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Protein Supplementation of Ammoniated Roughages. II. Wheat Straw Supplemented with Alfalfa, Blood Meal or Soybean Meal Fed to Wintering Steers

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PROTEIN SUPPLEMENTATION OF AMMONIATED ROUGHAGES. II. WHEAT STRAW SUPPLEMENTED WITH ALFALFA, BLOOD MEAL OR SOYBEAN MEAL FED TO WINTERING STEERS[1]

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ABSTRACT

Two winter steer growth trials were conducted to investigate responses of steer calves to ammoniation of wheat straw, level of alfalfa haylage (50 or 66.7% of diet) and source of supplemental protein, soybean meal (SBM), blood meal (BM), or a blood meal-urea mixture (BM-U). In trial 1, the main effect of ammoniation significantly increased average daily gain (ADG) from .15 to .24 kg/d, dry matter intake (DMI) from 4.86 to 5.29 kg/d and gain/feed from .029 to .044. The higher level of alfalfa haylage significantly increased DMI from 4.78 to 5.36 kg/d. Gain during a subsequent grazing period was unaffected by winter diet. In trial 2, the main effect of ammoniation significantly increased ADG from .26 to .38 kg/d and DMI from 4.28 to 4.78 kg/d. The main effect of supplement showed that ADG was significantly greater for the SBM-fed steers than for either the BM- or BM-U-fed steers. A significant ammonia × supplement interaction was noted for gain/feed; the response due to protein supplement differed, depending on whether or not the straw was ammoniated.

(Key Words: Ammoniated Feeds, Wheat Straw, Protein Supplements, Steers.)

Introduction

Wheat straw, due to its low energy density, may not support maintenance in weaned calves. However, if its digestibility and N content is improved by ammoniation, it might be utilized in combination with other ingredients for wintering calves returning to pasture the following year.

Positive associative effects have been reported for alfalfa inclusion in diets of NaOH- or NH_3-treated corn cobs or wheat straw (Maeng et., 1970; Paterson et al., 1981; Cook, 1981; Paterson et al., 1982). Therefore, alfalfa may be a good complementary feedstuff to be fed with ammoniated wheat straw.

Blood meal protein is essentially indigestible in the rumen (Stock, 1982), whereas soybean meal protein is 60 to 80% degraded in the rumen (Hume, 1974; Kropp et al., 1976 Merchen et al., 1979. Peterson 1981; Zinn et al., 1981). Additionally, a 50:50 mixture of blood meal and urea (on a protein basis) has been shown to support rates of gain approximately equal to those of soybean meal when supplementing a corn silage-corn cob diet fed to growing steers (Stock et al., 1981).

Ammoniation enhances the N content of feedstuffs, with the largest retained fraction as free ammonia (Solaiman et al., 1978; Abidin and Kempton, 1981). But N is also present in bound forms (Kowalczyk, 1977) that may (Millar, 1944; McCall and Graham, 1953; Horton, 1979; Horton and Steacy, 1979) or may not (Hershberger et al., 1959; Garrett et al., 1974; Oji et al., 1977 Borhami and Johnsen, 1981) be utilized. With high dry matter feedstuffs, however, the ammonia retained after ammoniation will be less than low dry matter feedstuffs due to the dissociation constant of NH_4OH and the pka of ammonia, allowing sizable volatile ammonia losses. The major objectives of the current studies were to investigate the responses in winter performance of steer calves due to ammoniation of wheat straw, level of alfalfa haylage and source of supplemental protein (soybean meal, blood meal or a blood meal urea mixture).

Experimental Procedure

Trial 1. Ninety-six Angus steers (261 kg) were randomly allotted to 12 pens of eight steers with three pens/treatment. A 2 × 2

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TABLE 1. DIET COMPOSITION (TRIAL 1)

Ingredient	High haylage: Control straw	High haylage: Ammoniated straw	Low haylage: Control straw	Low haylage: Ammoniated straw
	% DM basis			
Alfalfa haylage	66.7	66.7	50	50
Wheat straw	31.6		47.4	
Ammoniated straw		31.6		47.4
Supplement	1.7[a]	1.7[a]	2.6[b]	2.6[c]

[a]Supplement 1 (see table 2).

[b]Supplement 2 (see table 2).

[c]Supplement 3 (see table 2).

factorial arrangement of dietary treatments was utilized. The main effects investigated were ammoniation of wheat straw (0 or 4 g/100 g dry matter) and level of alfalfa haylage dry matter in the diet (50 or 66.7%). Supplements were fed as a fixed proportion of the straw component of the diet (tables 1 and 2) and were formulated so that the diet contained .5% Ca, .3% P, .25% salt, .05% trace minerals and 2,200 IU vitamin A per kg. Supplements 2 and 3 were formulated assuming the equal protein contribution from blood meal and corn gluten meal would be utilized at twice the efficiency of soybean meal (Stock et al., 1981). Urea was included in the supplement fed in conjunction with the untreated straw-low haylage level in an amount to provide the same quantity of N as the blood meal-corn gluten meal mixture. Thus, all diets contained at least 11.5% crude protein equivalent. The 150-d wintering period from December 17, 1980 to May 15, 1981 was followed by a 130-d grazing period (May 15, 1981 to September 21, 1981) where steers grazed a common, predominantly crested wheat grass, pasture. Initial and final steer weights for the wintering period, were the average of two consecutive day weighings. Steers were fed alfalfa haylage before the initial weight was

TABLE 2. SUPPLEMENT COMPOSITION (TRIAL 1)

Ingredient	Supplement number: 1	2	3
	% DM basis		
Corn (IFN 4-02-861)	64.75	10.91	24.96
Blood meal[a] (IFN 5-00-380)		19.43	18.60
Corn gluten meal (IFN 5-02-900)		25.41	24.33
Urea (IFN 5-05-070)		12.14	
Dicalcium phosphate (IFN 6-01-080)	17.68	20.42	20.42
Salt (IFN 6-20-226)	14.29	9.51	9.51
Trace minerals[b]	2.86	1.90	1.90
Vitamins[c]	.42	.28	.28
Calculated CP	6.48	68.24	34.12
Actual CP	9.26	74.66	34.65

[a]Ring dried.

[b]10% Mn, 10% Fe, 10% Zn, 1% Cu, .3% I, .1% Co.

[c]30,000 IU vitamin A, 8,000 IU vitamin D and 10 IU vitamin E per g.

recorded, and for 4 d before the final weight, to reduce fill differences.

Data were analyzed by analysis of variance (Snedecor and Cochran, 1967) for a factorial in a completely random design.

Trial 2. Ninety-six Angus steers (230 kg) were randomly allotted to 12 pens of eight steers with two pens/treatment. A 2 × 3 factorial arrangement of dietary treatments was utilized. The main effects investigated were ammoniation of wheat straw (0 or 3 g NH_3/100 g dry matter) and source of supplemental protein (soybean meal, blood meal or a blood meal-urea mixture). Supplements (table 3) were formulated assuming that blood meal was utilized at twice the efficiency of soybean meal (Stock et al., 1981), with or without urea, providing an equal amount of crude-protein-equivalent. Diets (on a dry matter basis) were 45% corn silage, 45% wheat straw and 10% supplement and were formulated to contain .31% Ca, .28% P, .15% salt, .05% trace minerals, 2,200 IU vitamin A per kg and at least 10.1% crude protein, with exception of the blood meal supplement fed in conjunction with the untreated straw. The 110-d wintering period was from December 18, 1981 to April 7, 1982. Initial and final steer weights were the average of weights recorded on two consecutive days. Steers were fed 75% alfalfa haylage, 25% corn silage before the initial weight, and for 4 d before the final weight, to reduce fill differences. Data were analyzed by analysis of variance for a factorial experiment in a completely random design (Snedecor and Cochran, 1967). Means within the main effect of supplemental protein were tested using the Least Significant Difference test, protected by a significant F-test (Snedecor and Cochran, 1967).

Straw Ammoniation and Feeding Regimen. The wheat straw was baled in 27-kg, square, wire-tied bales. Eight-hundred-fifty bales were stacked and covered with plastic. Anhydrous ammonia was injected at a single point into the straw stack in early October, in both years, using a pipe coupled to an anhydrous ammonia nurse tank with an anhydrous regulator. The stack remained sealed until initiation of feeding in mid-December, at which time the stack was opened and aeration was allowed. Core samples of 20 individual bales were collected as feeding progressed; samples were composited for subsequent analysis.

Steers were pen fed, once daily, allowing ad libitum intake of the complete diet. Straw was fed unground, behind slanted bars attached to the feed bunk, and was not mixed with the other diet ingredients. Therefore, straw consumption limited intake of the complete diet.

Dry matter (DM), crude protein (CP), in vitro dry matter disappearance (IVDMD), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL),

TABLE 3. SUPPLEMENT COMPOSITION (TRIAL 3)[a]

Ingredient	Supplement: Soybean meal	Blood meal	Blood meal urea
	% DM basis		
Soybean meal (IFN 5-04-604)	90.73		
Blood meal[b] (IFN 5-00-380)		18.71	19.82
Urea (IFN 5-05-070)			8.36
Corn (IFN 4-02-861)	2.75	72.60	62.96
Dicalcium phosphate (IFN 6-01-080)	4.45	6.62	6.78
Trace mineral premix[c]	.50	.50	.50
Salt (IFN 6-20-226)	1.50	1.50	1.50
Vitamin premix[c]	.07	.07	.07
Calculated CP	47.0	23.5	47.0
Actual CP	41.6	20.0	53.3

[a]Diets were 45% corn silage, 45% wheat straw and 10% supplement.

[b]Ring dried.

[c]See table 1.

TABLE 4. CHEMICAL ANALYSIS OF WHEAT STRAW

Item[a]	Trial 1 Wheat straw	Trial 1 Ammoniated straw	Trial 2 Wheat straw	Trial 2 Ammoniated straw
	% DM basis			
DM	92.5	91.9	94.3	92.3
IVDMD	50.0	56.2	44.5	48.7
NDF	82.2	80.6	88.6	84.2
ADF	53.5	54.6	60.8	59.9
ADL	5.9	5.9	12.5	10.1
Total N	.52	1.34	.41	.90
NH_3-N	.00	.35	.00	.43
NDF-N	.18	.21	.14	.22
ADF-N	.17	.18	.07	.18
N-remainder	.35	.77	.27	.26

[a]DM=dry matter, IVDMD=in vitro dry matter disappearance, NDF=neutral detergent fiber, ADF=acid detergent fiber, ADL=acid detergent lignin, n=nitrogen, NH_3=ammonia, N-remainder=total N-(NH_3-N+NDF-N+ADF-N).

ammonia (NH_3), and in vitro rate of digestion were determined as described by Nelson et al. (1984a).

Results

Trial 1. Ammoniation of wheat straw (table 4) increased the IVDMD by 6.2 percentage units (50.0 vs 56.2%) and CP content of the aerated straw by 5 percentage units (3.3 vs 8.4%), decreased NDF slightly and did not affect ADF or ADL. The N fractions (table 4) show that while some enrichment in cell wall N (NDF-N and ADF-N) occurred, the fraction showing the largest increase was in ammonia-N (NH_3-N). Ammoniation did not increase in vitro rate of straw ADF digestion or decrease lag phase, but it did increase (P=.08) the extent of ADF digestion (table 5). The alfalfa haylage contained 22.4% CP and 56.6% IVDMD.

Winter performance of the steers is shown in table 6. The main effect of ammoniation significantly increased average daily gain (ADG) from .15 to .24 kg/d, dry matter intake (DMI) from 4.86 to 5.29 kg/d and gain/feed from .029 to .044. The main effect of alfalfa haylage level significantly increased DMI from 4.78 to 5.36 kg/d, without improving ADG or gain/feed. The higher level of alfalfa haylage appeared to

TABLE 5. IN VITRO ACID DETERGENT FIBER RATE MEASUREMENTS OF WHEAT STRAW

Item	Trial 1 Ammonia, g/100 g DM 0	Trial 1 Ammonia, g/100 g DM 4	Trial 1 SE	Trial 1 P[a]	Trial 2 Ammonia, g/100 g DM 0	Trial 2 Ammonia, g/100 g DM 3	Trial 2 SE	Trial 2 P[a]
Rate of digestion, %/h	3.23	3.92	.16	.20	4.98	6.25	.11	.08
Extent of digestion, g ADF remaining at 96 h/100 g ADF	41.79	30.02	.97	.08	41.49	42.84	3.75	.74
Lag phase, h	11.58	7.16	.16	.03	11.45	15.16	.34	.08

[a]Probability for ammonia.

TABLE 6. PERFORMANCE OF STEERS FED WHEAT STRAW-ALFALFA HAYLAGE (TRIAL 1)

	Wheat straw		Ammoniated straw		
	Haylage level, %		Haylage level, %		
Item	50	66.7	50	66.7	SE
Winter ADG[a], kg/d	.12	.17	.23	.24	.015
Feed intake[ab], kg/d	4.60	5.12	4.96	5.61	.121
Gain/feed[a]	.026	.032	.046	.043	.003
Grazing ADG, kg/d	.74	.72	.69	.68	.029

[a]Increase due to main effect of ammoniation ($P<.01$).

[b]Increase due to main effect of alfalfa haylage level ($P<.01$).

improve winter gain and gain/feed with the control straw, but not with the ammoniated straw. Gain during the grazing period, while slightly less for the calves wintered on ammoniated straw, was not significantly affected by wintering treatment. Thus, calves wintered while fed ammoniated straw were heavier at the end of both the wintering and the grazing period than calves wintered while fed the control straw.

Trial 2. Ammoniation of the straw used in trial 2, which was weathered, resulted in only small increases in IVDMD (4.2 percentage units) and CP (3.0 percentage units) content, while NDF decreased by 4.4 percentage units (table 4). Additionally, the weathered straw appeared to contain more NDF, ADF, ADL and less IVDMD than the straw used in Trial 1 and the increase was less than previously observed (Solaiman et al., 1978; Faulkner, 1980). The N fractions (table 4), NH_3-N, NDF-N and ADF-N, were enriched to a greater extent, even though the total N enrichment was less, in the weathered straw (Trial 2) than in the unweathered straw (Trial 1). Inexplicably, the uncharacterized N (N remainder), which might be in the solubilized hemicellulose, less tightly bound in the cell wall than NDF-N and ADF-N or in forms not measured by the indophenol procedure, was not increased by ammoniation of the weathered straw in Trial 2. In vitro rate of ADF digestion (table 5) was increased ($P=.08$) and lag phase decreased ($P=.08$) without affecting the extent of ADF digestion by ammoniation. The corn silage fed contained 8.4% CP and 77.8% IVDMD.

Performance of steers in Trial 2 is shown in table 7. Ammoniation increased ($P<.05$) ADG from .26 to .38 kg/d and DMI from 4.28 to 4.78 kg/d. The main effect of protein supplement showed that ADG was greater ($P<.05$) for the soybean meal-fed steers (.40 kg/d) than for either the blood meal- (.25 kg/d) or the blood meal-urea- (.31 kg/d) fed steers. Dry matter intake, while slightly lower for the blood meal- and blood meal-urea-fed steers than the soybean meal-fed steers, was not affected by protein supplement. A significant ammonia × supplement interaction was detected for gain/-feed (table 7), wherein soybean meal equaled blood meal-urea and both appeared greater than blood meal with the untreated straw-fed steers. However, with the ammoniated straw the soybean meal-fed steers appeared to have a greater gain/feed than either the blood meal- or blood meal-urea-fed steers.

Discussion

Addition of alfalfa to NaOH-treated corncobs or wheat straw has resulted in positive associative effects on DM digestibility and daily gain (Maeng et al., 1970; Paterson et al., 1982). Similar responses have been noted by 50% alfalfa addition to NH_3-treated or untreated corncobs in ADG of steers (Paterson et al., 1981). However, no positive associative effect on DM digestibility was noted from alfalfa addition to 3 g NH_3/100 g DM treated or untreated cornstalks (Paterson et al., 1981).

Explanations for these positive associative effects include slowed rate of particulate passage and provision of additional minerals; especially K, Ca and Mg (Paterson et al., 1982). However, an additional explanation is an increase in microbial cell yields when small quantities of amino acids are present, as was shown by Maeng and Baldwin (1976) in vitro, with an ammonia-containing media. This is supported by data of Cook (1981), who noted

TABLE 7. PERFORMANCE OF STEERS FED WHEAT STRAW–CORN SILAGE (TRIAL 2)

	Wheat straw			Ammoniated straw			
	Supplement[a]			Supplement			
Item	SBM	BM	BM-U	SBM	BM	BM-U	SE
ADG[bc], kg/d	.32	.15	.30	.47	.36	.31	.039
Feed intake[b], kg/d	4.70	3.93	4.22	4.72	4.83	4.78	.244
Gain/feed[bcd]	.069	.039	.069	.100	.073	.066	.006

[a]SBM = soybean meal, BM = blood meal, BMU = blood meal-urea.

[b]Increase due to main effect of ammoniation (P<.05).

[c]Increase due to main effect of supplement (P<.05).

[d]Ammonia X supplement interaction (P=.045).

improved gain and DMI of steers fed untreated or ammoniated corn cobs with .91 kg alfalfa fed/head, even though adequate (based on the assumption used in supplement formulation for the current studies) levels of a blood meal-corn gluten meal mixture were fed. Further, Teather et al. (1980) noted soybean meal supplementation of corn silage plus concentrate supported a ruminal bacteria population 70% greater than diets supplemented with urea in lactating dairy cows. Additionally, the bacterial species that require, or are stimulated by, branched-chain volatile fatty acids showed the greatest increases in numbers, probably due to amino acid deamination to volatile fatty acids rather than to direct incorporation into microbial protein. Alfalfa protein, untreated, is similar in degradability in the rumen to soybean meal (Krause and Klopfenstein, 1972), which is 60 to 80% ruminally degraded (Hume, 1974; Kropp et al., 1976; Merchen et al., 1979; Peterson, 1981), while blood meal is essentially indigestible in the rumen (Stock, 1982).

Supplement formulation was based on data of Stock et al. (1981), which indicated that steers fed a corn silage-corncob diet gained as fast when fed one-half as much N from blood meal or corn gluten meal, in combination with urea, as soybean meal. This appears to be supported with the untreated wheat straw diets where the soybean meal- and blood meal-urea-fed steers had similar gains and gain/feed. The steers fed the untreated wheat straw supplemented with blood meal may have been limited in rumen ammonia due to the low degradability of the blood meal, wheat straw and corn protein in the rumen. However, when the straw was ammoniated, the soybean meal-fed steers appeared to gain faster with similar feed intakes than did the blood meal- or blood meal-urea-fed steers, which performed similarly. Thus, a significant ammonia × supplement interaction of gain/feed was observed. Similarly, inclusion of a blood meal-corn gluten meal mixture improved N retention in wethers (Nelson et al., 1984) and bacterial-N flow in steers (Nelson et al., 1982) fed ammoniated corncobs.

It appears then that the first limiting nutrient differed between diets. In the untreated straw diets, energy was first limiting with soybean meal and blood meal-urea supplements, but rumen ammonia was first limiting in the blood meal-supplemented diet. Energy availability was increased by ammonia treatment and the residual ammonia was sufficient to meet rumen ammonia needs. In the blood meal- and blood meal-urea-supplemented diets, rumen-degradable protein supplied by the soybean meal probably supplied peptides, amino acids or branched-chain fatty acids for microbial growth because ammonia should have been in excess. This would be in agreement with Brandt et al. (1984), who found a response to rumen degradable proteins with ammoniated corncobs. In trial 1, alfalfa probably supplied sufficient rumen degradable protein so that the digestible energy content of the diet was the first limiting nutrient.

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