Forage Characteristics, Steer Performance, and Water Quality from Bermudagrass Pastures Fertilized with Two Levels of Nitrogen from Swine Lagoon Effluent[1]

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ABSTRACT: Four .8-ha pastures of bermudagrass (*Cynodon dactylon* [L.] Pers.) were fertilized with either 456 or 873 kg/ha of nitrogen (N) from swine lagoon effluent (two replicates per treatment) and grazed by steers over two summers. Within each pasture, steers received forage only, an energy source (corn), a mixture of corn and soybean meal, or a mixture of corn and blood meal via electronic Calan feeders. All supplements were offered at a level of 1.36 kg/d, and the soybean meal and blood meal supplements provided similar quantities of protein. Weight gains were similar among supplemented steers, but supplemented steers gained faster ($P < .05$) than controls. Nitrogen fertilization level had no effect on steer gains, steer grazing days per hectare, or in vitro dry matter disappearance, NDF, and ADF of clipped forage samples. Plant protein and nitrate ion concentrations were greater ($P < .06$) in clipped forage samples receiving the higher N application rate. Nitrate ion concentrations were greater in available forage samples from the pastures with the high N application rate. Mean total N and nitrate N concentrations were similar in water samples obtained from monitoring wells for the two N treatments over the 2 yr and there were no year × N interactions. Chloride concentrations were greater ($P < .05$) and pH and specific conductance were less in water samples collected from the 873 kg than from the 456 kg/ha N treatment. Long-term studies are needed to examine the possible cumulative effects of applying various levels of swine waste to the same land area.

Key Words: Swine Lagoon Effluent, Forage, Beef Cattle, Water Quality

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Introduction

One of the largest problems facing confinement swine producers is developing economical and environmentally safe waste management systems. One way to minimize ground water contamination is to use lagoon waste N and minerals as a source of fertilizer for forage crops. Currently, there is little controlled research to document the amount of N from lagoon effluent that may be applied to grazed pastures without causing environmental problems. Also, producers using cattle in these bermudagrass systems have observed relatively low gains, and supplementation programs need to be evaluated to ensure optimal animal performance.

Growing cattle may have a higher requirement for metabolizable protein than they obtain from microbial protein (NRC, 1985), and research (Anderson et al., 1988) has shown a response to escape protein supplementation in cattle grazing smooth bromegrass (*Bromus inermis* Leyss.), bermudagrass (*Cynodon dactylon* [L.] Pers.), and other warm-season grass mixtures (Grigsby et al., 1989; Hafley et al., 1993). Hafley et al. (1993) observed a response in gain of heifers to a ruminally degradable protein compared with an energy supplement. The objectives of this study were 1) to evaluate the addition of 456 or 873 kg of N/ha from swine lagoon effluent on forage characteristics, cattle performance, and water quality, and 2) to evaluate energy and protein supplements for steers grazing bermudagrass fertilized with the two levels of lagoon effluent.

Materials and Methods

Four pastures (approximately .8 ha each) of a mixture of Tifton 44, Guymon, and common bermudagrass were fertilized with either 456 or 873 kg/

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Table 1. Element concentration and characteristics of swine lagoon effluent

Item	Yr 1	Yr 2
Total N, mg/L	392	402
Ammonia N, mg/L	326	343
Nitrate N, mg/L	.08	.01
Total phosphorus, mg/L	67	71
Orthophosphate, mg/L	59	63
K, mg/L	501	501
Ca, mg/L	50	46
Mg, mg/L	25	23
Na, mg/L	282	288
Cl, mg/L	380	360
Specific conductivity, μmhos/cm	4,257	4,771

ha of total N (two replicates per treatment and using same pastures per treatment each year) as swine lagoon effluent using sprinkler irrigation. The study was conducted at the Tidewater Research Station (Plymouth, NC) over a 2-yr period. Surface soils at this location are a Portsmuth fine sandy loam with 6 to 10% organic matter. Subsoils are massive clays ranging to medium-fine sandy loams at depths of 1.9 m or greater. The seasonal high water table ranges to within .31 m of the ground surface. Initial applications of 89.6 kg of N/ha from effluent were made in early May of each year. Beginning in early June (at initiation of grazing) and at 14-d intervals thereafter until early September, either 44.8 or 100.8 kg of N/ha were designed to be applied to the plots receiving the two N treatments. Although a total of 448 or 896 kg of N/ha was intended, actual N application rates (based on monthly samples of lagoon effluent and irrigation rates) were 464 and 844 kg/ha in yr 1 and 449 and 903 kg/ha of N in yr 2, for an average of 456 and 873 kg of N/ha, respectively. Composition of the swine lagoon effluent is shown in Table 1.

Each .8-ha pasture was subdivided into four equal paddocks and intensively grazed using a 3- or 4-d rotation depending on available forage as determined by daily visual inspection. Forage samples were obtained at approximately 14-d intervals (Table 2). Nine samples (30.5 × 30.5 cm each) per plot representing forage typical of what cattle were consuming (CLIPPED) were obtained within approximately 3.8 cm of ground level and composited; these samples were taken adjacent to areas that steers had grazed or were grazing. Another sample representing all available forage was obtained by clipping four .25-m^2 quadrats (one representing each subdivision) to ground level and compositing over each plot. Samples were dried at 54°C, ground to pass a 2-mm screen and analyzed for CP (AOAC, 1990), NDF and ADF (Goering and Van Soest, 1970; modified by omitting sodium sulfite and decalin), IVDMD (Burns and Cope, 1974), and nitrate concentration. Nitrate ion concentration was determined in yr 1 by ion chromatography using an HPLC system (Bradford and Cooke, 1985) and in yr 2 by an Orion nitrate ion electrode (Orion Research, Boston, MA). Estimates of forage quantity were made weekly using a falling plate disk meter with areas calibrated to harvested quadrats using simple linear regression analysis (Green et al., 1989).

In both years, yearling steers were used as tester (to monitor gains) and put-and-take animals (to control available forage). In yr 1, Angus crosses (initially averaging 322 kg) were used in the 98-d trial; in yr 2, Angus steers (initially averaging 286 kg) were used in the 112-d trial. Within each pasture, electronic Calan feeders were used to evaluate the effect of supplementing an energy source (corn), an energy and a plant protein source (67.7% corn and 33.3% soybean meal, **SBM**), and an energy and an escape protein source (83.3% corn and 17.7% ring dried blood meal, **BM**). Supplements were analyzed to contain 9.8, 29.1, and 31.0% protein for corn, corn-SBM, and corn-BM, respectively. All supplements were offered at 1.36 kg/d (as-fed basis), and the SBM and BM supplements provided similar quantities of protein per day. All steers including unsupplemented controls had free access to self-fed mineral blocks containing Bovatec. The mineral block contained a minimum of 3% calcium, 1.5% phosphorus, 6% salt, 2.75% magnesium, .90% sulfur, .00056%

Table 2. Forage sampling dates of pastures fertilized with swine lagoon waste effluent

Sampling date	Actual date		Actual date	
	Year 1	Year 2	Year 1	Year 2
	Clipped forage		Available forage	
1	June 4	May 28	June 3	June 6
2	June 19	June 12	June 19	June 23
3	July 2	June 25	July 2	July 7
4	July 16	July 9	July 16	July 22
5	July 30	July 23	August 13	August 6
6	August 13	August 6	August 26	September 3
7	August 26	August 26	September 10	September 17

selenium, and 374 mg of Bovatec/kg. Water was provided to steers by automatic waterers.

Sixteen steers (four steers/pasture) in yr 1 and 32 steers (eight steers/pasture) in yr 2 were used in the supplement comparison. Steers were grouped on the basis of weight and randomly assigned with group to treatment approximately 21 d before initiating grazing (to adjust to Calan gates). During the adjustment phase, all steers were provided 1.36 kg of corn daily in addition to pasture. The unsupplemented controls (four steers in yr 1 and eight steers in yr 2) were used to monitor the effects of supplementation. In yr 1, five other unsupplemented steers/pasture were randomly assigned over the N treatments at initiation of grazing. Therefore, over the 2-yr period, 12 individually supplemented steers/treatment were available for evaluating supplements and 34 steers/treatment were available for evaluating the effect of N level.

At initiation (June 3 and June 4 for yr 1 and 2, respectively) and at termination of the trial, steers were maintained in dry lot without feed or forage for 16 h before weighing. Water was provided to steers during this period.

Ruminal fluid (via stomach tube) and blood samples (via jugular venipuncture) were obtained on d 28, 56, and 84 of yr 2 approximately 3 h after providing supplements. Ruminal ammonia N was analyzed using an Orion ammonia electrode (Orion Research); serum urea N was analyzed using an enzymatic procedure (Sigma Chemical, 1980).

To monitor ground water quality, monitoring wells (depth –4.1 to 5.1 m) were installed in each plot (one per pasture) according to U.S. Environmental Protection Agency (USEPA, 1987) approved procedures. Each of the wells were purged before obtaining monthly samples (May to December, yr 1; January to December, yr 2). Samples were analyzed for total N, ammonia N, nitrate N, total phosphorus, orthophosphate, chloride, specific conductance, and pH. All analyses were performed according to standard methods for water and wastewater analyses (APHA, 1989).

Performance data were analyzed (SAS, 1988) for each year and then combined over years for evaluating supplement treatments that were represented over the 2 yr (control, energy, and energy + SBM). Steers assigned to the BM treatment were slow to begin consuming the supplement in yr 1 but were consuming all their supplement within 10 d after initiating grazing. In yr 2, seven of eight steers were consuming very little of the supplement after 21 d and the treatment was discontinued; however, steers were maintained on their respective paddocks and used in evaluating the effects of N fertilization level.

The model included year, N fertilization level, supplement, all two-way interactions, and year × N level × supplement. Initial weight was significant in the initial model and was subsequently used as a covariate in analyzing the data. When supplement effects were significant ($P < .10$), the following preplanned orthogonal contrasts were examined: yr 1, supplemented vs non-supplemented, protein vs energy and SBM vs BM; yr 2, supplemented vs non-supplemented, and energy vs SBM. Forage characteristics were analyzed using a model that included year, date, replicate, N fertilization level, and all interactions. There were no year × N treatment interactions with the exception of herbage mass, which was analyzed by year. When date effects were significant ($P < .05$), least squares means were separated using the PDIFF option of the GLM procedure of SAS (1988). Ruminal and serum data for yr 2 were analyzed using a model that included N level, supplement, date, and all interactions. Water samples were analyzed over years by pairing samples by month collected from May to December each year. The model included year, N level, date, and all interactions.

Results

Nitrogen application rate had no effect on IVDMD, NDF, or ADF values of clipped forage samples (Table 3). Crude protein and nitrate ion concentrations were slightly greater ($P < .06$) in forages receiving the higher N application rate; however, the nitrate concentrations resulting from the higher application rate averaged only .02 percentage units greater and would have little biological significance. Protein, nitrate ion, and NDF concentrations were not different in clipped forage samples over the 2 yr. However, IVDMD (58.8 vs 62.9%) concentrations were greater and ADF concentrations (28.9 vs 29.9%) were less in clipped forage samples for yr 1 than for yr 2; there were no N level × year or N level × date interactions ($P > .05$). Date of sampling affected IVDMD and plant composition ($P < .05$). Greatest IVDMD concentrations were noted at the initial sampling and decreased in August and early September compared with the earlier sampling dates. Crude protein and nitrate ion concentrations were lower in the late August sampling than in earlier samples, whereas NDF and ADF concentrations were greater in the late August than the June and early July samples.

Protein, IVDMD, nitrate ion, NDF content of available forage samples, and herbage mass values are shown by N treatment in Table 4. The ADF and NDF concentrations of available forage samples were not affected by N level. However, there was a trend for greater IVDMD (52.8 vs 54.4%, $P < .15$) and CP concentrations (15.7 vs 16.3%, $P < .10$) for the 873 kg/ha of N than the 456 kg/ha of N treatment. Nitrate ion concentrations were greater ($P < .05$), except for one sampling date, in samples from the high N application. Nitrate ion concentrations also decreased with the grazing season, with the smallest concentrations observed in the late August and early September

Table 3. Effect of nitrogen application rate and sampling date on clipped forage characteristics[a]

Characteristic and date	Nitrogen level 456 kg/ha	873 kg/ha	SEM
IVDMD, %			
1[b]	64.8	67.0	.7
2	60.4	60.8	.9
3	62.1	62.4	1.4
4	63.5	63.7	1.8
5	60.2	58.1	.9
6	57.2	58.0	.8
7	56.6	57.3	1.6
$\bar{x}$	60.7	61.0	
N × 6.25, %			
1[b**]	20.9	22.0	.8
2	20.2	20.2	.9
3	20.3	21.8	.4
4	22.2	25.4	.6
5	20.8	19.9	.6
6	18.9	18.7	.5
7	19.6	20.2	.4
$\bar{x}$	20.4[c]	21.2[d]	
Nitrate ion, %			
1[b**]	.19	.22	.01
2	.27	.25	.02
3	.15	.26	.03
4	.17	.24	.02
5	.27	.22	.03
6	.17	.23	.02
7	.12	.11	.01
$\bar{x}$	.19[c]	.21[d]	
NDF, %			
1[b**]	65.7	62.4	.9
2	67.1	66.8	.5
3	63.6	65.0	1.9
4	63.2	66.4	1.3
5	66.4	67.9	.9
6	68.5	69.2	.4
7	69.9	69.5	.8
$\bar{x}$	66.3	66.7	
ADF, %			
1[b**]	28.4	27.4	.4
2	29.7	29.4	.5
3	29.9	28.9	.7
4	28.1	27.4	.7
5	30.0	30.9	.4
6	31.0	31.1	.3
7	29.7	29.5	.3
$\bar{x}$	29.5	29.2	

[a]Mean values over 2 yr.
[b]Date effect; $P < .10$, $^{**}P < .01$.
[c,d]Within a row, means lacking a common superscript differ ($P < .06$).

samples. Date of sampling affected plant characteristics of available forage samples and clipped samples similarly, with smaller IVDMD and CP concentrations observed as the season progressed.

Performance data were analyzed by year and then over years (Tables 5 and 6). There were no year × N, supplement × N, or year × supplement interactions except for gain:supplement ratio. Therefore, data are summarized over N level, and gain and gain to supplement ratio are shown by year.

Weight gains were very similar for steers in each treatment both years. In yr 1, there was a tendency ($P = .08$) for improved gains of steers receiving the energy-protein supplements compared with the energy supplement, but in yr 2 and in the combined analysis, there was no difference in gain of steers fed the energy or energy-SBM supplements (.83 vs .84 kg/d, respectively). Over the 2-yr period, supplemented steers gained an average of .31 kg more than control steers ($P < .05$). Additional studies are needed to evaluate the effect of supplementing an escape protein with this system due to the small number of steers in yr 1 and the refusal problems encountered in yr 2. Gain: supplement ratios were higher in yr 1 and lower in yr 2 for the energy-SBM than for the energy supplement (year × supplement, $P < .05$).

Nitrogen application level had no effect ($P > .10$) on steer gains (Table 6). When summarized over supplements and years, gains were .71 and .76 kg /d for steers on the 456 and 873 kg/ha of N treatments, respectively. Without supplementation, steers gained .47 to .57 kg/d (yr 1 and 2, respectively). Animal grazing days per hectare were similar ($P > .10$) for the N treatments (1,146 vs 1,211 d/ha), and there were no year or N level × year interactions. Herbage mass (Table 4) was higher in yr 2 than in yr 1 and was probably a reflection of the lower grazing pressure on all plots in yr 2. Herbage mass was not influenced by N treatment in yr 1 but was greater for the high N treatment than the low N treatment in yr 2 (N level × year, $P < .07$).

Ruminal ammonia N and blood urea nitrogen (**BUN**) concentrations (data not shown) were not affected by supplement, and there were no N × supplement interactions. However, BUN concentrations were greater ($P < .05$) in steers grazing pastures fertilized with the higher N treatment. Ammonia N concentrations were greater in steers grazing the 873 kg than the 456 kg of N treatment at the July and August samples than the June sampling (N × date, $P < .05$). The BUN concentrations were also affected by date, with greater concentrations ($P < .05$) observed at the August sampling date than at the June or July sampling date.

Ground water quality characteristics are shown in Table 7. Mean total N and nitrate N concentrations were similar in samples obtained from underground wells for the two N treatments, and there were no date or year effects or any interactions. Ammonia N concentrations were greater ($P < .05$) in samples from plots receiving the 456 rather than the 873 kg of N/ha treatment. Total phosphorus and orthophosphate concentrations were greater in yr 1 than in yr 2 and were greater in September than for other monthly samples (May to December). Orthophosphate concentrations were similar for the two N treatments in yr 1 but were less for the high N treatment than for the low N treatment in yr 2 (year × N, $P < .05$). Chloride

Table 4. Effect of nitrogen application rate and sampling date on available forage characteristics[a]

Characteristic and date	Nitrogen level 456 kg/ha		Nitrogen level 873 kg/ha		SEM
IVDMD, %					
1[b]	51.2		55.2		2.8
2	51.4		52.5		1.4
3	54.2		55.0		1.7
4	58.3		59.5		.9
5	50.3		53.8		1.6
6	51.5		52.8		1.2
7	51.7		50.7		.6
$\bar{x}$	52.8[c]		54.4[d]		
N × 6.25, %					
1[b]	16.7		18.2		.6
2	15.3		17.1		1.0
3	16.4		17.7		.4
4	17.1		18.5		.5
5	14.4		14.9		.2
6	15.8		15.4		.7
7	14.0		12.9		.5
$\bar{x}$	15.7		16.3		
Nitrate ion, %					
1[b]	.35		.50		.14
2	.16		.34		.05
3	.17		.30		.05
4	.20		.46		.07
5	.12		.25		.05
6	.23		.19		.03
7	.07		.10		.02
$\bar{x}$	.19[e]		.31[f]		
NDF, %					
1[b]	65.6		71.7		2.5
2	70.5		69.3		.7
3	67.9		69.2		.6
4	68.2		68.2		.6
5	69.3		69.1		.5
6	68.8		68.6		.5
7	70.0		70.1		.4
$\bar{x}$	68.6		69.5		
	Herbage mass, kg/ha[g]				
	Yr 1	Yr 2	Yr 1	Yr 2	
1[b]	2,897	2,406	2,883	2,633	297
2	1,968	1,563	2,052	2,127	319
3	1,942	1,898	1,906	2,320	290
4	1,981	2,608	1,934	3,154	542
5	2,270	3,270	2,086	3,970	945
6	1,481	3,142	1,527	2,721	787
7	1,638	2,084	1,612	2,828	716
$\bar{x}$	2,025	2,425	2,000	2,822	

[a]Mean values over 2 y.
[b]Date effect, $P < .05$.
[cd]Within a row, means lacking a common superscript differ ($P < .5$) or [ef]($P < .05$).
[g]Treatment × year, $P < .07$.

concentrations were greater ($P < .05$) for the high N treatment, and there was less difference in concentration between the low and high N treatments in yr 1 than in yr 2 (year × N, $P < .05$). Both specific conductivity and pH of water samples were less ($P < .05$) in samples from the high N compared with the low N treatment. Acidity of water samples was also greater in yr 2 than in yr 1 (6.3 vs 5.9).

Table 5. Effect of protein and energy supplements on performance of steers grazing bermudagrass pastures

	Supplement[a]					
	None	E	E + SBM	E + BM	SEM	Significance[b]
No. of steers						
Yr 1	4	4	4	4		
Yr 2	8	8	8	—		
Combined	12	12	12	—		
Initial weight						
Yr 1	315.8	331.7	337.6	304.3	14.4	
Yr 2	277.5	290.8	288.6	—	9.4	
Combined	300.8	306.8	305.7	—	1.7	
ADG, kg						
Yr 1	.47	.78	.91	.90	.04	B*
Yr 2	.57	.88	.77	—	.03	B*
Combined	.52	.83	.84	—	.04	B*
Gain/supplement						
Yr 1	—	.61	.70	.66	.03	C*
Yr 2	—	.63	.55	—	.03	

[a]E = energy, SBM = soybean meal, BM = bone meal.
[b]B = Supplemented vs nonsupplemented, C = Supplement × year; *$P < .05$.

Discussion

There is very limited data to indicate what level of N from swine lagoon effluent may be applied to pastures, such as bermudagrass, without causing environmental concerns. Nitrogen may be lost to the atmosphere through volatilization or denitrification depending on the method of application, soil moisture level, type of soil, and ambient temperature, as well as other interacting factors. It is generally recommended that level of plant available nitrogen (**PAN**) to apply should correspond to expected plant uptake. For bermudagrass pasture, the recommended range of N (Mueller et al., 1994) is from 168 to 224 kg of N/ha (assuming yield ranges of 8,960 to 11,200 kg of DM/ha). Because approximately 50% of the N is lost to volatilization during lagoon effluent application (Mueller et al., 1994), the 456 kg of N/ha treatment corresponds closely to the recommended rate. When the rate was increased to 873 kg of N/ha, neither steer performance nor carrying capacity (based on animal grazing days) was significantly affected. Also, CP content of forage samples was increased only slightly when the higher level of N was applied. These results indicate that the plant's capacity to incorporate N was increased only slightly when the N level was increased from 456 to 873 kg of N/ha.

In small-plot studies simulating hay production, Burns et al. (1990) applied 335, 670, and 1,340 kg of total $N \cdot ha^{-1} \cdot yr^{-1}$ from swine lagoon effluent to bermudagrass over a 11-yr period. During the first 6 yr (Burns et al., 1985), only the highest rate resulted in a significant DM yield increase, although over the 11-yr period, yields were increased an average of 4 Mg/ha when the loading rate was increased from 335 to 670 kg of N/ha and was further increased at the high level. In contrast, based on the steer grazing days observed in this study, little difference was observed in carrying capacity (i.e., yield) when the rate of application was increased from 456 to 873 kg/ha of N. However, these results may change as these levels of application are continued over several years. In the small-plot studies, the forage was removed as hay compared with grazing in this study, and this may account for the difference. Slightly higher IVDMD values were observed in available forage samples ($P = .15$) with the high N treatment, which agrees with the results of Burns et al. (1990). In the study of Burns et al. (1990), nitrate N concentration in forage increased as N application rate increased. Similar results were observed in this study, although there was a large difference in concentration of nitrates in clipped and available forage samples between the two N application levels. However, none of the clipped or available forage samples for either N treatment were above the nitrate ion level considered toxic for growing steers (.66% and above).

Over the 2-yr period, gains were increased by .31 kg/d ($P < .05$) by supplementing either an energy source or a combination of energy and SBM compared with controls. Conflicting results have been obtained

Table 6. Effect of nitrogen application level from swine effluent on animal performance and animal days/hectare for steers grazing bermudagrass pasture

	Nitrogen level, kg/ha		
Item	456	873	SEM
No. steers	34	34	
Initial weight, kg	304.6	304.3	1.2
ADG, kg	.71	.76	.03
Steer days/hectare, d	1,146	1,211	34

Table 7. Characteristics of ground water from wells beneath pastures fertilized with 456 or 873 kg/ha of nitrogen from swine waste effluent

Item	Nitrogen level, kg/ha		SEM	Significance[a]
	456	873		
Total N, mg/L	2.06	1.76	.15	—
Ammonia N, mg/L	.64	.42	.06	N*
Nitrate N, mg/L	.10	.08	.02	—
Total phosphorus, mg/L				Y*, D*
Year 1	.68	.62	.04	
Year 2	.51	.40	.04	
Orthophosphate, mg/L				D*, Y*, Y × N
Year 1	.54	.53	.03	
Year 2	.41	.23	.03	
Chloride, mg/L				Y × N*, N*
Year 1	28.6	37.4	3.6	
Year 2	13.2	54.3	4.3	
Specific conductivity, μmhos/cm	392	240	23.0	N*
pH				Y*, N*
Year 1	6.5	6.1	.1	
Year 2	6.3	5.4	.1	

[a]N = level of nitrogen fertilization effect; D = date effect, Y = year effect; *$P < .05$.

when escape and ruminally degraded protein sources have been used as supplements for grazing cattle. Cattle grazing bermudagrass pastures tended to gain faster when molasses blocks containing either fish meal plus urea or cottonseed meal plus urea and blood meal were supplemented than when cattle grazed pasture alone (Grigsby et al., 1989). Dry supplements containing cottonseed meal, fish meal, or heat-treated soybean meal plus fish meal provided gains that were approximately .26 kg/d greater than gains from pasture only (Grigsby et al., 1989). The latter results agree closely with the response observed in this study due to supplementation. Rogers et al. (1994) also observed linear increases in gains of steers grazing bermudagrass when supplemented with graded levels of an escape protein source (combination of corn, blood meal, and feather meal).

Others (Hafley et al., 1993) have evaluated energy, escape protein, and ruminally degraded protein sources for cattle grazing a mixture of big bluestem (*Andropogon gerardi* vitman), switchgrass (*Panicum virgatum* L.) and indian grass (*Sorghastrum notans* [L.] Nash). In 1 yr, providing .2 kg of escape protein produced the greatest gains ($P < .10$), whereas no response was observed from supplementing .1 kg of escape protein. In another year, gains were similar for cattle receiving the control and escape protein treatments (.14 to .18 kg·cow^{-1}·d^{-1}). Supplying ruminally degraded protein also tended ($P = .12$) to increase gains compared with the energy control. A combination of escape and degradable protein sources provided a .13 kg/d response in gain compared with the control and escape protein treatments. Forcherio et al. (1994) observed that providing additional energy to lactating cows grazing fescue did not improve weight gains, but additional protein (blood meal) gave a response. Therefore, forage species seems to be a factor, and level of fertilization and grazing management are likely to be other factors that contribute to variability.

The ruminal ammonia concentrations observed in this study were quite high at all sampling dates and were influenced by N fertilization rate but not by supplement. Concentrations of ruminal ammonia were greater than required for optimal microbial growth and fermentation (Satter and Slyter, 1974; Kang-Meznarich and Broderick, 1980). Ruminal ammonia concentrations were also greater in steers grazing the 873 than in those grazing the 456 kg/ha N treatment in the July and August samplings. Concentrations were much greater at the August than the June or July sampling dates, which would also correspond to the time when IVDMD was decreasing in the forage, especially during the August sampling. Therefore, less digestible energy would be available in the forage to use the ammonia.

In general, nitrate N concentration in drainage water increases as N application rate increases (Devitt et al., 1976; Gast et al., 1978). Most studies have indicated that N application at rates recommended for crop utilization result in no increase in nitrate N concentrations above the 10 mg/L of drinking water standard (U.S. EPA, 1976; Gast et al., 1978). The similarity in nitrate N concentrations observed in shallow ground water for the 456 and 873 kg of N treatments in this study were surprising, because the high level of application was approximately two times the level of plant utilization. There is a possibility that N and other elements may accumulate in the soil; however, it seems that greater soil denitrification is occurring at the higher N treatment because soil inorganic N concentrations have been similar for the two treatments (J. P. Zublena, personal communication).

Implications

These results indicate that there is no difference in performance of steers when grazing bermudagrass fertilized with either 456 or 873 kg of N/ha from swine lagoon effluent, and supplements consisting of an energy source or a combination of energy and soybean meal provide similar response in gain. These results also indicate that no increase in nitrogen or phosphorus compounds in ground water occurred over a 2-yr period when up to 873 kg of nitrogen/hectare from swine effluent was applied to a highly organic soil.

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