from each other, nor did cattle fed U vs. B; however, cattle receiving B differed ($P = 0.05$) from those receiving C. No logical pattern of differences was noted across collection times. For example, on d 28, SUN was highest for B, followed in decreasing order by U and C. In contrast, on d 84 SUN was greatest for U and least for C, with B intermediate. Cattle in the C treatment frequently had the lowest SUN, except on d 112, when SUN was greatest for cattle receiving C. Cecava and Hancock (1994) also determined that increasing the proportion of undegradable intake protein as the supplemental protein source resulted in lower plasma urea N concentrations. In cattle limit-fed a corn silage diet, Huntington et al. (2001) reported that plasma urea N concentrations were less when a 2:1 mixture of corn gluten meal:soybean meal provided supplemental protein vs. soybean meal. Degradability of the cottonseed meal used in the present study would likely be considerably greater (NRC, 1996) than the corn gluten meal:soybean meal mixture used by Huntington et al. (2001).

Increasing dietary CP concentration has generally been shown to increase blood urea N concentrations (Bunting et al., 1987; Thomson et al., 1995; Huntington et al., 2001). Data from the present study suggest that CP concentrations of 11.5 and 13% were similar at d 28, 84, and 112, with the only difference between these two CP concentrations occurring at d 56. On all sampling days, cattle fed the 14.5% CP diet had the highest

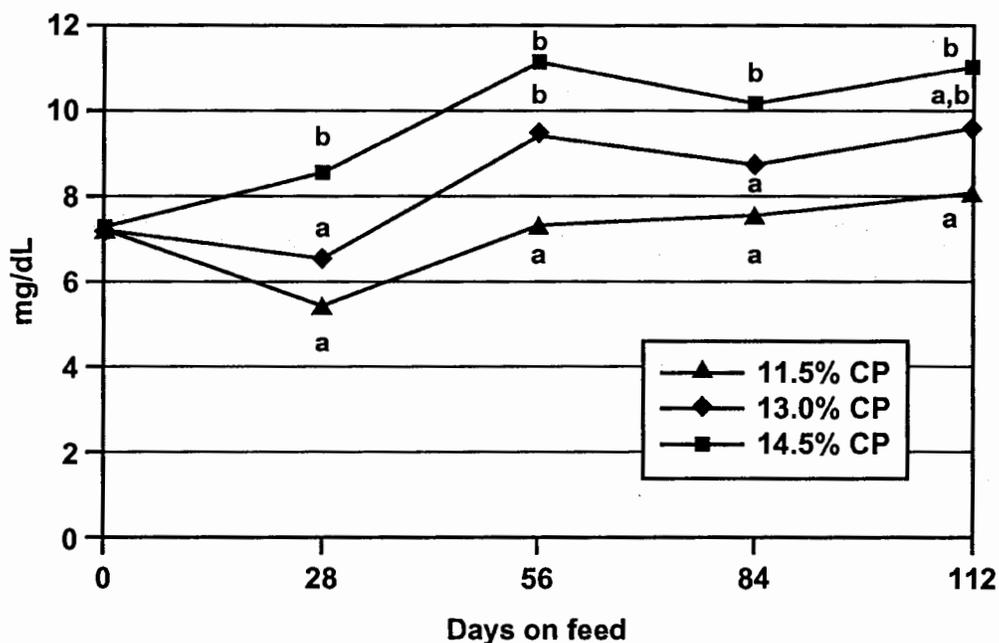


Figure 1. Effect of crude protein concentration on serum urea N concentrations across time for pooled data from Exp. 1 and 2. ^{a,b}Means within a time period that do not have a common superscript differ ($P < 0.05$). The SEM were as follows: d 0 = 0.89; d 28 = 0.32; d 56 = 0.52; d 84 = 0.34; d 112 = 0.49; n = 9 pens per treatment.

SUN concentrations. Previous research suggests that SUN concentrations greater than approximately 8 mg/100 mL are indicative of excessive N intake and N wastage (Cole et al., 2003). At all collection periods,

SUN concentrations for cattle fed the 11.5% diet were below or near the 8 mg/100 mL threshold (5.47, 7.34, 7.58, and 8.05 mg/100 mL for d 28, 56, 84, and 112, respectively). At d 84, a noticeable decrease in SUN

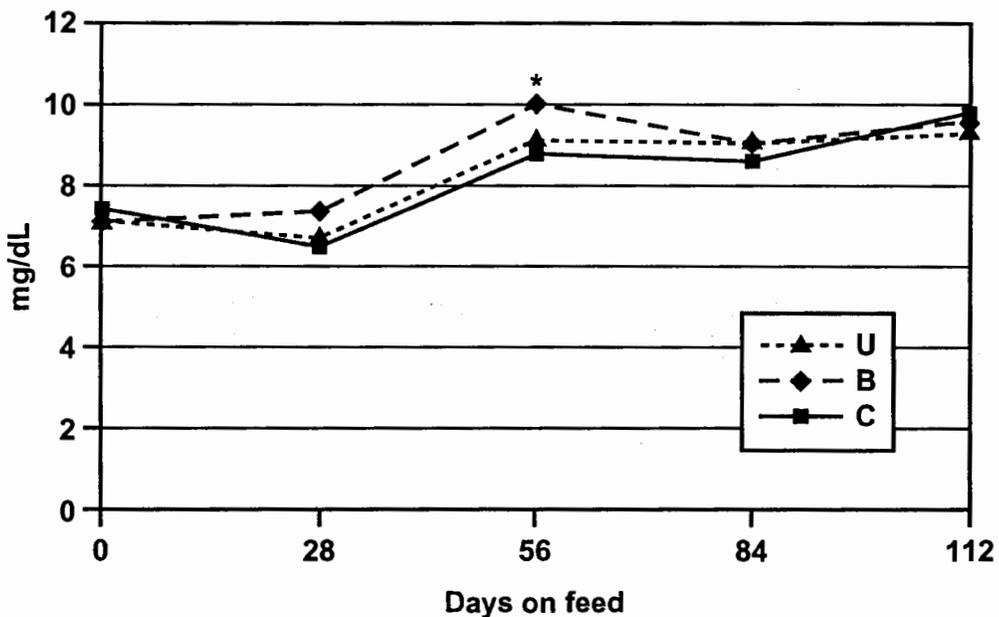


Figure 2. Effects of crude protein source (U = 100% urea:0% CSM; B = 50% urea:50% CSM; C = 0% urea:100% CSM [% N basis]) on serum urea N concentrations across time for pooled data from Exp. 1 and 2. *C < B ($P < 0.05$). The SEM were as follows: d 0 = 0.89; d 28 = 0.32; d 56 = 0.52; d 84 = 0.34; d 112 = 0.49; n = 9 pens per treatment.

was apparent in cattle fed 13 and 14.5% CP diets, but not for cattle fed 11.5% CP diets. This decrease might be attributable to reimplanting the cattle on d 56, thereby increasing N retention (Cecava and Hancock, 1994); however, in cattle that were limit-fed a corn silage-based diet, and therefore gaining much less than those in the present study, Huntington et al. (2001) showed no effect of a single estrogenic implant on plasma urea N concentrations.

Cattle fed the 11.5% CP diet in our study maintained a relatively constant SUN concentration, regardless of time, suggesting that this concentration of CP might be near or below the minimum required concentration. Nonetheless, SUN seemed to increase with time on feed regardless of CP concentration and CP source. This might be attributable to increased muscle protein degradation as BW increases (Rossi et al., 2001), and perhaps more importantly, to a constant or greater supply of CP as BW increased and proportional decrease in the rate of protein accretion.

Conclusions

Overall, our results suggest that ADG by cattle fed steam-flaked corn-based finishing diets responded quadratically to CP concentration, with maximal responses in ADG and other performance variables noted with a 13% CP diet. With regard to source of CP, carcass-adjusted gain and G:F (both live- and carcass-adjusted) improved as urea supplied more of the supplemental CP. Neither concentration nor source of CP had marked effects on carcass quality, but effects on HCW and DP paralleled effects on ADG. Serum urea N concentrations were affected more consistently by concentration of CP than by source. When cattle are finished on diets based on highly processed corn like the ones used in this study, urea seems to be the optimal source of supplemental CP.

Implications

These results suggest that the optimal crude protein concentration for finishing diets based on steam-flaked corn is approximately 13%. Increasing the crude protein concentration to 14.5% did not improve any of the performance or carcass measurements evaluated. Supplying supplemental crude protein in the form of urea seemed more beneficial for performance and carcass characteristics (e.g., hot carcass weight and dressing percent) than supplying crude protein in the form of cottonseed meal. Serum urea nitrogen concentrations increased with increasing concentrations of crude protein; however, no consistent pattern was observed for differences among crude protein sources. Few differences in serum urea nitrogen were noted between the 11.5 and 13% CP diets, but increasing dietary crude protein concentrations to 14.5% typically increased serum urea nitrogen, providing further evidence that this concentration of crude protein exceeded the requirements of the cattle in our two experiments.

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