THE EFFECT OF ADDING ANHYDROUS AMMONIA TO CORN SILAGE ON THE PERFORMANCE OF GROWING AND FINISHING BEEF CATTLE

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ABSTRACT

THE EFFECT OF ADDING ANHYDROUS AMMONIA
TO CORN SILAGE ON THE PERFORMANCE
OF GROWING AND FINISHING
BEEF CATTLE

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Two feeding trials and one metabolic trial were conducted to determine the feeding value of corn silage (CS) treated with anhydrous ammonia (AN) at ensiling with a cold-flow chamber. In trial 1, 26 steers (230 kg) each were fed for 202 days either untreated CS + soy (control) or CS treated with ammonia-mineral suspensions (AMS), aqueous ammonia (AQ), or AN. Crude protein (CP) level (%) in the ration DM, kg of ADG and kg DM/kg gain for the treatments were 11.5, 1.15, 6.92; 11,1, 1.15, 6.73; 12.7, 1.10, 7.19; 10.8, 1.06, 7.48, respectively, for control, AMS, AQ and AN. The same rations plus a negative control (neg. cont.) ration were fed to five Charolais cross steers (259 kg) in a nitrogen (N) balance trial. Grams of N retained and % of intake N retained per day were 36.5, 36.8; 67.3, 46.1; 54.0, 45.4; 63.2, 45.1; 50.8, 45.6, respectively, for neg. cont., control, AMS, AQ and AN. In trial 2, eight Hereford steers

(194 kg) and eight Charolais cross steers (272 kg) each were fed either untreated CS (neg. cont.); untreated CS + soy (control) or CS treated per 909 kg (35% DM) with 2.3 kg AN (2.3 AN); 3.2 kg AN (3.2 AN); or 4.1 kg AN (4.1 AN). Eight steers of each type were also fed 2.3 AN or 3.2 AN plus enough soy to obtain 12.5% CP in the ration dry matter which was approximately the same CP as in control and 4.1 AN rations. Neg. cont., 2.3 AN and 3.2 AN rations contained 8.0, 10.3, and 11.1% TP, respectively. Kg ADG and DM/kg gain for neg. cont., control, 2.3 AN, 2.3 AN + soy, 3.2 AN, 3.2 AN + soy, and 4.1 AN were .33, 14.40; 1.13, 7.08; .68, 7.88; 1.18, 6.30; .99, 5.85; 1.11, 6.64; 1.08, 5.63, respectively.

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I. INTRODUCTION

Corn silage has become more important as a major feed for growing and finishing cattle as grain prices have increased. Although a good energy source, corn silage is more deficient in total protein and lower in available protein than other high energy feeds. Because more supplemental protein must be added to high silage rations, it is important to find the most economical way to add usable nitrogen. Various forms of non-protein nitrogen, such as urea and ammonia in aqueous form, have been shown effective for this purpose, but little information has been available on the addition of anhydrous ammonia at ensiling.

Recently, however, a condensation chamber was developed at Pennsylvania State University which allowed direct application of anhydrous ammonia to corn silage. Anhydrous ammonia under pressure enters the chamber and causes a supercooling effect as it expands. The dramatic temperature drop condenses approximately 85% of the ammonia to a liquid at atmospheric pressure. Cold liquid ammonia then flows by gravity from the bottom of the chamber directly onto the silage and can be applied at the silo blower or in the field chopper.

This method has been called the "cold-flow" treatment due to the low temperature and resulting liquid form of the ammonia. When applied in the field, an ammonia tank is trailed behind the chopper or mounted on the tractor. A standard meter of the type used to apply anhydrous ammonia during tillage operations is used to control flow rate into the chamber.

The following experiments were conducted to determine:

1. The feeding value of anhydrous ammonia cold-flow treated corn silage as compared to silage treated with other forms of ammonia.

2. The effect of level of anhydrous ammonia treatment upon feedlot performance.

3. The benefit of adding soybean meal to anhydrous ammonia treated silage in the initial stages of growth.

4. The effect of a buffer added to high silage rations.

II. LITERATURE REVIEW

Different NPN Sources Compared

Non-protein nitrogen in various forms has been successfully used as an economical alternative to plant protein supplements for beef and dairy cattle. Huber et al. (1971) showed that cows fed corn silage treated with either ammonia-mineral suspension (Pro-Sil), ammonia gas, or urea were not significantly different in milk production. Very low recovery (48%) of nitrogen with the ammonia gas treatment was experienced, however. This was probably due to the application method since the ammonia was released into the silage in the field chopper, with no provision made to capture escaping gases. The ammonia gas treated silage did show a lower dry matter intake than the urea or ammonia-mineral suspension treatments, but this difference did not give a significant reduction in milk production.

In two trials reported by Henderson et al. (1971), steer calves were fed a 40% concentrate ration and yearlings were fed corn silage rations supplemented with urea, or treated at ensiling with ammonia-mineral suspension of aqueous ammonia. The NPN treatment used did not affect the average daily gains (ADG) of yearlings fed the all silage rations, and those fed NPN treated silage performed as well as soybean meal supplemented controls. Also, there were no significant differences in ADG for the urea, aqueous ammonia, ammonia-mineral suspension and soybean meal silage treatments when fed to calves in 40% concentrate rations.

Low nitrogen retention of corn silage treated with gaseous anhydrous ammonia was experienced by Henderson, Bergen and Hansen (1972). In a comparison of calves fed corn silage treated with anhydrous ammonia, urea-minerals or ammonia-mineral suspension, a significantly lower ADG and feed efficiency were shown for the anhydrous ammonia treatment. Part of this lower performance was likely due to the lower protein equivalent in the anhydrous treated silage. The anhydrous ammonia was applied through spray nozzles in the field blower, a method which had resulted in similar high losses in an earlier trial (Huber et al., 1974). However, when ammonia has been applied to corn silage as a liquid in aqueous mixture, retention of nitrogen and performance of cattle has been satisfactory. This would seem to indioate that poor performance encountered in previous trials with anhydrous ammonia treated silage was due to low crude protein level in the silage due to method of application and not due to the actual feeding value of anhydrous ammonia treated silage.

In a feeding trial utilizing 140 Angus steer calves, Cash et al. (1971) compared ammonia-mineral suspension and urea-mineral treated silages. Average daily gains were not significantly different between the two NPN treatments and two energy levels fed.

Under proper treatment and management, ammonia-mineral suspension has been found to give equal performance to soybean meal supplemented rations. Henderson et al. (1971a) found similar performance in yearlings fed ammonia-mineral and soybean meal supplemented rations with concentrate added at levels of 0, 40, 60 and 80%. The steers fed the ammonia-mineral treated silage received all their supplemental nitrogen from the treated silage, and the rations containing soybean meal (SBM) were supplemented to an equal total ration crude protein level.

The effect of adding different levels of ammonia-mineral suspension to corn silage was also examined by Henderson et al. (1971b). The silage was treated at levels of 10%, 12%, and 14% crude protein (DM) and fed alone or with 40% added concentrate to yearling Hereford steers. As the crude protein was increased from 10% to 12%, a corresponding increase in average daily gain and feed efficiency resulted at both energy levels. However, at 14% crude protein on the all silage ration, a marked decrease in dry matter intake occurred, which resulted in a significant reduction in ADG and feed efficiency. A similar reduction in performance resulted on the 40% concentrate ration, but differences were not as great. They concluded that the depressed dry matter intake of the 14% crude protein treated silage could be due to the significantly higher levels of lactic acid and total organic acids produced.

LaLonde (1975) used a condensation chamber or "cold-flow" chamber, developed at Pennsylvania State University, to treat corn silage with anhydrous ammonia. This method converts the gaseous anhydrous ammonia to a liquid before application, thus reducing nitrogen losses and increasing crude protein level of the treated silage. In a trial with corn silage and high moisture corn treated by the "cold-flow" method, performance of cattle on the ammonia treated rations was similar to controls supplemented with soybean meal. No depression of feed intake occurred with the anydrous ammonia treated rations as had been noted in earlier work by Henderson et al. (1971a) using a different application method.

Studies by Holter et al. (1968) and Huber et al. (1975) have shown that urea will support high milk production in dairy cows when fed at recommended levels of approximately 220 g/day. When lactating cows were fed equal crude protein levels as soybean meal or urea by Holter et al. (1968), no significant difference in milk production was recorded. Evidence from Michigan DHIA records also shows that NPN (mainly in the form of urea) was used in 55% of the herds on test for three out of five years. During this time, the herds fed NPN were not different in milk production from the herds supplemented with natural plant protein (Ryder et al., 1972).

Lactating cows fed corn silage treated with anhydrous ammonia by the "cold-flow" method had milk yields and dry matter intakes that did not differ significantly from soybean meal supplemented controls (Donaldson and Thomas, 1975). When Thomas and Donaldson (1975) averaged the results of six trials with lactating cows, they found identical values for kilograms of milk produced per day on rations of urea treated silage or anhydrous cold-flow treated silage with a low protein (10%) grain added to each.

Non-Protein Nitrogen for Calves

It has been generally accepted that different forms of NPN are well utilized by yearling beef steers, but trials with calves on NPN supplemented rations have been more variable. Mowat et al. (1974) fed lightweight calves on all corn silage rations supplemented with soybean meal or treated with ammonia-mineral suspension or a liquid urea additive. A depression in performance was experienced with the NPN treatments until the calves reached approximately 300 kg, but after that point, gains on the NPN treatments tended to equal those on the soybean meal supplemented ration. Results obtained by Henderson et al (1971) with three different NPN sources fed to calves averaging 231 kg indicated no difference in performance between the NPN and soybean meal supplemented groups over 219 days. The reduction in performance seen by Mowat et al. (1974) was likely due to the fact that their calves averaged only 185 kg initial weight or 46 kg lighter than those used by Henderson et al (1971). These lighter calves on NPN treatments could not make up for the poorer performance of the first part of the trial, even though gains in later stages (above 300 kg) were equal for NPN and soybean meal treatments.

Eight starting-on-feed trials were reported by Fox et al. (1977) which compared various NPN sources to soybean meal supplemented silage. Steer calves of 221 kg average weight on NPN treated silage gave much lower performance than untreated corn silage and soybean meal for the first 28 days, but feeding soybean meal with the NPN treated silage improved performance to near that of untreated silage plus soybean meal. Since these were starting trials, and the calves were then allotted to different experiments, it is unclear if calves fed only NPN treated silage could make up the deficit in performance by increased later gains. These trials also suggest that NPN utilization is poorest in stressed and sick calves, since the poorest performance on the NPN treated rations was seen in two trials where health problems were the greatest.

A study by Preston (1974) indicated that very lightweight calves of 175 kg average weight could effectively utilize a urea supplemented corn silage ration. Gains on the urea supplemented ration were improved 44% and feed efficiency was increased 25% over untreated corn silage with minerals only added. Further, they reported that the differences in performance between urea and soybean meal supplemented corn silage rations will decrease as the feeding period lengthens. In the initial periods of the feeding trial, soybean meal gave increased gains, but after 120 days or more on feed, the differences between urea and soybean meal supplemented rations were not significant.

A response to soybean meal addition to NPN supplemented corn silage was seen by Preston et al. (1975). Rations of corn silage supplemented with urea, one-third SBM and two-thirds urea, two-thirds SBM and one-third urea and all soybean meal were fed to light calves (177 kg average). In the first 27 days, as the level of SBM in the ration increased, an increase in ADG was seen. After the first 27 days, however, no

TABLE 1.--Summary of NPN feeding trials with beef steers.

Author	No. Hd. /Trt.	Init. Wt., Kg.	Days on Feed	% Corn Added	SBM Control		Urea		Ammonia	
					ADG, Kg	F/G	ADG, Kg	F/G	ADG, Kg	F/G
Calves: All silage, less than 100 days on feed										
Preston et al. '75	27	216	62	0	.67	6.50	.64[a]	6.70	--	--
Preston et al. '75	18	179	65	0	1.19	4.64	.95[a]	5.48	--	--
Byers & Smith '76	52	226	34	0	.54	5.60	.49[a]	5.90	--	--
Fox et al. '77	27	220	34	0	.92	5.20	--	--	.61[d]	7.79
Guyer et al. '77	20	261	83	0	.71	9.68	--	--	.69	9.71
Guyer et al. '77	32	295	74	0	.86	9.63	.88[b]	9.59	.89	8.72
Guyer et al. '77	19	294	84	0	.97	9.02	.91[b]	10.11	1.04	8.73
Guyer et al. '77	18	238	98	0	1.04	6.22	1.02[b]	6.46	1.00	6.12
Calves: All silage, more than 100 days on feed										
Krause et al. '76	20	193	130	0	.85	7.93	.77[b]	8.80	--	--
Woods & Tolman '69	46	211	130	0	.83	6.50	.76[b]	6.90	--	--
Cook & Fox '77	16	232	182	0	1.13	6.28	--	--	1.11[d]	6.64
Fox et al. '77	26	227	202	0	1.15	6.92	--	--	1.09	7.19
Henderson & Britt '73	48	236	206	0	1.18	6.00	--	--	1.15[c]	5.97
Ritchie et al. '75	8	183	154	0	1.22	4.68	1.14[b]	4.80	--	--
Cash et al. '71	10	245	227	0	.71	8.99	.76[a]	8.02	.73[c]	8.13
Henderson et al. '71	8	233	112	0	1.16	4.93	--	--	1.14[c]	4.72
Mowat et al. '74	48	183	140	0	1.04	6.30	.95[a]	7.00	.91	6.90
Calves: Added corn, less than 100 days on feed										
Henderson et al. '72	10	225	98	40	1.19	6.73	1.11[a]	6.75	1.08[c]	6.88
Calves: Added corn, more than 100 days on feed										
Preston '74	20	244	181	43	1.16	6.30	1.10[a]	6.40	--	--
Preston & Cahill '72	10	257	183	30	1.23	6.26	1.18[a]	6.32	--	--
Garrigus '66	10	217	164	65	.92	7.07	.92[b]	7.60	--	--
Woods '70	100	180	109	7	.78	7.61	.67[b]	8.61	--	--

Table 1.--Continued.

Author	No. Hd. /Trt.	Init. Wt., Kg	Days on Feed	% Corn Added	SBM Control		Urea		Ammonia	
					ADG, Kg	F/G	ADG, Kg	F/G	ADG, Kg	F/G
Calves: Added corn, more than 100 days on feed, cont'd.										
LaLonde '75	16	262	195	34	1.28	6.25	1.28[a]	6.41	1.18[d]	6.63
Henderson & Britt '73	16	236	206	40	1.18	6.15	--	--	1.14[c]	6.24
Henderson et al. '71	8	234	219	40	1.03	6.21	1.18[a]	5.99	1.15[c]	6.01
Yearlings: All silage, less than 90 days on feed										
Fox et al. '77	25	336	29	0	1.92	3.87	.91[b]	6.61	1.71[d]	3.89
Yearlings: All silage, more than 90 days on feed										
Henderson et al. '71	10	331	193	0	.83	8.36	--	--	.86[c]	8.54
Henderson et al. '71	9	370	125	0	1.05	6.99	--	--	1.04[c]	6.46
Henderson et al. '71	9	369	128	0	1.05	6.99	1.04[a]	6.75	1.04[c]	6.46
Henderson et al. '71	7	371	132	0	1.15	6.62	1.00[a]	6.60	.96[c]	6.98
Henderson et al. '71	8	345	106	0	--	--	1.23[a]	6.74	1.09[c]	7.69
Yearlings: Added corn, more than 90 days on feed										
Woods & Tolman '69	66	350	92	73	1.35	5.70	1.34[b]	5.82	--	--
Henderson & Geasler '70	16	338	136	60	1.44	6.16	1.29[b]	6.70	--	--
Henderson et al. '71	10	331	193	20	.84	8.27	--	--	.80[c]	8.59
Henderson et al. '71	10	330	193	40	.81	9.02	--	--	.83[c]	8.50
Henderson et al. '71	10	329	193	60	.87	8.15	--	--	.84[c]	8.86
Henderson et al. '71	10	328	193	80	.86	7.61	--	--	.85[c]	7.89
Henderson et al. '71	9	369	110	40	1.22	6.77	1.29[a]	6.55	1.25[c]	6.60

[a]Urea added at ensiling.
[b]Urea added at feeding.
[c]Ammonia source is Pro-Sil, added at ensiling.
[c]Ammonia source is anhydrous ammonia, added at ensiling.

consistent effect on the proportion of urea in the ration was seen. These data seem to support the hypothesis that after the initial adjustment period, NPN supplemented high silage rations will give performance equivalent to natural protein supplemented rations (Table 1).

The variability in performance of lightweight calves on NPN rations, reported by other workers, could be due to the fact that some results are reported for the full feeding period, and some for a much shorter trial. In this case, NPN sources would show poorer performance relative to natural protein in a short trial, but no significant difference if the trial extended over the full feeding period. Further length of time on SBM supplemented rations prior to beginning the trial, and cattle type could be factors.

Silage Fermentation

The fermentation process in untreated silage was described by Barnett (1954) in the following phases.

Phase 1: Respiration of the plant cells utilizes oxygen and simple carbohydrates to produce carbon dioxide and water. These biochemical reactions and mechanical compression of the mass results in some seepage from the silo.

Phase 2: Acetic and proprionic acids are produced in small quantities by organisms of the coliform group. This phase is short and merges into the third phase.

Phase 3: A lactic acid fermentation is initiated by lactobacilli and streptococci organisms. Soluble carbohydrate is thus utilized to produce lactic acid, the major organic acid end product of fermentation.

Phase 4: A quiescent period is reached as lactic acid production peaks with a resulting pH of approximately 4.2 or less.

The four phases require about three weeks for completion with the first three being complete after three days. If there is insufficient lactic acid produced to lower pH to 4.2 or less, or if air is allowed to penetrate the mass, then the fifth phase may result.

Phase 5: Butyric acid-producing organisms attack both residual soluble carbohydrates and the lactic acid which has been formed. In extreme cases, there may be deamination of amino acids with the formation of higher volatile fatty acids and ammonia, as well as decarboxylation leading to the formation of amines and carbon dioxide.

Watson and Nash (1960) stated that the formation of organic acids is the most striking feature of silage fermentation and that ethanol may be formed as a product of respiration.

Lactic acid is the major end product of fermentation and the most reliable predictor of silage quality found by Henderson and Bergen (1972). This is supported by Prigge and Owens (1976) who found lactate to be utilized more efficiently than soluble carbohydrates in the rumen due to decreased losses as methane. Prigge and Owens (1976) also stated that poor compaction of the silage decreased lactate, increased VFA production and increased energy losses due to heating. Allen and Henderson (1972) added lactic and acetic acid to corn silage rations and found a decrease in dry matter intake, average daily gain and feed efficiency with added acetate, but no effect with added lactate.

Acetic acid is the primary volatile fatty acid in corn silage, with traces of proprionic and butyric acids present in some silage (Barnett, 1954). When high levels of acetic and butyric acids are produced, heat losses increase, undesirable odors evolve, palatability is decreased, and higher energy losses occur during fermentation (Prigge and Owens, 1976).

Protein degradation during ensiling is primarily accomplished by proteolytic plant enzymes. Watson and Nash (1960) found that breakdown normally proceeds by way of relatively complex compounds to amino acids which can be deaminated to form ammonia and complex volatile bases. Protein hydrolysis ranges from 18% to 29% of the total nitrogen depending upon the dry matter of the ensiled material (Brody, 1965).

Bergen et al. (1974) examined the nitrogen fractions produced in corn silage during fermentation. The Michigan workers found water-soluble nitrogen and non-protein nitrogen levels increased rapidly to day 5, then remained constant until day 15, then increased slightly to the end of the 90-day sampling period. Large initial increases were observed for ammonia, water soluble NPN and unidentified nitrogen components which indicated that most proteolysis occurs in the first two days of ensiling. Unidentified nitrogen compounds were indicated as the major source of the increase in water soluble NPN.

Effects of NPN Treatment on Silage Fermentation

In a study with three ammonia treatments and one urea treatment, Beattie et al. (1970) found no difference in pH between the treated silage and control silage. However, Cash (1972) found significantly higher pH in ammonia-mineral treatments, and attributed the increase to neutralization of the organic acids by the basic nature of the silage additives. This effect tended to increase the fermentation, resulting in a much higher lactic acid content of the NPN treated silages. Acetate levels were unchanged with NPN treatment. Bergen et al. (1974) also found increased lactic acid in ammonia-mineral treated silage.

Total nitrogen, water-soluble nitrogen, water-soluble NPN, water insoluble nitrogen and ammonia nitrogen were found to be higher in ammonia-mineral treated silage than in control silage by Bergen et al. (1972). These findings agree with those of Cash (1972). The Michigan workers also found that the increase in soluble NPN was due to an increase in ammonia nitrogen; however, the unidentified nitrogen levels in the ammonia treated silage were slightly higher than in the control silage and appeared to be fairly constant during the fermentation period.

The increase in water insoluble nitrogen content was attributed by Bergen et al. (1974) to a possible protein sparing effect caused by a reduction in proteolysis. By the end of the 90-day test period, however, the increase in water insoluble nitrogen was no longer present; probably due to autolysis of microbial cells and further degradation of plant protein as levels of organic acids increased.

III. MATERIALS AND METHODS

Experimental Animals

Two hundred thirty-two choice steer calves were used in two feeding trials conducted during the period of December 1974 through June 1976. The cattle used in trial 1 were Charolais crossbred calves purchased in Montana. These calves arrived at East Lansing in November 1974 and were in average flesh condition. The cattle used in trial 2 were Charolais crossbreds and straightbred Herefords which were purchased at a feeder calf sale at West Branch, Michigan. The calves arrived in October 1975 and were in average flesh condition.

Preliminary Treatment

Upon arrival, all cattle were weighed, tattooed, ear-tagged, vaccinated for IBR, BVD, PI_3 and injected with 5 cc of vitamins A and D. A pour-on treatment for grubs and lice was given subject to recommended cut-off dates. The calves were checked twice daily for health and any sick animals were treated.

The cattle in trial 1 were allotted directly to a 28-day starting-on-feed trial with four different rations. At the end of the starting trial, the calves were healthy, consumption was normal, and trial 1 was begun in mid-December 1974. The steers in trial 2 were full-fed a standard starting ration of 88% corn silage plus 12% natural protein-mineral supplement (dry matter basis) prior to beginning the trial. These cattle became very ill with a respiratory infection and required 54 days to completely regain normal health prior to beginning the experiment in mid-December 1975. The starting rations were balanced for calcium, phosphorus, trace mineral salt, and vitamins A and D according to NRC recommendations.

Weighing and Implanting

Individual initial and final weights were taken after 16 hours without feed and water. In trial 1, the calves were group weighed every 28 days, after 16 hours without water; and in trial 2 individual weights were taken in the same manner.

In the first trial, cattle in each pen were implanted at random with DES, Ralgro or Synovex-S, on day one. All the cattle in trial 2 were implanted with Synovex-S, and were re-implanted at 112 days.

Allotment

The weights of the 104 Charolais crossbred calves in trial 1 were ranked in order from the lightest to the heaviest. The steers were then divided into 13 weight groups and one steer was selected at random from each group to form eight lots of 13 steers each.

In trial 2, 64 Charolais crossbred and 64 Hereford calves were allotted separately by breed using the same method as in trial 1. This produced eight lots of Charolais crossbreds and eight lots of Herefords with eight cattle in each lot.

Bunk Management

The complete rations were mixed in a horizontal mixer and fed once daily on an *ad libitum* basis. The steers were given a level that they would clean up just before the next feeding. Any feed that was refused was weighed and subtracted from the total consumed for that period.

Composition of Feeds

The silages were sampled once every two weeks and the supplements once a month. Crude protein was determined with the Technicon Auto Kjeldahl system and dry matter by forced air oven drying at 60°C (Tables 2 and 3).

Description of Feeds

Protein and mineral supplements were mixed at the Michigan State University feed mill. The supplement formulations are listed in Table 4.

TABLE 2.--Composition of feeds for different ammonia sources (trial 1).

Feed	Dry Matter[1] %	Crude Protein[1] % of DM
Corn silage, untreated control	38.3	8.0
Corn silage + am.-min. sus.	33.8	11.1
Corn silage + aqua am.	33.4	12.7
Corn silage + anhydr. am.	35.4	10.8
Protein-mineral supplement	91.4	48.1
Mineral supplement	99.2	--
Buffer	94.7	--

[1]Average of samples taken biweekly during the feeding period.

TABLE 3.--Composition of feeds for different levels of anhydrous ammonia (trial 2).

Feed	Dry Matter %	Crude Protein % of DM
Corn silage	30.5	7.98
Corn silage + 2.3 kg anhydr.[1] ammonia	33.8	10.3
Corn silage + 3.2 kg anhydr.[1] ammonia	33.5	11.1
Corn silage + 4.1 kg anhydr.[1] ammonia	34.9	12.3
Soybean meal	89.9	52.04
Protein supplement	90.2	47.62
Mineral supplement	91.5	7.79

[1]Denotes Kg of anhydrous ammonia added per 908 Kg of 35% DM silage.

TABLE 4.--Formulation of the supplements. (Values given in kg on an as-fed basis.)

Ingredient	Trial 1	Trial 2
Protein Supplement		
Soybean meal (48%)	927	927
Defl. phosphate	30	30
Limestone (39% Ca)	20	20
Trace mineral salt	20	20
Vitamin A (30,000 IU per lb)	1.5	1.5
Vitamin D (3,000 IU per lb)	1.5	1.5
	1,000.0	1,000.0
Mineral Supplement		
Ground shelled corn	325	831
Defl. phosphate	350	93
Trace mineral salt	125	36
Calcium sulfate	200	36
Vitamin A (30,000 IU per lb)	--	2
Vitamin D (3,000 IU per lb)	--	2
	1,000	1,000
Buffer		
Calcium hydroxide	--	500
Sodium bicarbonate	--	500
		1,000

The corn silage used for all treatments contained approximately 6 bu. of no. 2 corn per ton of 35% DM silage. Within each trial, the corn was of the same variety grown in the same field and was similar in dry matter at harvest. The silage was chopped to a particle size of 1/4"-3/8" and stored in concrete stave silos of approximately 250 ton capacity.

Ammonia Treatment of Silage

Anhydrous ammonia was added to the corn silage by the "cold-flow" method developed at Pennsylvania State University. The cold-flow chamber was mounted on a twin feed blower with the pressure line from the nurse tank entering the meter at the top of the chamber (Figures 1 and 2). Two lines at the bottom of the cold-flow chamber fed the condensed liquid ammonia to the point where the silage first contacted each blower feed (Figure 3). A vapor line from the top of the chamber was inserted at the point where the silage first entered the body of the blower. A Continental field-type meter was connected to the top of the cold-flow chamber to regulate flow. Liquid ammonia under pressure flowed from a wagon-mounted nurse tank, through the meter and into the cold-flow chamber where it was released as a gas. The gas emerging in the chamber causes a supercooling effect, thus condensing approximately 85% of the gas to a liquid at atmospheric pressure.

Figure 1.--Adding anhydrous ammonia to corn silage at the blower by the cold-flow method.

The liquid ammonia was then fed by gravity from the bottom of the cold-flow chamber to the blower. The remaining vapor exits at the top of the chamber and is placed with the silage as shown in Figure 1. The wagon-mounted nurse tank was weighed periodically and each load of corn silage was also weighed to determine if the meter setting was delivering the desired amount of anhydrous ammonia per ton of 35% DM silage.

Ammonia-mineral suspension (Pro-Sil) was added by the method described by Henderson et al (1971). This method uses a mobile tank with a low capacity pump and a

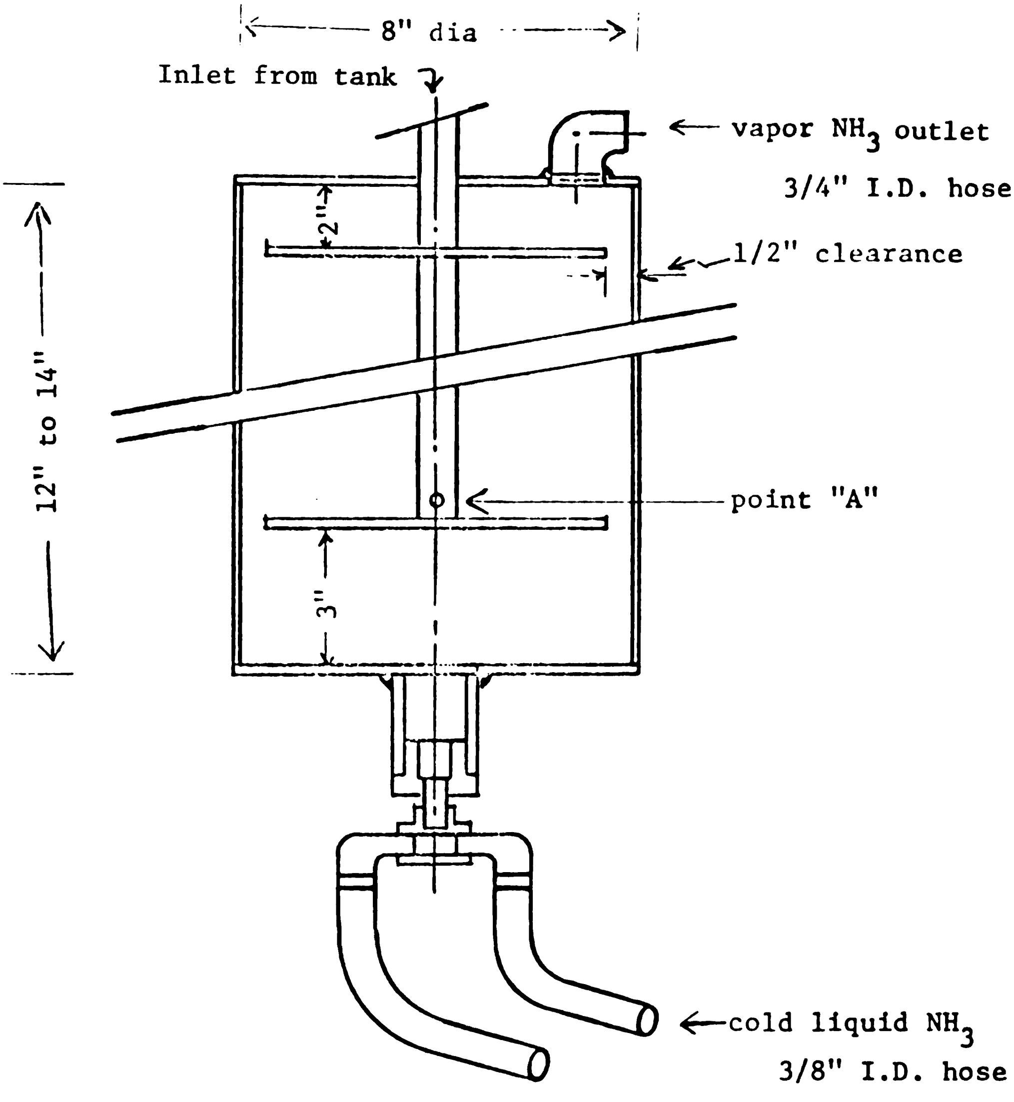

Figure 2.--Cross section of cold-flow chamber. NH_3 from supply tank enters reactor at point "A", evaporates, and cools. Cold liquid NH_3 and vapor flow through bottom and top openings, respectively.

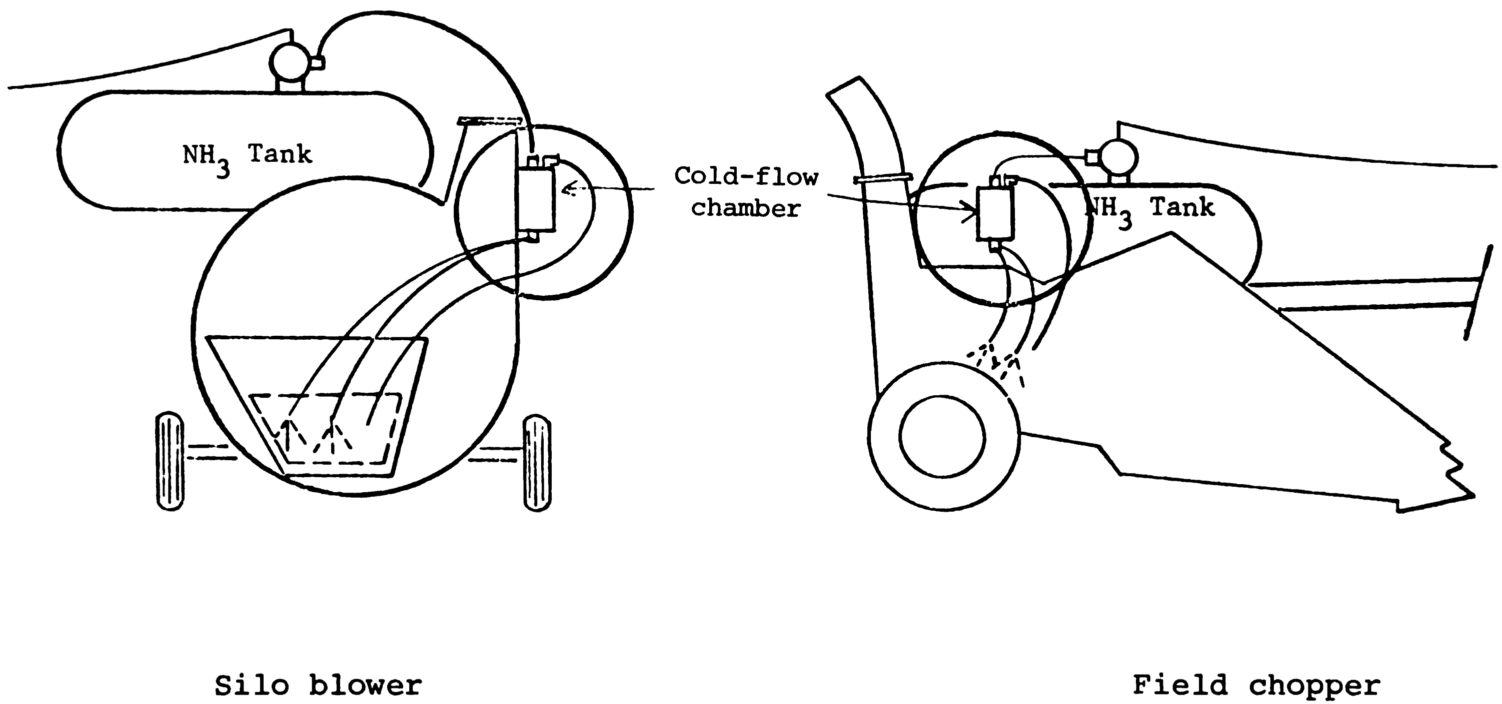

Figure 3.--Installation of the cold-flow chamber on a silo blower or a field chopper for "cold-flow" treatment of corn silage.

volumetric meter to apply the ammonia-mineral suspension directly to the silage. A gate valve between the tank/pump unit and the meter control flow which is registered on the meter. The valve is adjusted so the desired amount of the suspension is metered into each individually weighed load of corn silage. The hose from the meter is inserted into the top of the body of the silage blower.

Aqueous ammonia was added using the same apparatus and method as described above for the ammonia-mineral suspension.

Feeding Trial 1

Description of Feedlot

The steers were maintained in open dirt lots with no shelter. Protection from muddy conditions was afforded by dirt mounds near the feed bunks. During extremely wet periods, the mounds were bedded with straw. Each steer had approximately 176 $meters^2$ of lot space and .9 meters of bunk space with free access to an automatic waterer near the feed bunk. The steers were fed in a concrete fenceline feedbunk with a 2.9 meter wide concrete apron behind it.

Figure 4.--Steers fed ammonia treated corn silage, trial 1.

Experimental Rations

The following rations were fed once daily on an *ad libitum* basis to compare performance of corn silage treated with different ammonia sources (Table 5).

Lot 1: Corn silage plus protein-mineral supplement.

Lot 2: Corn silage plus protein-mineral supplement plus buffer.

Lot 3: Corn silage treated with ammonia-mineral suspension.

Lot 4: Corn silage treated with ammonia-mineral suspension plus buffer.

[illegible] UNIVE[illegible]
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NEGATIVE NUMBER [illegible]

TABLE 5.--Ration composition and experimental design, feeding trial 1.

	Control	Silage Treatments		
		Pro-Sil[2]	Aqueous NH_3	Anhydrous NH_3
Buffer, hd/trt.	13	13	13	13
No buffer, hd/trt.	13	13	13	13
Ingredient, % of DM				
Corn silage	90.5	99.5	97.8	97.8
Protein-mineral supp.	9.0	--	--	--
Mineral supp.	--	--	1.7	1.7
Buffer[1]	0.5	.5	.5	.5
	100.0	100.0	100.0	100.0
Selected Nutrients, % in Ration DM				
Crude protein	11.5	11.1	12.7	10.8
Calcium	.45	.45	.45	.45
Phosphorus	.34	.34	.34	.34
Trace mineral salt	.25	.25	.25	.25

[1]Twice this amount was fed to only one of two pens included in this average.

[2]A mixture of ammonia, water, molasses and minerals.

Lot 5: Corn silage treated with aqueous ammonia plus a mineral supplement.

Lot 6: Corn silage treated with aqueous ammonia plus a mineral supplement plus buffer.

Lot 7: Corn silage treated with anydrous ammonia plus a mineral supplement.

Lot 8: Corn silage treated with anyhydrous ammonia plus a mineral supplement plus buffer.

Feeding Trial 2

Description of Feedlot

The calves in this trial were housed in bedded concrete lots that were partially covered by a three-sided barn which opened to the south. Each animal had approximately 7.6 square meters of lot space, 5 meters of bunk space and free access to an automatic water fountain at one end of the the pen.

Experimental Rations

The following rations were fed once daily on an *ad libitum* basis (Table 6).

Lots 1 and 2: Corn silage plus continuous high level of soybean meal supplement plus minerals.

Lots 3 and 4: Corn silage plus a decreasing level of soybean meal supplement plus minerals.

Lots 5 and 6: Corn silage treated with 2.3 kg of anhydrous ammonia plus minerals.

TABLE 6.--Ration composition and experimental design, feeding trial 2.

	Neg. Control	Silage Treatments						
		2.3 Kg[1] NH_3	3.2 Kg NH_3	4.1 Kg NH_3	2.3 Kg NH_3 + Soy	3.2 Kg NH_3 + Soy	Decreasing Soy	Continuous Soy
Charolais X, hd/trt	8	8	8	8	8	8	8	8
Herefords, hd/trt	8	8	8	8	8	8	8	8
Ingredient, % of DM								
Corn silage	94.5	94.5	94.5	94.5	86.8	90.5	85.7	86.6
Soybean meal	--	--	--	--	7.4	3.6	6.7	--
Protein-mineral supp.	--	--	--	--	--	--	3.4	13.4
Corn-mineral supp.	5.5	5.5	5.5	5.5	5.8	5.9	4.2	--
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Selected Nutrients, % in Ration DM								
Crude protein	8.0	10.3	11.1	12.3	12.5→10.1	12.3→11.1	12.5→10.5	12.5
Calcium		.45	.45	.45	.45	.45	.45	.45
Phosphorus		.34	.34	.34	.34	.34	.34	.34
Trace mineral salt		.25	.25	.25	.25	.25	.25	.25

[1]Denotes Kg of anhydrous ammonia added per 908 Kg of 35% DM silage.

Lots 7 and 8: Corn silage treated with 3.2 kg of anhydrous ammonia plus minerals.

Lots 9 and 10: Corn silage treated with 4.1 kg of anhydrous ammonia plus minerals.

Lots 11 and 12: Corn silage treated with 2.3 kg of anhydrous ammonia plus minerals with added soybean meal to start.

Lots 13 and 14: Corn silage treated with 3.2 kg of anhydrous ammonia plus minerals with added soybean meal to start.

Lots 15 and 16: Corn silage plus minerals (negative control).

These rations were used to determine the feeding value of anhydrous ammonia treated corn silage and the effect of soybean meal addition to treated silage rations.

Nitrogen Balance Trial

A nitrogen balance trial was conducted to determine the efficiency of nitrogen utilization of the silages treated with different ammonia sources in trial 1. The same rations were used with the addition of an untreated corn silage plus minerals ration as a negative control. Five Charolais crossbred steers, similar to those used in trial 1 and averaging 259 kg, were placed in stanchions in the Metabolism room at the Beef Research Center (Table 7). The nitrogen balance trial consisted of four 5-day collection periods with a 14-day adjustment period preceding each. Each steer was allotted at random to a different ration for each period, with the restriction that each calf could not receive the same ration more than once.

All steers were fed once daily on an ad libitum basis. Each silage was taken fresh from the silo before feeding. The daily ration for each animal was weighed and mixed individually in a horizontal mixer. During collection periods, a grab sample of each ration was taken at feeding and frozen until analyzed. Total fecal weight was measured daily, and approximately 10% of the total was subsampled after mixing and frozen for later analysis. Urine volume was measured daily. The urine was then diluted to a constant volume, and a 1 liter subsample was taken daily and refrigerated until analyzed. To prevent loss of nitrogen or ammonia, 400 ml of a 16 normal solution of H_2SO_4 was added to each urine collection pan at the start of each collection day. Silage and feces were weighed to the nearest 227 g, concentrate was weighed to the nearest 22.7 g. Urine volume was measured to the nearest 5 ml.

After weighing, both silage and feces samples were placed in aluminum evaporating pans and dried in a forced-air oven at 55°C to obtain moisture data. Before drying, a 16 normal solution of H_2SO_4 was added to the fecal samples to prevent the escape of free ammonia in the drying process. After 72 hours the samples were removed from the oven, weighed, and the dry matter % was calculated. The

TABLE 7.--Ration composition and experimental design, nitrogen balance trial.

	Control	Pro-Sil	Aqueous NH_3	Anhydrous NH_3	Negative Control
Replications	4	4	4	4	4
<u>Ingredient, % of DM</u>					
Corn silage	91.0	100.0	98.3	98.3	98.3
Protein-mineral supplement[1]	9.0	--	--	--	--
Mineral supplement[1]	--	--	1.7	1.7	1.7
	100.0	100.0	100.0	100.0	100.0
<u>Selected Nutrients, % in Ration DM</u>					
Crude protein	11.5	11.1	12.7	10.8	8.0
Calcium	.45	.45	.45	.45	.45
Phosphorus	.34	.34	.34	.34	.34
Trace mineral salts	.25	.25	.25	.25	.25

[1]The formulation of these supplements was the same as those in feeding trial 1.

dried feces were then finely ground in a Thomas-Wiley mill before protein determination. A sample of the ration <u>as fed</u> was chopped in a Hobart chopper prior to protein analysis. Samples of feed, feces and urine were then analyzed for nitrogen content by the Technician Auto Analyzer system.

The nitrogen (N) retained as a percent of N intake was calculated by the following equations.

1. Intake N in grams = Feed intake (gr of DM) × % N in feed DM

2. Fecal N in grams = Total feces (grm of DM) × % N in feces DM

3. Urinary N in grams = Total urine in ml × % N in urine

4. Retained N in grams = Intake N - (Fecal N + Urinary N)

5. $$\text{Retained N as a \% of N intake} = \frac{\text{Retained N in grams}}{\text{Intake N in grams}} \times 100$$

Volatile fatty acid concentrations were determined by injecting samples into a Varian gas chromatograph. The column used was Chromosorb 101, flow rate was 30 ml/min, H_2; 30 ml/min, He; and 300 ml/min, air; column temperature was 180°C. Samples were prepared by adding 27 ml of a 20% silage-HOH homogenate and 3 ml of 50% sulfosalicylic acid, centrifuging at 15,000 rpm for 15 minutes. The peak areas were converted to micro moles per ml by comparing to standard solutions of volatile fatty acids analyzed at the same time. Lactate was determined by the method of Davidson (1965).

IV. RESULTS

Feeding Trial 1

An attempt was made to treat all the silages to a level of 2.5% crude protein. The aqueous ammonia treated silage approximated the desired level at 12.7%, but ammonia-mineral suspension treated silage was 11.1% CP and anhydrous ammonia was 10.8% CP. Subsequent investigation revealed that the ammonia-mineral suspension was stored in a tank containing a substantial quantity of old ammonia suspension, thus diluting the fresh material. Inadequate amounts of anhydrous ammonia were added to the "cold-flow" treated silage, due to higher than expected losses at ensiling. The amounts added were based on a 20% loss, but actual loss of ammonia was near 40%.

The performance of the cattle is given in Table 8. Over the entire experiment, the cattle fed ammonia-mineral suspension treated silaged gained as much as those fed the untreated silage plus soybean meal supplement ($P < .05$).

Cattle fed the aqueous or anhydrous ammonia treated silage did not gain as well as those fed ammonia-mineral suspension silage or soybean meal

TABLE 8.--Performance of steer calves fed corn silage treated with different ammonia sources.

	SBM Control	Am.-Min. Susp.	Aqueous Ammonia	Anhydrous Ammonia
No. steers	26	26	26	26
Initial weight, kg	225	230	227	227
Final weight, kg	457	463	449	441
Avg. daily gain, kg[1]	1.15[a]	1.15[a]	1.09[a,b]	1.06[b]
Avg. daily DM, kg				
Corn silage	7.19	7.72	7.69	7.74
Protein-min. supp., kg	.72	--	--	--
Mineral supp., kg	--	--	.14	.15
Buffer[2]	.04	.04	.04	.03
Total	7.95	7.76	7.87	7.92
DM/kg gain, kg	6.92[a,b]	6.72[a]	7.19[a,b]	7.45[b]
Avg. crude protein in ration DM, %	11.5[3]	11.1	12.7	10.8

[1]Based on 202 days of experiment.

[2]Twice this amount was fed to only one of the two pens included in this average.

[3]Crude protein was decreased from 12.5% to 10.5%, with an average of 11.5%.

[a,b]Values with different superscripts are significantly different ($P < .05$).

supplemented controls. The differences were significant only for the anyhydrous ammonia treatment ($P < .05$). This suggests that the addition of minerals at ensiling rather than at feeding may be beneficial.

Differences in organic acid production are presented in Table 9. Ammonia-mineral treated silage contained significantly more lactic acid ($P < .05$) than control silage, but performance on the two rations was indentical. Significantly ($P < .05$) more acetic acid was contained in the aqueous ammonia silage as compared to the ammonia-mineral treatment, but no corresponding difference in performance was seen. No significant differences in proprionic acid production were found. When compared to the other NPN treatments, ammonia-mineral treated silage tended to have higher lactic and total VFA levels, and depressed acetic acid production.

Overall, the buffer was not effective in increasing performance (Table 10). Average daily gain and feed efficiency was actually slightly less for those fed the buffer. These results suggest that buffers may not improve performance when added to high silage rations.

Feeding Trial 2

The performance of cattle fed corn silage full-treated with 4.1 kg of NH_3 or SBM supplemented untreated silage is shown in Table 11. The decreasing SBM ration

TABLE 9.--Organic acid levels in corn silage treated with different ammonia sources (in gm/100 gm DM).

	Untreated Control	Am.-Min. Susp.	Aqueous Ammonia	Anhydrous Ammonia
Lactic	3.50[a]	8.01[b]	5.56[a,b]	5.69[a,b]
Acetic	2.81[c,d]	2.47[c]	3.80[d]	3.20[c,d]
Proprionic	.05	.06	.07	.06
Butyric	trace[1]	trace	trace	trace
Total	6.36[a]	10.54[b]	9.43[b]	8.95[b]

[1]Level of less than .01 gm/100 gm DM.

[a,b,c,d]Numbers having different superscripts are significantly different ($P < .05$).

TABLE 10.--Effect of addition of a buffer on performance of silage fed cattle.

	Buffer	No Buffer
Avg. daily gain, kg	1.10[a]	1.13[a]
DM/kg gain, kg	7.18[b]	6.97[b]

[a,b]values with different superscripts are significantly different ($P < .05$).

TABLE 11.--Feed value of anhydrous ammonia treated corn silage.

	Neg. Control	4.1 kg NH_c	Continuous Soy	Decreasing Soy
Initial wt., kg.	240	234	231	232
Final wt., kg	300	435	432	441
Avg. daily gain, kg.	.33[a]	1.11[b]	1.11[b]	1.15[b]
Dry Matter Intake, kg/day				
Corn silage	4.51	6.92	6.10	6.11
Corn-mineral supp.	.26	.43	--	.30
Soy-mineral supp.	--	--	.94	.72
Total	4.77	7.35	7.04	7.13
Kg dry matter/kg gain	14.40	6.64	6.35	6.21

[a,b]Values having different superscripts are significantly different ($P < .05$).

Figure 5.--Negative controls (smallest Hereford and Charolais crossbred steer) gained only 30% as fast as steer mates fed corn silage treated with anhydrous ammonia (largest Hereford and Charolais), trial 2.

was started at 12.5% crude protein and was reduced .5% for each 45.4 kg of gain until the final level of 10.5% was reached.

Steers fed the decreasing SBM treatment had higher average daily gains and better feed efficiencies than those fed the "full treat" or 4.1 kg anhydrous ammonia silage. Also, steers in the decreasing soybean meal system had greater gains than the continuous high SBM level. However, no significant difference in average daily gain was demonstrated between the full-treat anhydrous ammonia, decreasing SBM, and continuous high SBM treatments. All treatments with added protein were different from the negative control. These date indicate that the cold-flow system of adding anhydrous ammonia to corn silage is an effective way of providing supplemental nitrogen to growing and finishing steers.

Table 12 shows the effect on performance of adding different levels of anhydrous ammonia to corn silage. Anhydrous ammonia was added at 2.3, 3.2 and 4.1 kg per 908 kg of 35% dry matter silage to obtain the 1/2, 3/4 and full treatments of ammonia. In the first 90 days, average daily gain and feed efficiency increased as the level of anhydrous ammonia increased. This response to increased protein level was similar in both Hereford and Charolais crossbred calves as shown in Figure 2. This response was expected, since both types were

TABLE 12.--Gain and dry matter intake of steers fed corn silage with 3 levels of ammonia.

	2.3 kg[1] NH_3	3.2 kg NH_3	4.1 kg NH_3
Crude protein, %	10.8	11.1	12.3
Performance First 90 Days			
Avg. daily gain, kg	.68[a]	.99[b]	1.08[b]
Dry matter intake, kg/day			
Corn silage	5.07	5.50	5.75
Corn-mineral supplement	.29	.33	.34
Total	5.36	5.83	6.09
Dry matter/kg gain/kg	7.88	5.85	5.63
Performance Last 92 Days			
Avg. daily gain, kg	1.11[a]	1.09[a]	1.13[a]
Dry matter intake, kg/day			
Corn silage	7.11	7.94	8.08
Corn-mineral supplement	.43	.51	.50
Total	7.54	8.45	8.58
Dry matter/kg gain/kg	6.80	7.77	7.59

[a,b]Values having different superscripts are significantly different ($P < .05$).

[1]Denotes kg of anhydrous ammonia added per 908 kg of 35% DM silage.

predicted to be at similar stages of growth during the trial. The Hereford steers averaged 194 kg and the Charolais crossbreds averaged 272 kg at the beginning of the experiment.

During the last 92 days, cattle fed the 1/2 treated silage were not significantly different in average daily gain from the 3/4 or full treatments. The excellent ADG and feed efficiency (DM/gain) of the 1/2 treated anhydrous group in the last 92 days was probably due to compensatory gain, since their growth rate was depressed in the first 90 days of the trial. Also, in the later stages of growth, the 1/2 treated silage was likely adequate in crude protein, but it was deficient in the first 90 days. These data indicate that corn silage treated with anhydrous ammonia to bring the overall crude protein to a level of 12.3% will support a higher overall ADG and feed efficiency in calves than lower levels of treatment. The data during the last 92 days indicate that lower levels of treatment may be adequate for yearlings since their % CP protein requirement is less than for calves.

Table 13 compares steers fed 1/2 treated anhydrous ammonia silage with added SBM in the early stages of the feeding period to those fed full treat anhydrous NH_3, continuous high soybean meal, or decreasing SBM supplemented rations. SBM was added to increase the crude

TABLE 13.--Effect of adding soybean meal to anhydrous ammonia treated corn silage.

	2.3 kg[2] NH_3 + soy	3.2 kg NH_3 + soy	Continuous Soy	Decreasing Soy
Initial wt., kg	233	234	231	232
Final wt., kg	448	435	432	441
Avg. daily gain, kg	1.18[a]	1.11[a]	1.11[a]	1.15[a]
DM intake, kg	7.46	7.36	7.04	7.13
DM/gain	6.30	6.64	6.37	6.21
Crude protein, %	12.5→10.8[1]	12.5→11.1	12.5	12.5→10.5

[a]Values are not significantly different ($P < .05$).
[1]Soybean meal withdrawn at 272 kg for Herefords, 318 kg for Charolais X.
[2]Denotes kg of anhydrous ammonia added per 908 kg of 35% DM silage.

protein content of the 1/2 treated anhydrous silage to the level of the SBM controls, and was withdrawn when the Charolais crossbred cattle reached approximately 318 kg and the Herefords reached approximately 272 kg.

For both cattle types, the 1/2 treated anhydrous (2.3 kg) NH_3 plus SBM ration gave the highest ADG of all treatments. The 1/2 treated plus SBM ration was significantly higher in ADG at 90 days, but there were no significant differences between 1/2 treat anhydrous NH_3 plus SBM, full treat anhydrous NH_3, continuous high SBM and decreasing SBM treatments at 182 days. Feed efficiency was comparable for the 1/2 treat plus SBM, continuous high SBM and decreasing SBM, but was lower for the full treat anhydrous ammonia silage. Thus, 1/2 treated anhydrous ammonia plus SBM in the early growth stages gave performance similar to SBM plus untreated silage in ADG and feed efficiency. Also, full treat anhydrous ammonia silage supported gains similar to SBM supplemented rations, but with a slight reduction in feed efficiency.

Organic acid production was measured for silage treated with anhydrous ammonia at three levels (Table 14). Lactic acid and total organic acid production was significantly higher than the untreated control for the 3.2 kg NH_3 treatment only. The 3.2 kg NH_3 treatment also had a significantly higher acetic acid production than 2.3 kg NH_3 silage. In general, lactate production was increased at all levels of ammonia treatment as compared to control silage. Acetate, the major volatile fatty acid was relatively unchanged between control silage and ammonia treatments, although the 2.3 kg and 3.2 kg NH_3 treatments were significantly different. Proprionate level was significantly higher in control silage than 1/2 treated AnA (anhydrous NH_3) silage, but was present in small quantities. Total organic acid production was increased for all three ammonia treatments, as compared to control silage, but only the 2.3 kg (3/4 treated) AnA silage was significantly higher.

TABLE 14.--Organic acid levels in silage treated with three levels of anhydrous ammonia (in gm/ 100 gm/DM).

Organic Acid	Control	Silage Treatment 2.3 kg NH_3	3.2 kg NH_3	4.1 kg NH_3
Lactic	5.78^{a}	$7.02^{a,b}$	7.92^{b}	$7.12^{a,b}$
Acetic	$2.60^{a,b}$	2.19^{a}	3.04^{b}	$2.78^{a,b}$
Proprionic	$.13^{a}$	$.02^{b}$	$.06^{a,b}$	$.05^{a,b}$
Total	8.51^{a}	$9.23^{a,b}$	11.02^{b}	$9.95^{a,b}$

[a,b]Values with different superscripts are significantly different ($P < .05$).

The steer weight gains for the two cattle types are shown in Figure 6. The Charolais crossbreds had a higher ADG than the Herefords throughout the trial. Due to their larger frame size, the Charolais crossbreds would be expected to have a higher maintenance requirement, offsetting the higher ADG.

The recovery of nitrogen from the silos treated with anhydrous ammonia is shown in Table 15. At the 1/2 (2.3 kg) and full (4.1 kg) treatment levels, recovery approached 80% which approximated the expected level, but on the 3/4 (3.2 kg) treatment of AnA, a recovery of only about 57% was calculated. This could be due in part to the higher DM losses in this silo. Further

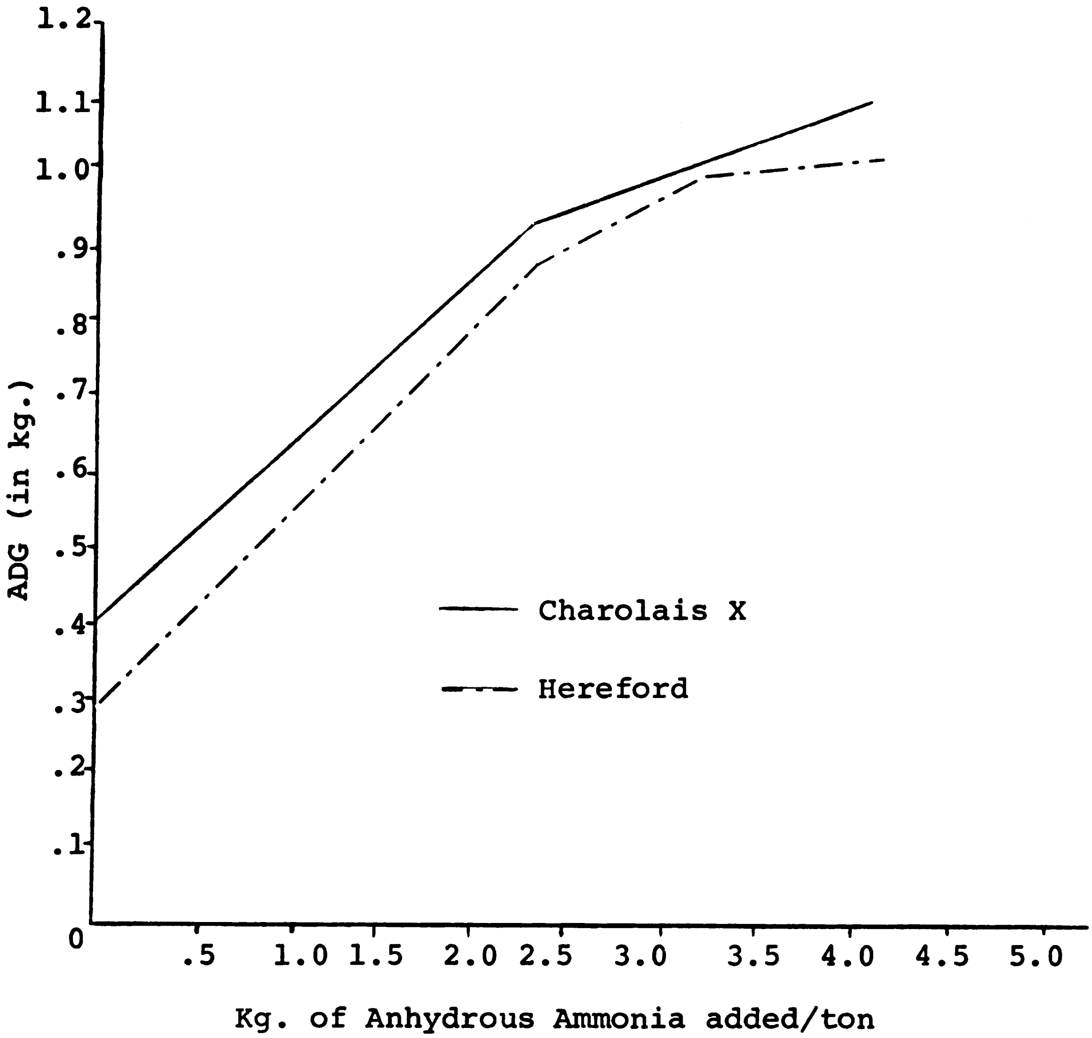

Figure 6.--Performance of two cattle types fed anhydrous NH_3 corn silage.

TABLE 15.--Recovery of nitrogen from silos treated with three levels of anydrous ammonia.

	2.3 kg NH_3	3.2 kg NH_3	4.1 kg NH_3
Kg DM in	60,399	54,950	54,936
C.P. % in	7.10	7.57	6.61
Kg plant protein in	4,288	4,160	3,631
Kg plant protein recovered	3,920	3,752	3,609
Kg DM out	55,217	49,565	54,606
C.P. % out	10.8	11.1	12.3
Kg C.P. out	5,560	5,611	6,580
DM % retained	91.42	90.20	99.40
Kg C.P.E. from NH_3	1,272	1,451	2,949
Kg N received from NH_3	203.4	232.2	471.8
Kg NH_3 added at ensiling	499.4	567.5	737.8
Kg N added at ensiling	409.5	465.4	605.0
% N recovered	49.3	49.9	77.4

research is under way at this station to increase retention of nitrogen when added to corn silage in the form of anhydrous ammonia.

Nitrogen Balance Trial

The results of the nitrogen balance trial are presented in Table 16. There was a wide variation in the total grams of nitrogen retained per day which appeared to correlate with the crude protein % of the

TABLE 16.--Nitrogen retention of steers fed corn silage treated with three different ammonia sources.

	Neg. Control	Soy Control	Ammonia Min.-Susp.	Aqueous Ammonia	Anhydrous Ammonia
DM intake, kg/da	6.80	7.32	6.46	6.42	5.96
N intake, g/da	99.4	146.0	119.2	140.3	111.1
Urinary N, g/da	21.2	38.5	33.5	36.0	23.2
Fecal N, g/da	41.6	40.2	31.7	41.1	37.2
Retained N, g/da	36.5	67.3	54.0	63.2	50.8
Retained N as a % of N intake	36.83[a]	46.07[b]	45.35[b]	45.06[b]	45.62[b]
CP, % of DM	8.0	11.5[1]	11.1	12.7	10.8

[1]Crude protein was decreased from 12.5 to 10.5% during the feeding period, with an average of 11.5%.

[a,b]Values with different superscripts are significantly different ($P < .05$).

ration. However, when nitrogen retention was expressed as a % of nitrogen intake, a more uniform relationship was seen. All the treatments with supplemental nitrogen retained a significantly ($P < .05$) higher % of intake nitrogen than the negative control with the soybean meal supplemented group having the highest N retention. However, differences between the ammonia-mineral suspension, aqueous ammonia, anhydrous ammonia or soybean meal supplemented rations in percent of nitrogen retained were not significant ($P < .05$).

The high percentage of nitrogen retained in all treatments was likely a result of compensatory gain, since the steers had been held on a maintenance ration prior to the N balance study.

V. DISCUSSION

Feeding Trial 1

In trial 1, corn silage treated with anhydrous ammonia had a significantly lower ADG than silage supplemented with SBM or treated with ammonia-mineral suspension (AMS). However, average daily DM consumption for the anhydrous ammonia (AnA) treated silage was nearly identical to the SBM supplemented treatment. Since energy intake was very similar between the two treatments, the decrease in ADG and feed efficiency could be due to the low protein level of the AnA treated silage, and not having minerals added at ensiling. Even though DM intake was comparable to or higher than the other treatments, total protein intake for the AnA treated ration was approximately 10.5% less than the SBM control ration, and was deficient in total protein according to values published by Fox (1975).

However, aqueous ammonia (AqA) treated silage had the highest tested crude protein level at 12.5%, but had only the third highest ADG. Thus, the advantage in performance of AMS as compared to AqA treated silage could be due to the minerals added at ensiling in the AMS, or the increased lactate level in the AMS silage.

It is notable that the AMS silage supported a significantly higher ADG than the AnA silage with only a .3% increase in CP level, but all of the reasons for this increase are not clear.

The level of lactate was markedly increased over the control silage by AMS treatment; this finding supports previous work at this station. This increase in lactate could account in part for the excellent performance at the relatively low protein level of the AMS. Since lactate fermentation in the rumen loses less energy as methane and heat than soluble carbohydrate fermentation, an increased lactate level in the silage could give a more efficient utilization of that silage. Increased lactate production could actually increase the energy value of silage, according to Prigge and Owens (1976).

The elevated acetate production by the AqA silage as compared to AMS silage did not cause a reduction in intake of the AqA silage.

Proprionic acid was relatively constant in all treatments, and was present in low levels.

Total organic acids were significantly increased for all NPN treatments as compared to control silage. Also, total organic acid level in the NPN treatments was correlated with ADG, but the trend was not statistically significant.

The increase in lactate and decrease in acetate in the AMS silage was likely due to the neutralizing effect of the ammonia which would tend to prolong the lactate fermentation; these results agree with those of Beattie (1970) and Cash (1972). Even though total organic acid production was similar for the three ammonia treatments, lactate levels were depressed and acetate levels were increased for the AqA and AnA silages compared to the AMS silage. No explanation could be given for this trend.

The addition of a buffer at feeding time showed no advantage in ADG or feed efficiency.

Feeding Trial 2

In a trial of 182 days, steers fed full treated anhydrous ammonia corn silage had gains similar to steers fed SBM supplemented rations. All were greater than the negative control. The slightly greater ADG of the decreasing SBM group as compared to the continuous high SBM group was likely due to the fact that the continuous high SBM treatment was oversupplemented with protein for part of the trial and energy was used to excrete the excess N. The value of AnA addition to corn silage is shown by comparing the negative control to full treat AnA silage. An increase in ADG of 70% for the AnA silage was noted, and feed efficiency was increased more than 100% when compared to the untreated controls.

Even though ADG was similar (P < .05) between full-treat AnA silage and SBM supplemented controls, DM intake was higher for the full-treat AnA silage, resulting in a lower feed efficiency for the ammonia treatment. A similar effect was seen by Preston (1975) in calves supplemented with urea. Since nearly all protein in the AnA ration must come from microbial protein synthesized in the rumen, calves fed SBM would likely have some additional protein reaching the small intestine due to SBM protein that bypasses the rumen. However, the excellent performance on full-treat AnA silage at heavier weights could indicate that heavier cattle can meet most of their protein needs from rumenally synthesized microbial protein.

Performance of the three levels of AnA treatment showed a direct relationship between level of ammonia added and ADG in the first 90 days of the trial. However, in the last 92 days, no such relationship existed, likely due to a reduction in protein requirements as the cattle increase in weight. Furthermore, steers on the on the lower (1/2 and 3/4) treated silages may have made compensatory growth during the last 92 days.

The addition of SBM to 1/2 and 3/4 treated AnA silage gave performance similar to SBM controls (Table 13).

Steers fed the 1/2 treated AnA + SBM had significantly greater ($P < .05$) ADG in the first 90 days of the trial, and ADG was greater, but not significantly so, for 182 days. The CP % of the 1/2 treat + SBM ration approximated the requirements reported by Fox (1975), which resulted in gains expected for the net energy content of the ration. A slight reduction in performance was seen with the 3/4 treated AnA + SBM ration, which was consistent with results reported by Preston (1975), in which ADG decreased as NPN level in the ration increased.

Total organic acid production was higher for all levels of NH_3 treatment, but no clear relationship existed between level of total organic acid and performance between the three treatment levels. Lactate was increased at all ammonia treatment levels, but was not directly related to performance. The increased ($P < .05$) lactate and acetate levels in the 3/4 treated silage gave a significantly higher total organic acid content, but this trend was not equated with ADG.

During the 182-day trial, Charolais crossbreds gained faster and had poorer feed efficiency than the Herefords. However, Crickenberger (1977) reported that in a study of different cattle types fed to the same carcass composition, feed efficiency and ADG was similar for average and crossbred beef cattle types over the complete feeding period.

Recovery of N from the silos treated with three levels of anhydrous ammonia approximated 50% for the 1/2 and 3/4 treatments, but 80% for the full treatment. Some of the N losses in the 1/2 and 3/4 treat silage may be due to the greater DM losses in those silos as compared to the full-treat silo. It is also possible that during application, an absolute amount of ammonia is lost regardless of rate of application, which would account for increased percentage losses at lower application rates.

Nitrogen Balance Trial

Nitrogen retention in grams varied widely between treatments, but all were higher than the negative control. Nitrogen intake also was variable due to differences between the N content of the treatments and dry matter consumption. However, when retained N was expressed as a % of intake N, all treatments with added N were similar ($P < .05$) among themselves but different from the negative control. These results show that the efficiency of N utilization was similar for all rations with supplemental N added.

VI. SUMMARY

One hundred and four Charolais crossbred calves were fed corn silage treated with ammonia-mineral suspension (Pro-Sil), aqueous ammonia, anhydrous ammonia (cold-flow) or supplemented with soybean meal. Steers fed soybean meal supplemented corn silage (controls) or Pro-Sil treated corn silage had similar daily gains and feed conversions (kg DM/kg gain). The cattle fed aqueous ammonia or anhydrous ammonia treated silage had lower daily gains and feed conversions than controls or those fed ammonia-mineral suspension treated silage. A buffer fed to one of two pens on each silage treatment resulted in a small decline in average daily gain and feed efficiency, but was not significant.

A second feeding trial was conducted with 64 Hereford and 64 Charolais crossbred calves to compare:

1. The effect on performance of adding different levels of anhydrous ammonia to corn silage.
2. The feeding value of full-treated anhydrous ammonia corn silage as compared to untreated corn silage supplemented with soybean meal.
3. The effect on performance of adding soybean meal to half-treated anhydrous ammonia corn silage in the early stages of growth.

The rations consisted of corn silage supplemented with (1) continuous high level of soybean meal, (2) decreasing level of soybean meal, (3) mineral mix only (negative control), (4) 1/2 treated with anhydrous NH_3, (5) 3/4 treated with anhydrous NH_3, (6) full-treated with anhydrous NH_3, (7) 1/2 treated plus soybean meal to start, and (8) 3/4 treated plus soybean meal to start.

There was no significant difference in average daily gain (ADG) between the full-treat anhydrous NH_3, decreasing and continuous high soybean meal treatments. Corn silage treated with anhydrous NH_3 to an overall level of 12.3% crude protein gave significantly higher ADG and better feed efficiency than lower treatment levels. Half-treated anhydrous NH_3 silage plus added soybean meal in the early growth stages only gave similar ADG and feed efficiencies to the soybean meal supplemented rations.

A nitrogen balance trial was also conducted with five 259 kg Charolais crossbred steers to compare corn silage alone, corn silage plus soybean meal supplement, or corn silage treated with ammonia-mineral suspension, aqueous ammonia, or anhydrous ammonia.

All treatments with supplemental nitrogen retained a significantly higher % of the intake nitrogen than the negative control (corn silage alone). There were no significant differences in nitrogen retained between the ammonia-mineral suspension, aqueous ammonia, anhydrous ammonia treated silage or soybean meal supplemented rations.

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