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EFFECT OF UREA AT DIFFERENT NITROGEN LEVELS ON DIGESTIBILITY AND ON PERFORMANCE OF GROWING STEERS FED LOW QUALITY FLOOD MEADOW ROUGHAGE [1]

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MOST roughage used for wintering beef cattle in eastern Oregon and in much of the west is a low quality native meadow hay. Generally, this hay is low yielding and is harvested near maturity to obtain maximum yield. While low in crude protein—7 to 9%—it has a gross energy content approximating that of better quality roughages. Hay harvested past maturity often has a crude-protein content as low as 4 or 5%. Cellulose digestibility is high—60 to 70%—but protein digestibility is low—45 to 50% (Wallace and Raleigh, 1960; Wallace *et al.*, 1961a, b).

Considerable research shows that increasing protein content of a low protein diet will increase feed intake and gains (Bush *et al.*, 1955; Ross *et al.*, 1954; Woods *et al.*, 1956). Urea as a protein extender for ruminant feeding has been studied extensively and the literature reviewed by Belasco (1954, 1955) and Anderson *et al.* (1959). The purpose of the work reported in this paper was to determine: (1) the level of protein supplementation to a meadow hay ration that would give optimum performance, and (2) to what degree urea could be used to replace the protein supplement.

Experimental Procedure

Thirty Hereford steer calves, averaging 395 lb., were stratified by weight into three replications of 10 each. Calves within each replication were randomly allotted to treatments (table 1). The feeding trial was conducted for 15 weeks. The steers were tied to feed mangers and fed individually daily from 7:00 a.m. to 3:00 p.m. They ranged in a common lot the rest of the time where water, salt and a salt-bonemeal mixture were available. Water was also available at the feed bunk.

Meadow hay from a uniform field harvested August 1 was used as the roughage. This hay contained 5.5% crude protein on a dry matter basis. Urea, cottonseed meal and a mixture of urea and cottonseed meal were used to establish desired crude-protein levels of 6, 9 and 12% (table 1). No attempt was made to adjust the energy or to make all diets isocaloric. When urea and cottonseed meal were both used in a diet they were supplied in amounts so that one-half the nitrogen came from urea and one-half from cottonseed meal. Salt and monosodium phosphate were mixed in equal parts and made up one percent of the diet. Chromic oxide, as an indicator, was mixed in the diet to make up 0.5% of the total. The hay was finely chopped, mixed with the other ingredients and pelleted in a 7/16-in. diameter pellet.

Measures of response were average daily gain, feed intake and efficiency, and apparent digestibility values for dry matter, organic matter, nitrogen and cellulose. Weekly feed intake was recorded and the steers were weighed every three weeks after overnight restriction from feed and water.

Digestion trials were conducted by the indicator method on all the animals during the twelfth week of the experiment. Grab fecal samples were obtained twice each day, 8:30 a.m. and 2:30 p.m., by removing a small handful from the rectum of the animal. These samples were composited and frozen in a covered plastic container until they could be processed. All samples were then dried at 70° C. for 24 hours and ground through a 1 mm. screen in a Wiley mill. Chromic oxide was determined by the perchloric acid digestion method of Kimura and Miller (1957). Cellulose was determined by the method of Crampton and Maynard (1938). Moisture, ash, and nitrogen were determined by the methods outlined by the A.O.A.C. (1950). All data were subjected to the analysis of variance procedure for statistical analysis. The experimental design was a 3 x 3 factorial

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TABLE 1. COMPONENTS OF THE EXPERIMENTAL DIETS

Level of crude protein	Diet ingredients	Meadow hay	Cotton-seed meal	Urea
%		%	%	%
5.5				
	Hay	100.00	....	....
6.0				
	Hay+urea	99.77	....	0.23
	Hay+cottonseed meal	98.42	1.58	....
	Hay+urea and cottonseed meal	99.14	0.74	0.12
9.0				
	Hay+urea	98.70	....	1.30
	Hay+cottonseed meal	90.05	9.95	....
	Hay+urea and cottonseed meal	94.58	4.69	0.73
12.0				
	Hay+urea	97.48	....	2.52
	Hay+cottonseed meal	81.70	18.30	....
	Hay+urea and cottonseed meal	90.06	8.59	1.35

with an extra control cell (table 2). Since one cell of the factorial was missing the experiment was analyzed as nine separate treatments with three replications; fractions of the factorial, excluding the missing cell, were then analyzed. This gave a 2 x 3 and 3 x 2 factorial within the experiment.

Results and Discussion

The steers accepted the pelleted diet readily. However, as the feeding trial progressed, they chewed more frequently on the lot fences. This did not appear to affect their appetites or their gains. During the fifth week of the trial one of the animals on the 12% protein diet, containing hay and urea alone, went off feed, into a state of convulsions and died. One week later a second animal on this same treatment became ill and died within 24 hours after the first symptoms appeared. Both of these animals exhibited symptoms associated with ammonia toxicity. The first symptoms were muscular twitching, especially the eyes and ears, and a general hypersensitivity followed by increased respiration and tetanic convulsions. In both cases death followed the convulsions within a few hours. These symptoms are similar to those observed by Lewis (1960) in sheep. Efforts were made to save the second steer by an intravenous injection of an amino acid solution, high in arginine content, but there was no apparent response. The third animal on this treatment was removed from the experiment.

The average daily gain for all the animals throughout the trial was 0.98 lb. with a range from 0.26 to 1.83 lb. (table 2). The animals on each higher level of crude protein gained more rapidly than animals on lower levels. Those receiving their nitrogen supplement from cottonseed meal alone, regardless of level of protein, appeared thriftier with more gloss to their hair and more finish than those on corresponding levels of crude protein supplemented by urea and cottonseed meal or urea alone. The steers receiving only urea as the nitrogen supplement were the least thrifty appearing group. The differences in gains between the 6 and 9% protein groups were highly significant ($P < .01$) while the differences between the 9 and 12% group were not significant (table 1). Source of nitrogen significantly ($P < .05$) affected gains at the 9 and 12% protein level with steers receiving an all cottonseed meal supplement gaining more than those receiving urea alone or in combination with cottonseed meal. This was not expected since the level of urea fed with cottonseed meal was within the limits recommended by the National Research Council (N.R.C., 1958) and gains

TABLE 2. AVERAGE DAILY GAIN, FEED INTAKE AND FEED REQUIRED PER POUND OF GAIN FOR THE THREE ANIMALS ON EACH TREATMENT [a]

Measure of performance / Diet	Crude Protein, % 5.5	6.0	9.0	12.0
	lb.	lb.	lb.	lb.
Daily gain (0.12) [b]				
Hay alone	0.27[g]	....	....	....
Hay+urea	....	0.39[g]	1.23[f]	....[c]
Hay+cottonseed meal	....	0.26[g]	1.62[d]	1.83[d]
Hay+urea and cottonseed meal	....	0.41[g]	1.35[ef]	1.51[e]
Average	0.27	0.35	1.40	1.67
Daily feed intake (0.15)				
Hay alone	9.53[i]	....	....	....
Hay+urea	....	10.10[i]	13.73[h]	....
Hay+cottonseed meal	....	9.33[i]	15.00[h]	15.33[h]
Hay+urea and cottonseed meal	....	11.03[i]	14.33[h]	14.50[h]
Average	9.53	10.15	14.35	14.92
Feed/lb. gain (10.09)				
Hay alone	35.30[k]	....	....	....
Hay+urea	....	25.90[k]	11.16[j]	....
Hay+cottonseed meal	....	35.88[k]	9.26[j]	8.38[j]
Hay+urea and cottonseed meal	....	26.90[k]	10.61[j]	9.60[j]
Average	35.30	29.56	10.34	8.99

[a] Any values with the same superscript are not significantly ($P > .05$) different.
[b] Numbers in parentheses are the standard errors for each measure of performance.
[c] Two of these animals died and the third was removed from the experiment.

comparable to those made from cottonseed meal alone should have occurred. However, the level of urea, when fed as the sole nitrogen supplement, was higher than that generally recommended. Briggs *et al.* (1947) found that when urea comprised 50% of the nitrogen of a protein supplement, nitrogen storage was the same as with an all cottonseed meal supplement, but urea alone was a poor protein supplement for steers on prairie hay.

The lesser response from the steers receiving urea may have been partially due to lack of available energy. The energy requirements of an animal must increase as dietary protein increases if the animal is to make efficient use of the protein. If the protein-energy ratio is low in energy some of the protein will be used for energy. While protein is not an efficient or economical source of energy, the animal is able to use it as such to balance requirements. In treatments where one-half of the protein supplement was urea, the energy available from this supplement would be considerably less than from an all cottonseed meal supplement. Practically no additional energy was provided when urea composed the entire supplement.

Other factors which may have affected results were the lack of minor nutrients and method of feeding. Several workers have reported that available minerals may influence maximum urea utilization (Albert *et al.*, 1956; Starks *et al.*, 1954; Ellis *et al.*, 1956). Unidentified or unknown protein synthesis factors present in most protein supplements and especially those found in legume forages were not present in these rations. The steers used in this study were hand-fed, having access to their feed for approximately 8 hours a day. Chalmers and Synge (1954), Ellis *et al.* (1956) and Starks *et al.* (1954) concluded that ruminants make better use of urea when self-fed than when hand-fed.

The feed intake and feed conversion data follow the same pattern as that of daily gains (table 2). The steers all started the trial with approximately the same feed intake. As the trial progressed those receiving higher levels of crude protein continually increased their feed intake up to the end of the trial. Regression analysis indicated this increase was significant ($P < .01$) with the 9 and 12% protein levels. There was essentially no difference in feed intake from the start to the finish of the trial for steers on hay alone and on the 6% protein level of feed. The steers on the 9 and 12% levels of crude protein consumed significantly ($P < .01$) more than those on the lower levels. Feed intake between the 9 and 12% groups was not significantly different.

Sources of nitrogen supplement did not significantly influence feed intake. However, the interaction of source and level of protein was significant ($P < .05$). This interaction is of little importance since it was apparently a result of the performance of the steers on the cottonseed meal supplement at the 6% protein level which was submarginal for normal growth (table 2). These steers were the least efficient of the entire experiment, whereas those supplemented with cottonseed meal alone at the other levels of protein were the most efficient of their respective groups. Campling *et al.* (1962) reported an increase in voluntary intake of a poor quality roughage (specifically oat straw) with rumenal infusions of urea. This could account for the higher, though not significant, increase in performance of the steers of the 6% crude-protein diets containing urea over the 6% diet with no urea. However, they did not compare urea to protein compounds containing equivalent amounts of nitrogen. All animals in this trial received the same roughage, and those on the 9% crude protein level, with no urea, gained significantly more than those receiving urea. This same trend, though not significant, was apparent for feed intake and feed efficiency.

Feed efficiency was calculated as total feed required for maintenance plus gain (table 2). Protein level had a significant ($P < .01$) effect on feed conversion efficiency with the 9 and 12% levels being more efficient than the 6% but not significantly different from each other. The 6% protein diets were apparently submarginal with respect to normal growth requirements and therefore those animals were meeting little more than their maintenance requirements, thus accounting for their poor feed efficiency. Source of nitrogen had no significant effect on feed efficiency and there were no significant interactions of source and level of nitrogen.

These data indicate a need for protein supplementation of low quality native meadow roughages to produce satisfactory gains of weaner calves. Supplementation to increase the crude-protein content to 9 or 12% will increase gains to a desirable level for growing animals. The small difference in response between the 9 and 12% crude-pro-

tein diets indicate that gains beyond this point are limited by a lack of nutrients other than protein.

Urea alone does not appear to be a suitable nitrogen supplement to this roughage, but urea in combination with cottonseed meal, while possibly not as good as cottonseed meal alone, was a satisfactory supplement. It should be considered that in many cases supplementing with urea can result in lower

TABLE 3. APPARENT DIGESTION COEFFICIENTS FOR NITROGEN, CELLULOSE, DRY MATTER AND ORGANIC MATTER FOR DIFFERENT LEVELS AND SOURCES OF NITROGEN [a]

Measure of digestibility	Crude Protein, %			
Diet	5.5	6.0	9.0	12.0
	%	%	%	%
Nitrogen (1.07) [b]				
Hay alone	33.4[f]	....	....	....
Hay+urea	....	34.1[f]	55.7[d]	....[e]
Hay+cottonseed meal	....	38.7[f]	47.8[d]	61.6[e]
Hay+urea and cottonseed meal	....	36.6[f]	51.0[d]	59.4[e]
Average	33.4	36.5	51.5	60.5
Cellulose (1.08)				
Hay alone	47.1[i]	....	....	....
Hay+urea	....	48.5[i]	54.2[h]	....
Hay+cottonseed meal	....	48.4[i]	55.8[gh]	60.2[g]
Hay+urea and cottonseed meal	....	47.8[i]	58.0[gh]	60.0[g]
Average	47.1	48.2	56.0	60.1
Dry matter (1.23)				
Hay alone	35.1[m]	....	....	....
Hay+urea	....	42.6[l]	47.5[kl]	....
Hay+cottonseed meal	....	45.5[l]	50.5[jk]	54.1[j]
Hay+urea and cottonseed meal	....	45.2[l]	50.7[jk]	52.5[jk]
Average	35.1	44.4	49.6	53.3
Organic matter (2.42)				
Hay alone	38.5[p]	....	....	....
Hay+urea	....	47.6[o]	50.2[no]	....
Hay+cottonseed meal	....	48.1[o]	53.5[no]	55.8[n]
Hay+urea and cottonseed meal	....	47.6[o]	52.6[no]	55.3[n]
Average	38.5	47.8	52.1	55.6

[a] Any values with the same superscript are not significantly ($P>.05$) different.
[b] Numbers in parentheses are the standard errors for the different digestibility measures.
[c] Two of these animals died and the third was removed from the experiment.

animal performance, but can well produce more economical animal products. When urea is used as a protein extender or substitute it is essential that we consider the balance of other nutrients in the diet.

Apparent digestion coefficients were determined for nitrogen, cellulose, dry matter and organic matter by the indicator method (table 3). Twice daily grab fecal samples were obtained with a minimum of distraction to the animals while they were tied to their feed bunks. The coefficients of variation were 6.91, 6.05, 7.84 and 8.39% of the apparent digestion coefficients for nitrogen, cellulose, dry matter and organic matter, respectively.

Level of nitrogen in the ration had a highly significant ($P<.01$) effect on the digestibility of cellulose, dry matter and organic matter with the 9 and 12% levels having higher values than the 6% level, but they were not different from each other. Apparent nitrogen digestibility significantly ($P<.01$) increased with each increase in nitrogen level from 6 to 12%, regardless of source of nitrogen supplement. These results are in accord with those reported by several investigators. Woods *et al.* (1956) found significant increases in nitrogen and dry matter digestibility with higher levels of protein. Raleigh (1959) reported that increasing the level of protein in the diet of lambs increased the digestibility of dry matter, energy and nitrogen.

Source of nitrogen in the diet had no significant effect on the digestibility of the nutrients studied. However, all digestibility values were higher, with the exception of nitrogen, when cottonseed meal alone, or in combination with urea, made up the supplement rather than when urea was the sole supplement. There was an interaction of source and level in the 6 and 9% levels of nitrogen for apparent nitrogen digestibility. Nitrogen digestibility was lower when urea was the sole source at the 6% level than when the supplement was cottonseed meal or cottonseed meal and urea. The reverse occurred at the 9% nitrogen level.

The all hay diet was significantly ($P<.05$) lower in apparent digestibility of dry matter and organic matter than all other diets, and significantly lower in cellulose and nitrogen digestibility than all 9 and 12% protein diets.

Summary

Urea in amounts to provide one-half and all the nitrogen supplement in 6, 9 and 12% protein rations was compared with an all cottonseed meal supplement in a wintering ration for steer calves fed a low quality native meadow hay.

Native meadow hay containing 5.5% crude protein or rations increased to 6% crude protein, regardless of supplement source, were not adequate to produce satisfactory gains of weaner steer calves. Body weight gains, feed intake and feed efficiency were significantly greater from the 9 and 12%

protein diets than from the 6% diets or meadow hay alone.

Urea used as the sole supplement to raise the crude-protein content of a low quality meadow hay roughage from 5.5 to 12% was highly toxic and caused fatalities in two animals from ammonia toxicity. The third animal on the treatment was removed from the experiment.

Source of protein had no significant effect on feed intake, feed efficiency or gains when comparing all levels of protein. However, at the 9 and 12% protein levels source of protein had a significant effect on daily gains. The steers on the cottonseed meal supplement alone out-performed the steers on cottonseed meal and urea at both levels of protein.

Level of nitrogen significantly affected digestibility of cellulose, dry matter and organic matter with the 9 and 12% crude-protein levels having higher values than the 6% level and hay alone, but they were not different from each other. Nitrogen digestibility significantly increased with each increase in nitrogen level of the diet, regardless of source of supplement.

Source of nitrogen in the diet had no significant effect on digestibility of the nutrients studied. However, there was an interaction of source and level of nitrogen in the 6 and 9% diets on nitrogen digestibility. Nitrogen digestibility was lowest at the 6% level but highest at the 9% level when urea was the sole source of nitrogen supplementation.

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