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IN VITRO AMMONIA RELEASE FROM UREA/CALCIUM COMPOUNDS AS COMPARED TO UREA AND COTTONSEED MEAL

J. L Cass and C. R. Richardson

SUMMARY

Two slow release urea/calcium products were evaluated for ammonia release. Four nitrogen sources (cottonseed meal, urea, 23-0-0-7 and 10-0-0-11) were mixed with corn starch or ground corn to produce in vitro substrates containing 10 and 14% crude protein. Each substrate was digested separately in 250-ml incubation flasks and sampled for ammonia determination after 2, 4, 6, 8, 16, and 24 h. Means for ammonia concentration ranged from 0 mg/dL (cottonseed meal) to 72.99 mg/dL (urea). Differences ($P < .05$) were observed among all products and within time period.

INTRODUCTION

Urea is the most commonly utilized nonprotein nitrogen (NPN) source for cattle feeding. However, urea is rapidly broken down for microbial protein synthesis in the rumen, resulting in immediate ammonia release for microbial protein synthesis, but excess ammonia is absorbed and can cause toxicity. Two of the NPN products used in this study were composed of 23-0-0-7 and 10-0-0-11 N, P, K, and Ca, respectively. The nitrogen source contained in these products was bound to calcium chloride. The purpose of this experiment was to evaluate these products, feed grade urea, and cottonseed meal in an experiment designed to determine ammonia release rate over time.

EXPERIMENTAL PROCEDURE

In vitro substrates were formulated using ground corn and corn starch. Nitrogen, not supplied by ground corn or corn starch, was supplied by one of the two urea/calcium compounds, feed grade urea, or cottonseed meal. The nitrogen sources were added at levels to achieve 10 and 14% crude protein fermentation media. One hundred grams of each medium were prepared in which each nitrogen source was weighed and then raised to 25 g with distilled water. This procedure was to insure similar mixing because of the fact that some nitrogen sources were already in a liquid form. A small stand mixer was used to mix the diets as the liquid was evenly applied by a hand spray bottle. The mixtures were digested by the procedure described by Dinus et al. (1974), and McDougal's buffer, without N, was added to all incubation flasks (Tilley and Terry, 1963). Samples taken during this procedure were analyzed for ammonia content by a colorimetric procedure (Chaney and Marbach, 1962). A Beckman DU - 50

Spectrophotometer was used in reading samples in this procedure.

RESULTS

10% Corn starch substrate medium. After 2 and 4 h of incubation In rumen fluid, the 10-0.0,11 compound had values of 1.02 and .87 mg/dL, respectively, which was the highest ammonia concentration (Table 1). The data showed no significant differences among any of the nitrogen sources at 2 and 4 h. At 6 h the 10-0-0-11 had the highest ammonia concentration at 3.26 mg/dL ($P < .05$). Differences were detected across all sources at 8 h with 10-0-0-11 having the highest ammonia concentration at 7.02 mg/dL while the lowest concentration was found for cottonseed meal at .55 mg/dL After 16 and 24 h, urea had the highest concentration of ammonia at 6.78 mg/dL and 4.59 mg/dL The 23-0-0-7 and 10-0-0-11 treatments were similar at 16 h with values of 5.42 mg/dL and 4.45 mg/dL.

Table 1. Ammonia concentrations for four substrate media

Medium and hours	Urea	23-0-0-7	10-0-0-11	CSM
10% cornstarch				
2	.73[a]	.61[a]	1.02[a]	.70[a]
4	.45[a]	.57[a]	.87[a]	.43[a]
6	1.66[b]	1.51[b]	3.26[a]	.82[b]
8	5.76[a]	3.43[b]	7.02[c]	.55[d]
16	6.78[a]	5.42[b]	4.45[b]	.12[c]
24	4.59[a]	4.36[a]	2.56[b]	.02[c]
14% cornstarch				
2	72.99[a]	43.20[b]	17.96[c]	.68[d]
4	67.14[a]	18.34[b]	12.35[c]	.79[d]
6	32.18[a]	7.89[b]	.59[c]	.14[c]
8	20.98[a]	1.27[b]	1.02[b]	.75[b]
16	27.70[a]	12.60[b]	8.83[c]	.35[d]
24	50.97[a]	24.40[b]	13.09[c]	.96[d]
10% ground corn				
2	3.90[a]	4.70[a]	2.10[a]	1.35[a]
4	4.90[a]	4.01[a]	4.68[a]	2.11[a]
6	4.83[a]	4.04[a]	4.96[a]	1.75[a]
8	3.45[a]	3.34[a]	4.14[a]	4.33[a]
16	6.69[bc]	5.56[c]	10.61[ab]	13.00[a]
24	19.97[a]	6.39[b]	13.93[a]	5.61[b]
14% ground corn				
2	4.80[a]	4.42[a]	4.74[a]	.49[b]
4	3.47[a]	3.72[a]	6.64[b]	1.33[c]
6	3.44[ac]	2.19[bc]	5.85[a]	.10[b]
8	7.39[a]	1.55[b]	5.05[a]	.12[b]
16	22.66[a]	11.77[b]	24.85[a]	.00[c]
24	44.86[a]	16.54[b]	11.89[b]	1.37[c]

[a, b, c, d] Means in a row with different superscripts differ (P < .05)

14% Corn starch substrate medium. The 2- and 4-h analyses all were different (P < .05) from one another. After 6 h, the 10-0-0-11 sample and the cottonseed meal samples did not differ from one another with values of .59 mg/dL and .14 mg/dL (P > .05). All other products were different (P< .05). Urea was different from all other sources (P < .05) at 8 h with a value of 20.98 mg/dL.. Urea remained at the highest concentration of ammonia for 16 and 24 h with values of 27.70 mg/dL and 50.97 mg/dL. The urea values were different (P < .05) from the cottonseed meal values, which were the lowest ammonia concentrations at .3 5 mg/dL and .96 mg/dL for 16- and 24-h samples.

10% Ground corn substrate medium. No differences were found until the 16-h samples. Cottonseed meal and 10-0-0-11 were similar at 16 h with values of 13.00 and 10.61 mg/dL. The data showed some differences (P < .05) between 23-0-0-7 and 10-0-0-11 as well as cottonseed meal, and cottonseed meal was different (P < .05) from urea. The 24-h samples showed that urea had the highest concentration of ammonia at 19.97 mg/dL, being not different from 10-0-0-11 at 13.93 mg/dL. Cottonseed meal had the lowest concentration at 5.61 mg/dL, with 23-0-0-7 not differing at 6.39 mg/dL.

14% Ground corn substrate medium. After 2 h of digestion, the lowest concentration of ammonia was obtained from cottonseed meal at .49 mg/dL, which was different (P < .05) from all other sources. With 4 h completed, 23-0-0-7 recorded the highest concentration of ammonia at 3.72 mg/dL, while cottonseed meal was still the lowest at 1.33 mg/dL. Urea was at a level of 3.47 mg/dL, which was similar to 23-0-0-7, while 10-00-11 and cottonseed meal were different (P < .05) from all other sources. Urea was similar to the 10-0-0-11 treatment after 6 h, with values of 3.44 mg/dL and 5.85 mg/dL. Urea also was similar to 23-0-0-7, which was at a level of 2.19 mg/dL. Cottonseed meal with a value of .103 mg/dL was different (P < .05) from urea and the 10-0-0-11. At 8 h, urea (7.39 mg/dL) and 10-0-0-11 (5.05 mg/dL) were similar while 23-0-0-7 had 1.537 mg/dL and cottonseed meal had .123 mg/dL. After 16 h, the 10-0-0-11 had the highest concentration of ammonia at 24.85 mg/dL while cottonseed meal had the lowest concentration (0 mg/dL). Urea was similar to 10-0-0-11 at a value of 22.66 mg/dL, while all other readings were different (P < .05). After 24 h, urea had the highest concentration of ammonia (44.86 mg/dL) while the 23-0-0-7 was 16.54 mg/dL and the 10-0-0-11 was 11.89 mg/dL. Cottonseed meal was different (P < .05) from all other readings at a level of 1.37 mg/dL.

CONCLUSIONS

Differences were clearly visible across the four NPN sources used in this experiment. In each analysis, one or both of the urea/calcium products produced values that were comparable to the values produced by the urea treatment. The use of 23-0-0-7 and 10-0-0-11 in the formulation of ruminant diets appears to be possible as an alternative to urea.

REFERENCES

Chaney, A. L. and E. P. Marbach. 1962. Modified reagents for determination of urea and ammonia. Clin. Chem. 8:130.

Dinius, D. A., C. K. Lyon, and H. G. Walker. 1974. ***In vitro*** evaluation of protein and protein - safflower oil complexes treated with formaldehyde. J. Anim. Sci. 38:467.

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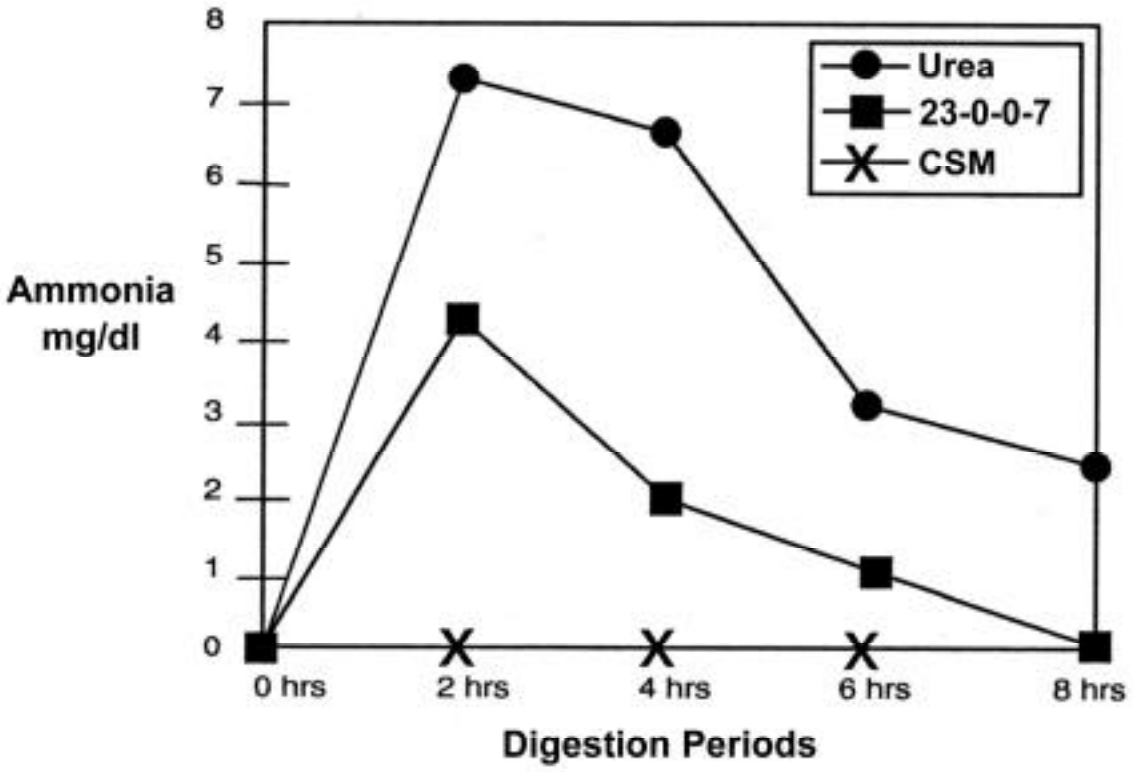
Corn Starch 14% Crude Protein



14% PROTEIN IN CORN STARCH (IN VITRO)

Throughout this digestion trial, urea had the highest concentration of Ammonia, and cottonseed meal had the lowest; while 23-0-0-7 was a very desirable intermediate as indicated on the above graph. The 2, 4, and 6 h analysis were all different from one another. Urea was different from other sources (P< .05) at 8 h with a value of 2.0983 mg/dl, while cottonseed meal and 23-0-0-7 were not different (P <.05) with values .075 mg/dl and .102 mg/dl respectively at 8 h. The 10-0-0-11 product was omitted from the above graph because it is not being offered as a commercial product until its specific usage is determined.

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EFFECTS OF SLOW RELEASE UREA PRODUCTS ON DIGESTIBILITY, NITROGEN RETENTION, AND CALCIUM UTILIZATION BY GROWING WETHERS

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SUMMARY

A metabolism experiment with 12 crossbred wethers, averaging 59 lb, was conducted to determine the nutritional value of two urea/calcium compounds. The compounds were composed of 23-0-0-7 and 10-0-0-11 N, P, K, and Ca, respectively. These two compounds were compared to feed grade urea and cottonseed meal for DM intake, overall diet digestibilities of DM and crude protein, nitrogen utilization, and calcium utilization. Diets were ground sorghum and cottonseed hull-based with feed grade urea, 23-0-0-7, 10-0-0-11, or cottonseed meal as a protein source. The diets (Table 1) were formulated to meet NRC requirements for growing wethers and pelleted through a 7/16-in. die.

Table 1. Composition of diets

Ingredients	Urea	23-0-0-7	10-0-0-11	CSM
Ground sorghum	57.06	55.64	51.26	46.51
Chopped alfalfa	10.00	10.00	10.00	10.00
Cottonseed hulls	28.00	28.00	28.00	28.00
Molasses	1.44	1.44	1.44	1.44
Urea	1.65			
23-0-0-7 compound[a]		3.20		
10-0-0-11 compound[a]			8.00	
Cottonseed meal				12.00
Calcium carbonate	.80	.40		.75
Vitamin A	.50	.50	.50	.50
Sodium chloride	.35	.35	.35	.35
Trace mineral premix	.20	.20	.20	.20
Ammonium sulfate		.25	.25	.25

[a]N, P, K, and Ca, %.

Feed intake and nitrogen intake were lower (P < .05) for the 10-0-0-11 treatment compared to urea, 23-0-0-7, and the cottonseed meal treatments. However, digestibilities of DM and crude protein were similar (P > .05) across all treatments. Nitrogen retention and percentage of nitrogen absorbed that was retained were similar (P > .05) for wethers fed diets containing urea, 23-0-0-7, or cottonseed meal. Wethers receiving the 10-0-0-11 dietary treatment had lower (P < .05) nitrogen retention, and lower utilization of absorbed nitrogen than those on all other treatments. Percentage of nitrogen intake that was retained was lowest for the 10-0-0-11 treatment, which reflects the amount of nitrogen consumed.

PROCEDURE

All lambs were adjusted to a common urea-based diet for 28 d before random assignment to treatments by weight group. After a 14 d adjustment period for the

assigned diets, the lambs were placed on a 7 - d total collection period of urine and feces. On d 7 of the collection, blood samples were taken 4 h post feeding and stored for plasma urea nitrogen analysis. After each 7-d collection period, lambs were randomly switched as groups to an additional treatment for a 14d adjustment and followed by a 7-d collection. This pattern continued until each lamb had received every diet, resulting in four collection periods. In the collection process, feces were collected, weighed, dried in an oven, and reweighed to determine a dry weight. A representative sample was taken from the ground feces and stored for subsequent analyses. Diluted HCI (20%) was added on a daily basis to urine containers to prevent ammonia nitrogen loss. Ten percent of the total urine volume was kept from each lamb and then subsampled for subsequent analysis. Orts were collected, weighed, sampled, and analyzed to determine composition.

RESULTS

DM intake for the 10-0-0-11 treatment was lowest (P < .05) at a level of 1,055 g/d and the 23-0-0-7 treatment was the highest at 1,423 g/day (Table 2).

Table 2. ***In vivo*** digestion results

Item	Urea	23-0-0-7	10-0-0-11	CSM	SEM
DM intake g/d	1361[a]	1423[a]	1055[b]	1401[a]	51.50
DMD, %[c]	70.90[a]	68.40[a]	69.30[a]	68.40	.79
CPD, %[d]	63.00[a]	62.57[a]	63.27[a]	55.67	1.13
Nitrogen					
N intake, g/d	32.62[a]	31.73[a]	24.39[b]	32.09	1.13
Retention, g/d	12.69[a]	10.35[a]	3.79[a]	11.73	1.13
Intake retained, %	37.72[a]	33.45[a]	19.00[b]	33.22	2.67
Absorbed retained, %	51.10[a]	54.62[a]	25.10[b]	55.87	4.26
Calcium					
Digestibility, %	48.10[a]	45.84[a]	50.93[a]	47.39	2.22
Retention, g/d	5.50[a]	5.79[a]	9.35[b]	5.83	.56
PUN, mg/dL[e]	10.82[a]	10.37[a]	7.81[a]	7.32	.86

[a,b]Means in a row with different superscripts differ (P < .05).
[c]DM digestibility.
[d]Crude protein digestibility.
[e]Plasma urea nitrogen.

Because of the lower intake, the 10-0-0-11 treatment was lower (P < .05) in nitrogen intake at 24.4 g/day with urea

having a value of 32.6 g/day. For DMD, no differences (P > .05) were detected across the four treatments. However, for CPD the cottonseed meal treatment was lower (P < .05) than the other three treatments. Urea had the highest percent of nitrogen intake retained at 37.7%, which was higher (P < .05) than 10-0-0-11 at 19.0 %, while 23-0-0-7 and cottonseed meal were similar to urea at 33.5 and 33.2%, respectively. The percentage of nitrogen absorbed that was retained was highest for cottonseed meal (58.9%), which was different (P < .05) from 10-0-0-11 (25.1%), while 23-0-0-7 and urea were not different from cottonseed meal at 54.6 and 51.1% respectively. No differences (P > .05) were found among the four diets for calcium digestibility, but the 10-0-0-11 treatment had a higher calcium retention (P < .05) than the three remaining treatments. Plasma urea nitrogen analysis also showed no differences (P > .05) across the four diets.

CONCLUSIONS

These data indicate that compounds that contain a mixture of urea and calcium could be utilized in ruminant diets as an NPN source. The 23-0-0-7 compound is preferred over the 10-0-0-11 compound. A cattle feeding experiment is in progress to determine the effects of 23-0-0-7 compared to feed grade urea or cottonseed meal.

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EFFECTS OF SLOW AMMONIA RELEASE UREA/CALCIUM COMPOUND ON PERFORMANCE AND CARCASS CHARACTERISTICS OF FEEDLOT STEERS

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SUMMARY

A feedlot experiment with growing/finishing crossbred steers (681 lb, n = 72) was conducted to determine the effects of a slow ammonia release urea/calcium compound compared to isonitrogenous diets containing feed grade urea or cottonseed meal. The slow ammonia release compound, as determined from previous research, contained 23% N and 7% Ca. Steers were weighted, ear tagged, dewormed, immunized against BVD, IBR, PI^3 and ***Clostridium perfringens*** types C and D, then randomly placed by weight group and breeding to three pens of eight steers per treatment. A steamed flaked grain sorghum and corn silage based diet was fed for 147 d. Carcass data were collected by experienced personnel. The slow ammonia release compound was manually added to the feed while it was being mixed and steers were fed once daily. Feeding the urea/calcium compound resulted in an 8.6% improvement (P < .05) in feed efficiency and a 5.9% increase (P > .05) in ADG as compared to cottonseed meal; and a 4.3% improvement (P > .05) in feed efficiency and a 2.8% decrease (P > .05) in ADG compared to urea. Feed intake was 3.2 and 6.9% lower when the urea/calcium was fed compared to cottonseed meal and urea, respectively. Carcass data show that the urea/calcium treatment tended to result in higher (P = .14) hot carcass weight as compared to cottonseed meal. Whereas, the urea/calcium treatment tended to result in improved kidney, heart and pelvic fat (P = .14) and yield grade (P = .11) compared to the urea treatment. In conclusion, these data show that the urea/calcium treatment improves feed efficiency over cottonseed meal, with a lesser improvement over urea; and tend to show a shift in carcass composition toward less fat.

INTRODUCTION

Ruminants are unique in that they can utilize nonprotein nitrogen sources to meet a portion of their crude protein needs. The host animal benefits from the microbial fermentation process that occurs in the forestomach by incorporating ammonia nitrogen and carbon structures into bacterial protein.

Urea is used extensively across the United States in diets for growing/finishing ruminants as a nonprotein nitrogen source because of its low price on a crude protein equivalent basis compared to natural protein supplements. Urea use could be increased by cattle feeders if ammonia release from urea breakdown in the forestomach could be slowed to a rate at which energy substrates became available. This problem in particular is prevalent for diets that contain substantial amounts of roughage(s), such as

growing diets, which have low urea fermentation potential. Several reports have been published on attempts to produce viable slow release urea products (2, 3, 4) with little or no industry application to date. However, Cass et al., (1)

reported that two compounds, containing either 23% nitrogen and 7% calcium or 10% nitrogen and 11% calcium, both resulted in slower ammonia release than urea in laboratory studies. This same 23% nitrogen and 7% calcium compound (23-0-0-7) was used in this experiment.

EXPERIMENTAL PROCEDURE

The steers used in this experiment were sorted from a large group of wheat pasture steers at the Texas Tech University farm at Pantex and transported to the Burnett Center research feedlot. Steers were vaccinated with Ivermectin (6.5 cc), 4 - way (2 cc), Clostridium type C & D (4 cc), ear tagged, dehorned, and initial weights were taken. The steers were divided into two pen groups (n = 37 and 38) and adjusted to a high grain diet over 26 d. After the adjustment period, all steers were weighed and implanted with Synovex S. Steers then were randomly sorted into nine pens containing eight head each by means of weight and also breed type. The steers were placed in partially slotted, concrete-floored pens for the duration of the experiment. The nine pens were in consecutive order with the automated feed bunk on the north side of the pens. All diets were formulated to meet NRC requirements and mixed automatically at the Burnett Center on a daily basis. The urea/calcium product was weighed and added into the mixer by hand for each pen allotment of feed on a daily basis. Water was blended with the urea/calcium product immediately before applying to the feed to assure adequate coverage and mixing throughout the feed. Bunks were read daily and rejected feed was removed, weighed and subtracted from the total intake values. Steers were initially weighed on trial on 3/22/94, followed by five weigh periods, which were

planned on 28-d intervals, and a final weight. After the steers were slaughtered at a commercial packing plant, and the carcasses chilled for 48 h, carcasses were ribbed and evaluated.

Composition of the basal diet, which is typical of many southwest feedlot diets, is presented in table 1. Laboratory analyses were conducted to determine the composition of the diet's DM, ash, nitrogen (CP), calcium and phosphorus (table 1). Pen was the experimental unit. Data were analyzed by ANOVA using a completely randomized

design procedure of SAS. The 23-0-0-7 treatment was compared to each of the other two treatments.

RESULTS AND DISCUSSION

The effects of urea/calcium treatment on DM intake, ADG, and feed efficiency are shown in table I. Supplementing the urea/calcium compound to meet CP needs in diets that were formulated to be equal in calcium content improved feed efficiency 8.6% ($P < .05$) and increased ADG 5.9% ($P > .05$) feed intake. These data indicate improved energetic efficiency by steers from supplementation to a rapidly rumen fermentable grain-based diet over the cottonseed meal. Both nonprotein nitrogen treatments (urea/calcium compound and urea) tended to improve feed efficiency and ADG over cottonseed meal. However, the extent of improvement was greater for feed efficiency when urea/calcium compound was supplemented, whereas, urea gave the greater gain response. Furthermore, the urea/calcium treatment resulted in a 4.3% improvement ($P > .05$) in feed efficiency over urea while reducing feed intake by 6.9% ($P < .05$).

Effects of treatment on carcass characteristics are given in table 2. No differences were found ($P > .05$) across treatments for any variable measured. However, when the urea/calcium treatment means are compared to either of the other two treatments alone, trends of differences appear. The urea/calcium treatment tended to produce higher ($P = .14$) hot carcass weight as compared to cottonseed meal. Whereas, the urea/calcium treatment was tended to improve kidney, heart and pelvic fat ($P = .14$) and yield grade ($P = .11$) compared to the urea treatment. These carcass data are supportive of the performance data and indicate that this nitrogen and calcium product is changing the growth/fattening process in a manner that tends to result in greater lean yield and a lower amount of waste fat compared to urea feeding.

IMPLICATIONS

The urea/calcium compound provides an alternative source of nitrogen and calcium for ruminants. Efficiency of gain is improved when the urea/calcium compound is formulated to provide supplemental nitrogen and calcium. Energetic efficiency is improved and carcasses tend to be leaner than when feeding urea. Feed consumption is reduced somewhat with the use of urea/calcium in place of urea or cottonseed meal

Table 1. Composition and analysis of diets

Ingredient	Cottonseed meall	Urea/ calcium	Urea
----------Composition, %----------			
Steamed flaked milo	75.02	81.25	81.96
Corn silage	11.35	11.35	11.35
Urea			1.01
23-0-0-7		2.10	
Cottonseed meal	7.98		
Molasses	3.00	3.00	3.00
$CaCO_3$	1.00	.65	1.03
NaCl	.20	.20	.20
Dical	.05	.05	.05
Rumensin	.90	.90	.90
Trace mineral premix	.25	.25	.25
Vitamin A premix	.25	.25	.25
----------Chemical analysis, %----------			
DM	73.89	73.76	73.65
CP	13.13	13.12	13.14
TDN	81.53	80.57	81.53
NEm	1.12	1.11	1.12
NEg	.59	.58	.59
Ca	.50	.63	.49
P	.40	.33	.33
----------Performance Data, %----------			
DM intake, lb	19.79[ab]	19.15[b]	20.56[a]
ADG, lb	2.90[a]	3.07[a]	3.16[a]
Feed:gain	6.83[a]	6.24[b]	6.52[ab]
Gain efficiency[c]	14.66[b]	16.02[a]	15.36[ab]

[a, b] Means in a row with different superscripts differ ($P < .05$)

[c] lb gain/100 lb intake

Table 2. Carcass data

Item	Cottonseed meal	Urea/ calcium	Urea	SEM	P Value
Hot carc. wt[a]	670	694	691	6.16	.26
Dressing percent	59.99	60.85	59.82		
Back fat Thick., in.	.52	.51	.56	.02	.48
KPHF[b], %	1.51	1.54	1.79	.07	.19
Ribeye area	11.09	11.40	11.00	.21	.77
Yield grade[c]	3.04	3.03	3.33	.07	.18
Marbling	4.00	3.95	4.07	.07	.80
Choice, %	65.00	66.70	58.00		

[a]Urea/calcium vs. cottonseed meal P = .14
[b]Urea/calcium vs. urea P = .14
[c]Urea/calcium vs. urea P = .11

LITERATURE CITED

1 . Cass, J. L., C. R. Richardson, and K. J. Smith. 1994. Evaluation of slow ammonia release from urea/calcium compounds. J. Anim. Sci. 72 (Suppl. 1:937 (Abstr.).1)
2. Helmer, L. G., E. E. Bartley and C. W. Deyoe. 1970. Feed processing. IV. Comparison of starea, urea and SBM as protein sources for lactation in dairy cows. J. Anim. Sci. 52:883.
3. Huston, J. E., M. Shelton and L. H. Brewer. 1974. Effects of rate of release of urea on its utilization by sheep. J. Anim. Sci. 39:618.
4. Owens, F. N., K. S. Lusby, K. Mizwicki and 0. Forero. 1980. Slow ammonia release from urea: Rumen and metabolism studies. J. Anim. Sci. 50:527.