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EFFECT OF ANHYDROUS AMMONIA TREATED CORN SILAGE ON THE PERFORMANCE OF GROWING AND FINISHING STEERS

By

Lyle Wayne Lomas

A DISSERTATION

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ABSTRACT

EFFECT OF ANHYDROUS AMMONIA TREATED CORN SILAGE ON THE PERFORMANCE OF GROWING AND FINISHING STEERS

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Two feedlot studies were conducted to determine the effect of cold-flow anhydrous ammonia treated corn silage on the performance of growing and finishing steers. In trial 1, an 8 x 2 factorial design with 8 protein treatments and 2 cattle types was used to determine the effect of anhydrous ammonia treated corn silage and protein supplementation strategy on the performance of growing and finishing steers. Eight Hereford (224 kg) and 8 Charolais crossbred steers (293 kg) were allotted to each of the following treatments: 1) unsupplemented control; 2) 7.80 g anhydrous ammonia (AN) per kg of corn silage dry matter (KGCSDM); 3) 7.80 g AN/KGCSDM plus added soybean meal (SBM) until the steers reached 318 kg equivalent weight; 4) 15.60 g AN/KGCSDM; 5) 15.60 g AN/KGCSDM plus a complete mineral mix added at time of ensiling; 6) 15.60 g AN/KGCSDM plus calcium hydroxide added at 3% of silage DM at time of ensiling; 7) untreated silage supplemented with SBM at a level which was decreased as the steers became heavier; 8) untreated silage supplemented with a constant level of SBM. All rations contained 33.0 ppm monensin in the ration DM. Cattle were on feed for 230 to 290 days. Since there were no interactions between treatment and cattle type, cattle types were

pooled within each treatment. Average daily gain (ADG) in kg and feed DM intake/gain (F/G) were: .61 and 10.14, .80 and 8.53, .81 and 8.20, .92 and 7.92, .81 and 8.04, .87 and 7.74, .99 and 7.43, and .98 and 7.12 for treatments 1, 2, 3, 4, 5, 6, 7, and 8, respectively. ADG (kg) and F/G were .78 and 8.09 and .91 and 8.19 for the Hereford and Charolais steers, respectively. Ammonia treated silage (treatments 4, 5, 6) resulted in a lower ADG ($P < .0005$), higher F/G ($P = .007$) and lower average daily dry matter intake (ADDMI) ($P = .009$) than supplementation of untreated silage with SBM (treatments 7, 8). Treatment 7 produced similar performance to treatment 8. There were no significant differences ($P > .20$) in performance between treatments 2 and 3. No improvement in performance was obtained from adding minerals or calcium hydroxide to AN treated silage at ensiling.

In trial 2, a 3 x 3 factorial design with 3 levels of AN treated corn silage and 3 levels of monensin was used to evaluate the performance of 135 Brangus steers (229 kg) fed on a two-phase system. Corn silage was treated at the time of ensiling with 0, 7.90 or 15.70 g AN/KGCSDM. Monensin was included in the ration at either 0, 16.5 or 33.0 ppm of ration DM. All steers were fed corn silage rations during the growing phase until they reached an average weight of 372 kg and then they were switched by pen to a corn + corn silage finishing ration that contained 77% high-moisture corn on a DM basis. Cattle received the same respective silage and monensin treatment during both the growing and finishing phases and were on feed for a total of 260 to 281 days. There were no AN x monensin interactions for overall ADG, ADDMI or F/G. Average daily gain (kg) and F/G for the 0, 7.90, and 15.70 g AN/KGCSDM treatments were:

.91 and 7.47, .93 and 7.37, and .99 and 7.02, respectively. Average daily gain (kg) and F/G for the 0, 16.5 and 33.0 ppm monensin treatments were: .95 and 7.38, .98 and 7.12, and .92 and 7.33, respectively. AN treatment of corn silage resulted in a higher ADG (P = .102). Application of 15.70 g AN/KGCSDM resulted in a higher ADG (P = .014) and lower F/G (P = .005) than 7.90 g AN/KGCSDM. Monensin resulted in no significant change (P > .20) in ADG or F/G but decreased ADDMI (P = .087). The intermediate level of monensin (16.5 ppm) resulted in a higher ADG (P = .095) than the recommended level (33.0 ppm).

Complete carcass and body composition data, net energy values and silage characterization data were obtained and analyzed for each feedlot study.

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INTRODUCTION

Corn silage is a popular feedstuff for growing and finishing beef cattle in the United States. On suitable land with climatic conditions favorable for corn production, no other feed crop grown in the U. S. will equal corn silage in the quantity of beef produced per hectare of crop fed. However, corn silage rations must be adequately supplemented with protein in order to produce satisfactory animal performance.

Supplemental protein may be provided in corn silage rations by feeding preformed protein or non-protein nitrogen (NPN) which can be used by the microbial population in the rumen to synthesize protein. Corn silage is well suited for NPN supplementation since it is low in total protein and high in energy which is necessary for efficient incorporation of NPN into microbial protein. Addition of NPN at the time of ensiling has generally resulted in similar animal gains but a lower feed requirement per unit of gain when compared to supplementing untreated control silage with an isonitrogenous level of NPN at feeding time (Essig, 1968; Ely, 1978).

Treatment of corn silage with anhydrous ammonia (AN) at the time of ensiling is one method of adding NPN that lends itself well to mechanization. Henderson _et al_. (1972) treated corn silage at the blower with gaseous AN at the time of ensiling but only recovered slightly more than one-third of the added nitrogen from the silo at feeding time. Nitrogen recovery was improved by the development of a cold-flow condensation chamber which made it possible to apply AN as a stable anhydrous liquid to the fresh corn plant material at the time of ensiling (Lalonde, 1976).

In August, 1978, the Food and Drug Administration approved the use of cold-flow AN at the time of ensiling for treatment of corn silage which was to be fed to cattle. Since this is a recent development, there is a very limited amount of information available concerning treatment of corn silage with AN at the time of ensiling. Research is needed to evaluate this method of NPN supplementation with respect to both animal performance and economic feasibility in order to determine how it compares with other sources of supplemental nitrogen.

LITERATURE REVIEW

Due to increased costs of preformed protein supplements and potential for future price escalations, attention has been focused on feeding NPN and determining the exact protein requirements for feedlot cattle. Protein requirements predicted by the Michigan (Fox *et al*., 1977; Bergen *et al*., 1978), Iowa (Burroughs *et al*., 1974) and N.R.C. (1976) systems differ widely, and thus protein needs of growing and finishing beef cattle are uncertain. Requirements for protein are further confounded by the fact that monensin has a protein-sparing effect and may thereby permit feeding a lower concentration of dietary protein than would otherwise be possible (Dartt, 1978; Perry *et al*., 1979; Hanson and Klopfenstein, 1979).

Burroughs *et al*. (1974), Fox *et al*. (1977) and Bergen *et al*. (1978) have outlined constraints for adding NPN to feedlot rations. Bergen *et al*. (1978) noted that the extent of NPN utilization depends on level of dry matter intake, ration energy density, characteristics of basal feed proteins and ruminal fermentation. Recent work (Van Nevel and Demeyer, 1977; Tolbert *et al*., 1977; Poos *et al*., 1978) has indicated that monensin may also affect utilization of NPN. Monensin decreases the efficiency of microbial growth and may be of limited value in rations supplemented with NPN.

This review relates to these issues and addresses the following topics: effect of NPN treatment of corn silage on feedlot performance, effect of NPN treatment of corn silage on silage fermentation, protein requirements of finishing steers, and effect of monensin on feedlot performance.

Effect of NPN Treatment of Corn Silage on Feedlot Performance

Perhaps no other area of research within the field of ruminant nutrition has received as much attention and yet has been as frequently misinterpreted as NPN treatment of corn silage. Research has been conducted in this area to evaluate the effect of supplementing corn silage with various nitrogen sources on the performance of feedlot cattle. These experiments have been conducted over a diverse range of conditions with age of cattle, length of feeding period, and energy density of the ration varying from one study to another. Wide variation has also existed in previous nutritional treatment of cattle prior to going on experiment. In some studies, feeder cattle were immediately started on experiment upon arrival at the feedlot, while in others they were fed untreated corn silage supplemented with soybean meal for as long as 90 days before going on experiment. Each of these factors will influence animal performance and are of particular importance when comparing NPN to preformed protein as a source of supplemental nitrogen. However, several review articles on NPN treatment of corn silage have completely ignored these factors and pooled performance data by nitrogen treatment across different experiments, made comparisons and drawn conclusions without consideration of any of these variables.

A review of literature for feedlot performance of feedlot steers fed corn silage rations supplemented with various forms of nitrogen is presented in tabular form in Table 1. Studies have been categorized according to age of cattle, length of feeding period and whether or not corn was added to the ration. In this review, an effort was made to concentrate on experiments where steers were fed two or more of the nitrogen treatments listed in Table 1, with particular emphasis on studies where ammonia or Pro-Sil treated silage was fed. Feed/gain (F/G) is presented on a 100% dry matter (DM) basis.

Measures were taken to reduce the amount of variation between studies listed in Table 1 by categorizing them as previously described, reporting F/G on a 100% DM basis and including data for steers only. However, results of different experiments are often variable and occasionally conflicting. For this reason, extreme care should be taken in evaluating past research and making comparisons between different studies. It is more appropriate to make similar comparisons on a percentage basis within experiments and to compare relative performance between different studies, rather than comparing absolute performance.

Differences in design and interpretation of feedlot trials make it difficult to compare absolute performance from different experiments. Average daily gain (ADG) has been calculated on a liveweight basis in some studies, while in others liveweight ADG has been adjusted to a constant dressing percent to reduce variation due to fill (Goodrich and Meiske, 1971; Black and Fox, 1977). Cattle type frequently varies from one experiment to another and will also affect ADG (Crickenberger, 1977; Harpster, 1978).

Research has revealed that DM intake of fermented feeds can be underestimated by as much as 10% when DM is determined by oven drying,

Table 1.--Performance of Feedlot Cattle Fed Corn Silage Rations With Various Nitrogen Sources

					Nitrogen treatment							
Reference	No. of hd./trt.	Initial wt, kg	Days on feed	% Corn added	No. supp. N	Supp. with SBM	Supp. with urea	Pro-Sil silage	Urea silage	NH_3 silage	Urea + mineral silage	Pro-Sil at feeding time
Calves: All silage; less than 100 days on feed:												
Henderson et al. (1972)	10	225	98	0								
Daily gain, kg					--	1.06	--	1.03	--	.72	.89	--
Feed/gain					--	5.96	--	5.40	--	6.80[a]	6.09	--
Preston (1974)	38	174	56	0								
Daily gain, kg					.39	--	.57	--	--	--	--	--
Feed/gain					10.10	--	7.60	--	--	--	--	--
Preston et al. (1975a)	18	174	69	0								
Daily gain, kg					--	1.19	.95	--	--	--	--	--
Feed/gain					--	4.64	5.48	--	--	--	--	--
Preston et al. (1975c)	27	216	56	0								
Daily gain, kg					--	.67	--	--	.64	--	--	--
Feed/gain					--	6.50	--	--	6.70	--	--	--
Byers and Preston (1976)	40	249	78	0								
Daily gain, kg					--	1.30	--	--	1.16	--	--	--
Feed/gain					--	4.71	--	--	5.08	--	--	--
Byers and Smith (1976)	52	227	34	0								
Daily gain, kg					--	.55	.49	--	--	--	--	--
Feed/gain					--	5.60	5.90	--	--	--	--	--
Fox et al. (1977c)	135	221	35	0								
Daily gain, kg					--	.92	--	--	--	.61[a]	--	--
Feed/gain					--	5.20	--	--	--	7.79[a]	--	--
Perry et al. (1978)	20	268	77	0								
Daily gain, kg					--	--	.81	.91	--	--	--	--
Feed/gain					--	--	6.85	6.45	--	--	--	--
Hendrix (1979)	15	246	64	0								
Daily gain, kg					.54	1.11	1.03	--	--	1.01[a]	--	--
Feed/gain					8.86	5.74	6.56	--	--	6.28[a]	--	--

[a]Anhydrous ammonia.

Table 1--Continued

Reference	No. of hd./trt.	Initial wt. kg	Days on feed	% Corn added	Nitrogen treatment: No supp. N	Supp. with SBM	Supp. with urea	Pro-Sil silage	Urea silage	NH_3 silage	Urea + mineral silage	Pro-Sil at feeding time
Calves: All silage; more than 100 days on feed:												
Cash et al. (1971)	10	245	208	0								
Daily gain, kg					--	.71	--	.73	--	--	.76	.69
Feed/gain					--	8.99	--	8.13	--	--	8.02	9.39
Henderson et al. (1971c)	8	233	112	0								
Daily gain, kg					.49	1.16	--	1.11	--	1.13[b]	--	--
Feed/gain					6.82	4.93	--	4.36	--	4.91[b]	--	--
Salas et al. (1971)	20	246	220	0								
Daily gain, kg					--	.77	--	.79	--	--	.81	.72
Feed/gain					--	8.70	--	8.49	--	--	8.22	8.99
Henderson and Bergen (1972a)	10	225	124	0								
Daily gain, kg					--	1.03	--	1.02	--	--	.95	--
Feed/gain					--	6.07	--	5.85	--	--	6.16	--
Henderson and Bergen (1972b)	10	225	246	0								
Daily gain, kg					--	--	--	.95	--	--	.87	--
Feed/gain					--	--	--	6.23	--	--	6.73	--
Mowat et al. (1974)	48	182	140	0								
Daily gain, kg					--	1.04	--	.91	--	--	--	--
Feed/gain					--	6.30	--	6.90	--	--	--	--
Ritchie et al. (1974)	8	219	251	0								
Daily gain, kg					--	.93	--	.84	--	--	--	--
Feed/gain					--	7.12	--	7.25	--	--	--	--
Henderson et al. (1975)	8	260	194	0								
Daily gain, kg					.49	1.03	.92	.95	--	--	--	--
Feed/gain					10.64	6.75	7.32	6.52	--	--	--	--
Krause et al. (1976)	26	203	136	0								
Daily gain, kg					.50	.85	.77	--	--	--	--	--
Feed/gain					11.35	7.93	8.80	--	--	--	--	--
Cook and Fox (1977)	16	233	182	0								
Daily gain, kg					.33	1.13	--	--	--	1.11[a]	--	--
Feed/gain					14.40	6.28	--	--	--	6.64[a]	--	--
Fox and Cook (1977)	26	227	202	0								
Daily gain, kg					--	1.15	--	1.15	--	1.06[a](1.09)[b]	--	--
Feed/gain					--	6.92	--	6.72	--	7.45[a](7.19)[b]	--	
Fox et al. (1977b)	8	200	248	0								
Daily gain, kg					.54	1.10	1.05	--	--	--	--	--
Feed/gain					10.78	8.10	8.20	--	--	--	--	--

[a]Anhydrous ammonia.

[b]Aqueous ammonia.

Table 1--Continued

Reference	No. of hd./trt.	Initial wt, kg	Days on feed	% Corn added	Nitrogen treatment: No supp. N	Supp. with SBM	Supp. with urea	Pro-Sil silage	Urea silage	NH_3 silage	Urea + mineral silage	Pro-Sil at feeding time
Calves: Added corn; more than 100 days on feed--continued:												
Fox et al. (1977b)	8	200	248	46								
Daily gain, kg					1.06	1.25	1.20	--	--	--	--	--
Feed/gain					7.75	6.95	7.39	--	--	--	--	--
Yearlings: All silage; less than 100 days on feed:												
Henderson and Geasler (1970)	16	346	92	0								
Daily gain, kg					--	1.33	1.12	--	--	--	--	--
Feed/gain					--	5.81	6.44	--	--	--	--	--
Fox et al. (1977b)	25	335	29	0								
Daily gain, kg					--	1.92	--	--	--	1.71[a]	--	--
Feed/gain					--	3.87	--	--	--	3.89[a]	--	--
Guyer et al. (1977)	20	261	83	0								
Daily gain, kg					--	.71	--	.64	--	--	--	--
Feed/gain					--	9.68	--	10.50	--	--	--	--
	32	295	74	0								
Daily gain, kg					--	.86	.88	.89	--	--	--	--
Feed/gain					--	9.63	9.59	8.72	--	--	--	--
	19	294	84	0								
Daily gain, kg					--	.97	.91	1.04	--	--	--	--
Feed/gain					--	9.02	10.11	8.73	--	--	--	--
	18	238	98	0								
Daily gain, kg					--	1.04	1.02	1.00	--	--	--	--
Feed/gain					--	6.22	6.46	6.12	--	--	--	--
Yearlings: All silage: more than 100 days on feed:												
Henderson et al. (1970)	24	345	106	0								
Daily gain, kg					--	--	--	1.19	1.14	--	1.25	--
Feed/gain					--	--	--	7.15	6.62	--	6.59	--
Beattie et al. (1971)	9	369	128	0								
Daily gain, kg					.71	1.05	--	1.04	1.04	--	--	--
Feed/gain					8.19	6.98	--	6.46	6.75	--	--	--
Henderson et al. (1971a)	10	330	176	0								
Daily gain, kg					--	.83	--	.86	--	--	--	--
Feed/gain					--	8.64	--	8.37	--	--	--	--

[a]Anhydrous ammonia.

Table 1--Continued

Reference	No. of hd./trt.	Initial wt, kg	Days on feed	% Corn added	Nitrogen treatment: No supp. N	Supp. with SBM	Supp. with urea	Pro-Sil silage	Urea silage	NH_3 silage	Urea + mineral silage	Pro-Sil at feeding time
Yearlings: All silage; more than 100 days on feed--continued												
Henderson et al. (1971b)	9	369	128	0								
Daily gain, kg					.71	1.05	--	.92	--	--	--	--
Feed/gain					8.19	6.98	--	7.09	--	--	--	--
Henderson et al. (1971d)	7	370	132	0								
Daily gain, kg					--	1.15	--	.96	1.00	.97[b]	.98	--
Feed/gain					--	6.62	--	7.23	6.58	6.74[b]	7.71	--
Henderson et al. (1971e)	7	337	121	0								
Daily gain, kg					--	1.11	--	1.03	--	--	--	--
Feed/gain					--	6.49	--	6.29	--	--	--	--
Yearlings: Added corn; less than 100 days on feed:												
Henderson and Geasler (1970)	16	346	92	62								
Daily gain, kg					--	1.39	1.29	--	--	--	--	--
Feed/gain					--	6.15	6.58	--	--	--	--	--
Combs et al. (1978)	14	247	75	18								
Daily gain, kg					1.03	1.16	1.21	1.17	1.29	1.10[a]	--	--
Feed/gain					6.18	5.76	5.47	6.16	5.26	6.63[a]	--	--
Yearlings: Added corn; more than 100 days on feed:												
Allen et al. (1971)	17	299	170	68								
Daily gain, kg					--	.84	.80	--	--	--	--	--
Feed/gain					--	7.35	7.48	--	--	--	--	--
Beattie et al. (1971)	9	369	110	40								
Daily gain, kg					1.03	1.22	--	1.25	1.29	--	--	--
Feed/gain					6.95	6.76	--	6.61	6.61	--	--	--
Bucholtz and Henderson (1971)	9	311	134	75								
Daily gain, kg					1.39	1.51	1.40	--	--	--	--	--
Feed/gain					6.65	5.93	6.16	--	--	--	--	--

[a]Anhydrous ammonia.

[b]Aqueous ammonia.

Table 1--Continued

Reference	No. of hd./trt.	Initial wt, kg	Days on feed	% Corn added	Nitrogen treatment: No supp. N	Supp. with SBM	Supp. with urea	Pro-Sil silage	Urea silage	NH_3 silage	Urea + mineral silage	Pro-Sil at feeding time
Yearlings: Added corn; more than 100 days on feed--continued												
Henderson et al. (1971a)	10	330	176	20								
Daily gain, kg					--	.84	--	.80	--	--	--	--
Feed/gain					--	8.36	--	9.03	--	--	--	--
	10	330	176	40								
Daily gain, kg					--	.81	--	.83	--	--	--	--
Feed/gain					--	9.12	--	8.73	--	--	--	--
	10	330	176	60								
Daily gain, kg					--	.87	--	.84	--	--	--	--
Feed/gain					--	8.32	--	9.00	--	--	--	--
	10	330	176	80								
Daily gain, kg					--	.86	--	.85	--	--	--	--
Feed/gain					--	8.01	--	8.18	--	--	--	--
Henderson et al. (1971b)	9	369	110	40								
Daily gain, kg					1.03	1.22	--	1.16	--	--	--	--
Feed/gain					6.95	6.76	--	6.80	--	--	--	--
Henderson et al. (1971e)	7	337	121	40								
Daily gain, kg					--	1.23	--	1.34	--	--	--	--
Feed/gain					--	7.29	--	5.93	--	--	--	--
	7	337	121	60								
Daily gain, kg					--	1.40	--	1.46	--	--	--	--
Feed/gain					--	6.74	--	6.48	--	--	--	--
	7	337	121	80								
Daily gain, kg					--	1.22	--	1.18	--	--	--	--
Feed/gain					--	7.09	--	7.08	--	--	--	--
Allen et al. (1972)	10	358	128	40								
Daily gain, kg					--	1.47	1.33	--	--	--	--	--
Feed/gain					--	6.52	6.99	--	--	--	--	--
	10	358	128	80								
Daily gain, kg					--	1.43	1.41	--	--	--	--	--
Feed/gain					--	6.58	6.56	--	--	--	--	--
Perry et al. (1978)	20	334	147	40								
Daily gain, kg					--	--	1.03	1.08	--	--	--	--
Feed/gain					--	--	7.00	7.10	--	--	--	--

[a]Anhydrous ammonia.

[b]Aqueous ammonia.

Table 1--Continued

Reference	No. of hd./trt.	Initial wt, kg	Days on feed	% Corn added	Nitrogen treatment: No supp. N	Supp. with SBM	Supp. with urea	Pro-Sil silage	Urea silage	NH_3 silage	Urea + mineral silage	Pro-Sil at feeding time
Calves: Added corn; less than 100 days on feed:												
Henderson et al. (1972)	10	225	98	40								
Daily gain, kg					--	1.19	--	1.17	--	.98[a]	1.11	--
Feed/gain					--	5.72	--	5.19	--	6.03[a]	5.74	--
Calves: Added corn; more than 100 days on feed:												
Cash et al. (1971)	10	245	194	40								
Daily gain, kg					--	.89	--	1.01	--	--	.99	.80
Feed/gain					--	7.87	--	6.92	--	--	7.21	8.07
Henderson et al. (1971c)	8	233	112	40								
Daily gain, kg					.79	1.28	--	1.30	--	1.26[b]	--	--
Feed/gain					5.93	4.92	--	4.76	--	4.61[b]	--	--
Henderson et al. (1971d)	8	233	219	40								
Daily gain, kg					--	1.09	--	1.15	1.17	1.15[b]	1.13	--
Feed/gain					--	6.21	--	6.14	5.99	5.88[b]	6.41	--
Henderson and Bergen (1972a)	10	225	124	40								
Daily gain, kg					--	1.13	--	1.14	--	--	1.10	--
Feed/gain					--	6.32	--	5.74	--	--	6.12	--
Henderson and Bergen (1972b)	10	225	225	40								
Daily gain, kg					--	--	--	1.13	--	--	1.09	--
Feed/gain					--	--	--	6.18	--	--	6.29	--
Henderson and Britt (1974)	8	235	209	40								
Daily gain, kg					--	1.30	--	1.22	--	--	--	--
Feed/gain					--	5.75	--	5.98	--	--	--	--
	8	235	209	60								
Daily gain, kg					--	1.26	--	1.29	--	--	--	--
Feed/gain					--	5.90	--	5.47	--	--	--	--
	8	235	209	80								
Daily gain, kg					--	1.19	--	1.19	--	--	--	--
Feed/gain					--	5.51	--	5.38	--	--	--	--
Ritchie et al. (1974)	8	225	248	40								
Daily gain, kg					--	1.04	--	.95	--	--	--	--
Feed/gain					--	7.14	--	6.98	--	--	--	--
Henderson et al. (1975)	8	260	194	40								
Daily gain, kg					.89	1.16	1.12	1.17	--	--	--	--
Feed/gain					7.69	6.71	6.80	6.48	--	--	--	--
Ritchie et al. (1975)	16	178	154	47								
Daily gain, kg					--	1.36	1.28	--	--	--	--	--
Feed/gain					--	4.68	4.88	--	--	--	--	--
Lalonde (1976)	16	258	183	54								
Daily gain, kg					--	1.11	--	--	--	1.05[a]	--	--
Feed/gain					--	6.48	--	--	--	6.68[a]	--	--

[a]Anhydrous ammonia. [b]Aqueous ammonia.

due to loss of energy containing volatiles (Goodrich and Meiske, 1971; Larsen and Jones, 1973; Fox and Fenderson, 1978). Therefore, the common tendency is to underestimate DM consumption of cattle fed fermented feeds. In recent years, some researchers have made an effort to correct DM intake for volatiles lost during DM determination in an oven. However, other researchers have not recognized this fact and have not made any adjustment to DM intakes of cattle receiving fermented feeds.

Many recent studies have fed monensin sodium which has been demonstrated to decrease feed intake, while allowing animals to maintain a similar rate of gain (Thonney, 1977). Therefore, the net effect of monensin is to decrease the amount of feed required per unit of gain. For these reasons, extreme caution must be exercised in comparing absolute performance between different experiments.

Comparisons between different treatments are presented in Table 2. Data from Table 1 have been summarized within each of the previously described categories. Weighted averages of performance based on number of cattle are listed in this table and were computed based on only the trials in which both treatments involved in the comparison were included. These data are further summarized with comparisons being made on a percentage basis in Table 3. In interpreting the results of Table 3, the number of trials and trends within each of these trials should also be considered. As the number of trials increases, a greater amount of confidence can be obtained from the results.

Comparison 1 emphasized the importance of supplemental nitrogen in rations containing corn silage. The severe depressions in rate of

Table 2.--Summary of Feedlot Performance of Cattle Fed Corn Silage Rations With Various Nitrogen Sources[a]

	Daily gain, kg	Feed/gain
Calves: All silage; less than 100 days on feed		
No. of trials	1	1
No supplemental N	.54	8.86
Supplemented with soybean meal	1.11	5.74
No. of trials	3	3
Supplemented with soybean meal	.78	5.42
Supplemented with urea	.68	5.93
No. of trials	1	1
Supplemented with soybean meal	1.06	5.96
Pro-Sil treated silage	1.03	5.40
No. of trials	3	3
Supplemented with soybean meal	.95	5.30
NH_3 treated silage	.65	7.59
No. of trials	1	1
Pro-Sil treated silage	1.03	5.40
Urea + mineral treated silage	.89	6.09
No. of trials	1	1
Pro-Sil treated silage	1.03	5.40
NH_3 treated silage	.72	6.80
Calves: All silage; more than 100 days on feed		
No. of trials	5	5
No supplemental N	.46	11.39
Supplemented with soybean meal	1.01	7.04
No. of trials	3	3
Supplemented with soybean meal	.93	7.74
Supplemented with urea	.85	8.40
No. of trials	8	8
Supplemented with soybean meal	1.00	6.94
Pro-Sil treated silage	.94	6.96
No. of trials	3	3
Supplemented with soybean meal	1.15	6.40
NH_3 treated silage	1.09	6.92

Table 2--Continued

	Daily gain, kg	Feed/gain
Calves: All silage; more than 100 days on feed--continued		
No. of trials	4	4
Pro-Sil treated silage	.86	7.44
Urea + mineral treated silage	.84	7.47
No. of trials	2	2
Pro-Sil treated silage	1.14	6.16
NH_3 treated silage	1.08	7.00
Calves: Added corn; less than 100 days on feed		
No. of trials	1	1
Supplemented with soybean meal	1.19	5.72
Pro-Sil treated silage	1.17	5.19
No. of trials	1	1
Supplemented with soybean meal	1.19	5.72
NH_3 treated silage	.98	6.03
No. of trials	1	1
Pro-Sil treated silage	1.17	5.19
Urea + mineral treated silage	1.11	5.74
No. of trials	1	1
Pro-Sil treated silage	1.17	5.19
NH_3 treated silage	.98	6.03
Calves: Added corn; more than 100 days on feed		
No. of trials	3	3
No supplemental N	.91	7.12
Supplemented with soybean meal	1.23	6.19
No. of trials	3	3
Supplemented with soybean meal	1.28	5.76
Supplemented with urea	1.22	5.99
No. of trials	9	9
Supplemented with soybean meal	1.14	6.30
Pro-Sil treated silage	1.15	6.00
No. of trials	3	3
Supplemented with soybean meal	1.15	6.02
NH_3 treated silage	1.13	5.96

Table 2--Continued

	Daily gain, kg	Feed/gain
Calves: Added corn; more than 100 days on feed--continued		
No. of trials	4	4
Pro-Sil treated silage	1.11	6.25
Urea + mineral treated silage	1.07	6.52
No. of trials	2	2
Pro-Sil treated silage	1.22	5.45
NH_3 treated silage	1.20	5.24
No. of trials	1	1
Urea treated silage	1.17	5.99
Urea + mineral treated silage	1.13	6.41
Yearlings: All silage; less than 100 days on feed		
No. of trials	4	4
Supplemented with soybean meal	1.01	8.05
Supplemented with urea	.96	8.45
No. of trials	4	4
Supplemented with soybean meal	.89	8.82
Pro-Sil treated silage	.89	8.60
No. of trials	1	1
Supplemented with soybean meal	1.92	3.87
NH_3 silage	1.71	3.89
Yearlings: All silage; more than 100 days on feed		
No. of trials	2	2
No supplemental N	.71	8.19
Supplemented with soybean meal	1.05	6.98
No. of trials	5	5
Supplemented with soybean meal	1.02	7.23
Pro-Sil treated silage	.96	7.15
No. of trials	1	1
Supplemented with soybean meal	1.15	6.62
NH_3 treated silage	.97	6.74
No. of trials	2	2
Pro-Sil treated silage	1.14	7.17
Urea + mineral treated silage	1.19	6.84

Table 2. --Continued

	Daily gain, kg	Feed/gain
Yearlings: All silage; more than 100 days on feed--continued		
No. of trials	2	2
Urea treated silage	1.11	6.61
Urea + mineral treated silage	1.19	6.84
Yearlings: Added corn; less than 100 days on feed		
No. of trials	1	1
No supplemental N	1.03	6.18
Supplemented with soybean meal	1.16	5.76
No. of trials	2	2
Supplemented with soybean meal	1.28	5.97
Supplemented with urea	1.25	6.06
No. of trials	1	1
Supplemented with soybean meal	1.16	5.76
Pro-Sil treated silage	1.17	6.16
No. of trials	1	1
Supplemented with soybean meal	1.16	5.76
NH_3 treated silage	1.10	6.63
No. of trials	1	1
Pro-Sil treated silage	1.17	6.16
NH_3 treated silage	1.10	6.63
Yearlings: Added corn; more than 100 days on feed		
No. of trials	3	3
No supplemental N	1.15	6.85
Supplemented with soybean meal	1.32	6.48
No. of trials	4	4
Supplemented with soybean meal	1.24	6.14
Supplemented with urea	1.17	6.92
No. of trials	9	9
Supplemented with soybean meal	1.05	7.69
Pro-Sil treated silage	1.05	7.68

[a]Based on data in Table 1. Weighted averages were computed in each comparison utilizing only the trials in which both treatments involved in the comparison were included.

Table 3.--Comparison of Feedlot Performance of Cattle Fed Corn Silage Rations With Various Sources of Nitrogen[a]

No.	Comparison	Calves: All silage <100 days	Calves: All silage >100 days	Calves: Added corn <100 days	Calves: Added corn >100 days	Yearlings: All silage <100 days	Yearlings: All silage >100 days	Yearlings: Added corn <100 days	Yearlings: Added corn >100 days
1	No supplemental N vs. supplementation with soybean meal								
	No. of trials	1	5	0	3	0	2	1	3
	Daily gain, %	-51.4	-54.5	--	-26.0	--	-32.4	-11.2	-12.9
	Feed/gain, %	+54.4	+61.8	--	+15.0	--	+17.3	+7.3	+5.7
2	Supplementation with soybean meal vs. supplementation with urea								
	No. of trials	3	3	0	3	4	0	2	4
	Daily gain, %	+14.7	+9.4	--	+4.9	+5.2	--	+2.4	+6.0
	Feed/gain, %	-8.6	-7.9	--	-3.8	-4.7	--	-1.5	-11.3
3	Supplementation with soybean meal vs. Pro-Sil treated silage								
	No. of trials	1	8	1	9	4	5	1	9
	Daily gain, %	+2.9	+6.4	+1.7	-0.9	0.0	+6.2	-0.9	0.0
	Feed/gain, %	+10.4	-0.3	+10.2	+5.0	+2.6	+1.1	-6.5	+0.1
4	Supplementation with soybean meal vs. NH_3 treated silage								
	No. of trials	3	3	1	3	1	1	1	0
	Daily gain, %	+46.2	+5.5	+21.4	+1.8	+12.3	+18.6	+5.5	--
	Feed/gain, %	-30.2	-7.5	-5.1	+1.0	-0.5	-1.8	-13.1	--
5	Pro-Sil treated silage vs. urea + mineral treated silage								
	No. of trials	1	4	1	4	0	2	0	0
	Daily gain, %	+15.7	+2.4	+5.4	+3.7	--	-4.2	--	--
	Feed/gain, %	-11.3	-0.4	-9.6	-4.1	--	+4.8	--	--
6	Pro-Sil treated silage vs. NH_3 treated silage								
	No. of trials	1	2	1	2	0	0	1	0
	Daily gain, %	+43.1	+5.6	+19.4	+1.7	--	--	+6.4	--
	Feed/gain, %	-20.6	-12.0	-13.9	+4.0	--	--	7.1	--
7	Urea treated silage vs. urea + mineral treated silage								
	No. of trials	0	0	0	1	0	2	0	0
	Daily gain, %	--	--	--	+3.5	--	-6.7	--	--
	Feed/gain, %	--	--	--	-6.6	--	-3.4	--	--

[a]Based on data in Table 2.

gain and feed efficiency for unsupplemented rations in these trials are likely a result of the low quantity and poor utilization of corn silage protein. Supplemental nitrogen appears to be more critical for rations containing all silage than for those where corn is added. This is probably due to the fact that the added corn increases the preformed protein content as well as the energy density of the ration. Comparison 1 also demonstrates that calves have a greater need for supplemental protein than yearlings, as would be expected.

In Comparison 2, soybean meal (SBM) was superior to urea with respect to feedlot performance under all conditions examined. However, differences in performance between rations supplemented with SBM and urea tended to decrease when corn was added to the ration, the length of the feeding period increased or yearlings were fed rather than calves.

Performance of steers fed Pro-Sil treated silage or untreated silage supplemented with SBM is examined in Comparison 3. Cattle fed Pro-Sil treated silage generally required less feed per unit of gain than those cattle fed untreated corn silage supplemented with SBM. When corn was added or the length of the feeding period increased, the difference in ADG decreased. Although yearlings performed better on Pro-Sil than calves relative to SBM, Pro-Sil and SBM were equivalent with respect to ADG for both calves and yearlings fed added corn for a period greater than 100 days.

Analysis of Comparison 4 reveals that with respect to animal performance SBM was superior to ammonia as a source of supplemental nitrogen for corn silage rations. Performance data of cattle receiving anhydrous or aqueous ammonia have been pooled, and both are included in the values presented for ammonia treated silage. Few studies have been conducted in which performance of cattle fed aqueous or anhydrous ammonia have been compared. A study by Fox and Cook (1977) revealed that cattle receiving corn silage treated with aqueous ammonia had a slightly higher ADG and a lower F/G than those receiving silage treated with AN. Differences in performance between cattle supplemented with SBM and ammonia tended to decrease as corn was added to the ration or the length of the feeding period increased. Sufficient data are not available on yearling steers fed ammonia treated silage to make valid comparisons between yearlings and calves. However, based on data for other forms of NPN, performance of yearlings would be expected to be superior to that of calves when fed silage treated with ammonia relative to untreated silage supplemented with SBM.

Animal performance resulting from feeding Pro-Sil or urea + mineral treated silage is contrasted in Comparison 5. Pro-Sil addition resulted in a higher ADG and a lower F/G than urea + minerals. However, differences in performance were decreased as corn as added to the ration or length of feeding period increased. In two studies with yearlings, it appears that they perform as well or better on silage treated with urea + minerals than on silage treated with Pro-Sil.

Performance of steers receiving corn silage treated with Pro-Sil or ammonia at the time of ensiling is contrasted in Comparison 6. Aqueous and anhydrous ammonia data have been pooled as in Comparison 4. Few studies have been conducted in which Pro-Sil and ammonia treatment have been compared. Based on the limited data, Pro-Sil treatment resulted in a higher ADG and a lower F/G than ammonia treatment. These differences in performance decreased in magnitude as the length of the feeding period increased or as corn was added to the ration. Ammonia treatment resulted in a 1.7% lower ADG but a 4.0% lower F/G than Pro-Sil treated silage in a summary of two studies where steer calves received added corn and were fed for a period greater than 100 days.

Results comparing animal performance from urea or urea + mineral treated silage in Comparison 7 are variable. However, cattle receiving the urea treated silage required less feed per unit of gain than those cattle that received silage treated with urea + minerals based on the limited data available. Further work is needed to make a valid judgment.

Analysis of Table 3 reveals that NPN was more efficiently used when corn was added to the ration, length of feeding period increased or yearlings were fed rather than calves. Rations containing added corn would contain a greater amount of preformed protein and a higher energy density than all silage rations. Fox et al. (1977a) and Bergen et al. (1978) noted that it was unlikely that cattle started on feed as calves could generate sufficient microbial protein from corn silage treated with NPN to fully meet their protein requirement during the initial part of the feeding period. These scientists recognized that calves have a relatively high protein requirement during the initial phase of the feeding period and that corn silage protein is poorly utilized and is present in low quantity. They concluded that supplementation of NPN treated corn silage with a source of preformed protein such as SBM would be beneficial during the initial part of the feeding period.

Fox et al. (1977c) summarized the results of eight starting-on-feed trials in which performance obtained from feeding NPN treated corn silage and untreated corn silage supplemented with SBM were compared. Performance of steer calves (221 kg) was evaluated for a 35-day period commencing at the time the cattle arrived at the feedlot. In all experiments, cattle fed NPN treated silage alone gained slower and had a higher F/G than cattle fed untreated corn silage supplemented with SBM. SBM supplementation of the NPN treated silage significantly improved ADG and F/G to near those levels obtained with untreated silage plus SBM. These results suggest that NPN utilization by calves during periods of stress is poor and reflect the requirement of calves for preformed protein during the initial part of the feeding period. Since these were starting-on-feed trials and the cattle were subsequently used for other experiments, it was impossible to determine the effect of nitrogen treatment on overall performance.

Preston et al. (1975a) conducted a starting-on-feed experiment in which steer calves (177 kg) and heifer calves (194 kg) were fed limestone treated corn silage supplemented with SBM only, two-thirds SBM and one-third urea, one-third SBM and two-thirds urea or urea only. This study had a duration of 69 and 66 days for the steers and heifers, respectively. Maximum gains were observed by those calves supplemented with SBM only. However, most of the difference in feedlot performance occurred during the first 27 days of the experiment. After the first 27 days, no consistent effect on the proportion of urea in the ration was noted. These data support the contention that after an initial adjustment period, NPN may be equivalent to preformed protein as a source of supplemental nitrogen for calves fed corn silage rations, depending on initial weight and availability of insoluble nitrogen in the silage.

Mowat et al. (1974) conducted an experiment in which lightweight steer calves (182 kg) were fed NPN treated corn silage or untreated silage supplemented with SBM. During the initial part of the feeding period, those cattle receiving the NPN treated silage gained significantly slower, but after they reached approximately 300 kg gains were equivalent to those obtained from feeding untreated corn silage plus SBM. However, calves that received the NPN treated silage did not fully compensate for the poor performance during the initial phase of the feeding period, and as a result, overall performance was poorer for those cattle receiving NPN treated silage.

While calves fed corn silage rations have generally gained faster when fed untreated silage supplemented with SBM rather than corn silage to which NPN has been added, NPN supplementation has resulted in superior performance to feeding no supplemental nitrogen. Preston (1974) reported that lightweight steer calves (174 kg) could effectively utilize urea in corn silage based rations. Steers receiving urea supplementation had a 44% higher ADG and required 25% less feed per unit of gain than those steers that received no supplemental protein.

Effect of NPN Treatment of Corn Silage on Silage Fermentation

Addition of NPN to corn silage at the time of ensiling results in a higher pH than untreated control silage due to the buffering of fermentation acids by ammonia (Klosterman et al., 1963; Cash, 1972;

Shirley et al., 1972). Since fermentation is prolonged, lactic acid levels are increased in NPN treated corn silage. Addition of a mineral mixture to corn silage at the time of ensiling will also buffer the fermentation process and will further increase lactate production when added to silage being treated with NPN prior to ensiling (Henderson et al., 1971c; Fox and Cook, 1977).

Henderson et al. (1972) noted that lactic acid, a major end product of silage fermentation, was the most reliable indicator of silage quality. Lactate was found to be utilized more efficiently than soluble carbohydrates in the rumen due to decreased losses of methane in a study by Prigge and Owens (1976). They concluded that poor compaction of the silage decreased lactate production, increased total volatile fatty acids (VFA) and increased energy losses due to heating.

Allen and Henderson (1972) added acetic and lactic acid to corn silage rations and found that acetic acid depressed daily DM intake, ADG and increased feed requirement per unit gain. Addition of lactic acid had little effect on ADG, DM consumption or F/G. Allen et al. (1971) added ammonium salts to feedlot rations as the only source of supplemental protein for yearling steers and found ammonium salts of acetate and lactate were equivalent to SBM and superior to urea in promoting gain and decreasing F/G.

Although NPN treated corn silages contain more ammonia and NPN (Johnson et al., 1967; Bergen et al., 1974), they also have more water insoluble nitrogen, which appears related to decreased degradation of true plant protein (Johnson et al., 1967; Owens et al., 1970; Cash, 1972; Bergen _et al._, 1974; Huber _et al._, 1979). However, the utilization of the undegraded corn silage protein or residual N is of questionable value. Very little research has been conducted in which utilization of corn silage undegraded or residual N have been studied. Bergen _et al._ (1974) indicated that corn silage residual N had an amino acid pattern similar to that observed for corn kernel protein. It would seem likely that protein that escapes ruminal degradation would pass to the small intestine where further digestion might occur. However, Bergen _et al._ (1974) conducted pepsin-pancreatin digestion studies that revealed that the residual N from corn silage was poorly utilized in the small intestine.

In addition to containing more lactate and true protein and having a higher pH value, ammonia treated silage also is higher in acetate (Huber and Santana, 1972; Huber _et al._, 1973; Core _et al._, 1974). Ammonia treated silage is also more stable than untreated silage when exposed to air (Britt and Huber, 1973; Huber, 1973; Lalonde _et al._, 1975; Soper and Owen, 1977). Huber (1973) suggested that ammonia treated silages are more stable than urea treated silages because of partial hydrolysis of urea.

Protein Requirements of Finishing Steers

The National Research Council (N.R.C., 1976) has made recommendations for the protein levels to be fed to finishing cattle for various weights and compositions of gain. While these standards have generally resulted in satisfactory performance, research efforts have been directed at defining the precise protein requirements for finishing cattle. Increased costs of protein supplements and the potential for future price escalations have mandated that protein requirements for finishing cattle be determined more precisely.

The N.R.C. (1976) recommends 10.9 and 10.5% crude protein for steers weighing 350 kg and 400 kg, respectively. However, several researchers have reported that supplemental nitrogen was not necessary during the latter part of the feeding period for 350 to 400 kg steers fed a basal grain ration containing 8.0 to 8.5% crude protein (DM basis).

Preston and Cahill (1972, 1973) demonstrated that supplemental protein was not required during the latter part of the feeding period when the cattle were heavier and were receiving a corn-corn silage ration containing 8.5% crude protein (DM basis). Preston et al. (1975b) concluded that steers weighing over 340 kg when started on grain based rations require at least 8.2 to 8.3% crude protein (DM basis) in order to perform as well as steers fed higher levels of protein during this same part of the feeding period.

Young et al. (1973) fed ground ear corn finishing diets to Angus steers (332 kg) in a 112-day finishing trial. All steers were fed an SBM supplemented diet which contained 11% crude protein (DM basis) during the first 56 days of the study. During the last 56 days of the trial, SBM was removed from the diet of one-half of the steers, yielding a ration that contained 6.98% crude protein (DM basis). ADG and F/G were similar for both groups of steers.

Klett et al. (1973) conducted a study in which all steers (250 kg) were fed a grain sorghum based ration that contained 11.5%

crude protein (DM basis) until they reached a weight of 385 kg. At this point, all supplemental nitrogen was withdrawn from the ration of one-half of the steers, resulting in a crude protein content of 9% (DM basis). The remainder of the cattle continued receiving 11.5% crude protein (DM basis). The authors concluded that supplemental nitrogen could be removed from grain sorghum finishing rations after steers reach a weight of 385 kg without affecting performance or carcass traits.

Two finishing studies were conducted by Riley et al. (1975) to determine the effect of removing supplemental protein from the diet on the performance and carcass traits of finishing steers. Supplemental protein was removed from the ration when the steers weighed 340 kg, 385 kg or 430 kg or added protein was fed throughout the duration of the feeding period. Finishing rations contained 11.2% crude protein (DM basis) prior to supplemental protein removal and 9.3 and 8.7% crude protein (DM basis) after removal in trials 1 and 2, respectively. Protein supplementation strategy resulted in no significant differences in performance or carcass traits in either of the two finishing studies. These results led the authors to conclude that British breeds of cattle do not require supplemental protein in high concentrate rations after they reach 430 kg and that withdrawal may occur as early as 340 or 385 kg with minimal effects.

Canadian workers (Snoddon et al., 1976) performed a study with yearling Hereford and Hereford-cross steers (338 kg) to determine at what weight supplemental protein could be withdrawn from the ration of steers fed an all corn silage ration without having any detrimental effects on ADG, F/G and carcass quality. Four dietary treatments were evaluated: 1) no supplemental protein; 2) protein supplement withdrawn at 385 kg; 3) protein supplement withdrawn at 430 kg; and 4) protein supplement fed throughout the entire trial. The supplemented ration and basal ration contained 10.6 and 8.5% crude protein (DM basis), respectively. Results of this study indicated that supplemental protein can be withdrawn from a moderate to high corn silage ration at a steer liveweight of approximately 400 kg providing the basal ration contains 8.5 to 9% crude protein (DM basis). These authors also noted that later maturing European breeds may require supplemental protein beyond the weight at which it can be withdrawn from British breeds. This is in agreement with the "equivalent weight" concept of Fox and Black (1977).

In a study by Cook and Fox (1977), decreasing the level of SBM supplementation of an all corn silage ration as the cattle became heavier was examined. Hereford and Charolais crossbred steers were fed either a 12.5% crude protein (DM basis) ration throughout the entire feeding period or they were fed a 12.5% crude protein (DM basis) ration until they reached an equivalent weight of 318 kg and then they received a 10.5% crude protein (DM basis) throughout the remainder of the feeding period. No significant differences in performance were noted when the level of protein was decreased from 12.5% to 10.5% when the steers reached an equivalent weight of 318 kg.

Young (1978) conducted two finishing trials with Holstein steers to determine the effect of steer weight and corn intake on protein withdrawal from the ration. In both trials, steers were fed a high grain (80% corn and 20% corn silage, DM basis) or a high silage (40% corn and 60% corn silage, DM basis) ration. The crude protein content of the basal and protein supplemented rations were approximately 9.6% and 12.8%, and 8.8% and 12.4% for the high grain and high silage rations, respectively. In experiment 1, removal of supplemental protein when steer calves (253 kg) reached 318, 386 or 454 kg had no effect on ADG, F/G or carcass merit on either ration when compared to steers fed protein continuously. In experiment 2, supplemental protein was withdrawn when daily intake of corn by yearling steers (310 kg) reached 4.5, 5.9 or 7.3 kg. Withdrawal of supplemental protein when daily corn intake reached 4.5, 5.9 or 7.3 kg resulted in no significant differences in ADG, F/G or carcass merit when compared to steers fed protein continuously. These authors concluded that supplemental protein could be removed from the ration of Holstein steers when they reached a weight of 318 kg or when they were consuming 4.5 kg of corn per day.

Illinois workers (Peterson et al., 1973) studied the influence of concentration of dietary energy on the protein needs of growing and finishing Angus x Hereford steer calves (210 kg). The four levels of dietary protein evaluated were 9, 11, 13 and 15% on a DM basis. Significantly ($P > .05$) greater gains were observed by increasing the protein level with higher concentrations of dietary energy. Increased dietary protein levels showed the greatest response during the first 55 days of the experiment. Level of protein had no significant effect on ADG during the remainder of the feeding period. Similar response to supplemental protein was noted by Braman et al. (1973). They conducted a study with Brangus x Hereford-Shorthorn steers (253 kg) to determine the effect of protein concentration on the performance of ruminants fed a high concentrate diet. All concentrate diets composed of high-moisture corn and protein supplement were formulated to provide dietary protein concentrations of approximately 10.8, 13.8, 15.7 and 18.4% on a DM basis. Within each level of dietary protein, urea or SBM was the source of supplemental nitrogen. The greatest response to increased dietary protein concentrations was observed early in the finishing period with little advantage to supplemental protein observed in the later phase. Dietary protein concentration had little apparent effect on carcass parameters. The results of these two studies support the concept that the level of supplemental protein can be decreased as cattle become heavier and their need for protein decreases as a percentage of ration DM.

Workman et al. (1979) conducted two studies with Hereford and Hereford-cross steers to determine the effect of protein withdrawal during the finishing phase on feedlot performance. Cattle were fed a whole corn based ration that contained 8.2% and 11.1% and 9.8% and 12.7% crude protein (DM basis) before and after protein supplementation in trials 1 and 2, respectively. In trial 1, all steers (315 kg) received supplemental protein until they reached a weight of 382 kg and then supplemental protein was removed from the ration of one-half of the steers. In trial 2, all steers (224 kg) received supplemental protein until they reached a weight of 342 kg and then supplemental protein was removed from the ration of one-half of the steers. Removal of supplemental protein in trial 1 resulted in no differences in performance. However, removal of protein resulted in a lower ADG and a higher F/G when compared to cattle that received continuous protein supplementation throughout the entire feeding period in trial 2. The differences in performance between the two trials was due to heavier cattle in trial 1 when protein was removed from the ration. Thus, the protein requirement of these cattle was lower on a percentage basis. Cattle in trial 1 also had a higher DM intake and consumed more total protain per day.

Byers and Moxon (1979) used Hereford steers (340 kg) to determine the effect of supplemental protein on the performance of finishing steers fed an 80% whole shelled corn and 20% corn silage (DM basis) ration for 112 days. The basal ration contained 9.8% crude protein (DM basis) and 12.1% crude protein (DM basis) after supplementation. Cattle that received supplemental protein gained faster ($P < .05$) and required less feed per unit of gain than those fed the unsupplemented basal ration.

Dartt _et_ _al_. (1978) utilized Hereford and Angus steers (279 kg) to study the effects of monensin and supplemental protein withdrawal on feedlot performance of finishing steers. The basal ration was composed of corn and corn silage and contained 7.4% crude protein (DM basis). Half of the cattle received 200 mg monensin per head daily, while the other half received no monensin. Soybean meal was fed to all cattle at .71 kg per head daily for the first 84 days when cattle reached a weight of approximately 393 kg. At that time, supplemental protein was withdrawn from one-half of the steers receiving the control diet and from one-half of the steers receiving monensin. Removal of supplemental protein from the control diet resulted in a decreased ADG ($P < .05$). However, removal of protein from the ration containing monensin resulted in no significant decrease in ADG. These authors concluded that monensin had a protein-sparing effect in steers fed a corn silage diet.

In the studies reviewed where protein withdrawal had no effect on weight gains, daily crude protein intakes were usually maintained at .70 kg or higher for the unsupplemented rations. N.R.C. (1976) recommendation is .83 kg. Thus, it would appear that supplemental protein can be withdrawn from corn-corn silage finishing rations for cattle over 318 kg equivalent weight provided crude protein intake remains near N.R.C. (1976) recommendations. However, this depends on soluble N and bound protein content of the ration. Withdrawal of supplemental protein, resulting in basal rations that furnished only .40 to .60 kg of crude protein per day, resulted in significantly lower weight gains.

Effect of Monensin on Feedlot Performance

Feeding monensin sodium to growing and finishing cattle has been a major area of research during the past five years. Feeding monensin has resulted in a decreased acetate and increased propionate in the rumen, but very little change in total VFA production. Since propionate is used more efficiently as a source of metabolizable energy than acetate, cattle fed monensin should gain more efficiently than cattle not fed monensin (Raun et al., 1976; Hungate, 1966).

Data collected from 28 university experiments in which monensin was fed to steers and heifers were summarized by Goodrich et al. (1976). These experiments involved a total of 3,042 cattle and included both calves and yearlings. Monensin was fed at 5.5, 11.0, 22.0, 27.5, 33.0 or 44.0 ppm of the ration DM. With the exception of cattle receiving 44.0 ppm monensin, daily gains of cattle fed monensin were equal to or greater than gains of cattle not fed monensin. Cattle receiving 44.0 ppm monensin had lower daily gains than those fed the control ration or any other level of monensin. DM intakes declined as the level of monensin in the diet increased, and all levels of monensin resulted in a lower F/G than the control ration. Feed efficiency was improved 6.5, 6.1, 7.4, 10.3, 8.4 or 8.5 percent for cattle fed rations containing 5.5, 11.0, 22.0, 27.5, 33.0 or 44.0 ppm monensin. Maximum reduction in F/G was obtained by feeding 27.5 ppm monensin. Carcass traits were not significantly influenced by monensin.

In an effort to determine the effect of monensin on carcass traits, Brown et al. (1974) collected data on quality grade and cutability of 1,147 cattle fed various levels of monensin. Analysis of the data revealed that monensin had little or no effect on carcass quality or cutability. Thonney (1977) also concluded that monensin had no consistent effect on carcass characteristics.

Embry (1976) summarized the results of six experiments in which monensin was fed and analyzed feedlot performance during the growing phase and the finishing phase, separately. Monensin had only a small effect on weight gain during the growing phase. Cattle receiving 33.0 ppm monensin or less gained as much as the control group, while cattle receiving 44.0 ppm monensin gained slightly less than controls. Lowest F/G was obtained by feeding 33.0 ppm monensin. These cattle consumed 9.6% less DM per day and required 9.0% less F/G than the control group. Similar benefits from feeding monensin were noted during the finishing phase with 33.0 ppm resulting in most efficient performance.

There appears to be a beneficial additive effect from feeding monensin to cattle implanted with growth stimulants. Woody and Fox (1977) fed heifers 33.0 ppm monensin and noted a 5.8% lower F/G compared to heifers receiving no monensin. However, when heifers were fed 33.0 ppm monensin and also implanted with Synovex-H, they had an 11.5% higher ADG and a 6.5% lower F/G than heifers receiving monensin without a growth stimulant. Burroughs _et al_. (1976) and Embry (1976) also concluded that there was an additive response to monensin and growth promoting implants. Since monensin cannot be mixed in a ration with other feed additives, growth stimulants must be implanted when monensin is fed.

Monensin feeding has been shown to initially reduce feed intake by as much as 15 to 30 percent. However, consumption gradually returns to approximately 90% of controls within 30 days (Nissen and Trenkle, 1976). This may be due to adaptation of the animal, adaptation of the rumen microbial population, or both. The increased levels of propionate commonly observed when monensin is fed also suggest an alteration in rumen fermentation.

Van Nevel and Demeyer (1977) conducted an _in vitro_ study with incubations of mixed rumen microorganisms to determine the effect of monensin on the metabolism of carbohydrate or protein substrate. Monensin was found to partially inhibit methanogenesis and to increase propionate production. Microbial growth and efficiency of microbial growth were considerably lowered by the addition of monensin to the incubation. Besides affecting carbohydrate fermentation in the rumen, monensin decreased protein degradation, resulting in lower rumen ammonia levels. Therefore, monensin increased the quantity of protein digested postruminally. This would seem reasonable since cattle fed monensin generally consume less feed, but gain similarly to controls while consuming less protein. Therefore, it seems logical to conclude that monensin has a protein-sparing effect.

Tolbert et al. (1977) used an in vitro study to determine the effect of monensin on DM disappearance and proteolytic activity. These workers reported that monensin depressed free ammonia levels when sorghum plus SBM or sorghum plus urea was used as the substrate. Free amino acid levels were decreased when monensin was added to sorghum plus SBM, but were increased when monensin was added to sorghum plus urea. They suggested that monensin inhibits deamination by the rumen microflora.

Several experiments have been conducted to determine whether or not monensin has a protein-sparing effect. Hanson and Klopfenstein (1979) utilized two cattle growth trials to evaluate the response to monensin when diets were supplemented with various sources and levels of protein. In trial 1, performance of growing steers (260 kg) fed two sources of supplemental protein (brewers dried grains or urea), two levels of dietary crude protein (10.5% or 12.5%) and two levels of monensin (0 or 200 mg/head daily) was evaluated. Monensin resulted in a 16.3% and 8.7% decrease in F/G for the 10.5% and 12.5% protein treatments, respectively. Monensin addition with either level of urea supplementation tended to decrease ADG and increase F/G. The authors speculated that the differing responses in performance between brewers dried grains and urea may have been due to inhibition of microbial protein synthesis by monensin. Monensin resulted in higher concentrations of propionate and lower levels of ammonia nitrogen when diets were supplemented with either source of supplemental protein. In trial 2, performance of growing steers (214 kg) fed two levels of dietary protein provided by SBM (11.1% or 13.1%) and two levels of monensin (0 ppm or 33.0 ppm) was evaluated. Monensin resulted in an 8.1% and 3.2% decrease in F/G for the 11.1% and 13.1% protein treatments, respectively. Since the largest response in F/G was observed for the lower protein diets, it was concluded that monensin addition did not increase the need for supplemental protein as a percentage of ration DM for growing and finishing steers.

Dartt et al. (1978) investigated the effects of protein withdrawal and monensin on the performance of finishing steers. Dietary protein was more efficiencly utilized when supplemental SBM was removed from steers previously fed monensin compared to controls that did not receive monensin. Perry et al. (1979) also suggested that monensin may have a protein-sparing effect in diets borderline to deficient in protein.

Poos et al. (1979) evaluated the influence of monensin on diet digestibility, microbial protein synthesis and ruminal bypass of dietary plant protein from grain sorghum diets supplemented with brewers dried grains or urea, using two lamb trials and a steer trial. In the lamb trials, monensin reduced ruminal acetate : propionate ratios, protozoal populations and ammonia levels; conversely, it increased plasma urea. Abomasally cannulated steers were used to evaluate monensin effects on nitrogen fractions entering the small intestine when brewers dried grains or urea was fed as the source of supplemental nitrogen. Monensin addition decreased bacterial nitrogen and increased plant nitrogen flow with both sources of supplemental nitrogen. Monensin addition increased amino acid flow on diets supplemented with brewers dried grains but not on those supplemented with urea. The authors concluded that monensin may spare dietary protein by decreasing ruminal proteolysis and that monensin may reduce urea utilization since flow of bacterial nitrogen was significantly reduced when monensin was added to the diet.

In summary, addition of monensin to diets supplemented with preformed protein is more beneficial than addition to diets supplemented with NPN. Monensin appears to decrease the efficiency of microbial growth and thereby reduces microbial protein synthesis resulting in less flow of bacterial nitrogen to the lower gut.

OBJECTIVES

1. To determine the impact on performance of feeding corn silage treated with cold-flow anhydrous ammonia vs. untreated corn silage supplemented with soybean meal.
2. To determine the impact on performance of feeding a decreasing level of protein in the ration as steers become heavier vs. a constant percentage of protein throughout the entire feeding period.
3. To determine whether it would be beneficial to supplement corn silage treated with 7.80 g of cold-flow anhydrous ammonia per kg of corn silage dry matter with soybean meal until cattle reach an equivalent weight of 318 kg.
4. To determine the effect of adding a complete mineral mix to fresh corn forage at the time of ensiling on feedlot performance.
5. To determine the effect of calcium hydroxide addition to fresh corn forage at the time of ensiling on cattle performance.
6. To obtain net energy values for corn silage treated with cold-flow anhydrous ammonia at the time of ensiling.
7. To determine the effect of feeding various levels of cold-flow anhydrous ammonia treated corn silage on the performance of cattle fed on a two-phase system.
8. To determine the effect of feeding various levels of monensin sodium on the performance of cattle fed on a two-phase system.
9. To determine if any anhydrous ammonia x monensin interactions exist on the performance of cattle fed on a two-phase system.

MATERIALS AND METHODS

Feedlot Studies

Silage Treatments

Corn silage utilized in feedlot trials 1 and 2 was harvested during the third week of September, 1976 and 1977, respectively, and was estimated to have a potential yield of 6.0 bushels of shelled corn per ton of 35% DM silage. Silage was treated with cold-flow anhydrous ammonia (AN) as it passed through the blower and stored in concrete upright silos. Representative samples were taken from each load of fresh corn forage prior to AN treatment and were later analyzed for crude protein (N x 6.25) and dry matter (DM) content.

For trial 1, five different silages were made:

1) an untreated control;
2) 7.80 g AN per kg of corn silage dry matter (KGCSDM);
3) 15.60 g AN/KGCSDM;
4) 15.60 g AN/KGCSDM plus a complete mineral mix that contained 55.15% defluorinated phosphate, 26.47% calcium sulfate and 18.38% trace mineral salt which was added at 1.68% of silage DM at the time of ensiling;
5) 15.60 g AN/KGCSDM plus calcium hydroxide added at 3% of silage DM at the time of ensiling.

Two levels of AN were evaluated in this study. The low level (7.80 g AN/KGCSDM) was designed to meet the crude protein (N x 6.25) requirement of the cattle after they reached an equivalent weight of 318 kg, while the high level (15.60 g AN/KGCSDM) was formulated to fully meet the crude protein (N x 6.25) requirement of the cattle during the entire feeding period.

Since recent research (Klopfenstein, 1978) has shown that alkali treatment improved the digestibility of crop residues, calcium hydroxide was applied to determine if it would increase the digestibility of corn silage and thereby improve feedlot performance. Previous research from this station (Fox and Cook, 1977) has shown that silage treated with an ammonia mineral suspension (Pro-Sil) produced higher ADG and lower F/G than that treated with cold-flow AN. A complete mineral mix was added to AN treated silage to determine the effect of treating silage with the same minerals at ensiling vs. at feeding time. The calcium hydroxide and mineral mix were added to the silage by evenly distributing them over the fresh corn forage prior to unloading into the blower.

For feedlot trial 2, three different silages were made:

1) 0 g AN/KGCSDM (untreated control);
2) 7.90 g AN/KGCSDM;
3) 15.70 g AN/KGCSDM.

<u>Silage Analyses</u>

Silages fed in feedlot trials 1 and 2 were sampled bi-weekly throughout the feeding trial and were analyzed for crude protein (N x 6.25) and DM content. Total N was determined using the Technicon Auto-Kjeldahl System and DM was determined by drying in a 60^{o} C oven for 48 hours.

Silages in both trials were also analyzed every 28 days for water soluble nitrogen, water insoluble nitrogen (Bergen *et al.*, 1974), lactate, acetate, propionate, butyrate, pH and acid detergent fiber (Van Soest, 1963; Van Soest and Wine, 1967). For analysis, silage samples (40 g) were homogenized in 160 ml of distilled water and strained through two layers of cheesecloth. The pH was then determined from an aliquot of the liquid extract using a pH meter. The remaining liquid extracted from the homogenate was treated with .1 volume of 50% sulfosalicyclic acid and centrifuged at 15,000 x *g* for 10 minutes. The resulting supernatant was analyzed for N by micro-kjeldahl. This value was termed the water soluble nitrogen. Water insoluble nitrogen was determined by difference between total nitrogen and water soluble nitrogen. The supernatant was also analyzed for lactate by the method of Barker and Summerson (1941) and for volatile fatty acids by gas chromotography.

Nitrogen recovery values computed for each of the AN treated silages were based on the N content of the silage prior to treatment, the amount of N applied and the amount of N present in the silage upon removal from the silo. The following equations were used to determine the percentage of nitrogen recovered:

$$\text{Nitrogen recovery (\%), uncorrected for VFA loss during DM determination} = \frac{\text{\% total protein at feeding time} - \text{\% total protein prior to treatment}}{\dfrac{(5.12)\,(\text{lbs. AN added/ton})}{(\text{lbs. of DM/ton of silage at time of ensiling})}}$$

Nitrogen recovery (%), corrected for VFA loss during DM determination (Fox and Fenderson, 1978)

$$= \frac{\dfrac{(.936)\ (\%\ \text{total protein at feeding time}) - (\%\ \text{total protein prior to treatment})}{(5.12)\ (\text{lbs. AN added/ton})}}{(1.068)(\text{lbs. of DM/ton of silage at time put in silo})}$$

Experimental Design and Rations for Trial 1

In trial 1, an 8 x 2 factorial design with 8 protein treatments and 2 cattle types was used. Protein treatments evaluated were:

1) untreated corn silage with no supplemental protein (unsupplemented control);
2) 7.80 g AN/KGCSDM;
3) 7.80 g AN/KGCSDM plus added SBM until the cattle reached an equivalent weight of 318 kg;
4) 15.60 g AN/KGCSDM;
5) 15.60 g AN/KGCSDM plus a complete mineral mix added at the time of ensiling;
6) 15.60 g AN/KGCSDM plus calcium hydroxide added at the time of ensiling;
7) untreated corn silage supplemented with SBM at a level which was decreased as the steers became heavier (declining soy);
8) untreated corn silage supplemented with a constant level of SBM throughout the entire feeding period (constant soy).

Treatments 1, 2, 4, 5, 6, and 8 contained 7.50, 9.49, 12.19, 12.36, 12.50, and 12.57 percent crude protein (DM basis), respectively, throughout the entire feeding period. The protein level in treatments 3 and 7 were decreased as the cattle became heavier, because their protein requirements on a percentage basis were thought to decrease. Cattle receiving treatment 3 were supplemented with SBM to provide 12.14% crude protein (DM basis) until they reached an equivalent weight of 318 kg, at which time SBM was removed from the diet. Cattle on treatment 7 received a 12.64, 11.61, and 10.60 percent crude protein ration (DM basis) until they reached an equivalent weight of 227 kg, when they had an equivalent weight of 227 to 272 kg, and when they had an equivalent weight greater than 318 kg, respectively.

All rations contained similar levels of calcium (.60%), phosphorous (.35-.41%), trace mineral salt (.25%) and vitamins A and D (3307 and 331 I.U./kg of DM, respectively). In addition, monensin was fed at 33.0 ppm of ration DM to all cattle. Supplement composition for trial 1 is listed in Table 4.

Sixty-four Hereford (224 kg) and 64 Charolais crossbred steers (293 kg) were fed in trial 1. These calves were purchased in October, 1976, from the Arthur King Ranch in Channing, Texas and were trucked 1,931 km to the MSU Beef Cattle Research Center. After being on a 28-day starting on feed study, all cattle were fed a 13% crude protein ration comprised of untreated corn silage and soybean meal for 7 days. The steers were then allotted by weight groups within each breed to the 8 treatments listed earlier. Eight steers of each cattle type (or a total of 16) were allotted to each treatment.

Experimental Design and Rations for Trial 2

In trial 2, a 3 x 3 factorial design (3 levels of AN treated corn silage and 3 levels of monensin sodium) with unbalanced replication

Table 4.--Supplement Composition for Trial 1 (DM Basis)

Ingredient	Supplement no.					
	I	II	III	IV	V	VI
Crude protein content of supplement, %	5.35	41.86	36.80	9.72	6.47	52.01
	% of DM					
Ground corn, dent yellow, US #2	45.00	8.66	14.10	94.46	47.77	--
Defluorinated phosphate	28.28	--	--	--	--	--
Calcium sulfate	14.14	2.72	4.43	--	15.01	--
Trace mineral salt	9.95	1.91	3.11	--	10.56	--
Rumensin 30 premix[a]	1.83	.35	.57	3.84	1.94	--
Vitamin A premix[b]	.40	.08	.13	.85	.43	--
Vitamin D_3 premix[c]	.40	.08	.13	.85	.43	--
Soybean meal	--	78.95	64.24	--	--	100.00
Ground limestone	--	4.67	7.59	--	--	--
Monosodium phosphate	--	2.58	5.70	--	23.86	--

[a] 66.14 g monensin sodium per kg.

[b] 30,000 IU vitamin A per g.

[c] 3,000 IU vitamin D_3 per g.

was used to evaluate the effect of supplemental nitrogen and monensin on the performance of growing and finishing cattle fed on a two-phase system. Corn silage fed in this study was treated at the time of ensiling with 0, 7.90 or 15.70 g AN/KGCSDM. Monensin was added at 0, 16.5 or 33.0 ppm of ration DM.

One hundred thirty-five Brangus steers (229 kg) were fed in trial 2. These calves were purchased in November, 1977, from the Arthur King Ranch in Channing, Texas and were trucked 1,931 km to the MSU Beef Cattle Research Center. After being on a 13% crude protein ration of untreated corn silage and soybean meal for 28 days, the cattle were allotted by weight groups to the following treatment combinations:

1) 0 g AN/KGCSDM with 0 ppm monensin in ration DM;
2) 0 g AN/KGCSDM with 16.5 ppm monensin in ration DM;
3) 0 g AN/KGCSDM with 33.0 ppm monensin in ration DM;
4) 7.90 g AN/KGCSDM with 0 ppm monensin in ration DM;
5) 7.90 g AN/KGCSDM with 16.5 ppm monensin in ration DM;
6) 7.90 g AN/KGCSDM with 33.0 ppm monensin in ration DM;
7) 15.60 g AN/KGCSDM with 0 ppm monensin in ration DM;
8) 15.60 g AN/KGCSDM with 16.5 ppm monensin in ration DM;
9) 15.60 g AN/KGCSDM with 33.0 ppm monensin in ration DM.

Treatment combinations 4 through 9 were replicated, while 1 through 3 were not. Nine steers were assigned to each pen. A small amount of urea was added to the AN treated silages to make them approximately equal in crude protein content (N x 6.25) to corn silages treated with 7.80 and 15.60 g AN/KGCSDM in trial 1.

All steers were fed corn silage rations during the growing phase until their respective pen had an average weight of approximately 372 kg. At that time, 2 steers were randomly selected from that pen for intermediate slaughter and the remaining 7 were switched to a corn-corn silage finishing ration containing 77% high-moisture whole corn on a DM basis. The finishing ration initially contained 27% high-moisture corn on a DM basis and the amount of corn was increased 5% per day over a 10-day period until it reached 77%. Cattle received the same respective AN and monensin treatments during both the growing and finishing phases.

The crude protein levels in the growing and finishing rations were: 8.5 and 10.5, 10.5 and 10.8, and 12.3 and 11.4 for the 0, 7.90, and 15.70 g AN/KGCSDM treatments, respectively. All rations contained similar levels of trace mineral salt (.25%) and vitamins A and D (3307 and 331 I.U./kg, respectively). Growing and finishing rations contained .60% and .46% calcium, respectively, and .35% and .36% phosphorous, respectively. Supplement composition for trial 2 is listed in Table 5.

Management Procedures

Within 12 hours of arrival to the MSU Beef Cattle Research Center, all steers were tattooed, ear-tagged and vaccinated for pasteurella, IBR, BVD and PI_3. All cattle were injected with 2 million I.U. of vitamin A.

At the onset of the experiment, cattle in trial 1 were implanted and were reimplanted after being on feed for 111 days with Ralgro.

Table 5.--Supplement Composition for Trial 2 (DM Basis)

Ingredient	Supplement no.					
	I	II	III	IV	V	VI
Crude protein content of supplement, %	5.25	4.95	4.98	7.15	6.55	6.35
	% of DM					
Ground corn, dent yellow, US #2	46.74	46.30	45.85	64.93	64.62	64.31
Defluorinated phosphate	28.29	28.28	28.27	--	--	--
Calcium sulfate	14.14	14.13	14.13	--	--	--
Trace mineral salt	9.95	9.95	9.95	6.43	6.43	6.43
Rumensin 60 premix[a]	--	.46	.92	--	.32	.64
Vitamin A premix[b]	.44	.44	.44	.29	.29	.29
Vitamin D_3 premix[c]	.44	.44	.44	.29	.29	.29
Potassium chloride	--	--	--	2.32	2.31	2.31
Ground limestone	--	--	--	25.74	25.73	25.73

[a] 132.28 g monensin sodium per kg.

[b] 30,000 IU of Vitamin A/gram of premix.

[c] 3,000 IU of Vitamin D_3/gram of premix.

Steers in trial 2 were intiially implanted with DES and were reimplanted with Synovex-S when they were switched to the finishing ration.

Ration ingredients were mixed immediately prior to feeding in a horizontal batch mixer. Complete rations were fed once daily. Daily feed records were maintained and unconsumed feed was removed, weighed and the amount recorded. Sufficient feed was furnished so that bunks were nearly clean before each feeding.

Cattle were individually weighed at the beginning of each experiment and every 28 days thereafter until they were terminated from the study. Initial and final weights were taken after 16 hours without feed and water. Intermediate weights were taken after a 16-hour withdrawal from water only.

All cattle were group-fed and housed in concrete lots which were partially covered, and bedded with straw. Approximately one-half of the floor space of each pen was covered by a roof. Cattle in each pen had access to an automatic waterer.

Initial and Intermediate Slaughter Procedures

Initial slaughter calves were selected to be representative of those cattle placed on feed in both trials. Eight steers (four of each cattle type) were slaughtered at the beginning of trial 1 and nine steers were slaughtered at the onset of trial 2 to estimate initial body composition of their respective steer mates placed on experiment.

Trial 1 initial slaughter cattle were killed at a commercial packing plant (Walters Packing Plant, Coldwater, Michigan) located 105 km from the MSU Beef Cattle Research Center. Trial 2 initial slaughter cattle were killed at the MSU Meats Lab. Carcass composition of the initial slaughter group was estimated by analysis of the 9-10-11 rib cut from one side of each carcass (Hankins and Howe, 1946). Rib sections were removed and further processed at the MSU Meats Lab. The soft tissue portion of the 9-10-11 rib cut was ground five times through a .47 cm screen, thoroughly mixed, and a subsample (1 kg) was frozen (-20^{o}C) until analyzed for fat, protein (N x 6.25) and moisture. Total N was determined on a 1 g wet sample using a Technicon Auto-Kjeldahl System. After thawing, moisture content was determined by drying approximately 6 to 7 g in a 100^{o}C oven for 24 hours. Ether extractable fat was determined on the oven dried sample by the Goldfisch procedure. The following equations derived by Hankins and Howe (1946) were used to estimate carcass composition from composition of the rib cut:

$$y = .66x + 5.98$$

where: y = carcass protein (%) and
x = rib protein (%).

$$y = .77x + 2.82$$

where: y = carcass fat (%) and
x = rib fat (%).

Empty body composition was calculated from carcass composition using the following equations developed by Garrett and Hinman (1969):

$$y = .7772x + 4.456$$

where: y = empty body protein (%) and
x = carcass protein (%).

$$y = .9246x - .647$$

where: y = empty body fat (%) and
x = carcass fat (%).

Two steers were randomly selected from each pen in trial 2 for intermediate slaughter at the end of the growing phase. These cattle were killed at the MSU Meats Lab and body composition was determined by the specific gravity technique (Kraybill *et al.*, 1952).

$$\text{Specific gravity} = \frac{\text{carcass wt. in air}}{(\text{carcass wt. in air} - \text{carcass wt. in water})(\text{correction for water and carcass temp.})}$$

Weights were obtained on the chilled carcass in air and in water. A Toledo Pan Balance was mounted over a steel tank that had a diameter of 112 cm and a height of 183 cm. The tank was filled nearly full with water, and crushed ice was added to maintain the temperature of the water at $10^{\circ}C$ or lower. The front and rear quarters of the left side of each carcass were individually suspended from the balance and weighed while totally immersed under water. Carcass and water temperatures were obtained periodically. The following equations derived by Garrett and Hinman (1969) were used to estimate carcass composition from carcass density:

$$y = (20.0x - 18.57)(6.25)$$

where: y = carcass protein (%) and

x = carcass specific gravity.

$$y = 587.86 - 530.45x$$

where: y = carcass fat (%) and

x = carcass specific gravity.

Final Slaughter and Carcass Evaluation Procedures

In trial 1, Hereford and Charolais crossbred steers were slaughtered at average final shrunk weights of 436 and 523 kg, respectively.

In trial 2, cattle were slaughtered at an average final shrunk weight of 486 kg. Steers were withheld from feed and water for 16 hours before final weights were taken, and cattle in trial 1 were scanned over the 12th rib for fat thickness using an Ithaco Ultrasonic Scanprobe. Cattle were trucked 177 km to Dinner Bell Meats in Archbold, Ohio where they were slaughtered. Hot carcass weights were obtained and complete carcass data were collected by a USDA grader after the carcasses had been chilled for a minimum of 24 hours. Following grader evaluation, final body composition of each steer was determined by the specific gravity technique described earlier.

Net Energy Evaluation

Net energy values were computed for each protein treatment in trial 1 and for each of the treatments in trial 2 using the system developed by Lofgreen and Garrett (1968). Empty body weight and empty body composition were estimated from hot carcass weight and carcass density, respectively, using the following equations developed by Garrett and Hinman (1969):

$$y = 1.362x + 30.26$$

where: y = empty body weight (kg) and
x = hot carcass weight (kg).

$$y = (15.97x - 14.17)(6.25)$$

where: y = empty body protein (%) and
x = carcass specific gravity.

$$y = 551.38 - 498.5x$$

where: y = empty body fat (%) and
x = carcass specific gravity.

Protein and fat were assumed to contain 5686 kcal/kg (Garrett *et al.*, 1959) and 9367 kcal/kg (Blaxter and Rook, 1953), respectively. Net energy calculations were based on N.R.C. (1976) metabolizable energy values and dry matter intakes were not adjusted for loss of volatiles during DM determination.

Lofgreen and Garrett (1968) observed that it was possible to indirectly measure heat production (HP) at zero feed intake by deducting energy balance (EB) from metabolizable energy intake (ME), thus

$$HP = ME - EB.$$

These investigators also indicated that over the range from maintenance to *ad libitum* feed intake, there was a linear relationship between daily heat production and daily ME intake. By computing HP at *ad libitum* intake from the previously described equation and using 77 kcal as HP at zero ME intake, a regression equation describing the linear relationship between log(HP) and ME was established. This equation made it possible to determine the ME intake at which energy equilibrium could be achieved. Net energy values for maintenance (NE_m) and gain (NE_g) were determined using the following equations described by Lofgreen and Garrett (1968):

$$NE_m = \frac{77\ \text{kcal}}{\left(\frac{\text{ME intake required for energy equilibrium}}{\text{ME of ration}}\right)}$$

$$NE_g = \frac{\text{energy balance}}{\text{total DM intake} - \left(\frac{\text{ME intake required for energy equilibrium}}{\text{ME of ration}}\right)}$$

Economic Analyses

Economic analyses of the treatments fed in trials 1 and 2 were performed using feed ingredient prices that reflect current as well as historical market relationships. Corn silage was priced relative to the value of the corn it contained and was priced to yield equal earnings per hectare of land as grain production (Woody and Black, 1978). Non-feed costs were fixed at $0.33/head/day for all treatments and included interest on investment, housing and labor, and equipment for feeding, but did not include charges for death loss and marketing expenses.

Break-even prices for AN and SBM were computed based on performance obtained in trial 1 and were used to determine future profitability of the 15.60 g AN/KGCSDM, declining soy and constant soy treatments.

Nitrogen Balance

Trial Design

A metabolism study was conducted to evaluate the nitrogen status of eight Hereford steers (270 kg) fed the unsupplemented control, 7.80 g AN/KGCSDM or 15.60 g AN/KGCSDM treatments from feedlot trial 1. These treatments were fed with 33.0 ppm monensin or without monensin.

Steers were confined to individual stalls (91 x 244 cm) and were elevated approximately 30 cm above the floor on wooden platforms. Platforms were designed to make fecal collection possible without animal interference and a coarse mesh area in the center of the platform facilitated the collection of urine in a pan placed underneath. Steers were fed twice daily at 12-hour intervals and had free access to water.

Cattle were adjusted to each ration for 21 days prior to collection. Each collection period had a duration of 8 days, with fecal and urine output measured, recorded and sampled daily. Prior to each collection period, animals were allowed one day of rest before being adjusted to the next treatment for 21 days. Nitrogen balance was expressed as total nitrogen intake - (fecal N + urinary N).

Sample Collection and Preparation

Total fecal output was collected on large plastic sheets placed directly behind each steer at floor level. Feces were removed each day, weighed, and a 10% subsample secured. Subsamples were composited for each steer at the end of each collection period. The composite samples were thoroughly mixed, and 10% of the composite was frozen for later analysis.

Urine was collected in the bottom sections of 208 liter drums in containers that had a capacity of approximately 30 liters. The urine collection pans were of such dimension that they would fit directly under the mesh area of the wooden platforms. Prior to placing the urine collection pans under the platforms, 400 ml of 6N hydrochloric acid was added to prevent escape of ammonia or other nitrogenous compounds from the urine, and the collection pans were covered with wire screening to prevent contamination of the urine by foreign material. Urine was collected daily and the volume per steer was recorded. If the volume was less than 10 liters, urine was diluted to that volume with water. A 10% subsample was secured each day, and at the end of the 8-day collection subsamples were composited for each steer. Composite samples were thoroughly mixed and a 10% aliquot was frozen for later analysis.

Ration grab samples were obtained at each feeding as the feed was discharged from a small horizontal mixer. Feed samples were composited for each steer at the end of the collection period, chopped in a Hobart food chopper, and a 1 kg subsample was frozen for later analysis.

Nitrogen and DM Determination

Total nitrogen content of feed, feces and urine samples were determined on wet samples using the Technicon Auto-Kheldahl System. Dry matter of feed and fecal samples were obtained by drying in a 60^{o}C oven for 48 hours.

Data Calculation and Statistical Analysis

In feedlot trials 1 and 2, average daily gain was based on an adjusted final liveweight which was calculated by dividing the hot carcass weight of each steer by the mean dressing percentage for that trial (Goodrich and Meiske, 1971). High-moisture corn and corn silage dry matter intakes were adjusted by multiplicative factors of 1.03 and 1.068, respectively, to correct for loss of volatiles during DM determination in a 60^{o}C oven (Fox and Fenderson, 1978).

Analysis of variance (Snedecor and Cochran, 1967) was used to examine main effects and interactions for average daily gain (ADG), average daily dry matter intake (ADDMI), relative dry matter intake (RELDMI) which represents g of dry matter intake/kg of weight $^{.75}$, feed efficiency (F/G), net energy values, nitrogen balance and N retained/N intake. Least squares analyses (Snedecor and Cochran, 1967) were used to examine main effects and interactions on carcass quality, yield and body composition parameters. The model included final warm carcass weight as a continuous covariate across all treatments. Least squares analyses were also used to determine the effect of various ammonia and mineral treatments at the time of ensiling on silage characterization. When appropriate, orthogonal contrasts (Snedecor and Cochran, 1967) were designed for comparing selected treatment combinations of primary interest. If $P < .20$, the level of statistical significance was reported. If this level of statistical significance existed for a given trait in consecutive studies, it would be significant for the pooled data (Gill, 1979; Black and Harpster, 1978). It is not claimed that these values are significant, but rather are candidates for being significant if the results were repeated in a large number of trials. Procedures for pooling data from independent experiments have been described by Black and Harpster (1978).

RESULTS AND DISCUSSION

Silage Characterization

Characterizations of the silages fed in trials 1 and 2 are listed in Tables 6 and 7, respectively. Orthogonal contrasts were constructed for the treatment combinations of primary interest to determine whether differences between treatments were statistically significant. These contrasts and their respective results are presented in Tables 8 and 9, respectively.

Trial 1

In Table 8, contrast 1 reveals that AN treatment of corn silage resulted in increased crude protein ($P < .0005$), soluble nitrogen ($P = .022$), lactate ($P = .086$), acetate ($P = .011$), propionate ($P = .027$), butyrate ($P = .004$) and pH ($P = .013$). These results are in agreement with previous research which has shown that compared to untreated silage, those treated with ammonia solutions are higher in lactate and insoluble nitrogen (Cash, 1972; Huber *et al*., 1973; Huber, 1975). The higher levels of lactate and volatile fatty acids and higher pH of the AN treated silages suggest that the ammonia buffered and prolonged fermentation. Ammonia treatment resulted in no significant difference ($P > .20$) in acid detergent fiber content.

Contrast 2 shows that silage treated with 15.60 g AN/KGCSDM had more crude protein ($P < .0005$), soluble nitrogen ($P < .0005$), insoluble nitrogen ($P = .014$), acetate ($P = .037$), propionate ($P = .016$),

Table 6.--Effect of Treatment on Silage Characteristics (Trial 1)

Item	Silage treatment				
	Untreated control	7.80 g AN/KGCSDM	15.60 g AN/KGCSDM	15.60 g AN/KGCSDM + minerals	15.60 g AN/KGCSDM + $Ca(OH)_2$
Treatment no.	1	2	3	4	5
Dry matter at time of feeding, %	34.68	32.07	31.78	32.14	32.36
Crude protein, %	7.75	9.78	12.41	12.51	12.78
Soluble nitrogen[a]	.60	.90	1.22	1.24	1.13
Insoluble nitrogen[a]	.64	.66	.77	.76	.91
Lactate[a]	3.85	5.50	5.43	6.29	4.27
Acetate[a]	1.94	2.20	2.43	2.50	3.17
Propionate[a]	.01	.02	.04	.03	.19
Butyrate[a]	<.01	<.01	.06	.19	3.80
pH	3.90	4.14	4.50	4.32	5.32
Acid detergent fiber, %	27.37	26.18	26.98	26.70	29.12
Nitrogen recovery values of ammonia treated silage					
Uncorrected for VFA loss	--	72.00	75.95	73.00	76.62
Corrected for VFA loss[b]	--	60.18	70.22	66.60	70.63

[a]These values are reported as grams/100 grams of dry matter.

[b]Fox and Fenderson (1978).

Table 7.--Effect of Anhydrous Ammonia Treatment on Silage Characteristics (Trial 2)

Item	Level of anhydrous ammonia treatment		
	0 g AN/KGCSDM	7.90 g AN/KGCSDM	15.70 g AN/KGCSDM
Dry matter at time of feeding, %	31.27	31.16	30.94
Crude protein, %	8.81	9.82	10.82
Soluble nitrogen[a]	.66	.68	.70
Insoluble nitrogen[a]	.75	.89	1.03
Lactate[a]	4.91	7.36	8.04
Acetate[a]	2.57	3.00	3.41
Propionate[a]	.60	.18	.16
Butyrate[a]	.11	.20	.20
pH	4.16	3.94	4.01
Acid detergent fiber, %	27.99	26.51	28.36
Nitrogen recovery values of ammonia treated silage			
Uncorrected for VFA loss	-	87.10	63.60
Corrected for VFA loss[b]	-	76.65	58.74

[a]These values are reported as grams/100 grams of dry matter.

[b]Fox and Fenderson (1978).

Table 8.--Orthogonal Contrasts for Selected Treatment Comparison of Silage Characteristics (Trial 1)[a]

Item	Orthogonal contrast			
	(1) Untreated control (T_1) vs. ammonia treated silages (T_2 ... T_5)	(2) 7.80 g AN/KGCSDM (T_2) vs. 15.60 g AN/KGCSDM (T_3)	(3) 15.60 g AN/KGCSDM (T_3) vs. 15.60 g AN/KGCSDM + minerals and 15.60 g AN/KGCSDM + $Ca(OH)_2$ (T_4, T_5)	(4) 15.60 g AN/KGCSDM + minerals (T_4) vs. 15.60 g AN/KGCSDM + $Ca(OH)_2$ (T_5)
Dry matter at time of feeding, %	34.68 vs. 32.09 (<.0005)	32.07 vs. 31.78 (NS)	31.78 vs. 32.25 (NS)	32.14 vs. 32.36 (NS)
Crude protein, %	7.75 vs. 11.87 (<.0005)	9.78 vs. 12.41 (<.0005)	12.41 vs. 12.64 (NS)	12.51 vs. 12.78 (NS)
Soluble nitrogen[b]	.60 vs. 1.12 (<.0005)	.90 vs. 1.22 (<.0005)	1.22 vs. 1.18 (NS)	1.24 vs. 1.13 (.028)
Insoluble nitrogen[b]	.64 vs. .78 (.022)	.66 vs. .77 (.014)	.77 vs. .84 (.190)	.76 vs. .91 (.015)
Lactate[b]	3.85 vs. 5.37 (.086)	5.50 vs. 5.43 (NS)	5.43 vs. 5.28 (NS)	6.29 vs. 4.27 (.047)
Acetate[b]	1.94 vs. 2.58 (.011)	2.20 vs. 2.43 (.037)	2.43 vs. 2.84 (.089)	2.50 vs. 3.17 (.019)
Propionate[b]	.01 vs. .07 (.027)	.02 vs. .04 (.016)	.04 vs. .11 (.006)	.03 vs. .19 (<.0005)
Butyrate[b]	<.01 vs. 1.01 (.004)	<.01 vs. .06 (<.0005)	.06 vs. 2.00 (<.0005)	.19 vs. 3.80 (<.0005)
pH	3.90 vs. 4.57 (.013)	4.14 vs. 4.50 (.028)	4.50 vs. 4.82 (NS)	4.32 vs. 5.32 (.001)
Acid detergent fiber, %	27.37 vs. 27.24 (NS)	26.18 vs. 26.98 (.196)	26.98 vs. 27.91 (NS)	26.70 vs. 29.12 (.080)

[a]Subscripts following the "T's" in parentheses correspond to the treatment numbers in Table 6 and denote the treatments involved in the contrast. NS = Not statistically different; $P > .20$.

[b]These values are reported as grams/100 grams of dry matter.

Table 9. --Orthogonal Contrasts for Selected Comparisons of Silage Characteristics (Trial 2)[a]

Item	Contrast: No anhydrous ammonia (0 g AN/KGCSDM) vs. with anhydrous ammonia (7.90 g AN/KGCSDM, 15.70 g AN/KGCSDM)	Contrast: 7.90 g AN/KGCSDM vs. 15.70 g AN/KGCSDM
Dry matter at time of feeding, %	31.27 vs. 31.05 (NS)	31.16 vs. 30.94 (NS)
Crude protein, %	8.81 vs. 10.32 (.001)	9.82 vs. 10.82 (.025)
Soluble nitrogen[b]	.66 vs. .69 (.003)	.68 vs. .70 (.074)
Insoluble nitrogen[b]	.75 vs. .96 (NS)	.89 vs. 1.03 (NS)
Lactate[b]	4.91 vs. 7.70 (<.0005)	7.36 vs. 8.04 (NS)
Acetate[b]	2.57 vs. 3.20 (NS)	3.00 vs. 3.41 (NS)
Propionate[b]	.60 vs. .17 (.005)	.18 vs. .16 (NS)
Butyrate[b]	.11 vs. .20 (.004)	.20 vs. .20 (NS)
pH	4.16 vs. 3.98 (NS)	3.94 vs. 4.01 (NS)
Acid detergent fiber, %	27.99 vs. 27.44 (NS)	26.51 vs. 28.36 (.023)

[a]NS = Not statistically different; $P > .20$.

[b]These values are reported as grams/100 grams of dry matter.

butyrate (P < .0005), slightly more acid detergent fiber (P = .196) and a higher pH (P = .028) than silage treated with 7.80 g AN/KGCSDM. There was no significant difference in the level of lactate (P > .20). While 15.60 g AN/KGCSDM appears to have resulted in greater buffering of the fermentation process than 7.80 g AN/KGCSDM as evidenced by the higher pH, lactate production was unchanged.

Contrast 3 compares the silage characteristics resulting from treatment with 15.60 g AN/KGCSDM to silage treated with the same level of AN to which a complete mineral mix or calcium hydroxide were added at the time of ensiling. Addition of these materials resulted in more acetate (P = .089), propionate (P = .006) and butyrate (P < .0005). Silages to which the mineral mix or calcium hydroxide were added at the time of ensiling also had slightly more insoluble nitrogen (P = .190). There was no significant difference (P > .20) in the level of crude protein, soluble nitrogen, lactate, pH or acid detergent fiber.

Contrast 4 compares the effects on silage characterization of adding a complete mineral mix or calcium hydroxide at the time of ensiling to silage treated with 15.60 g AN/KGCSDM. Silage to which calcium hydroxide had been added contained less soluble nitrogen (P = .028) and lactate (P = .047), but had more insoluble nitrogen (P = .015), acetate (P = .019), propionate (P < .0005), butyrate (P < .0005), acid detergent fiber (P = .080) and a higher pH (P = .001).

All silages in trial 1 were very uniform in crude protein and DM composition (6.9% and 33%, respectively) at the time of harvest.

Trial 2

Addition of AN resulted in higher levels of crude protein (P = .001), soluble nitrogen (P = .003), lactate (P < .0005) and butyrate (P = .004), but no significant difference (P > .20) in acid detergent fiber (Table 9). These results are in agreement with those obtained for trial 1. However, in trial 1, AN treatment resulted in higher levels of insoluble nitrogen (P = .022), acetate (P = .011), propionate (P = .027) and pH (P = .013), but in trial 2, AN treatment resulted in no significant difference (P > .20) in insoluble nitrogen, acetate or pH and lower levels of propionate (P = .005).

Silage treated with 15.70 g AN/KGCSDM contained more crude protein (P = .025), soluble nitrogen (P = .074) and acid detergent fiber (P = .023) than silage treated with 7.90 g AN/KGCSDM. There were no significant differences in the levels of insoluble nitrogen, lactate, acetate, propionate, butyrate or pH. Lactate production was not significantly improved by increasing the level of AN treatment from 7.90 to 15.70 g AN/KGCSDM. Similar results were obtained in trial 1.

In comparing the effects of AN treatment on silage characteristics between trials 1 and 2, it is important to note that all silages in trial 1 were very uniform in DM and crude protein composition (33% and 6.9%, respectively) at the time of harvest. In trial 2, all silages were harvested at similar levels of DM content (32%) but varied in crude protein content. Silages treated with 0, 7.80, and 15.60 g AN/KGCSDM contained 8.5, 6.2, and 5.9 percent crude protein, respectively, at the time of ensiling. Therefore, these differences must be considered when interpreting the contrasts in Table 9 and comparing results between trials 1 and 2. Bias in trial 2 was against the AN treated silages and least favored the 15.70 g AN/KGCSDM treatment. Therefore, in instances where this silage treatment was superior, it would be expected to have even greater superiority if all silages contained the same level of crude protein at ensiling.

Nitrogen recovery values for AN treated silages are listed in Tables 6 and 7. These values ranged from 58.74% to 76.65% when corrected for loss of volatiles during DM determination (Fox and Fenderson, 1978).

Feedlot Trial 1

Feedlot Performance

Summaries of the performance obtained from each protein treatment for the Hereford and Charolais crossbred steers are reported in Tables 10 and 11, respectively. Since there were no interactions between protein treatment and cattle type, cattle types were pooled within each protein treatment and the pooled data appear in Table 12. The supplement numbers listed in Tables 9, 10 and 11 correspond to those in Table 4. Seven orthogonal contrasts were constructed for the treatment combinations of primary interest to determine whether differences in animal performance were statistically significant. These contrasts and their respective results are presented in Table 13.

Examination of contrast 1 reveals that cattle that received supplemental protein had a 44.3% higher ADG ($P < .0005$), an 11.1% higher ADDMI ($P = .001$) and required 22.6% less feed per unit of gain ($P < .0005$). There was no significant difference in RELDMI ($P > .20$). These results

Table 10.--Effect of Source and Level of Supplemental Protein on Performance of Hereford Steers (Trial 1)[a]

Item	Protein treatment							
	Unsupplemented control	7.80 g AN/KGCSDM	7.80 g AN/KGCSDM + soy	15.60 g AN/KGCSDM	15.60 g AN/KGCSDM + minerals	15.60 g AN/KGCSDM + $Ca(OH)_2$	Declining soy	Constant soy
Treatment no.	1	2	3	4	5	6	7	8
Crude protein in ration (DM basis), %	7.50	9.49	12.14→9.66	12.19	12.36	12.50	12.64→11.61→10.60	12.57
Initial wt., kg[b]	225	222	225	224	222	223	223	225
Final wt., kg[c]	379	417	440	445	430	435	471	474
Days on feed	279	279	279	265	279	265	265	265
Average daily gain, kg	.55	.70	.77	.84	.74	.80	.93	.94
Average daily DM intake, kg	5.61	6.22	6.18	6.46	5.95	6.15	6.76	6.60
Corn silage[d]	5.46	6.06	5.90	6.29	5.88	6.00	6.09	5.72
Supplement I	.15	.16	.18	.17	--	--	.17	--
Supplement II	--	--	--	--	--	--	--	.88
Supplement III	--	--	.44[e]	--	--	--	--	--
Supplement IV	--	--	--	--	.07	--	--	--
Supplement V	--	--	--	--	--	.15	--	--
Supplement VI	--	--	--	--	--	--	.50	--
RELDMI, grams/wt.$^{.75}_{kg}$	77.4	82.4	79.5	82.7	77.7	79.7	84.1	81.8
F/G	10.14	8.88	8.04	7.72	8.01	7.68	7.23	7.01
Carcass fat, %[f]	25.0	26.1	27.4	28.4	26.8	25.8	27.4	27.7

[a]There were eight Hereford steers on each protein treatment.

[b]Initial wts. were taken after 16 hours without feed and water.

[c]Final wts. were adjusted to a constant dressing percentage of 59.36 using the following formula:

$$\text{final wt.} = \frac{\text{hot carcass wt.}}{.5936}$$

[d]Corn silage DM intakes were multiplied by a factor of 1.068 to compensate for loss of volatiles during DM determination in a 60° C oven (Fox and Fenderson, 1978).

[e]Supplement III was fed for the first 111 days and Supplement I was fed for the remainder of the feeding period.

[f]Carcass fat was determined by the specific gravity technique (Kraybill _et al._, 1952).

Table 11.--Effect of Source and Level of Supplemental Protein on Performance of Charolais Crossbred Steers (Trial 1)[a]

Item	Protein treatment							
	Unsupplemented control	7.80 g AN/KGCSDM	7.80 g AN/KGCSDM + soy	15.60 g AN/KGCSDM	15.60 g AN/KGCSDM + minerals	15.60 g AN/KGCSDM + $Ca(OH)_2$	Declining soy	Constant soy
Treatment no.	1	2	3	4	5	6	7	8
Crude protein in ration (DM basis), %	7.50	9.49	12.14→9.66	12.19	12.36	12.50	12.64→11.61→10.60	12.57
Initial wt., kg[b]	291	288	298	293	298	293	291	295
Final wt., kg[c]	479	527	525	543	518	529	533	531
Days on feed	279	265	265	252	252	252	230	230
Average daily gain, kg	.68	.90	.86	.99	.87	.94	1.05	1.03
Average daily DM intake, kg	6.83	7.35	7.17	8.08	7.02	7.30	8.02	7.43
Corn silage[d]	6.65	7.16	6.83	7.88	6.93	7.12	7.20	6.43
Supplement I	.18	.19	.20	.20	--	--	.21	--
Supplement II	--	--	--	--	--	--	--	1.00
Supplement III	--	--	.53[e]	--	--	--	--	--
Supplement IV	--	--	--	--	.09	--	--	--
Supplement V	--	--	--	--	--	.18	--	--
Supplement VI	--	--	--	--	--	--	.61	--
RELDMI, grams/wt.$_{kg}^{.75}$	78.7	81.1	78.6	87.5	77.3	80.0	87.8	81.1
F/G	10.13	8.18	8.36	8.12	8.06	7.79	7.63	7.23
Carcass fat, %[f]	24.8	25.0	25.7	29.0	28.1	25.6	25.8	25.4

[a]There were eight Charolais crossbred steers on each protein treatment

[b]Initial wts. were taken after 16 hours without feed and water.

[c]Final wts. were adjusted to a constant dressing percentage of 59.36 using the following formula:

$$\text{final wt.} = \frac{\text{hot carcass wt.}}{.5936}$$

[d]Corn silage DM intakes were multiplied by a factor of 1.068 to compensate for loss of volatiles during DM determination in a 60° C oven (Fox and Fenderson, 1978).

[e]Supplement III was fed for the first 111 days and Supplement I was fed for the remainder of the feeding period.

[f]Carcass fat was determined by the specific gravity technique (Kraybill *et al.*, 1952).

Table 12.--Effect of Source and Level of Supplemental Protein on Performance (Trial 1)[a]

Item	Protein treatment							
	Unsupplemented control	7.80 g AN/KGCSDM	7.80 g AN/KGCSDM + soy	15.60 g AN/KGCSDM	15.60 g AN/KGCSDM + minerals	15.60 g AN/KGCSDM + $Ca(OH)_2$	Declining soy	Constant soy
Treatment no.	1	2	3	4	5	6	7	8
Crude protein in ration (DM basis), %	7.50	9.49	12.14→9.66	12.19	12.36	12.50	12.64→11.61→10.60	12.57
Initial wt., kg[b]	258	255	261	258	260	258	257	260
Final wt., kg[c]	429	472	482	494	474	482	502	502
Days on feed	279.0	272.0	272.0	258.5	265.5	258.5	247.5	247.5
Average daily gain, kg	.61	.80	.81	.92	.81	.87	.99	.98
Average daily DM intake, kg	6.22	6.79	6.68	7.27	6.49	6.73	7.39	7.01
Corn silage[d]	6.06	6.61	6.37	7.08	6.41	6.57	6.65	6.07
Supplement I	.16	.18	.19	.19	--	--	.19	--
Supplement II	--	--	--	--	--	--	--	.94
Supplement III	--	--	.49[e]	--	--	--	--	--
Supplement IV	--	--	--	--	.08	--	--	--
Supplement V	--	--	--	--	--	.16	--	--
Supplement VI	--	--	--	--	--	--	.55	--
RELDMI, grams/wt.$^{.75}_{kg}$	78.1	81.6	79.0	85.2	77.4	79.8	86.1	81.4
F/G	10.14	8.53	8.20	7.92	8.04	7.74	7.43	7.12
Carcass fat, %[f]	24.9	25.6	26.6	28.7	27.4	25.7	26.6	26.6

[a]There were eight Hereford and eight Charolais crossbred steers on each protein treatment.

[b]Initial wts. were taken after 16 hours without feed and water.

[c]Final wts. were adjusted to a constant dressing percentage of 59.36 using the following formula:

$$\text{final wt.} = \frac{\text{hot carcass wt.}}{.5936}$$

[d]Corn silage DM intakes were multiplied by a factor of 1.068 to compensate for loss of volatiles during DM determination in a 60° C oven (Fox and Fenderson, 1978).

[e]Supplement III was fed for the first 111 days and Supplement I was fed for the remainder of the feeding period.

[f]Carcass fat was determined by the specific gravity technique (Kraybill et al., 1952).

Table 13.--Orthogonal Contrasts for Selected Treatment Comparisons of Performance (Trial 1)[a]

No.	Contrast	ADG (kg)	ADDMI[b] (kg)	RELDMI (grams/wt.$_{kg}^{.75}$)	F/G
1	No supplemental protein (T_1) vs. supplemental protein (T_2 ... T_8)	.61 vs. .88 (<.0005)	6.22 vs. 6.91 (.001)	78.1 vs. 81.5 (NS)	10.14 vs. 7.85 (<.0005)
2	High protein (T_4 ... T_8) vs. low protein (T_2, T_3)	.91 vs. .80 (<.0005)	6.98 vs. 6.74 (.039)	82.0 vs. 80.3 (NS)	7.65 vs. 8.37 (.002)
3	7.80 g AN/KGCSDM (T_2) vs. 7.80 g AN/KGCSDM + Soy (T_3)	.80 vs. .81 (NS)	6.79 vs. 6.68 (NS)	81.6 vs. 79.0 (NS)	8.53 vs. 8.20 (NS)
4	15.60 g AN/KGCSDM (T_4) vs. 15.60 g AN/KGCSDM + minerals (T_5)	.92 vs. .81 (.016)	7.27 vs. 6.49 (.002)	85.2 vs. 77.4 (.022)	7.92 vs. 8.04 (.002)
5	15.60 g AN/KGCSDM (T_4, T_5) vs. 15.60 g AN/KGCSDM + $Ca(OH)_2$(T_6)	.86 vs. .87 (NS)	6.88 vs. 6.73 (NS)	81.3 vs. 79.8 (NS)	7.98 vs. 7.74 (NS)
6	Soybean meal (T_7, T_8) vs. 15.60 g AN/KGCSDM (T_4, T_5, T_6)	.98 vs. .86 (<.0005)	7.20 vs. 6.83 (.009)	83.7 vs. 80.8 (NS)	7.28 vs. 7.90 (.007)
7	Declining soy (T_7) vs. constant soy (T_8)	.99 vs. .98 (NS)	7.39 vs. 7.01 (.055)	86.0 vs. 81.4 (.120)	7.43 vs. 7.12 (NS)

[a]The subscripts following the "T's" in parentheses correspond to the treatment numbers in Table 12 and denote the treatments involved in the contrast. NS = not statistically different; $P > .20$.

[b]Dry matter intake of corn silage was adjusted using a correction factor of 1.068 to account for loss of volatiles during DM determination in a 60° oven (Fox and Fenderson, 1978).

are consistent with the literature and correspond quite closely to results obtained by Preston (1974), who showed that steer calves (174 kg) receiving a corn silage ration supplemented with nitrogen had a 44% higher ADG and required 25% less feed per unit gain than steers that received no supplemental protein.

In contrast 2, the performance of steers receiving a high level of supplemental protein (12.5%) was compared to that of steers receiving a low level of supplemental protein (10%). Cattle that received the high level of supplementation gained 13.8% faster ($P < .0005$), had a 3.6% higher ADDMI ($P = .039$) and an 8.6% lower F/G ($P = .002$).

The feasibility of the "half-treat" system is examined in contrast 3. Since the protein requirement is thought to decrease on a percentage basis as cattle become heavier (Fox et al., 1977a), it was anticipated that cattle could be fed silage treated with 7.80 g AN/KGCSDM with SBM supplementation during the initial phase of the feeding period only, when they had an equivalent weight less than 318 kg. Such a feeding system was expected to produce superior performance to feeding corn silage treated with 7.80 g AN/KGCSDM without SBM supplementation and equivalent performance to SBM supplementation of untreated corn silage to yield an equivalent percentage of crude protein in the ration. Bergen et al. (1978) noted that it was unlikely that cattle started on feed as calves could generate sufficient microbial protein from the "full-treat" silage (15.60 g AN/KGCSDM) to meet their initial protein requirement. Therefore, it would seem warranted to feed a supplemental source of higher quality preformed protein during the initial phase that could at least partially escape rumen degradation to ammonia. The results of this trial do not support this contention and are inconsistent with the results of an earlier study by Cook and Fox (1977). Figures 1 and 2 graphically compare the 7.80 g AN/KGCSDM and 7.80 g AN/KGCSDM + soy treatments for the study by Cook and Fox (1977) and this trial, respectively. In the earlier study (Cook and Fox, 1977), cattle receiving the 7.80 g AN/KGCSDM + soy treatment had a 31% higher overall ADG than those cattle receiving silage treated with the same level of AN without SBM supplementation. In Figure 2, it appears that cattle that received SBM supplementation during the initial part of the feeding period maintained a superior level of performance when SBM was included in the ration. However, after the cattle reached an equivalent weight of 318 kg and SBM was removed from the diet, cattle not receiving SBM supplementation earlier tended to compensate later in the feeding period, and as a result, overall performance was equivalent. It is possible that the differing responses between the two trials may be related to use of monensin sodium which was fed in this trial but not by Cook and Fox (1977). Dartt et al. (1978) and Perry et al. (1979) have concluded that monensin may have a protein sparing effect on diets borderline to deficient in protein. This may explain why cattle receiving 7.80 g AN/KGCSDM + soy did not perform significantly better than those receiving the 7.80 g AN/KGCSDM treatment in trial 1. In Figure 1, where monensin was not fed, most of the difference in performance between the two treatments was obtained before the cattle reached an equivalent weight of 318 kg, and this difference was maintained

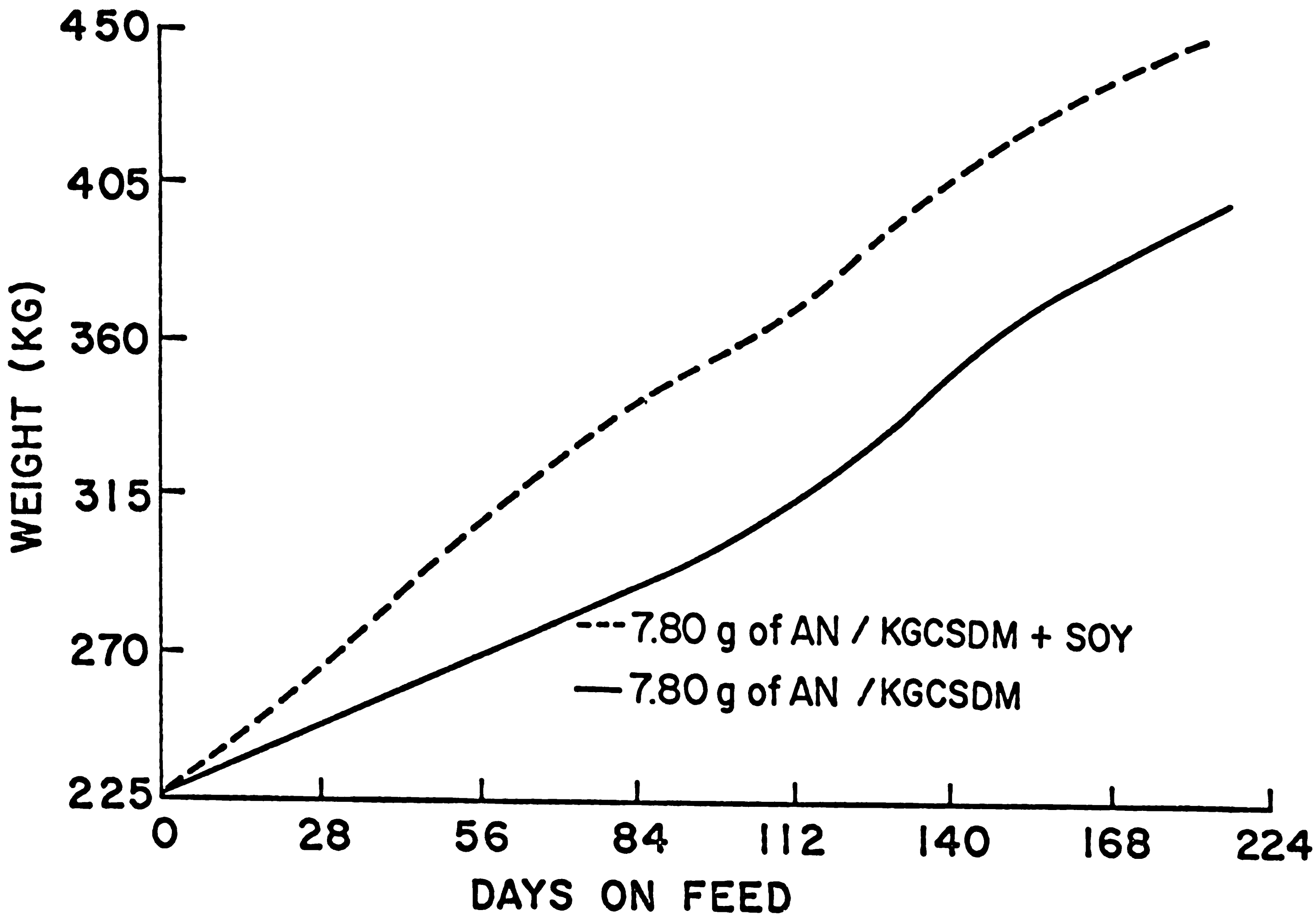

FIGURE 1.--EFFECT OF SUPPLEMENTING ANHYDROUS AMMONIA TREATED CORN SILAGE WITH SBM UNTIL THE CATTLE REACHED AN EQUIVALENT WEIGHT OF 318 KG (COOK AND FOX, 1977)

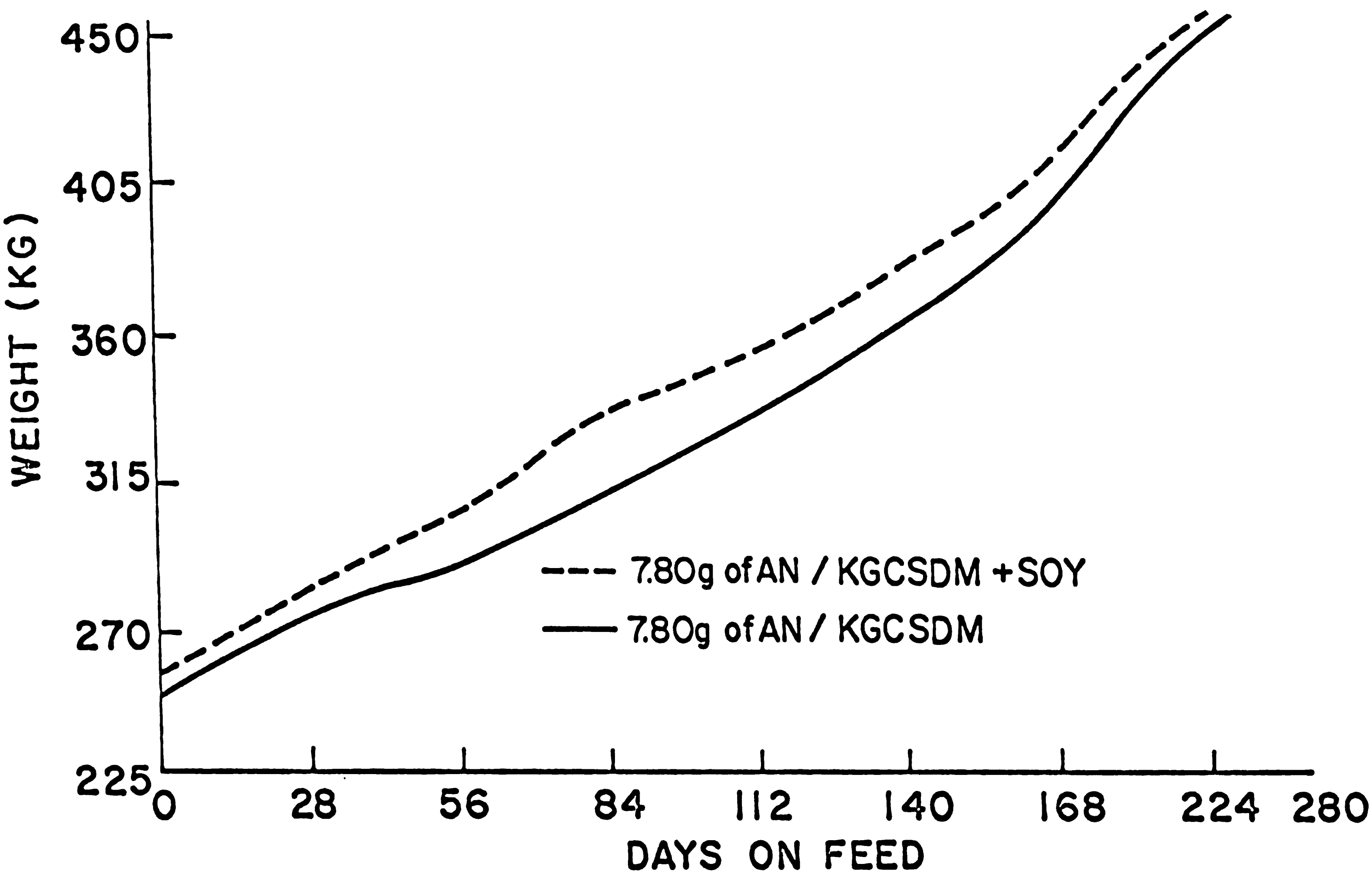

FIGURE 2.--EFFECT OF SUPPLEMENTING ANHYDROUS AMMONIA TREATED CORN SILAGE WITH SBM UNTIL THE CATTLE REACHED AN EQUIVALENT WEIGHT OF 318 KG (TRIAL 1)

throughout the remainder of the feeding period. In Figure 2, where monensin was fed, differences between the two treatments were of smaller magnitude when the cattle reached an equivalent weight of 318 kg and performance was equivalent at the end of the feeding period. Monensin may have had a protein sparing effect on the 7.80 g AN/KGCSDM treatment that resulted in similar performance to feeding a higher level of supplemental protein during the initial part of the feeding period.

Contrast 4 reveals that addition of the mineral mix to the ammonia treated silage at ensiling resulted in no improvement in animal performance. Addition of the mineral mix at ensiling resulted in a 12.0% lower ADG ($P = .016$), 10.7% lower ADDMI ($P = .002$), a 9.2% lower RELDMI ($P = .022$) and a 1.5% higher F/G ($P = .002$).

Analysis of contrast 5 reveals that addition of calcium hydroxide to the ammonia treated silage at the time of ensiling resulted in no significant change in animal performance ($P > .20$).

Performance of steers that were on the declining or constant soy treatments is compared with that of cattle receiving silage treated with 15.60 g AN/KGCSDM in contrast 6. Cattle receiving untreated corn silage supplemented with SBM had a 14.0% higher ADG ($P < .0005$), a 5.4% higher ADDMI ($P = .009$) and consumed 7.8% less DM per kg of gain ($P = .007$). There was no significant difference in RELDMI ($P > .20$). The constant soy and 15.60 g AN/KGCSDM treatments are graphically compared in Figure 3. Cattle receiving the AN treated silage gained at a similar level as the cattle supplemented with SBM during the last

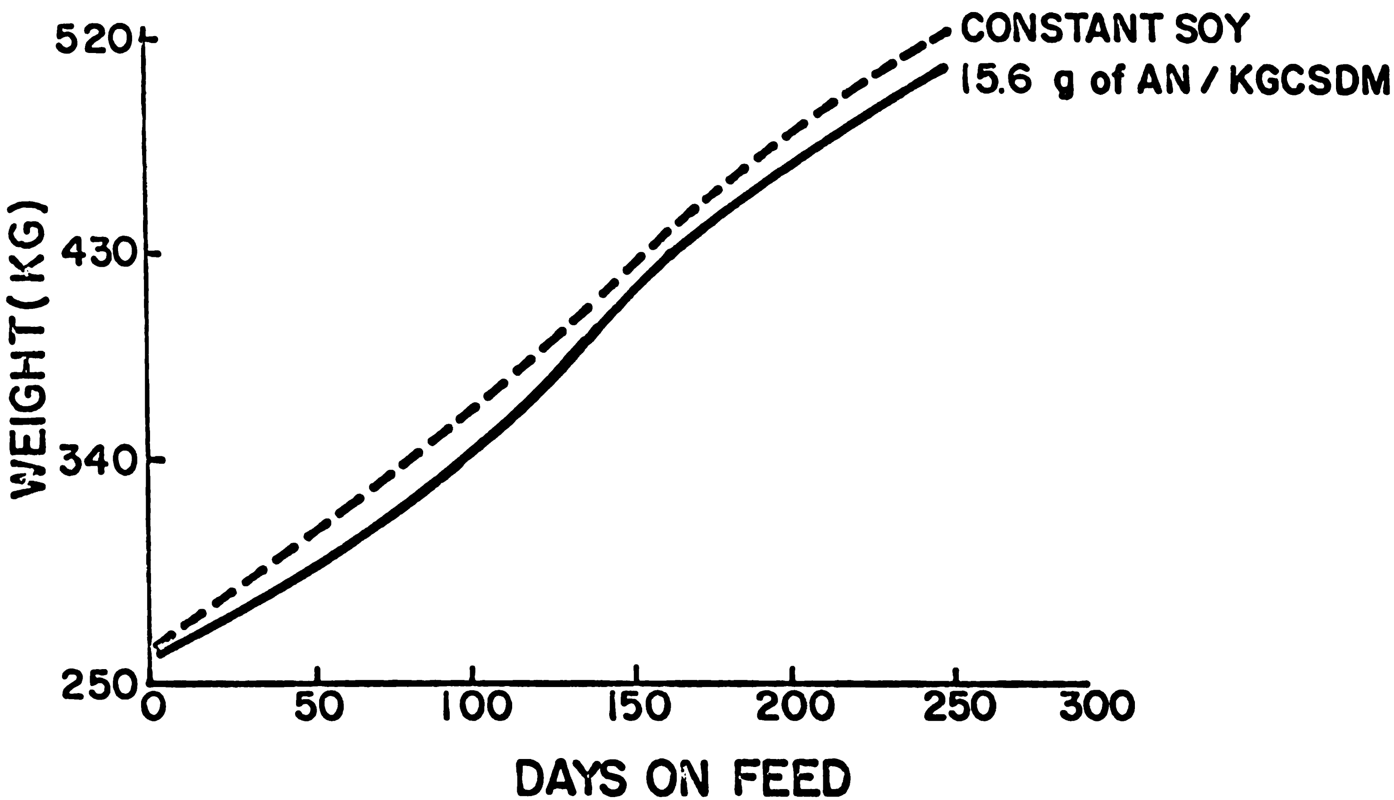

FIGURE 3.--EFFECT OF NITROGEN SOURCE ON ANIMAL PERFORMANCE

half of the feeding period, but they did not fully compensate for their poorer initial performance.

Performance of steers that received the declining soy and constant soy treatments is compared in contrast 7. Cattle on the declining soy system had a 5.4% higher ADDMI (P = .055) and a 5.7% higher RELDMI (P = .120). There were no significant differences (P > .20) in ADG or F/G. Similar results were obtained in a study by Cook and Fox (1977).

Feedlot performance of the Hereford and Charolais crossbred steers is summarized across all treatments by cattle type in Table 14. Charolais crossbred steers had a 16.7% higher ADG (P < .0005) and an 18.6% higher ADDMI (P < .0005) than did their Hereford counterparts. There were no significant differences (P < .20) in RELDMI, F/G or the percentage of carcass fat.

Carcass Parameters

Carcass data obtained from each protein treatment are listed for the Hereford and Charolais crossbred steers in Tables 15 and 16, respectively. Since there were no significant interactions between protein treatment and cattle type, cattle types were pooled within each protein treatment and the pooled data appear in Table 17. Orthogonal f-tests were performed on the carcass parameters using the same contrasts that were used to evaluate animal performance. These contrasts and their respective results are presented in Table 18.

Cattle that received no supplemental protein had smaller rib eye areas (P = .002) and higher numerical yield grades (P = .132) than those cattle that did not receive supplemental protein.

Table 14.--Effect of Cattle Type on Performance (Trial 1)[a]

Item	Cattle type: Hereford	Cattle type: Charolais	Statistical significance of difference[b]
Initial wt., kg[c]	224	293	<.0005
Final wt., kg[d]	436	523	<.0005
Days on feed	272	253	--
ADG, kg	.78	.91	<.0005
DM intake[e]			
ADDMI, kg/day	6.24	7.40	<.0005
RELDMI, grams/wt.$_{kg}^{.75}$	80.70	81.50	NS
F/G	8.09	8.19	NS
Carcass fat, %[f]	26.80	26.20	NS

[a]There were eight steers of each cattle type on each of eight protein treatments.

[b]NS = not statistically different; P > .20.

[c]Initial wt. was taken after 16 hr. without feed and water.

[d]Final wts. were adjusted to a constant dressing percentage of 59.36 using the following formula:

$$\text{final wt.} = \frac{\text{hot carcass wt.}}{.5936}$$

[e]Dry matter intake of corn silage was adjusted using a correction factor of 1.068 to account for loss of volatiles during DM determination in a 60°C oven (Fox and Fenderson, 1978).

[f]Carcass fat was determined by the specific gravity technique (Kraybill et al., 1952).

Table 15.--Effect of Source and Level of Supplemental Protein on Carcass Parameters of Hereford Steers (Trial 1)[a]

Parameter	Protein treatment							
	Unsupplemented control	7.80 g AN/KGCSDM	7.80 g AN/KGCSDM + soy	15.60 g AN/KGCSDM	15.60 g AN/KGCSDM + minerals	15.60 g AN/KGCSDM + $Ca(OH)_2$	Declining soy	Constant soy
Treatment no.	1	2	3	4	5	6	7	8
Dressing percentage	59.7	57.8	59.1	58.8	59.7	58.5	60.3	59.5
Maturity score[b]	2.4	2.4	2.3	2.0	2.4	2.4	2.3	2.5
Adj. fat thickness, cm	1.02	1.17	1.22	1.22	1.27	1.30	1.35	1.22
Ribeye area, cm^2	67.03	74.45	77.16	75.03	71.87	71.81	76.13	75.61
KPH fat, %	2.9	2.8	2.8	2.8	2.9	2.8	2.8	2.8
Marbling score[c]	6.7	7.3	7.2	10.3	8.5	8.6	9.3	8.5
Quality grade[d]	7.1	7.3	7.3	8.9	8.4	8.5	8.7	8.3
Yield grade	3.1	2.8	2.8	2.9	3.1	3.1	2.9	2.8
Carcass fat, %[e]	27.8	27.8	28.5	29.3	28.2	27.0	27.6	27.9

[a]There were 8 Hereford steers on each protein treatment. Carcass parameters were adjusted to a constant empty body weight of 382 kg which corresponds to a final shrunk wt of 436 kg.

[b]Maturity: A- = 1, A = 2, A+ = 3

[c]Marbling score: Slight- = 7; Slight = 8; Slight+ = 9, Small- = 10; Small = 11.

[d]Quality grade: Good- = 7; Good = 8; Good+ = 9, Choice- = 10.

[e]Carcass fat was determined by the specific gravity technique (Kraybill et al., 1952).

Table 16.--Effect of Source and Level of Supplemental Protein on Carcass Parameters of Charolais Crossbred Steers (Trial 1)[a]

Parameter	Protein treatment							
	Unsupplemented control	7.80 g AN/KGCSDM	7.80 g AN/KGCSDM + soy	15.60 g AN/KGCSDM	15.60 g AN/KGCSDM + minerals	15.60 g AN/KGCSDM + $Ca(OH)_2$	Declining soy	Constant soy
Treatment no.	1	2	3	4	5	6	7	8
Dressing percentage	59.9	59.6	59.7	59.3	59.2	59.2	59.7	60.5
Maturity score[b]	2.1	2.2	2.5	1.7	1.7	2.0	2.4	2.4
Adj. fat thickness, cm	.86	.64	.61	.86	.74	.56	.81	.51
Ribeye area, cm^2	76.65	73.87	82.26	81.55	81.74	81.87	81.48	80.52
KPH fat, %	2.6	2.8	2.8	2.9	3.1	2.9	2.9	2.8
Marbling score[c]	10.6	8.7	7.6	10.9	9.1	10.5	8.5	7.8
Quality grade[d]	9.4	8.3	7.6	9.8	8.7	9.3	8.2	7.9
Yield grade	2.4	2.4	1.9	2.2	2.1	1.9	2.1	1.9
Carcass fat, %[e]	24.8	23.7	24.4	27.3	27.1	24.2	24.3	24.0

[a]There were 8 Charolais crossbred steers on each protein treatment. Carcass parameters were adjusted to constant empty body weight of 453 kg which corresponds to a final shrunk wt of 523 kg.

[b]Maturity: A- = 1; A = 2; A+ = 3.

[c]Marbling score: Slight- = 7; Slight = 8; Slight+ = 9; Small- = 10, Small = 11.

[d]Quality grade: Good- = 7; Good = 8; Good+ = 9; Choice- = 10.

[e]Carcass fat was determined by the specific gravity technique (Kraybill et al., 1952).

Table 17.--Effect of Source and Level of Supplemental Protein on Carcass Parameters (Trial 1)[a]

Parameter	Protein treatment							
	Unsupplemented control	7.80 g AN/KGCSDM	7.80 g AN/KGCSDM + soy	15.60 g AN/KGCSDM	15.60 g AN/KGCSDM + minerals	15.60 g AN/KGCSDM + $Ca(OH)_2$	Declining soy	Constant soy
Treatment no.	1	2	3	4	5	6	7	8
Dressing percentage	59.8	58.7	59.4	59.0	59.5	58.9	60.0	60.0
Maturity score[b]	2.3	2.3	2.4	1.9	2.1	2.2	2.3	2.4
Adj. fat thickness, cm	.94	.91	.91	1.04	1.02	.94	1.07	.86
Ribeye area, cm^2	71.61	74.19	80.00	78.06	76.77	76.77	78.71	78.06
KPH fat, %	2.8	2.8	2.8	2.9	3.0	2.9	2.8	2.8
Marbling score[c]	8.7	8.0	7.4	10.5	8.8	9.6	8.9	8.1
Quality grade[d]	8.3	7.8	7.4	9.3	8.6	8.9	8.4	8.1
Yield grade	2.8	2.6	2.3	2.6	2.6	2.5	2.5	2.4
Carcass fat, %[e]	26.3	25.8	26.4	28.3	27.6	25.6	26.0	25.9

[a]There were 8 Hereford and 8 Charolais crossbred steers on each protein treatment. Carcass parameters were adjusted to constant empty body weights of 382 and 453 kg for the Hereford and Charolais crossbred steers, respectively, which correspond to final shrunk wts of 436 and 523 kg, respectively.

[b]Maturity: A- = 1; A = 2; A+ = 3.

[c]Marbling score: Slight- = 7; Slight = 8; Slight+ = 9; Small- - 10; Small = 11.

[d]Quality grade: Good- = 7; Good = 8; Good+ = 9; Choice- = 10.

[e]Carcass fat was determined by the specific gravity technique (Kraybill et al., 1952).

Table 18.--Orthogonal Contrasts for Selected Treatment Comparisons of Carcass Parameters (Trial 1)[a]

No.	Contrast	Dressing percentage	Adj. fat thickness (cm)	Rib eye area (cm^2)	KPH fat (%)	Marbling[b] score	Quality[c] grade	Yield grade	Carcass fat[d] (%)
1	No supplemental protein (T_1) vs. supplemental protein (T_2 ... T_8)	59.8 vs. 59.4 (NS)	.94 vs. .97 (NS)	71.61 vs. 77.51 (.002)	2.8 vs. 2.9 (NS)	8.7 vs. 8.8 (NS)	8.3 vs. 8.4 (NS)	2.8 vs. 2.5 (.132)	26.3 vs. 26.5 (NS)
2	High protein (T_4 ... T_8) vs. low protein (T_2, T_3)	59.5 vs. 59.0 (.199)	.99 vs. .91 (NS)	77.68 vs. 77.10 (NS)	2.9 vs. 2.8 (NS)	9.2 vs. 7.7 (.002)	8.7 vs. 7.6 (.001)	2.5 vs. 2.4 (NS)	26.7 vs. 26.1 (NS)
3	7.80 g AN/KGCSDM (T_2) vs. 7.80 g AN/KGCSDM + soy (T_3)	58.7 vs. 59.4 (.195)	.91 vs. .91 (NS)	74.19 vs. 80.00 (.013)	2.8 vs. 2.8 (NS)	8.0 vs. 7.4 (NS)	7.8 vs. 7.4 (NS)	2.6 vs. 2.3 (NS)	25.8 vs. 26.4 (NS)
4	15.60 g AN/KGCSDM (T_4) vs. 15.60 g ANAM/KGCSDM + minerals (T_5)	59.0 vs. 59.5 (NS)	1.04 vs. 1.02 (NS)	78.06 vs. 76.77 (NS)	2.9 vs. 3.0 (NS)	10.5 vs. 8.8 (.030)	9.3 vs. 8.6 (.155)	2.6 vs. 2.6 (NS)	28.3 vs. 27.6 (NS)
5	15.60 g AN/KGCSDM (T_4, T_5) vs. 15.60 g AN/KGCSDM + $Ca(OH)_2$ (T_6)	59.2 vs. 58.9 (NS)	1.03 vs. .94 (NS)	77.42 vs. 76.77 (NS)	3.0 vs. 2.9 (NS)	9.6 vs. 9.6 (NS)	9.0 vs. 8.9 (NS)	2.6 vs. 2.5 (NS)	28.0 vs. 25.6 (.039)
6	Soybean meal (T_7, T_8) vs. 15.60 g AN/KGCSDM (T_4, T_5, T_6)	60.0 vs. 59.1 .(.012)	.96 vs. 1.00 (NS)	78.38 vs. 77.20 (NS)	2.8 vs. 2.9 (NS)	8.5 vs. 9.6 (.030)	8.2 vs. 8.9 (.032)	2.4 vs. 2.6 (NS)	26.0 vs. 27.2 (.146)
7	Declining soy (T_7) vs. constant soy (T_8)	60.0 vs. 60.0 (NS)	1.07 vs. .86 (.117)	78.71 vs. 78.06 (NS)	23.8 vs. 2.8 (NS)	8.9 vs. 8.1 (NS)	8.4 vs. 8.1 (NS)	2.5 vs. 2.4 (NS)	26.0 vs. 25.9 (NS)

[a]Carcass parameters were adjusted to constant empty body weights of 382 and 453 kg for the Hereford and Charolais crossbred steers, respectively, which correspond to final shrink weights of 436 and 523 kg, respectively. The subscripts following the "T's" in parentheses correspond to the treatment numbers in Table 17 and denote the treatments involved in the contrast. NS = not statistically different; P > .20.

[b]Marbling score: Slight- = 7; Slight = 8; Slight+ = 9; Small- = 10; Small = 11.

[c]Quality grade: Good- = 7; Good = 8; Good+ = 9; Choice- = 10.

[d]Carcass fat was determined by the specific gravity technique (Kraybill et al., 1952).

Feeding a high level of supplemental protein (12.5%) resulted in a slightly higher dressing percent (P = .199), a higher marbling score (P = .002) and a higher quality grade (P = .001) than feeding a low level of supplemental protein (10%).

When cattle fed corn silage treated with 7.80 g AN/KGCSDM were supplemented with SBM until they reached an equivalent weight of 318 kg, they had a larger rib eye area (P = .013) than their counterparts which received corn silage treated with the same level of AN without SBM supplementation.

Addition of the complete mineral mix to the ammonia treated silage at the time of ensiling resulted in a lower marbling score (P = .030) and a lower quality grade (P = .155) when compared to addition of the same mineral mix to ammonia treated silage at feeding time.

Addition of calcium hydroxide to the ammonia treated silage at the time of ensiling resulted in less total carcass fat (P = .039).

When SBM and AN were compared as sources of supplemental nitrogen, cattle that received silage treated with 15.60 g AN/KGCSDM had a lower dressing percent (P = .012), a higher marbling score (P = .030), a higher quality grade (P = .032) and a greater percentage of carcass fat (P = .146). Since acetate is a precursor for fatty acid synthesis, the higher marbling scores and quality grades observed in those cattle that received AN treated silage may have been due at least in part to the higher levels of acetate present in these silages.

Cattle that received the declining soy ration had a greater adjusted fat thickness (P = .117) than cattle fed the constant soy ration.

Carcass data for the Hereford and Charolais crossbred steers has been summarized across all protein treatments by cattle type in Table 19. Charolais steers had a higher dressing percent ($P < .0005$), less external fat thickness ($P = .001$), larger rib eye area ($P < .0005$), higher quality grade ($P < .0005$) and a lower numerical yield grade ($P < .0005$). There was no difference in the percentage of carcass fat ($P > .20$).

Net Energy Evaluation

Net energy values obtained for the protein treatments evaluated in trial 1 are listed in Table 20. Since there were no interactions between protein treatment and cattle type, cattle types were pooled within each protein treatment. Orthogonal f-tests were performed on the net energy values using the same contrasts that were used to evaluate animal performance and carcass parameters. These contrasts and their respective results are presented in Table 21.

Rations supplemented with protein had higher NE_m ($P = .001$) and NE_g ($P = .005$) values than the control ration that was not supplemented with protein.

A high level of supplemental protein (12.5%) resulted in larger NE_m ($P = .008$) and NE_g ($P = .063$) values than a low level of supplemental protein (10%).

Soybean meal supplementation of corn silage treated with 7.80 g AN/KGCSDM during the initial phase of the feeding period resulted in higher NE_m ($P = .104$) and NE_g ($P = .050$) values.

Table 19.--Effect of Cattle Type on Carcass Parameters (Trial 1)[a]

Parameter	Cattle type		Statistical significance of difference[b]
	Hereford	Charolais	
Dressing percentage	58.6	60.2	< .0005
Maturity score[c]	2.3	2.1	.039
Adj. fat thickness, cm	1.09	.84	.001
Rib eye area, cm^2	70.39	83.29	< .0005
KPH fat, %	2.8	2.9	.052
Marbling score[d]	8.1	9.4	.001
Quality grade[e]	7.9	8.8	< .0005
Yield grade	2.8	2.3	< .0005
Carcass fat[f]	26.8	26.2	NS

[a]There were eight steers of each cattle type on each of eight protein treatments. Carcass parameters were adjusted to constant empty body weights of 382 and 453 kg for the Hereford and Charolais crossbred steers, respectively, which correspond to final shrunk wts. of 436 and 523 kg, respectively.

[b]NS = not statistically different; $P > .20$.

[c]Maturity: A = 2; A+ = 3.

[d]Marbling score: Slight = 8; Slight+ = 9; Small- = 10.

[e]Quality grade: Good = 8; Good+ = 9.

[f]Carcass fat was determined by the specific gravity technique (Kraybill _et al_., 1952).

Table 20.--Net Energy Values for Protein Treatments (Trial 1)[a]

No.	Protein treatment	Cattle type: Hereford	Cattle type: Charolais	$\bar{X}$
1	Unsupplemented control			
	NE_m	1.52	1.48	1.50
	NE_g	1.06	.95	1.00
2	7.80 g AN/KGCSDM			
	NE_m	1.54	1.53	1.54
	NE_g	1.05	1.02	1.04
3	7.80 g AN/KGCSDM + soy			
	NE_m	1.61	1.54	1.58
	NE_g	1.18	1.06	1.12
4	15.60 g AN/KGCSDM			
	NE_m	1.58	1.57	1.58
	NE_g	1.15	1.06	1.10
5	15.60 g AN/KGCSDM + minerals			
	NE_m	1.62	1.62	1.62
	NE_g	1.19	1.19	1.19
6	15.60 g AN/KGCSDM + $Ca(OH)_2$			
	NE_m	1.59	1.56	1.58
	NE_g	1.17	1.09	1.13
7	Declining soy			
	NE_m	1.62	1.55	1.58
	NE_g	1.14	.98	1.06
8	Constant soy			
	NE_m	1.64	1.60	1.62
	NE_g	1.20	1.10	1.15
	$\bar{X}$			
	NE_m	1.59	1.56	
	NE_g	1.14	1.06	

[a]There were 8 Hereford and 8 Charolais crossbred steers on each protein treatment. Net energy values for maintenance (NE_m) and gain (NE_g) are listed as Mcal/kg of ration DM.

Table 21.--Orthogonal Contrasts for Selected Treatment Comparisons of Net Energy Values (Trial 1)[a]

No.	Contrast	NE_m[b]	NE_g[c]
1	No supplemental protein (T_1) vs. supplemental protein (T_2 ... T_8)	1.50 vs. 1.59 (.001)	1.00 vs. 1.11 (.005)
2	High protein (T_4 ... T_8) vs. low protein (T_2, T_3)	1.60 vs. 1.56 (.008)	1.13 vs. 1.08 (.063)
3	7.80 g AN/KGCSDM (T_2) vs. 7.80 g AN/KGCSDM + soy (T_3)	1.54 vs. 1.58 (.104)	1.04 vs. 1.12 (.050)
4	15.60 g AN/KGCSDM (T_4) vs. 15.60 g AN/KGCSDM + minerals (T_5)	1.58 vs. 1.62 (.046)	1.10 vs. 1.19 (.040)
5	15.60 g AN/KGCSDM (T_4, T_5) vs. 15.60 g AN/KGCSDM + $Ca(OH)_2$(T_6)	1.60 vs. 1.58 (NS)	1.14 vs. 1.13 (NS)
6	Soybean meal (T_7, T_8) vs. 15.60 g AN/KGCSDM (T_4, T_5 T_6)	1.60 vs. 1.59 (NS)	1.10 vs. 1.14 (.180)
7	Declining soy (T_7) vs. constant soy (T_8)	1.58 vs. 1.62 (.073)	1.06 vs. 1.15 (.041)

[a]Subscripts following the "T's" in parentheses correspond to the treatment numbers in Table 20 and denote the treatments involved in the contrast. NS = not statistically different; P > .20.

[b]Net energy for maintenance, Mcal/kg of ration DM.

[c]Net energy for gain, Mcal/kg of ration DM.

Addition of the mineral mix to the ammonia treated silage at the time of ensiling resulted in a higher NE_m ($P = .040$) and a higher NE_g ($P = .040$). The high net energy values obtained by the 15.60 g AN/KGCSDM treatment to which minerals were added at the time of ensiling may have been at least partially due to the high level of lactate that was present in this silage. Prigge and Owens (1976) noted that lactate was utilized more efficiently in the rumen than soluble carbohydrates.

Calcium hydroxide addition to the ammonia treated silage at the time of ensiling resulted in no significant change ($P > .20$) in net energy values.

When SBM and AN were compared as sources of supplemental nitrogen, silages treated with 15.60 g AN/KGCSDM had a slightly higher NE_g ($P = .180$) than the untreated silage supplemented with SBM. However, there was no significant difference ($P > .20$) in NE_m.

The constant soy supplementation system resulted in higher NE_m ($P = .073$) and NE_g ($P = .041$) values than the declining soy protein supplementation strategy.

When cattle type was compared across all protein treatments, rations had higher NE_m ($P = .008$) and NE_g ($P = .002$) values when fed to the Hereford steers rather than their Charolais crossbred counterparts. This was largely due to the fact that the Herefords were leaner at the start of the experiment than were the Charolais crossbreds (14.16% vs. 16.98% empty body fat), but were equivalent in body composition at the termination of the experiment. Therefore, the Herefords were depositing more fat and were more energetically efficient.

Economic Analysis

An economic analysis of the protein treatments evaluated in trial 1 is presented in Table 22. All protein supplementation systems resulted in lower feed and nonfeed costs than did the unsupplemented control.

Least total cost system was the 15.60 g AN/KGCSDM treatment. This treatment was superior to all of the other AN treatments with respect to both animal performance and cost of gain.

Total cost per 45.4 kg of gain was $1.24 less for cattle on the declining soy treatment when compared to those that were on the constant soy treatment. Since performance was equivalent between these two treatments, the declining soy supplementation strategy would be more economically feasible if it were possible to group cattle according to weight.

Based on feedlot performance and cost of gain, the 15.60 g AN/KGCSDM and declining soy treatments appear to be the two most relevant treatments. If anhydrous ammonia were to remain at the current price of $175/ton, the break-even price for soybean meal (soy 47) for the declining soy treatment would be $173.42/ton when compared to the 15.60 g AN/KGCSDM treatment. Conversely, if soybean meal (soy 47) were $200/ton, the break-even price for anhydrous ammonia for the 15.60 g AN/KGCSDM treatment would be $390.12/ton when compared to the declining soy treatment. If it were not possible to group cattle according to weight and the constant soy ration were fed, AN would be even more favorable economically. Therefore, based on the current market situation,

Table 22.--Economic Analysis of the Protein Treatments Evaluated in Trial 1[a]

	Protein treatment							
	Unsupplemented control	7.80 g AN/KGCSDM	7.80 g AN/KGCSDM + soy	15.60 g AN/KGCSDM	15.60 g AN/KGCSDM + minerals	15.60 g AN/KGCSDM + $Ca(OH)_2$	Declining soy	Constant soy
Feed cost/45.4 kg of gain, $	29.82	25.51	26.27	24.31	24.06	25.25	26.55	27.65
Nonfeed costs/45.4 kg of gain, $	24.44	18.75	18.44	16.34	18.54	17.19	15.07	15.21
Total cost/45.4 kg of gain, $	54.26	44.26	44.71	40.65	42.60	42.44	41.62	42.86

[a]Feed costs reflect the following prices: (a) anhydrous ammonia, $175/ton; (b) corn silage (as harvested basis), $17.50/ton; (c) corn, shelled, $2.40/bushel; (d) soybean meal (soy 47), $200/ton. Nonfeed costs were calculated at $0.33/head/day which included interest on investment, housing and labor and equipment for feeding, but did not include charges for death loss and marketing expenses. If anhydrous ammonia were $175/ton, the break-even price for soybean meal (soy 47) would be $173.42/ton and $148.04/ton for the declining soy and constant soy treatments, respectively, when compared to the 15.60 g AN/KGCSDM treatment. If soybean meal (soy 47) were $200/ton, the break even price of anhydrous ammonia for the 15.60 g AN/KGCSDM treatment would be $390.12 and $595.38/ton when compared to the declining soy and constant soy treatments, respectively. Application costs and increase in silage value due to the preservative property of anhydrous ammonia were not included in the above calculations.

it appears that anhydrous ammonia will be quite competitive with soybean meal from an economic point of view.

Feedlot Trial 2

Feedlot Performance

Growing and finishing phase performance of the cattle in trial 2 are listed in Tables 23 and 24, respectively, for each treatment combination. A summary of overall performance for the entire feeding period is presented in Table 25. For traits where there were no significant AN x monensin interactions, monensin treatments were pooled with AN treatments and AN treatments were pooled within monensin treatments. Orthogonal contrasts were then constructed for the treatment combinations of primary interest to determine whether differences in ADG, ADDMI, RELDMI or F/G were statistically significant.

Contrasts for the growing phase and their respective results are listed in Table 26. There was a significant AN x monensin interaction ($P = .067$) for feed efficiency during the growing phase. Lowest F/G was obtained by the 16.5, 0, and 33.0 ppm levels of monensin for the 0, 7.90, and 15.70 g AN/KGCSDM treatments, respectively.

Analysis of contrast 1 reveals that supplemental nitrogen resulted in a 9.9% higher ADG ($P = .013$), but no significant differences ($P > .20$) in ADDMI or RELDMI were observed. The difference in ADG between cattle that received supplemental nitrogen and those that did not receive supplemental nitrogen was smaller than those observed in the literature from other studies (Preston, 1974; Cook and Fox, 1977). This may have been partially due to the fact that the untreated control

Table 23.--Summary of Growing Phase Performance (Trial 2)

Item	0 g AN/KGCSDM			7.90 g AN/KGCSDM			15.70 g AN/KGCSDM		
	Level of monensin in ration DM								
	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm
Crude protein level of ration DM, %	8.5	8.5	8.5	10.5	10.5	10.5	12.3	12.3	12.3
No. of steers	9	9	9	18	18	18	18	18	18
Initial wt., kg[a]	228	229	226	229	231	228	230	230	228
Final wt., kg[a]	365	373	365	391	381	369	367	370	366
Days on feed	190	190	190	188	188	190	169	169	169
Average daily gain, kg	.72	.76	.73	.86	.80	.74	.81	.83	.81
Average daily DM intake, kg	6.12	5.94	5.77	6.09	5.77	5.72	6.08	5.99	5.79
Corn silage[b]	5.96	5.79	5.62	5.90	5.59	5.55	5.89	5.81	5.61
Supplement I	.16	--	--	.16	--	--	.16	--	--
Supplement II	--	.15	--	--	.15	--	--	.15	--
Supplement III	--	--	.15	--	--	.14	--	--	.15
Urea	--	--	--	.03	.03	.03	.03	.03	.03
RELDMI, grams/wt.$^{.75}_{kg}$	85.8	82.3	81.1	82.5	79.0	79.7	84.7	83.2	81.0
F/G	8.54	7.80	7.90	7.09	7.23	7.72	7.52	7.22	7.11

[a]Initial and final wts. were taken after 16 hr without feed and water.

[b]Corn silage dry matter intakes were multiplied by a factor of 1.068 to compensate for loss of volatiles during DM determination in a 60° C oven (Fox and Fenderson, 1978).

Table 24.--Summary of Finishing Phase Performance (Trial 2)

	0 g AN/KGCSDM			7.90 g AN/KGCSDM			15.70 g AN/KGCSDM		
	Level of monensin in ration DM								
Item	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm
Crude protein level of ration DM, %	10.5	10.5	10.5	10.8	10.8	10.8	11.4	11.4	11.4
No. of steers	7	7	7	14	14	14	14	14	14
Initial wt., kg[a]	362	370	359	388	388	367	371	368	358
Final wt., kg[b]	484	491	469	483	482	483	502	493	486
Days on feed	91.0	91.0	91.0	82.5	72.0	91.0	101.5	91.0	101.5
Average daily gain, kg	1.33	1.33	1.21	1.17	1.30	1.28	1.30	1.37	1.26
Average daily DM intake, kg	8.97	8.59	8.50	8.98	9.21	9.20	8.67	9.11	8.69
Corn silage[c]	1.92	1.86	1.83	2.05	2.17	2.03	1.91	2.05	1.90
HM corn[d]	6.71	6.40	6.35	6.60	6.70	6.83	6.40	6.69	6.42
Supplement IV	.34	--	--	.33	--	--	.33	--	--
Supplement V	--	.33	--	--	.34	--	--	.34	--
Supplement VI	--	--	.32	--	--	.34	--	--	.32
Urea	--	--	--	--	--	--	.03	.03	.03
RELDMI, grams/wt.$^{.75}_{kg}$	96.2	91.1	92.7	94.3	96.8	98.4	90.9	96.5	93.3
F/G	6.74	6.48	7.02	7.77	7.10	7.20	6.68	6.65	6.89

[a]Initial wts. were taken after 16 hr without feed and water.

[b]Final wts. were adjusted to a constant dressing percentage of 60.54 using the following formula:

$$\text{final wt.} = \frac{\text{hot carcass weight}}{.6054} .$$

[c]Corn silage dry matter intakes were multiplied by a factor of 1.068 to compensate for loss of volatiles during DM determination in a 60° C oven (Fox and Fenderson, 1978).

[d]HM corn dry matter intakes were multiplied by a factor of 1.03 to compensate for loss of volatiles during DM determination in a 60° C oven (Fox and Fenderson, 1978).

Table 25.--Summary of Overall Performance (Trial 2)

Item	0 g AN/KGCSDM			7.90 g AN/KGCSDM			12.70 G AN/KGCSDM		
	Level of monensin in ration DM								
	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm
Crude protein level of ration DM, %	8.5→10.5	8.5→10.5	8.5→10.5	10.5→10.8	10.5→10.8	10.5→10.8	12.3→11.4	12.3→11.4	12.3→11.4
No. of steers	7	7	7	14	14	14	14	14	14
Initial wt., kg[a]	224	226	225	232	236	227	232	228	226
Final wt., kg[b]	484	491	469	483	482	483	502	493	486
Days on feed	281.0	281.0	281.0	270.5	260.0	281.0	270.5	260.0	270.5
Average daily gain, kg	.93	.94	.87	.93	.95	.91	1.00	1.02	.96
Average daily DM intake, kg	7.11	6.77	6.55	6.81	6.79	6.81	7.11	7.07	6.73
Corn silage[c]	4.72	4.49	4.29	4.57	4.70	4.37	4.46	4.48	4.09
HM corn[d]	2.17	2.07	2.05	2.01	1.86	2.21	2.40	2.34	2.41
Supplement I	.11	--	--	.11	--	--	.10	--	--
Supplement II	--	.10	--	--	.11	--	--	.10	--
Supplement III	--	--	.10	--	--	.10	--	--	.09
Supplement IV	.11	--	--	.10	--	--	.12	--	--
Supplement V	--	.11	--	--	.10	--	--	.12	--
Supplement VI	--	--	.11	--	--	.11	--	--	.12
Urea	--	--	--	.02	.02	.02	.03	.03	.02
RELDMI, grams/wt.$^{.75}_{kg}$	87.26	82.25	81.55	82.92	82.40	83.31	84.93	85.53	82.21
F/G	7.68	7.21	7.52	7.36	7.18	7.47	7.10	6.96	7.00
Carcass fat, %[e]	30.14	30.17	30.60	31.95	29.77	32.26	32.36	33.52	33.28

[a]Initial wts. were taken after 16 hr without feed and water.

[b]Final wts. were adjusted to a constant dressing percentage of 60.54 using the following formula:

$$\text{final wt.} = \frac{\text{hot carcass wt.}}{.6054}$$

[c]Corn silage DM intakes were multiplied by a factor of 1.068 to compensate for loss of volatiles during DM determination in a 60° C oven (Fox and Fenderson, 1978).

[d]HM corn dry matter intakes were multiplied by a factor of 1.03 to compensate for loss of volatiles during DM determination in a 60° C oven (Fox and Fenderson, 1978).

[e]Carcass fat was determined by the specific gravity technique (Kraybill et al., 1952).

Table 26.--Orthogonal Contrasts for Selected Treatment Comparisons of Growing Phase of Performance (Trial 2)[a]

No.	Contrast	ADG (kg)	ADDMI (kg)	RELDMI (grams/wt.$^{.75}_{kg}$)	F/G
1	No supplemental nitrogen (0 g AN/KGCSDM) vs. supplemental nitrogen (7.90 g AN/KGCSDM, 15.70 g AN/KGCSDM)	.73 vs. .81 (.013)	5.95 vs. 5.91 (NS)	83.1 vs. 81.7 (NS)	Interaction
2	7.90 g AN/KGCSDM vs. 15.70 g AN/KGCSDM	.80 vs. .82 (NS)	5.86 vs. 5.95 (NS)	80.4 vs. 83.0 (.051)	Interaction
3	No monensin (0 ppm) vs. with monensin (16.5 ppm, 33.0 ppm)	.79 vs. .78 (NS)	6.10 vs. 5.83 (.001)	84.3 vs. 81.0 (.011)	Interaction
4	16.5 ppm monensin in ration DM vs. 33.0 ppm monensin in ration DM	.80 vs. .76 (NS)	5.90 vs. 5.76 (.087)	81.5 vs. 80.6 (NS)	Interaction

[a]The numbers in parentheses under the parameter means are statistical significance levels; NS means that $P > .20$ and therefore was not statistically significant. There was a significant AN x monensin interaction ($P = .067$) for F/G.

silage (0 g AN/KGCSDM) was unusually high in crude protein content (8.81%, DM basis) as noted in Table 7. Therefore, there was not as much difference in the level of crude protein between the rations that were supplemented with nitrogen and those that were not supplemented with nitrogen in this study as there have been in earlier studies.

Examination of contrast 2 shows that there was no significant difference (P > .20) in ADG or ADDMI between cattle receiving corn silage treated with 7.90 or 15.70 g AN/KGCSDM, but steers that received silage treated with 15.70 g AN/KGCSDM had a 3.2% higher RELDMI (P = .051). Results of trial 1 and a previous study by Cook and Fox (1977) have shown that cattle fed corn silage treated with 15.60 g AN/KGCSDM had a higher ADG, ADDMI, RELDMI and a lower F/G than those receiving the 7.80 g AN/KGCSDM treatment. However, cattle in the previous work were fed corn silage rations with no added corn throughout the entire feeding period and as a result received an all silage ration for a longer period of time.

Performance of cattle that did or did not receive monensin is compared in contrast 3. Monensin resulted in a 4.6% lower ADDMI (P = .001) and a 4.1% lower RELDMI (P = .011) during the growing phase. However, monensin had no significant effect on ADG (P > .20). These results compare favorably with those of previous research (Goodrich et al., 1976; Embry, 1976; Thonney, 1977).

Performance of cattle that received 16.5 or 33.0 ppm monensin in the ration DM are compared in contrast 4. Cattle receiving 33.0 ppm monensin had a 2.4% lower ADDMI (P = .087) than those that received 16.5 ppm, but there were no significant differences (P > .20) in ADG or RELDMI.

Orthogonal contrasts for finishing phase performance and their respective results are presented in Table 27. During the finishing phase there were significant AN x monensin interactions for ADDMI (P = .140) and RELDMI'(P = .014). Lowest ADDMI was obtained by the 16.5, 0, and 0 ppm levels of monensin for the 0, 7.90, and 15.70 g AN/KGCSDM treatments, respectively. RELDMI followed the same trend.

Examination of contrast 1 reveals that cattle that received supplemental nitrogen during the finishing phase did not have a significantly different (P > .20) ADG or F/G than those cattle which received no supplemental protein. This may have been due to a greater amount of compensatory gain during the finishing phase by the cattle that received the untreated silage. Since these cattle received only an 8.5% crude protein ration (DM basis) during the growing phase, the finishing ration, which contained 10.5% crude protein (DM basis), may have resulted in a greater amount of compensatory growth than the rations that were supplemented with nitrogen during the growing phase.

Finishing phase performance of cattle that received silage treated with 7.90 or 15.60 g AN/KGCSDM is compared in contrast 2. Cattle that received 15.70 g AN/KGCSDM had a 5.1% higher ADG (P = .141) and an 8.4% lower F/G (P = .024). The results of this contrast together with those of contrast 2 in Table 26 suggest that cattle that received silage treated with 15.70 g AN/KGCSDM were not able to efficiently utilize the AN above 7.90 g AN/KGCSDM during the initial phase of the feeding period. Fox _et_ _al_. (1977a) and Bergen _et_ _al_. (1978) noted that it was unlikely that cattle started on feed as calves could generate sufficient microbial

Table 27.--Orthogonal Contrasts for Selected Treatment Comparisons of Finishing Phase Performance (Trial 2)[a]

No.	Contrast	ADG (kg)	ADDMI (kg)	RELDMI (grams/wt.$_{kg}^{.75}$)	F/G
1	No supplemental nitrogen (0 g AN/KGCSDM) vs. supplemental nitrogen (7.90 g AN/KGCSDM, 15.70 g AN/KGCSDM)	1.29 vs. 1.28 (NS)	Interaction	Interaction	6.75 vs. 7.05 (NS)
2	7.90 g AN/KGCSDM vs. 15.70 g AN/KGCSDM	1.25 vs. 1.31 (.141)	Interaction	Interaction	7.36 vs. 6.74 (.024)
3	No monensin (0 ppm vs. with monensin (16.5 ppm, 33.0 ppm)	1.27 vs. 1.29 (NS)	Interaction	Interaction	7.06 vs. 6.89 (NS)
4	16.5 ppm monensin in ration DM vs. 33.0 ppm monensin in ration DM	1.33 vs. 1.25 (.091)	Interaction	Interaction	6.74 vs. 7.04 (NS)

[a]The numbers in parentheses under the parameter means are statistical significance levels; NS means that $P > .20$ and therefore was not statistically significant. There were significant AN x monensin interactions for ADDMI ($P = .140$) and RELDMI ($P = .014$).

protein from corn silage treated with 15.60 g AN/KGCSDM to meet their protein requirement during the initial part of the feeding period. The results of this study indirectly support this contention. During the initial part of the feeding period, there was no significant difference ($P > .20$) in ADG between the 7.90 and 15.70 g AN/KGCSDM treatments, but during the finishing phase those cattle that received corn silage treated with 15.70 g AN/KGCSDM gained faster and consumed less feed per kg of gain. The finishing ration also provided more preformed protein and a higher energy density.

Analysis of contrast 3 reveals that monensin resulted in no significant difference ($P > .20$) in ADG or F/G during the finishing phase.

Finishing phase performance of cattle that received 16.5 or 33.0 ppm monensin in the ration DM is compared in contrast 4. Cattle that received 16.5 ppm monensin had a 6.9% higher ADG ($P = .091$) during the finishing phase than those that received 33.0 ppm monensin. There was no significant difference in F/G ($P > .20$) but cattle receiving 16.5 ppm monensin required 4.3% less feed per kg of gain than those that received 33.0 ppm monensin in the ration DM.

Overall feedlot performance is graphically depicted by AN and monensin treatment in Figures 4 and 5, respectively. Orthogonal contrasts for overall performance and their respective results are listed in Table 28. There was a significant AN x monensin interaction ($P = .033$) for RELDMI. Lowest RELDMI was obtained by the 33.0, 16.5, and 33.0 ppm levels of monensin for the 0, 7.90, and 15.70 g AN/KGCSDM treatments, respectively.

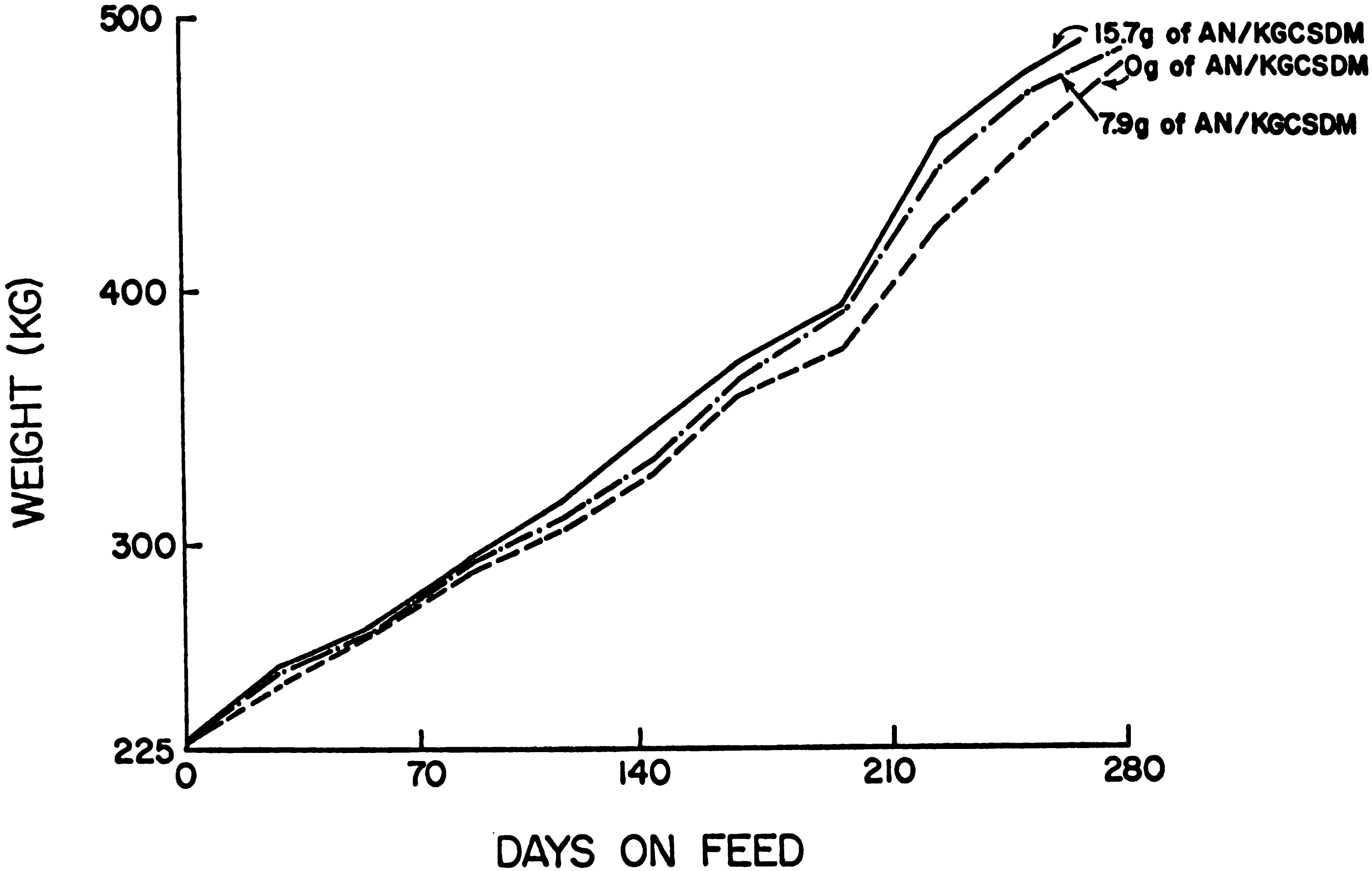

FIGURE 4.--EFFECT OF ANHYDROUS AMMONIA LEVEL ON PERFORMANCE

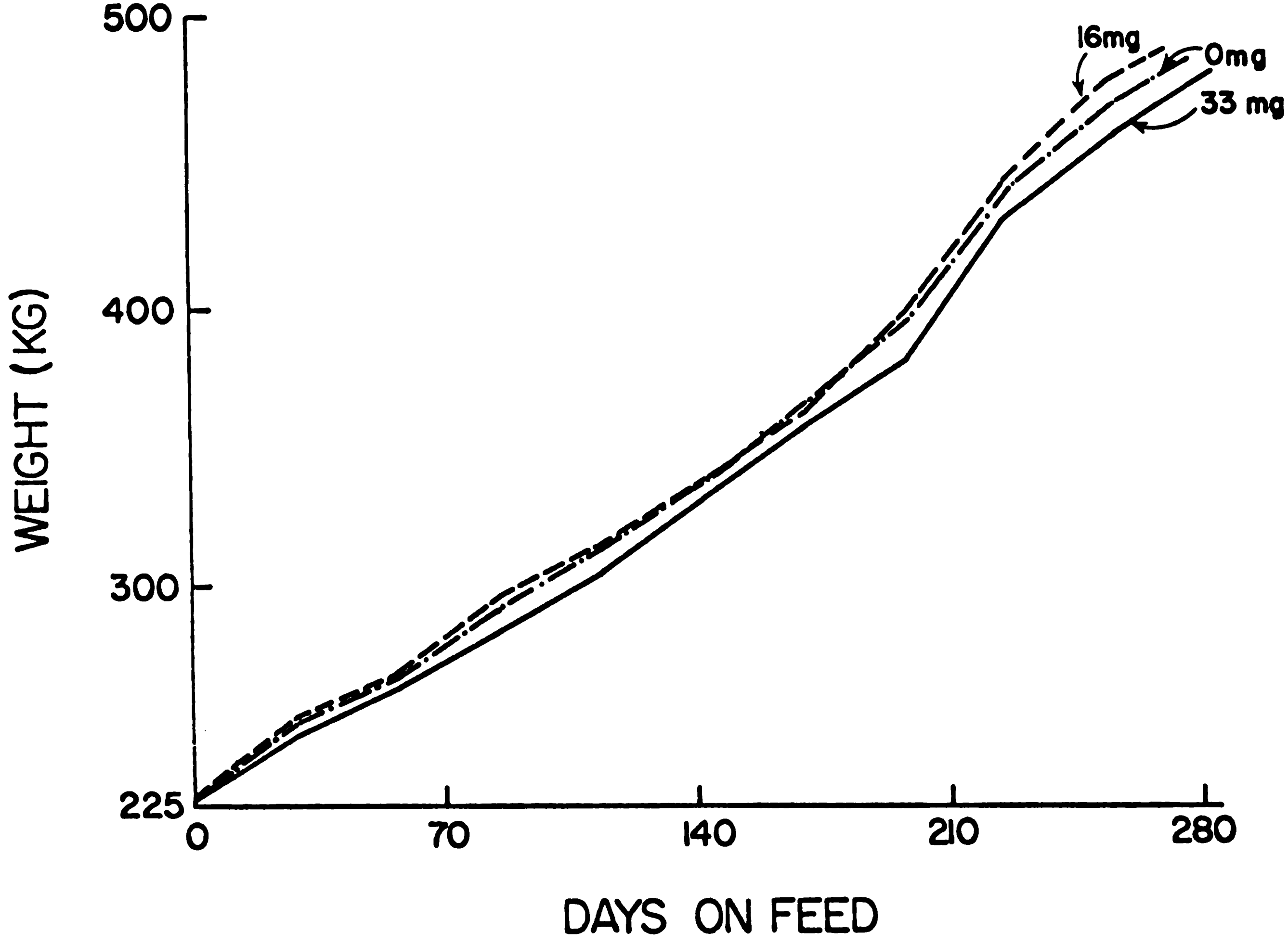

Figure 5.--Effect of Level of Monensin on Performance

Table 28.--Orthogonal Contrasts for Selected Treatment Combinations of Overall Performance (Trial 2)[a]

No.	Contrast	ADG (kg)	ADDMI (kg)	RELDMI (grams/wt.$^{.75}$ kg)	F/G
1	No supplemental nitrogen (0 g AN/KGCSDM) vs. supplemental nitrogen (7.90 g AN/KGCSDM, 15.70 g AN/KGCSDM)	.91 vs. .96 (.102)	6.81 vs. 6.89 (NS)	Interaction	7.47 vs. 7.20 (.015)
2	7.90 g AN/KGCSDM vs. 15.70 g AN/KGCSDM	.93 vs. .99 (.014)	6.80 vs. 6.97 (.159)	Interaction	7.37 vs. 7.02 (.005)
3	No monensin (0 ppm) vs. with monensin (16.5 ppm, 33.0 ppm)	.95 vs. .94 (NS)	7.02 vs. 6.79 (.087)	Interaction	7.38 vs. 7.22 (NS)
4	16.5 ppm monensin in ration DM vs. 33.0 ppm monensin in ration DM	.98 vs. .92 (.095)	6.88 vs. 6.70 (.159)	Interaction	7.12 vs. 7.33 (NS)

[a]The numbers in parentheses under the parameter means are statistical significance levels; NS means that $P > .20$ and therefore was not statistically significant. There was a significant AN x monensin interaction ($P = .033$) for RELDMI.

The effect of supplemental nitrogen on overall performance is examined in contrast 1. Cattle that received the AN treated corn silage had a 5.5% higher ADG (P = .102) and 3.6% lower F/G (P = .015) than those that received no supplemental nitrogen. There was no significant difference in ADDMI (P > .20).

Analysis of contrast 2 reveals that cattle that received corn silage treated with 15.70 g AN/KGCSDM had a 7.4% higher overall ADG (P = .014), 2.5% higher ADDMI (P = .159) and consumed 4.7% less feed per kg of gain (P = .005) than those cattle that received 7.80 g AN/KGCSDM.

The effect of monensin on overall performance is examined in contrast 3. Cattle that received monensin had a 3.3% lower overall ADDMI (P = .087), but there was no significant difference (P > .20) in ADG or F/G. These results are in conflict with other reports in which monensin significantly decreased ADDMI and F/G, but resulted in no change in ADG (Goodrich *et al*., 1976; Embry, 1976; Thonney, 1977). Monensin decreased F/G in the present study but the difference was not significant (P > .20).

Examination of contrast 4 shows that steers that received 16.5 ppm monensin had a 6.4% higher ADG (P = .095) and a 2.6% higher ADDMI (P = .159) than those cattle that received 33.0 ppm monensin in the ration DM. There was no significant difference in F/G (P > .20) although cattle that received 16.5 ppm monensin required less feed per kg of gain than those cattle that received 33.0 ppm in the ration DM. In contrast to earlier work (Goodrich *et al*., 1976; Embry, 1976), 33.0 ppm monensin was not the optimum level in this trial. In this study, the highest level of animal performance was obtained by feeding 16.5 ppm monensin in the ration DM.

Carcass Parameters

A summary of the carcass data obtained for each treatment combination in trial 2 is listed in Table 29. Since there were no significant AN x monensin interactions, monensin treatments were pooled within AN treatments and AN treatments were pooled within monensin treatments, and the respective results are reported in Tables 30 and 31, respectively. Orthogonal contrasts were constructed for the treatment combinations of primary interest, and these contrasts and their respective results are presented in Table 32.

Cattle that received supplemental nitrogen had more KPH fat ($P = .015$), a slightly higher marbling score ($P = .194$) and a greater amount of carcass fat ($P = .048$) than those that received no supplemental nitrogen.

When carcass parameters of cattle that received 7.90 or 15.70 g AN/KGCSDM were compared, cattle that received 15.70 g AN/KGCSDM had a higher dressing percent ($P = .025$), more external fat ($P = .087$) and a greater percentage of total carcass fat ($P = .065$).

Cattle that received monensin had a slightly lower dressing percent ($P = .127$), a greater amount of KPH fat ($P = .038$) and a slightly higher quality grade ($P = .137$) than those cattle that received no monensin.

Table 29.--Summary of Carcass Parameters (Trial 2)[a]

Parameter	0 g AN/KGCSDM			7.90 g AN/KGCSDM			15.70 g AN/KGCSDM		
	Level of monensin in ration DM								
	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm
No. of steers	7	7	7	14	14	14	14	14	14
Dressing percentage	60.5	60.9	60.1	60.2	60.3	60.0	61.7	60.4	60.7
Maturity score[b]	2.1	2.0	2.3	2.1	2.0	2.1	2.0	2.0	2.1
Adj. fat thickness, cm	1.17	1.55	1.19	1.57	1.04	1.40	1.52	1.52	1.57
Ribeye area, cm^2	74.97	74.71	75.48	71.55	77.42	73.35	75.61	74.58	75.03
KPH fat, %	2.7	2.9	2.9	2.9	3.1	2.9	2.9	3.2	3.0
Marbling score[c]	7.3	7.7	9.4	8.2	9.1	9.1	8.9	8.5	9.0
Quality grade[d]	7.3	7.7	9.0	8.2	8.5	8.7	8.2	8.4	8.4
Yield grade	2.9	3.3	2.9	3.5	2.8	3.2	3.2	3.4	3.3
Carcass fat, %[e]	30.2	30.1	31.1	32.1	29.9	32.4	31.9	33.3	33.3

[a]Carcass parameters were adjusted to a constant empty body weight of 431 kg which corresponds to a final shrunk weight of 486 kg.

[b]Maturity: A = 2, A+ = 3.

[c]Marbling score: Slight$^-$ = 7; Slight = 8; Slight$^+$ = 9, Small$^-$ = 10.

[d]Quality grade: Good$^-$ = 7; Good = 8; Good$^+$ = 9.

[e]Carcass fat was determined by the specific gravity technique (Kraybill et al., 1952).

Table 30.--Effect of Level of Anhydrous Ammonia Treatment of Corn Silage on Carcass Parameters (Trial 2)[a]

	Level of anhydrous ammonia		
Parameter	0 g AN/KGCSDM[b]	7.90 g AN/KGCSDM[c]	15.70 g AN/KGCSDM[c]
Dressing percentage	60.5	60.1	60.9
Maturity score[d]	2.2	2.1	2.0
Adj. fat thickness, cm	1.30	1.35	1.52
Rib eye area, cm^2	74.84	74.19	74.84
KPH fat, %	2.8	3.0	3.0
Marbling score[e]	8.1	8.8	8.8
Quality grade[f]	8.0	8.5	8.3
Yield grade	3.1	3.2	3.3
Carcass fat, %[g]	30.5	31.5	32.8

[a]Since there were no significant interactions between anhydrous ammonia treatment and monensin treatment, monensin treatments were pooled within each anhydrous ammonia treatment. Carcass parameters were adjusted to a constant empty body weight of 431 kg which corresponds to a final shrunk weight of 486 kg.

[b]Twenty-one steers received this anhydrous ammonia treatment.

[c]Forty-two steers received this anhydrous ammonia treatment.

[d]Maturity: A = 2, A+ = 3.

[e]Marbling: Slight = 8, Slight+ = 9.

[f]Quality grade: Good = 8, Good+ = 9.

[g]Carcass fat was determined by the specific gravity technique (Kraybill _et al_., 1952).

Table 31.--Effect of Level of Monensin on Carcass Parameters (Trial 2)[a]

	Level of monensin in ration DM		
Parameter	0 ppm[b]	16.5 ppm[b]	33.0 ppm[b]
Dressing percentage	60.8	60.5	60.3
Maturity score[c]	2.1	2.0	2.2
Adj. fat thickness, cm	1.42	1.37	1.37
Rib eye area, cm^2	74.19	75.48	74.84
KPH fat, %	2.9	3.1	2.9
Marbling score[d]	8.1	8.4	9.1
Quality grade[e]	7.9	8.2	8.7
Yield grade	3.2	3.2	3.2
Carcass fat, %[f]	31.4	31.1	32.3

[a]Since there were no significant interactions between anhydrous ammonia treatment and monensin treatment, anhydrous ammonia treatments were pooled within each monensin treatment. Carcass parameters were adjusted to a constant empty body weight of 431 kg which corresponds to a final shrunk weight of 486 kg.

[b]Thirty-five steers received each monensin treatment.

[c]Maturity: A = 2; A+ = 3.

[d]Marbling: Slight = 8; Slight+ = 9; Small- = 10.

[e]Quality grade: Good- = 7; Good = 8; Good+ = 9.

[f]Carcass fat was determined by the specific gravity technique (Kraybill et al. (1952).

Table 32.--Orthogonal Contrasts for Selected Treatment Comparisons of Carcass Parameters (Trial 2)[a]

No.		Dressing percent	Adj. fat thickness (cm)	Rib eye area (cm^2)	KPH fat (%)	Marbling[b] score	Quality[c] grade	Yield grade	Carcass[d] fat (%)
1	No supplemental nitrogen (0 g AN/KGCSDM) vs. supplemental nitrogen (7.90 g AN/KGCSDM, 15.70 g AN/KGCSDM)	60.5 vs. 60.5 (NS)	1.30 vs. 1.42 (NS)	74.84 vs. 74.84 (NS)	2.8 vs. 3.0 (.015)	8.1 vs. 8.8 (.194)	8.0 vs. 8.4 (NS)	3.1 vs. 3.2 (NS)	30.5 vs. 32.1 (.048)
2	7.90 g AN/KGCSDM vs. 15.70 g AN/KGCSDM	60.1 vs. 60.9 (.025)	1.35 vs. 1.52 (.087)	74.19 vs. 74.84 (NS)	3.0 vs. 3.0 (NS)	8.8 vs. 8.8 (NS)	8.5 vs. 8.3 (NS)	3.2 vs. 3.3 (NS)	31.5 vs. 32.8 (.065)
3	No monensin (0 ppm) vs. with monensin (16.5 ppm, 33.0 ppm)	60.8 vs. 60.4 (.127)	1.42 vs. 1.37 (NS)	74.19 vs. 74.84 (NS)	2.9 vs. 3.0 (.038)	8.1 vs. 8.8 (NS)	7.9 vs. 8.4 (.137)	3.2 vs. 3.2 (NS)	31.4 vs. 31.7 (NS)
4	16.5 ppm monensin in ration DM vs. 33.0 ppm monensin in ration DM	60.5 vs. 60.3 (NS)	1.37 vs. 1.37 (NS)	75.48 vs. 74.84 (NS)	3.1 vs. 2.9 (.042)	8.4 vs. 9.1 (NS)	8.2 vs. 8.7 (NS)	3.2 vs. 3.2 (NS)	31.1 vs. 32.3 (.163)

[a]The numbers in parentheses under the parameter means are statistical significance levels; NS means that P > .20 and therefore was not statistically significant.

[b]Marbling: Slight = 8; Slight+ = 9; Small- = 10.

[c]Quality grade: Good- = 7; Good = 8; Good+ = 9.

[d]Carcass fat was determined by the specific gravity technique (Kraybill *et al.*, 1952).

Monensin added to the ration at the level of 16.5 ppm resulted in more KPH fat ($P = .042$) but slightly less total carcass fat ($P = .163$) than 33.0 ppm monensin in the ration DM.

Net Energy Evaluation

Net energy values for the growing ration, finishing ration and the entire feeding period are listed in Tables 33, 34 and 35, respectively. No significant AN x monensin interactions were found to exist for any of the net energy values. Monensin and AN treatment had no significant effect ($P > .20$) on NE_m and NE_g during the growing phase, but did affect finishing ration and entire feeding period net energy values. Since there were no significant AN x monensin interactions, monensin treatments were pooled within AN treatments and AN treatments were pooled within monensin treatments for finishing ration and entire feeding period net energy values and orthogonal contrasts were constructed for the treatment combinations of primary interest. These contrasts and their respective results are presented for finishing ration and entire feeding period net energy values in Tables 36 and 37, respectively.

During the finishing phase, feeding supplemental nitrogen resulted in a higher NE_m ($P = .097$) than when rations were not supplemented with nitrogen. There was no significant difference ($P > .20$) in NE_g. There were no significant differences ($P > .20$) in NE_m or NE_g between the 15.70 and 7.90 g AN/KGCSDM treatments during the finishing period.

During the finishing phase, monensin had no significant effect ($P > .20$) on NE_m or NE_g. There was also no significant difference

Table 33.--Net Energy Values for Growing Ration (Trial 2)[a]

Level of anhydrous ammonia	Level of monensin in ration DM			
	0 ppm[b]	16.5 ppm[b]	33.0 ppm[b]	$\overline{X}$
0 g AN/KGCSDM[c]				
NE_m	1.54	1.44	1.55	1.51
NE_g	1.04	.87	1.09	1.00
7.90 g AN/KGCSDM[d]				
NE_m	1.50	1.54	1.55	1.53
NE_g	.99	1.09	1.11	1.06
15.70 g AN/KGCSDM[d]				
NE_m	1.57	1.53	1.48	1.53
NE_g	1.11	1.05	.96	1.04
$\overline{X}$				
NE_m	1.54	1.51	1.53	
NE_g	1.05	1.01	1.05	

[a]Net energy values for maintenance (NE_m) and gain (NE_g) are listed as Mcal/kg of ration DM.

[b]There were 45 steers on each monensin treatment.

[c]There were 27 steers on this AN treatment.

[d]There were 54 steers on this AN treatment.

Table 34.--Net Energy Values for Finishing Ration (Trial 2)[a]

Level of anhydrous ammonia	Level of monensin in ration DM			
	0 ppm[b]	16.5 ppm[b]	33.0 ppm[b]	$\overline{X}$
0 g AN/KGCSDM[c]				
NE_m	1.97	2.09	1.99	2.01
NE_g	.98	1.34	1.10	1.14
7.90 g AN/KGCSDM[d]				
NE_m	2.14	2.13	2.04	2.10
NE_g	1.41	1.31	1.12	1.28
15.70 g AN/KGCSDM[d]				
NE_m	2.02	2.08	2.08	2.06
NE_g	1.19	1.31	1.34	1.28
$\overline{X}$				
NE_m	2.04	2.10	2.04	
NE_g	1.19	1.32	1.19	

[a]Net energy values for maintenance (NE_m) and gain (NE_g) are listed as Mcal/kg of ration DM.

[b]There were 35 steers on each monensin treatment.

[c]There were 21 steers on this AN treatment.

[d]There were 42 steers on this AN treatment.

Table 35.--Net Energy Values for Entire Feeding Period (Trial 2)[a]

Level of anhydrous ammonia	Level of monensin in ration DM			$\overline{X}$
	0 ppm[b]	16.5 ppm[b]	33.0 ppm[b]	
0 g AN/KGCSDM[c]				
NE_m	1.70	1.71	1.73	1.71
NE_g	1.05	1.08	1.17	1.10
7.90 g AN/KGCSDM[d]				
NE_m	1.75	1.73	1.75	1.74
NE_g	1.21	1.19	1.18	1.20
15.70 g AN/KGCSDM[d]				
NE_m	1.78	1.79	1.80	1.79
NE_g	1.20	1.25	1.27	1.24
$\overline{X}$				
NE_m	1.74	1.74	1.76	
NE_g	1.16	1.17	1.21	

[a]Net energy values for maintenance (NE_m) and gain (NE_g) are listed as Mcal/kg of ration DM.

[b]There were 35 steers on each monensin treatment.

[c]There were 21 steers on this AN treatment.

[d]There were 42 steers on this AN treatment.

Table 36.--Orthogonal Contrasts for Selected Treatment Comparisons of Finishing Ration Net Energy Values (Trial 2)[a]

No.	Contrast	NE_m[b]	NE_g[c]
1	No supplemental nitrogen (0 g AN/KGCSDM) vs. supplemental nitrogen (7.90 g AN/KGCSDM, 15.70 g AN/KGCSDM)	2.01 vs. 2.08 (.097)	1.14 vs. 1.28 (NS)
2	7.90 g AN/KGCSDM vs. 15.70 g AN/KGCSDM	2.10 vs. 2.06 (NS)	1.28 vs. 1.28 (NS)
3	No monensin (0 ppm) vs. with monensin (16.5 ppm, 33.0 ppm)	2.04 vs. 2.07 (NS)	1.19 vs. 1.26 (NS)
4	16.5 ppm monensin in ration DM vs. 33.0 ppm monensin in ration DM	2.10 vs. 2.04 (NS)	1.32 vs. 1.19 (NS)

[a]The numbers in parentheses under the parameter means are statistical significance levels; NS means that $P > .20$ and therefore was not statistically significant.

[b]Net energy for maintenance, Mcal/kg of ration DM.

[c]Net energy for gain, Mcal/kg of ration DM.

Table 37.--Orthogonal Contrasts for Selected Treatment Comparisons of Net Energy Values for Entire Feeding Period (Trial 2)[a]

No.	Contrast	NE_m[b]	NE_g[c]
1	No supplemental nitrogen (0 g AN/KGCSDM) vs. supplemental nitrogen (7.90 g AN/KGCSDM, 15.70 g AN/KGCSDM)	1.71 vs. 1.76 (<.0005)	1.10 vs. 1.22 (.001)
2	7.90 g AN/KGCSDM vs. 15.70 g AN/KGCSDM	1.74 vs. 1.79 (<.0005)	1.20 vs. 1.24 (.089)
3	No monensin (0 ppm) vs. with monensin (16.5 ppm, 33.0 ppm)	1.74 vs. 1.75 (NS)	1.16 vs. 1.19 (NS)
4	16.5 ppm monensin in ration DM vs. 33.0 ppm monensin in ration DM	1.74 vs. 1.76 (NS)	1.17 vs. 1.21 (NS)

[a]The numbers in parentheses under the parameter means are statistical significance levels; NS means that P > .20 and therefore was not statistically significant.

[b]Net energy for maintenance, Mcal/kg of ration DM.

[c]Net energy for gain, Mcal/kg of ration DM.

(P > .20) in net energy values between the 16.5 and 33.0 ppm monensin treatments.

Feeding supplemental nitrogen resulted in higher NE_m ($P < .0005$) and NE_g ($P = .001$) for the entire feeding period. Higher NE_m ($P < .0005$) and NE_g ($P = .089$) values were obtained with the 15.70 g AN/KGCSDM treatment than with the 7.90 g AN/KGCSDM treatment.

Monensin resulted in no significant difference ($P > .20$) in NE_m or NE_g. There was also no significant difference ($P > .20$) in net energy values obtained with the 16.5 and 33.0 ppm monensin treatments.

Economic Analysis

An economic analysis of the treatment combinations evaluated in trial 2 is presented in Table 38. Lowest total cost per 45.4 kg of gain was obtained by feeding 16.5 ppm monensin in combination with 15.70 g AN/KGCSDM. This treatment was superior to all others with respect to both animal performance and cost of gain.

When monensin treatments were pooled within each AN treatment and AN treatments were pooled within each monensin treatment, 15.70 g AN/KGCSDM and 16.5 ppm were the AN and monensin treatments, respectively, that resulted in the lowest cost of gain. Highest costs of gain were obtained by the 0 g AN/KGCSDM and 33.0 ppm monensin treatments, respectively.

Nitrogen Balance

Nitrogen balance data are presented in Table 39 for the six treatment combinations evaluated.

Table 38.--Economic Analysis of Treatment Combinations Evaluated in Trial 2[a]

	0 g AN/KGCSDM			7.90 g AN/KGCSDM			15.70 g AN/KGCSDM		
	Level of monensin in ration DM								
	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm
Feed cost/45.4 kg of gain, $	27.36	25.64	27.51	26.31	25.53	27.77	26.29	25.94	26.78
Nonfeed cost/45.4 kg of gain, $	16.18	15.94	17.19	16.18	15.79	16.42	14.93	14.73	15.57
Total cost/45.4 kg of gain, $	43.54	41.58	44.70	42.49	41.32	44.19	41.22	40.67	42.35

[a]Feed costs reflect the following prices: (a) anhydrous ammonia $175/ton; (b) corn silage (as harvested basis) $17.50/ton; (c) corn, shelled $2.40/bushel. Nonfeed costs were calculated at $0.33/head/day which included interest on investment, housing and labor and equipment for feeding, but did not include charges for death loss and marketing expense. Application costs and increase in silage value due to the preservative property of anhydrous ammonia were not included in the above calculations.

Table 39.--Effect of Monensin and Level of Anhydrous Ammonia Treatment on Nitrogen Utilization

Item	Level of monensin in ration DM (ppm)	Level of anhydrous ammonia (g AN/KGCSDM)		
		0	7.80	15.60
No. of steers[a]		8	8	8
Nitrogen intake, g/day	0	39.1	67.5	84.3
	33	38.9	67.3	84.0
Fecal N excreted, g/day	0	19.2	27.9	29.5
	33	14.9	27.8	25.7
Urine N excreted, g/day	0	14.1	25.1	26.7
	33	10.1	24.8	35.0
Nitrogen retained, g/day[b]	0	5.8	14.5	28.1
	33	13.9	14.7	23.3
Nitrogen retained/nitrogen intake[c]	0	15.0	21.6	33.4
	33	35.8	22.5	28.2
Apparent nitrogen digestibility, %[d]	0	50.9	58.9	65.0
	33	61.4	60.8	69.6

[a]Within each level of AN treated corn silage, 4 steers received each monensin treatment.

[b]SE = 5.7. Level of AN treatment had a significant effect on nitrogen balance ($P < .0005$). There was an AN x monensin interaction ($P = .087$).

[c]SE = 8.1. There was a significant AN x monensin interaction ($P = .010$). Percentage of nitrogen retained was affected by monensin ($P = .104$) and level of AN treatment ($P = .107$).

[d]SE = 5.6. Nitrogen digestibility was significantly affected by monensin ($P = .021$) and level of AN treatment ($P = .002$). There was no significant AN x monensin interaction ($P > .20$).

Monensin resulted in no significant difference (P > .20) in grams of nitrogen retained per day, but the level of AN did have a significant effect (P < .0005) on this parameter. Nitrogen retention (g/day) increased as the level of nitrogen in the ration increased. There was an AN x monensin interaction (P = .087) for nitrogen retention.

A significant AN x monensin interaction (P = .010) also existed for the percentage of nitrogen retained. This parameter was also affected by monensin (P = .104) and AN treatment (P = .107). Monensin resulted in a higher percentage of nitrogen being retained for the 0 and 7.80 g AN/KGCSDM treatments but a lower percentage of nitrogen retained for the 15.60 g AN/KGCSDM treatment. These results appear to be consistent with those obtained by other researchers (Van Nevel and Demeyer, 1977; Tolbert et al., 1977; Hanson and Klopfenstein, 1977; Perry et al., 1979; Poos et al., 1979) which suggest that monensin is more beneficial for diets that are borderline to deficient in protein and for diets supplemented with preformed protein rather than NPN.

Monensin resulted in a higher level of apparent nitrogen digestibility (P = .021). The level of AN treatment also had a significant effect on apparent nitrogen digestibility (P = .002). As the level of nitrogen in the ration increased, apparent nitrogen digestibility also increased. There was no significant AN x monensin interaction (P > .20). When the percentage of nitrogen retained and apparent nitrogen digestibility are both considered, it appears that the decrease in the percentage of nitrogen retained when monensin was fed with silage treated with 15.60 g AN/KGCSDM was due to a greater loss of nitrogen in the urine. This may be due to a decrease in microbial growth efficiency which would limit the production of microbial protein, and as a result more of the ammonia arising from NPN would be lost in the urine.

CONCLUSIONS

Based on the results of this study, the following conclusions were made:

1. Animal response was similar for the declining soy and constant soy feeding systems.
2. Soybean meal was superior to anhydrous ammonia as a source of supplemental protein when evaluated in terms of animal performance; however, anhydrous ammonia was more favorable economically.
3. When evaluated in terms of total cost of gain, the most desirable protein treatment was 15.60 g AN/KGCSDM.
4. Overall performance was not improved by supplementing anhydrous ammonia treated corn silage with soybean meal during the initial phase of the feeding period, but this response may have been influenced by monensin.
5. Addition of the mineral mix or calcium hydroxide at the time of ensiling did not improve animal performance.
6. Charolais crossbred steers were superior to Hereford steers with respect to carcass quality and yield grades at the same percentage of body fat.
7. Addition of the mineral mix to the ammonia treated silage at the time of ensiling resulted in higher NE_m and NE_g values than adding the same minerals to ammonia treated silage at feeding time.

8. Addition of calcium hydroxide to the ammonia treated silage at the time of ensiling resulted in no significant change in net energy values.
9. Corn silage treated with 15.60 g AN/KGCSDM had similar net energy values as untreated silage supplemented with soybean meal.
10. When evaluated in terms of feedlot performance and cost of gain, 16.5 ppm monensin was superior to 33.0 ppm monensin in the ration DM.
11. 15.70 g AN/KGCSDM was the level of anhydrous ammonia that resulted in the highest net energy values in trial 2.
12. Monensin had no influence on net energy values.
13. There was a significant AN x monensin interaction for the percentage of nitrogen retained.
14. Monensin increased the percentage of nitrogen retained for corn silage treated with 0 or 7.80 g AN/KGCSDM, but decreased the proportion of nitrogen retained for the 15.60 g AN/KGCSDM treatment.

APPENDIX

Table A.1.--Ration Ingredients

Ingredient	International Reference No.
Corn silage	3-07-739
Corn	4-02-931
Soybean meal	5-04-604
Calcium sulfate	6-01-089
Defluorinated phosphate	6-01-780
Ground limestone	6-02-632
Potassium chloride	6-03-756
Monosodium phosphate	6-04-288
Calcium hydroxide	-
Anhydrous ammonia[a]	-
Urea[b]	-
Trace mineral salt	-
Vitamin A premix[c]	-
Vitamin D premix[d]	-
Rumensin 30 premix[e]	-
Rumensin 60 premix[f]	-

[a]82% N.

[b]45% N.

[c]30,000 IU vitamin A per g.

[d]3,000 IU vitamin D_3 per g.

[e]66.14 g monensin sodium per kg.

[f]132.28 g monensin sodium per kg.

Table A.2.--Individual Shrunk Weights, Carcass Weights, and Carcass Composition of Initial Slaughter Cattle (Trial 1)

Steer no.	Cattle[a] type	Shrunk wt, kg	Carcass wt, kg	Dressing %	Carcass protein, %	Carcass fat %
387	C	263.1	156.0	59.3	17.40	22.44
405	C	272.2	143.3	52.7	18.15	15.92
414	C	301.6	164.2	54.4	17.55	18.02
426	C	317.5	180.1	56.7	17.32	19.88
219	H	260.8	139.7	53.6	17.34	16.96
225	H	226.8	127.0	56.0	18.41	14.99
234	H	204.1	109.8	53.8	17.10	16.51
243	H	210.9	117.9	55.9	18.12	15.62

[a]Cattle type: C = Charolais crossbred; H = Hereford.

Table A.3.--Individual Shrunk Weights, Carcass Weights, and Carcass Composition of Initial Slaughter Cattle (Trial 2)

Steer no.	Shrunk wt, kg	Carcass wt, kg	Dressing %	Carcass protein, %	Carcass fat %
380	244.9	141.5	57.8	18.08	16.87
384	206.4	116.1	56.3	18.57	14.15
392	222.3	133.8	60.2	18.95	13.86
405	272.2	156.9	57.7	18.21	19.19
406	213.2	112.9	53.0	19.45	12.58
422	222.3	125.6	56.5	17.88	18.42
441	220.0	131.1	59.6	18.36	15.61
487	233.6	132.9	56.9	16.66	25.15
499	249.5	148.3	59.5	17.48	19.69

Table A.4.--Individual Shrunk Weights, Carcass Weights, and Carcass Composition of Intermediate Slaughter Cattle (Trial 2)

Pen no.	Treatment no.	Steer no.	Shrunk wt, kg	Carcass wt, kg	Dressing %	Carcass protein, %	Carcass fat, %
46	1	433	376.5	231.3	61.4	16.19	26.62
46	1	465	369.7	216.4	58.5	17.13	22.63
47	2	470	367.4	213.6	58.2	18.38	17.35
47	2	508	406.0	233.6	57.5	17.30	21.92
48	3	408	365.1	220.9	60.5	17.48	21.17
48	3	479	403.7	242.7	60.1	16.72	24.36
34	4	458	378.7	223.2	58.9	17.98	19.04
34	4	468	371.9	213.2	56.3	17.93	19.26
37	4	453	399.2	223.6	56.0	16.37	25.89
37	4	483	455.9	258.5	56.7	17.20	22.35
35	5	418	313.0	177.8	56.8	17.41	21.47
35	5	519	392.4	226.8	57.8	18.06	18.68
38	5	477	360.6	217.7	60.4	16.36	25.92
38	5	517	356.1	197.3	55.4	17.06	22.95
36	6	432	353.8	202.8	57.3	17.81	19.75
36	6	518	415.0	238.6	57.5	17.10	22.79
39	6	496	365.1	212.7	58.3	17.84	22.39
39	6	527	378.7	223.2	58.9	16.22	30.97
40	7	502	347.0	208.2	60.0	15.93	27.75
40	7	526	351.5	211.8	60.3	16.70	24.47
43	7	404	337.9	205.0	60.7	17.77	19.92
43	7	491	376.5	217.3	57.7	17.05	22.97
41	8	439	383.3	233.6	61.0	16.58	24.97
41	8	471	428.6	254.9	59.5	16.53	25.19
44	8	366	326.6	187.8	57.5	18.32	17.59
44	8	416	362.9	211.8	58.4	17.78	19.89
42	9	389	303.9	176.0	57.9	18.03	18.81
42	9	430	433.2	246.3	56.9	16.98	23.30
45	9	409	387.8	222.7	57.4	17.31	21.90
45	9	405	440.0	245.4	55.8	18.11	18.49

Table A.5.--Individual Performance and Carcass Data (Trial 1)

Pen[a] no.	Steer no.	Treat-ment no.	Days on feed	Initial wt, kg	Final wt, kg	ADG, KG	Hot carcass wt, kg	Marb.[b]	Qual.[c] grade	Fat thick., cm	KPH fat %	Rib eye area, cm^2	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain, kg	Daily fat gain kg	Daily energy gain protein, kcal	Daily energy gain fat, kcal
33	366	1	279	351.5	553.4	.72	323.0	11	10	.64	2.0	79.4	2.2	18.22	18.00	.1169	.0821	664.8	768.6
33	374	1	279	328.9	489.9	.58	303.0	11	10	.89	3.0	80.0	2.5	16.33	26.06	.0876	.1990	498.2	1864.1
33	375	1	279	244.9	385.6	.50	227.7	7	7	.51	2.5	65.8	2.1	17.66	20.39	.0845	.0917	480.6	859.3
33	390	1	279	283.5	462.7	.64	276.2	9	9	.76	2.5	75.5	2.3	15.01	31.66	.0752	.2687	427.7	2516.2
33	398	1	279	244.9	421.8	.63	238.1	8	8	.76	2.0	76.1	1.8	18.70	15.97	.1046	.0484	594.4	453.3
33	399	1	279	294.8	442.3	.53	271.7	14	11	.89	2.5	74.2	2.4	16.73	24.35	.0851	.1580	484.0	1480.0
33	422	1	279	267.6	501.2	.84	301.2	17	12	1.52	3.0	71.0	3.6	14.52	33.73	.0976	.3426	555.1	3208.8
33	424	1	279	310.7	535.2	.80	332.5	8	8	1.02	3.0	91.0	2.3	15.83	28.18	.1154	.2765	656.2	2589.9
34	245	1	279	238.1	415.0	.63	247.7	10	10	.89	2.5	65.2	2.7	14.24	34.92	.0668	.3117	380.0	2919.6
34	250	1	279	208.7	415.0	.74	237.2	8	8	1.02	3.0	49.7	3.6	16.39	25.77	.0978	.1999	555.9	1871.8
34	254	1	279	215.5	365.1	.54	214.6	7	7	.51	3.0	57.4	2.5	17.09	22.83	.0813	.1393	462.3	1305.0
34	294	1	279	208.7	356.1	.53	213.2	7	7	1.52	3.0	51.6	3.8	16.40	25.73	.0778	.1724	442.1	1614.9
34	298	1	279	229.1	344.7	.41	196.4	4	5	.13	2.5	58.1	1.8	18.12	18.43	.0665	.0709	377.8	663.9
34	317	1	279	240.4	421.8	.65	253.6	2	4	.51	2.5	61.3	2.5	17.52	21.01	.1053	.1439	598.8	1348.1
34	323	1	279	220.0	362.9	.51	208.2	4	5	.51	3.0	67.1	2.0	16.25	26.38	.0657	.1685	373.4	1577.9
34	325	1	279	238.1	394.6	.56	227.3	8	8	.64	3.0	65.2	2.3	16.61	24.84	.0746	.1648	424.2	1543.5
41	368	2	265	306.2	528.4	.84	319.3	7	7	1.27	3.0	80.6	3.0	16.45	25.55	.1218	.2333	692.5	2185.2
41	371	2	265	317.5	598.8	1.06	352.4	10	10	1.27	2.5	78.1	3.3	16.98	23.28	.1524	.2247	866.6	2104.5
41	382	2	265	288.0	526.2	.90	313.0	8	8	.76	3.0	87.1	2.1	16.56	25.07	.1280	.2278	727.8	2133.2
41	389	2	265	328.9	598.8	1.02	375.1	8	8	.38	3.0	89.0	2.2	16.72	24.36	.1622	.2635	922.1	2467.5
41	393	2	265	310.7	594.2	1.07	359.3	9	9	.64	3.5	84.5	2.6	15.79	28.35	.1439	.3291	818.0	3082.0
41	394	2	265	272.2	499.0	.86	298.9	14	11	1.27	3.5	68.4	3.5	14.38	34.30	.0964	.3635	548.1	3403.9
41	403	2	265	233.6	401.4	.63	240.0	7	7	.38	2.5	60.6	2.3	17.16	22.51	.1019	.1413	579.1	1323.1
41	419	2	265	251.7	403.7	.57	242.7	8	8	.25	2.0	71.0	1.6	18.49	16.88	.1080	.0619	613.9	579.3
42	209	2	279	233.6	458.1	.80	265.8	6	6	.64	3.0	72.9	2.3	16.63	24.75	.1103	.2077	627.0	1945.3
42	258	2	279	181.4	381.0	.72	211.8	7	7	.76	2.0	67.7	2.0	17.16	22.51	.0993	.1484	564.4	1390.4
42	274	2	279	229.1	462.7	.84	265.8	8	8	1.14	3.0	58.1	3.5	14.26	34.83	.0862	.3429	489.9	3211.5
42	277	2	279	238.1	471.7	.84	274.0	8	8	1.52	3.0	73.5	3.2	15.77	28.43	.1043	.2644	593.2	2475.8
42	290	2	279	242.7	453.6	.76	264.4	7	7	1.65	2.5	66.5	3.5	16.05	27.24	.0974	.2350	553.5	2200.6
42	310	2	279	210.9	426.4	.77	250.8	4	5	.76	2.5	78.7	1.9	17.12	22.69	.1157	.1759	657.6	1647.2
42	357	2	279	215.5	446.8	.83	231.3	7	7	.76	2.5	68.4	2.2	16.56	25.07	.0904	.1820	514.2	1704.6
42	372	2	279	222.3	369.7	.53	215.5	9	9	.64	3.0	72.3	1.9	16.96	23.37	.0770	.1432	437.7	1341.3

[a]Odd numbered pens contained Charolais crossbred steers and even numbered pens contained Hereford steers.

[b]Marbling score: Slight° = 8; Slight⁺ = 9; Small⁻ = 10.

[c]Quality grade: Average good = 8; High good = 9; Low choice = 10.

Table A.5.--Continued

Pen[a] no.	Steer no.	Treat-ment no.	Days on feed	Initial wt, kg	Final wt, kg	ADG, kg	Hot carcass wt, kg	Marb.[b]	Qual.[c] grade	Fat thick., cm	KPH fat %	Rib eye area, cm^2	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain, kg	Daily fat gain, kg	Daily energy gain protein, kcal	Daily energy gain fat, kcal
43	369	3	265	276.7	476.3	.75	289.9	8	8	.51	3.0	90.3	1.5	16.48	25.41	.0977	.1981	555.6	1854.8
43	380	3	265	292.6	467.2	.66	271.3	6	6	1.02	2.0	87.1	1.8	17.19	22.40	.0892	.1330	507.4	1245.7
43	391	3	265	376.5	655.5	1.05	391.0	9	9	1.40	3.0	87.1	3.4	14.72	32.87	.1592	.4669	905.1	4372.8
43	397	3	265	244.9	442.3	.74	273.5	8	8	.51	3.0	84.5	1.6	16.39	25.79	.0774	.1797	439.8	1683.1
43	401	3	265	315.3	537.5	.84	329.3	7	7	.51	3.0	80.0	2.3	16.17	26.70	.1334	.2709	758.4	2537.1
43	404	3	265	324.3	551.1	.86	325.7	7	7	.64	3.0	77.4	2.6	16.30	26.16	.1226	.2485	697.0	2327.0
43	423	3	265	260.8	480.8	.83	286.2	7	7	.76	3.0	91.0	1.7	17.53	20.94	.1024	.1222	582.3	1144.1
43	431	3	265	290.3	526.2	.89	325.7	10	10	.64	3.0	87.7	2.1	16.60	24.89	.1274	.2277	724.4	2132.4
44	198	3	279	240.4	487.6	.89	291.7	7	7	1.65	3.0	80.6	3.1	15.23	30.72	.1108	.3184	630.2	2981.6
44	201	3	279	233.6	458.1	.80	264.0	7	7	.76	3.0	84.5	1.8	15.92	27.78	.1006	.2452	572.1	2296.5
44	249	3	279	197.3	396.9	.72	227.7	7	7	.51	2.5	69.7	1.9	17.67	20.36	.1086	.1322	617.6	1238.1
44	276	3	279	233.6	376.5	.51	216.4	4	5	.89	2.5	66.5	2.3	15.78	28.39	.0601	.1938	341.7	1814.8
44	293	3	279	213.2	471.7	.93	274.9	9	9	.76	3.0	76.8	2.3	15.34	30.24	.1146	.3013	651.4	2821.4
44	333	3	279	220.0	424.1	.73	252.7	7	7	.76	2.0	74.8	2.0	17.16	22.50	.1124	.1709	639.2	1600.8
44	342	3	279	242.7	476.3	.84	281.2	8	8	1.78	3.0	66.5	3.9	15.91	27.82	.1095	.2631	622.5	2463.7
44	346	3	279	220.0	462.7	.87	276.2	7	7	1.65	3.0	73.5	3.3	15.15	31.05	.1095	.3112	622.8	2914.6
39	378	4	252	281.2	508.0	.90	299.4	11	10	.76	3.0	78.7	2.4	16.66	24.66	.1278	.2205	726.4	2065.2
39	395	4	252	267.6	528.4	1.04	316.2	12	10	1.40	3.0	91.0	2.6	15.94	27.68	.1415	.3003	804.3	2812.0
39	396	4	252	310.7	571.5	1.04	348.8	11	10	1.02	3.0	83.2	2.8	15.45	29.77	.1366	.3585	776.3	3357.1
39	412	4	252	283.5	533.0	.99	319.8	10	10	1.27	3.0	85.2	2.8	15.56	29.29	.1294	.3240	735.6	3034.8
39	415	4	252	328.9	571.5	.96	342.0	11	10	1.14	2.5	91.6	2.4	15.77	28.40	.1245	.3130	707.6	2931.4
39	418	4	252	322.1	603.3	1.12	370.6	11	10	1.78	3.0	94.8	3.2	14.43	34.12	.1313	.4701	746.7	4402.9
39	432	4	252	308.4	533.0	.89	316.6	11	10	.76	3.5	85.8	2.3	15.99	27.50	.1171	.2738	665.8	2564.5
39	434	4	252	238.1	444.5	.82	267.2	12	10	.38	3.0	80.6	1.7	15.19	30.86	.1060	.2982	602.8	2792.8
40	203	4	265	233.6	474.0	.91	280.3	10	10	1.52	3.0	74.2	3.2	15.16	31.02	.0647	.2909	367.8	2724.8
40	213	4	265	215.5	430.9	.81	240.9	8	8	.64	2.0	72.3	1.9	15.48	29.66	.0394	.2201	224.2	2061.5
40	222	4	265	190.5	365.1	.66	213.2	8	8	.38	3.5	61.9	2.2	17.63	20.50	.0402	.0805	228.3	754.2
40	232	4	265	213.2	415.0	.76	242.7	8	8	.51	2.5	76.8	1.7	16.29	26.22	.0502	.1789	285.6	1675.3
40	236	4	265	229.1	478.5	.94	283.0	11	10	1.52	3.5	63.9	3.9	13.99	35.98	.1011	.4062	574.6	3803.9
40	257	4	265	238.1	499.0	.98	288.9	12	10	1.78	3.0	71.0	3.7	14.91	32.08	.1119	.3529	635.9	3305.2
40	334	4	265	226.8	478.5	.95	283.5	7	7	1.14	2.0	86.5	2.1	17.01	23.14	.1407	.2183	800.1	2044.4
40	365	4	265	240.4	480.8	.91	283.0	17	9	1.52	2.5	73.5	3.2	15.76	28.44	.1165	.2897	662.3	2713.2

[a]Odd numbered pens contained Charolais crossbred steers and even numbered pens contained Hereford steers.

[b]Marbling score: Slight° = 8; Slight$^+$ = 9; Small$^-$ = 10.

[c]Quality grade: Average good = 8; High good = 9; Low choice = 10.

Table A.5.--Continued

Pen[a] no.	Steer no.	Treat-ment no.	Days on feed	Initial wt, kg	Final wt, kg	ADG, kg	Hot carcass wt, kg	Marb.[b]	Qual.[c] grade	Fat thick., cm	KPH fat %	Rib eye area, cm^2	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain, kg	Daily fat gain, kg	Daily energy gain protein, kcal	Dailey energy gain fat, kcal
45	376	5	252	313.0	503.5	.76	316.6	9	9	.76	3.0	92.9	1.8	16.09	27.07	.1158	.2639	658.1	2471.2
45	379	5	252	265.4	546.6	1.12	326.1	7	7	.76	3.0	79.4	2.6	16.83	23.90	.1655	.2482	941.1	2324.6
45	411	5	252	394.6	614.6	.87	375.1	9	9	.76	3.0	97.4	2.1	16.69	24.49	.1290	.2416	733.4	2262.3
45	421	5	252	233.6	471.7	.95	277.1	10	10	1.02	3.5	75.5	2.7	16.32	26.10	.1320	.2434	750.6	2279.9
45	425	5	252	281.2	464.9	.73	274.0	7	7	.38	3.0	77.4	1.9	17.05	22.97	.1088	.1644	618.3	1540.0
45	427	5	252	306.2	528.4	.88	307.5	8	8	.64	2.5	91.0	1.6	14.82	32.45	.0938	.3460	533.0	3240.1
45	429	5	252	276.7	485.4	.83	286.7	11	10	1.78	3.5	76.8	3.5	14.11	35.45	.0845	.3768	480.4	3529.2
45	430	5	252	317.5	501.2	.73	296.2	13	11	.76	4.0	86.5	2.2	14.79	32.57	.0764	.3234	434.5	3029.0
46	200	5	279	213.2	430.9	.78	254.5	10	10	1.40	3.0	65.8	3.3	16.46	25.49	.1105	.2139	628.3	2003.2
46	218	5	279	233.6	487.6	.91	290.8	9	9	1.78	3.0	72.3	3.7	15.02	31.61	.1116	.3332	634.7	3120.5
46	268	5	279	240.4	462.7	.80	279.4	7	7	1.40	3.0	74.2	3.1	16.69	24.51	.1186	.2162	674.0	2025.1
46	278	5	279	224.5	460.4	.85	263.1	8	8	.89	3.0	69.7	2.7	16.06	27.18	.1068	.2406	607.3	2253.8
46	308	5	279	213.2	408.2	.70	262.6	10	10	1.27	3.0	70.3	3.0	15.72	28.64	.1089	.2640	619.2	2472.1
46	320	5	279	231.3	410.5	.64	239.5	8	8	.76	2.5	67.7	2.3	17.03	23.07	.0932	.1600	529.9	1498.8
46	324	5	279	240.4	426.4	.67	240.4	7	7	.76	2.5	63.9	2.5	15.45	29.79	.0727	.2379	413.2	2228.3
46	353	5	279	181.4	360.6	.64	207.7	7	7	.76	2.5	60.6	2.4	16.84	23.89	.0926	.1588	526.4	1487.2
47	370	6	252	267.6	503.5	.94	284.0	12	10	.25	3.5	87.7	1.4	17.05	22.98	.1268	.1836	720.9	1719.5
47	383	6	252	285.8	530.7	.97	316.2	9	9	.51	3.0	78.1	2.3	15.68	28.80	.1264	.3091	718.3	2894.6
47	384	6	252	351.5	576.1	.89	359.3	12	10	1.02	2.5	92.3	2.4	16.66	24.63	.1403	.2502	797.8	2342.8
47	385	6	252	263.1	501.2	.95	286.7	8	8	1.27	3.0	74.8	3.0	16.87	23.76	.1297	.2015	737.2	1887.5
47	400	6	252	244.9	430.9	.74	265.8	11	10	.51	3.0	80.0	1.8	15.96	27.63	.1100	.2449	625.2	2293.6
47	402	6	252	313.0	544.3	.92	332.0	7	7	.25	2.5	98.7	1.1	17.53	20.93	.1521	.1738	864.9	1627.5
47	408	6	252	317.5	557.9	.95	332.9	13	11	1.27	3.0	90.3	2.6	15.59	29.20	.1202	.3211	683.5	3007.1
47	420	6	252	301.6	557.9	1.02	337.5	14	11	.64	3.5	83.2	2.5	16.10	27.01	.1423	.2969	808.7	2780.9
48	208	6	265	192.8	401.4	.79	231.3	6	6	.76	2.5	63.2	2.5	16.72	24.39	.1107	.1939	629.1	1816.5
48	241	6	265	235.9	476.3	.91	284.4	7	7	.76	2.0	74.8	2.3	17.08	22.84	.1371	.2105	779.4	1971.5
48	280	6	265	215.5	437.7	.84	261.7	10	10	1.40	3.0	69.0	3.2	16.45	25.52	.1213	.2332	689.8	2183.8
48	319	6	265	208.7	430.9	.84	249.0	9	9	.51	2.5	76.8	1.7	16.58	24.98	.1153	.2140	655.7	2004.0
48	347	6	265	233.6	458.1	.85	263.5	8	8	1.52	3.0	67.1	3.4	15.79	28.33	.1040	.2654	591.5	2485.4
48	350	6	265	231.3	460.4	.86	259.9	10	10	1.52	3.0	63.9	3.6	15.39	30.04	.0976	.2850	555.0	2668.9
48	361	6	265	244.9	455.9	.80	263.5	7	7	1.27	3.0	67.1	3.2	16.46	25.48	.1051	.2207	597.5	2066.8
48	364	6	265	220.0	440.0	.83	251.3	10	10	1.52	3.0	65.8	3.4	16.71	24.41	.1121	.2039	637.3	1909.4

[a] Odd numbered pens contained Charolais crossbred steers and even numbered pens contained Hereford steers.

[b] Marbling score: Slight° = 8; Slight$^+$ = 9; Small$^-$ = 10.

[c] Quality grade: Average good = 8; High good = 9; Low choice = 10.

Table A.5.--Continued

Pen[a] no.	Steer no.	Treat-ment no.	Days on feed	Initial wt, kg	Final wt, kg	ADG, kg	Hot carcass wt, kg	Marb.[b]	Qual.[c] grade	Fat thick., cm	KPH fat %	Rib eye area, cm^2	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain, kg	Daily fat gain, kg	Daily energy gain protein, kcal	Daily energy gain fat, kcal
35	367	7	230	315.3	528.4	.93	305.7	11	10	1.27	3.0	81.9	2.8	15.81	28.23	.1103	.2933	627.1	2746.4
35	386	7	230	383.5	521.6	1.04	324.3	13	11	1.02	3.5	76.8	3.1	15.29	30.43	.1420	.3843	807.4	3599.3
35	392	7	230	326.6	573.8	1.07	349.7	7	7	.25	3.0	98.7	1.3	17.25	22.12	.1715	.2260	975.0	2117.0
35	407	7	230	233.6	514.8	1.22	298.0	10	10	1.40	3.0	86.5	2.6	15.15	31.05	.1483	.3843	843.2	3598.8
35	409	7	230	260.8	458.1	.86	284.0	8	8	1.52	3.0	78.7	3.0	16.05	27.23	.1291	.2778	733.8	2601.9
35	410	7	230	340.2	578.3	1.04	361.5	7	7	.76	3.0	91.0	2.3	17.40	21.50	.1773	.2176	1008.8	2037.6
35	413	7	230	267.6	503.5	1.03	303.5	7	7	.76	2.5	89.0	1.8	17.34	21.74	.1640	.2027	932.3	1898.0
35	433	7	230	297.1	510.3	.93	303.9	7	7	.76	2.5	81.3	2.2	16.88	23.70	.1371	.2198	779.5	2058.1
36	226	7	265	215.5	453.6	.90	267.2	8	8	.76	3.0	73.5	2.4	16.16	26.77	.1225	.2570	696.4	2406.9
36	230	7	265	235.9	462.7	.86	280.3	8	8	1.40	3.0	79.4	2.8	16.82	23.96	.1297	.2223	737.5	2081.9
36	231	7	265	238.1	501.2	.99	294.4	8	8	1.52	2.5	74.8	3.2	15.60	29.12	.1255	.3160	713.3	2959.1
36	259	7	265	188.2	394.6	.78	240.9	17	12	.76	3.0	72.9	2.2	15.70	28.71	.1111	.2618	631.7	2452.2
36	266	7	265	233.6	4 0.4	.86	268.5	8	8	1.40	3.0	78.7	2.8	16.88	23.72	.1213	.2072	689.8	1940.8
36	309	7	265	208.7	496.7	1.09	302.1	10	10	1.78	2.5	72.3	3.6	15.40	29.98	.1472	.3537	836.8	3312.3
36	354	7	265	220.0	476.3	.97	288.9	7	7	1.40	2.5	85.2	2.5	16.45	25.53	.1425	.2630	810.2	2462.8
36	355	7	265	244.9	467.2	.84	293.0	8	8	1.52	3.0	67.1	3.7	15.09	31.31	.1136	.3444	645.6	3225.0
37	373	8	265	306.2	494.4	.71	316.2	7	7	.76	3.0	94.2	1.8	15.69	28.75	.1083	.2817	615.4	2638.6
37	377	8	265	328.9	578.3	.94	361.1	8	8	.51	3.0	98.7	1.7	16.35	25.94	.1437	.2769	817.1	2593.7
37	381	8	265	244.9	430.9	.70	255.4	7	8	.25	3.0	63.2	2.3	17.79	19.83	.1166	.1150	663.0	1077.4
37	388	8	265	310.7	598.8	1.09	367.9	7	7	.89	2.5	91.0	2.4	15.77	28.42	.1511	.3417	859.1	3199.8
37	406	8	265	249.5	460.4	.80	284.0	9	9	.38	3.0	80.0	1.8	17.07	22.91	.1315	.1837	747.4	1720.4
37	416	8	265	288.0	478.5	.72	281.7	7	7	.38	2.5	82.6	1.6	17.22	22.24	.1086	.1501	617.2	1405.4
37	417	8	265	272.2	471.7	.75	282.1	9	9	1.27	2.5	72.3	3.0	16.40	25.75	.1082	.2112	615.4	1977.6
37	428	8	265	358.3	605.6	.93	373.8	10	10	.89	3.0	92.9	2.4	15.57	29.25	.1248	.3391	709.7	3175.5
38	211	8	265	229.1	449.1	.83	264.4	11	10	1.52	3.0	63.9	3.6	15.98	27.53	.1099	.2578	624.6	2414.1
38	247	8	265	235.9	512.6	1.04	308.4	8	8	1.52	3.5	84.5	3.0	15.48	29.65	.1371	.3444	779.2	3225.7
38	251	8	265	240.4	503.5	.99	293.5	7	7	1.65	3.0	67.1	3.8	15.24	30.68	.1185	.3374	673.9	3159.8
38	279	8	265	210.9	435.5	.85	255.4	11	10	1.02	3.0	76.8	2.4	15.98	27.51	.1132	.2546	643.5	2384.0
38	301	8	265	215.5	462.7	.93	269.0	8	8	.76	2.5	82.6	1.9	17.37	21.62	.1386	.1865	788.0	1746.7
38	326	8	265	222.3	444.5	.84	273.1	7	7	.89	2.5	76.1	2.3	15.95	27.66	.1212	.2738	688.9	2564.5
38	356	8	265	238.1	480.8	.92	282.1	8	8	.38	2.0	78.7	1.7	16.28	26.26	.1234	.2572	701.7	2409.0
38	359	8	265	204.1	499.0	1.11	303.9	8	8	1.78	3.0	71.6	3.8	15.16	30.99	.1482	.3741	842.3	3503.1

[a]Odd numbered pens contained Charolais crossbred steers and even numbered pens contained Hereford steers.

[b]Marbling score: Slight° = 8; Slight⁺ = 9; Small⁻ = 10.

[c]Quality grade: Average good = 8; High good = 9; Low choice = 10.

Table A.6.--Scanoprobe Estimates of Fat Thickness Over the Twelfth Rib (Trial 1)[a]

Pen no.	Steer no.	Estimated fat cm	Actual fat cm	Pen no.	Steer no.	Estimated fat cm	Actual fat cm
33	366	.51	.64	37	373	.76	.51
	374	.38	1.02		377	.64	.64
	375	.25	.38		381	.51	.51
	390	.64	.51		388	.64	.89
	398	.51	.64		406	.64	.51
	399	.64	1.02		416	.38	.51
	422	1.27	1.52		417	.76	.76
	424	.89	.89		428	1.02	.64
34	245	.76	.76	38	211	.51	.76
	250	.38	1.02		247	.76	1.02
	254	.38	.64		251	1.02	1.52
	294	.51	1.02		279	.51	.89
	298	.25	.05		301	.64	.76
	317	.38	.64		326	.51	.76
	323	.25	.64		356	.64	.64
	325	.51	.51		359	.89	1.65
35	367	.76	.89	39	378	.25	.38
	386	.51	.76		395	.76	1.02
	392	.64	.38		396	.76	.89
	407	.89	1.02		412	.76	1.14
	409	1.02	1.14		415	1.02	1.02
	410	.76	.76		418	1.27	1.65
	413	.64	.51		432	1.02	.76
	433	.64	.89		434	.51	.25
36	226	.64	.64	40	203	.89	1.02
	230	.76	.76		213	.64	.51
	231	1.02	1.27		222	.25	.64
	259	.64	.76		232	.51	.51
	266	.76	1.14		236	.64	1.40
	309	.76	1.78		257	1.02	1.78
	354	.76	1.14		334	.51	.89
	355	.76	1.52		365	.64	1.14

[a]ITHACO ultrasonic SCANOPROBE, Ithaca, New York.

Table A.6.--Continued

Pen no.	Steer no.	Estimated fat cm	Actual fat cm	Pen no.	Steer no.	Estimated fat cm	Actual fat cm
41	368	.51	1.27	45	376	.76	.76
	371	.51	1.14		379	1.02	1.02
	382	.76	.89		411	.76	.51
	389	.76	.51		421	.25	.64
	393	.51	1.02		425	1.02	.38
	394	.51	1.02		427	.76	.51
	403	.38	.51		429	1.27	1.78
	419	.38	.38		430	.25	1.14
42	209	.51	.64	46	200	.76	.89
	258	.38	.64		218	.76	1.27
	274	.64	.64		268	.51	1.02
	277	.76	1.40		278	.64	.76
	290	.89	1.27		308	.51	.76
	310	.51	.76		320	.38	.76
	357	.76	.51		324	.64	.76
	372	.25	.25		353	.51	.64
43	369	.38	.51	47	370	.51	.25
	380	.64	.89		383	.76	.25
	391	.76	1.27		384	.76	.76
	397	.51	.38		385	.76	1.02
	401	.64	.38		400	.25	.38
	404	.51	.51		402	.64	.38
	423	.64	.64		408	1.27	.89
	431	.51	.64		420	1.02	.51
44	198	.76	1.27	48	208	.51	.64
	201	.89	.89		241	.64	.89
	249	.38	.25		280	.51	.89
	276	.51	.64		319	.51	.51
	293	.51	.76		347	.64	1.02
	333	.38	.76		350	.51	1.27
	342	.64	.89		361	.76	.64
	346	.76	1.78		364	.51	1.52

[a]ITHACO ultrasonic SCANOPROBE, Ithaca, New York.

Table A.7.--Calculation of Net Energy Values of Rations Fed to Hereford Steers (Trial 1)[a]

	Protein treatment							
	Unsupplemented control	7.80 g AN/ KGCSDM	7.80 g AN/ KGCSDM + soy	15.60 g AN/ KGCSDM	15.60 g AN/ KGCSDM + minerals	15.60 g AN/ KGCSDM + $Ca(OH)_2$	Declining soy	Constant soy
Treatment no.	1	2	3	4	5	6	7	8
Initial wt, lb	495.625	488.750	496.250	591.125	490.000	491.250	491.875	495.000
Initial empty body protein, %	18.240	18.240	18.240	18.240	18.240	18.240	18.240	18.240
Final empty body protein, %	17.351	17.139	16.905	16.713	17.015	17.208	16.898	16.834
Initial empty body fat, %	14.160	14.160	14.160	14.160	14.160	14.160	14.160	14.160
Final empty body fat, %	22.409	23.469	24.639	25.601	24.088	23.125	24.665	24.993
Final empty body wt, lb	741.500	809.750	848.875	860.750	831.750	841.625	905.750	911.250
Days on feed	279.000	279.000	279.000	265.000	279.000	265.000	265.000	265.000
Average daily DM intake, lb[b]	11.590	12.870	12.760	13.360	12.290	12.720	14.040	13.740
Initial empty body weight, lb	436.200	430.149	436.750	520.249	431.249	432.349	432.899	435.650
Protein gain, lb	48.885	60.014	63.530	48.540	62.659	65.966	74.007	73.760
Energy gain protein, Mcal	126.059	154.758	163.824	125.169	161.578	170.106	190.840	190.205
Fat gain, lb	105.449	130.670	148.853	148.798	140.292	133.388	162.511	166.924
Energy gain fat, Mcal	447.957	555.095	632.337	632.103	595.972	566.642	690.358	709.104
Daily NE req. for maintenance, Mcal	5.085	5.284	5.430	5.731	5.357	5.394	5.598	5.624
Daily NE expended for maint. + gain, Mcal	7.142	7.828	8.284	8.589	8.073	8.174	8.923	9.018
Ration ME value, Mcal/lb	.616	.608	.649	.643	.657	.643	.636	.656
Daily ME intake, Mcal	13.178	14.633	14.534	15.190	14.170	14.475	16.160	15.856
Daily ME intake/unit met. wt, Kcal/kg	199.938	214.066	206.687	204.287	204.453	207.005	222.784	217.357
Daily heat prod./unit met. wt, Kcal/kg	168.965	177.261	166.543	166.051	165.634	167.326	177.092	171.041
Daily ME intake req. for energy equil., Kcal	127.223	125.375	120.930	123.268	121.082	121.248	121.026	119.398
NE value of ration for maint., Mcal/lb	.692	.701	.729	.718	.736	.723	.734	.746
NE value of ration for gain, Mcal/lb	.480	.477	.536	.521	.542	.529	.519	.546
Efficiency of ME use for production, %	42.250	41.913	47.021	45.828	46.988	46.463	45.051	47.325
Energy req. for maintenance, Mcal	2338.520	2392.536	2371.013	2426.635	2343.338	2248.819	2329.014	2307.837

[a]There were 8 Hereford steers on each protein treatment.

[b]Corn silage dry matter intakes were not corrected for loss of volatiles during DM determination.

Table A.8.--Calculation of Net Energy Values of Rations Fed to Charolais Crossbred Steers (Trial 1)[a]

	Protein treatment							
	Unsupplemented control	7.80 g AN/ KGCSDM	7.80 g AN/ KGCSDM + soy	15.60 g AN/ KGCSDM	15.60 g AN/ KGCSDM + minerals	15.60 g AN/ KGCSDM + $Ca(OH)_2$	Declining soy	Constant soy
Treatment no.	1	2	3	4	5	6	7	8
Initial wt, lb	641.250	636.250	674.125	645.000	658.125	646.250	640.625	650.000
Initial empty body protein, %	18.140	18.140	18.140	18.140	18.140	18.140	18.140	18.140
Final empty body protein, %	17.390	17.343	17.228	16.589	16.760	17.231	17.208	17.276
Initial empty body fat, %	16.980	16.980	16.980	16.980	16.980	16.980	16.980	16.980
Final empty body fat, %	22.228	22.458	23.029	26.214	25.359	23.001	23.126	22.784
Final empty body wt, lb	920.000	1005.125	1002.375	1035.250	989.625	1010.250	1016.625	1013.250
Days on feed	279.000	265.000	265.000	252.000	252.000	252.000	230.000	230.000
Average daily DM intake, lb[b]	14.130	15.200	14.810	16.700	14.500	15.100	16.670	15.470
Initial empty body weight, lb	554.168	549.847	582.579	557.409	568.752	558.489	553.628	561.730
Protein gain, lb	58.980	74.095	66.412	70.431	62.904	72.762	74.768	72.507
Energy gain protein, Mcal	152.090	191.067	171.255	181.620	162.209	187.630	192.804	186.972
Fat gain, lb	112.802	134.733	134.876	177.672	153.316	137.577	139.803	138.707
Energy gain fat, Mcal	479.190	572.354	572.963	754.766	651.298	584.438	593.894	589.239
Daily NE req. for maintenance, Mcal	6.012	6.255	6.353	6.374	6.269	6.302	6.307	6.317
Daily NE expended for maint. + gain, Mcal	8.275	9.136	9.161	10.090	9.497	9.365	9.728	9.692
Ration ME value, Mcal/lb	.586	.601	.619	.604	.655	.620	.584	.626
Daily ME intake, Mcal	16.066	17.282	16.869	18.988	16.719	17.184	19.187	17.852
Daily ME intake/unit met. wt, Kcal/kg	207.312	214.914	204.963	230.413	206.571	211.090	235.141	219.507
Daily heat prod./unit met. wt, Kcal/kg	178.599	179.955	171.449	185.666	166.718	173.649	193.063	178.990
Daily ME intake req. for energy equil., Kcal	131.331	126.481	126.565	122.994	120.919	123.936	126.196	123.193
NE value of ration for maint., Mcal/lb	.673	.697	.700	.714	.736	.709	.703	.726
NE value of ration for gain, Mcal/lb	.432	.464	.483	.479	.541	.495	.444	.499
Efficiency of ME use for production, %	37.978	40.806	42.407	42.146	46.889	43.489	38.553	43.270
Energy req. for maintenance, Mcal	2847.169	2703.362	2754.416	2559.985	2475.993	2550.077	2378.639	2307.329

[a]There were 8 Charolais crossbred steers on each protein treatment.

[b]Corn silage dry matter intakes were not corrected for loss of volatiles during dry matter determination.

Table A.9.--Calculation of Net Energy Values of Rations Containing Various Sources and Levels of Supplemental Nitrogen (Trial 1)[a]

	Protein treatment							
	Unsupplemented control	7.80 g AN/ KGCSDM	7.80 g AN/ KGCSDM + soy	15.60 g AN/ KGCSDM	15.60 g AN/ KGCSDM + minerals	15.60 g AN/ KGCSDM + $Ca(OH)_2$	Declining soy	Constant soy
Treatment no.	1	2	3	4	5	6	7	8
Initial wt, lb	568.438	562.500	585.188	618.063	574.063	568.063	568.750	572.500
Initial empty body protein, %	18.190	18.190	18.190	18.190	18.190	18.190	18.190	18.190
Final empty body protein, %	17.371	17.241	17.066	16.651	16.888	17.219	17.053	17.055
Initial empty body fat, %	15.570	15.570	15.570	15.570	15.570	15.570	15.570	15.570
Final empty body fat, %	22.318	22.963	23.834	25.908	24.723	23.063	23.896	23.888
Final empty body wt, lb	830.750	907.438	925.625	948.000	910.687	925.937	961.188	962.250
Days on feed	279.000	272.000	272.000	258.500	265.500	258.500	247.500	247.500
Average daily DM intake, lb[b]	12.860	14.035	13.785	15.030	13.395	13.910	15.355	14.605
Initial empty body weight, lb	495.184	489.998	509.664	538.829	500.000	495.419	493.264	498.690
Protein gain, lb	53.932	67.055	64.971	59.486	62.781	69.364	74.388	73.134
Energy gain protein, Mcal	139.074	172.913	167.540	153.394	161.893	178.868	191.822	188.588
Fat gain, lb	109.126	132.701	141.864	163.235	146.804	135.483	151.157	152.816
Energy gain fat, Mcal	463.574	563.725	602.650	693.434	623.635	575.540	642.126	649.172
Daily NE req. for maintenance, Mcal	5.549	5.769	5.892	6.053	5.813	5.848	5.953	5.971
Daily NE expended for maint. + gain, Mcal	7.709	8.482	8.723	9.339	8.785	8.770	9.325	9.355
Ration ME value, Mcal	.601	.605	.634	.624	.656	.631	.610	.641
Daily ME intake, Mcal	14.622	15.958	15.701	17.089	15.444	15.830	17.674	16.854
Daily ME intake/unit met. wt, Kcal/kg	203.625	214.490	205.825	217.350	205.512	209.048	228.963	218.432
Daily heat prod./unit met. wt, Kcal/kg	173.782	178.608	168.996	175.858	166.176	170.488	185.077	175.016
Daily ME intake req. for energy equil., Kcal	129.277	125.928	123.747	123.131	121.000	122.592	123.611	121.295
NE value of ration for maint., Mcal/lb	.682	.699	.714	.716	.736	.716	.718	.736
NE value of ration for gain, Mcal/lb	.456	.470	.509	.500	.541	.512	.481	.523
Efficiency of ME use for production, %	40.114	41.360	44.714	43.987	46.939	44.976	41.802	45.298
Energy req. for maintenance, Mcal	2592.844	2547.949	2562.715	2493.310	2409.666	2399.448	2353.826	2307.583

[a]There were 8 Hereford and 8 Charolais crossbred steers on each protein treatment.

[b]Corn silage dry matter intakes were not corrected for loss of volatiles during dry matter determination.

Table A.10.--Individual Performance and Carcass Data (Trial 2)

Pen no.	Steer no.	Treatment no.	Days on feed	Initial wt, kg	Final wt, kg	ADG, kg	Hot carcass wt, kg	Marb.[a]	Qual.[b] grade	Fat thick cm	KPH fat, %	Rib eye area, cm²	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain, kg	Daily fat gain, kg	Daily energy gain protein, kcal	Daily energy gain fat, kcal
46	400	1	281	222.3	485.4	.94	292.6	7	7	1.65	2.5	70.3	3.5	15.86	28.02	.1215	.2745	690.9	2570.4
46	414	1	281	256.3	535.2	.99	331.6	7	7	.89	3.0	88.4	2.3	15.92	27.80	.1333	.3016	758.0	2824.6
46	461	1	281	235.9	544.3	1.10	328.4	7	7	.76	3.0	88.4	2.2	15.75	28.48	.1410	.3190	801.7	2987.7
46	474	1	281	238.1	510.3	.97	320.7	7	7	1.65	2.5	67.7	3.9	13.68	37.29	.1060	.4462	602.8	4178.6
46	501	1	281	213.2	494.4	1.00	279.0	7	7	.38	3.0	82.6	1.7	16.15	26.82	.1193	.2459	678.0	2303.2
46	529	1	281	204.1	385.6	.65	230.9	8	8	.51	2.5	67.7	2.0	16.52	25.22	.0889	.1757	505.4	1645.4
46	533	1	281	195.0	428.7	.83	264.4	8	8	2.29	2.5	57.4	4.6	13.67	37.33	.0909	.3754	516.9	3515.7
47	412	2	281	192.8	424.1	.82	257.2	7	7	1.78	2.5	81.9	2.8	15.74	28.55	.1093	.2526	621.4	2365.5
47	425	2	281	210.9	489.9	.99	304.4	7	7	1.52	3.5	66.5	3.9	15.37	30.12	.1320	.3260	750.2	3053.0
47	428	2	281	285.8	526.2	.86	322.5	11	10	1.27	3.0	72.9	3.4	15.08	31.36	.0970	.3319	551.3	3108.8
47	442	2	281	231.3	521.6	1.03	328.4	8	8	2.03	3.5	71.0	4.4	14.17	35.19	.1223	.4285	695.6	4013.4
47	473	2	281	217.7	467.2	.89	273.1	4	5	1.40	2.5	69.0	3.2	16.16	26.76	.1120	.2362	636.7	2211.9
47	516	2	281	208.7	492.2	1.01	292.6	10	10	1.52	2.5	67.1	3.6	14.79	32.59	.1166	.3468	663.1	3248.3
47	531	2	281	238.1	485.4	.88	299.8	7	7	1.40	2.5	96.1	2.1	16.20	26.61	.1221	.2549	694.1	2387.3
48	393	3	281	265.4	528.4	.94	318.4	8	8	1.40	3.0	87.7	2.7	14.61	33.35	.1001	.3675	568.9	3441.8
48	437	3	281	215.5	446.8	.82	272.2	10	10	1.78	3.0	67.1	3.8	14.25	34.87	.0907	.3449	515.7	3229.9
48	445	3	281	217.7	458.1	.86	279.4	--	--	--	--	--	--	15.33	30.30	.1074	.2921	610.7	2735.8
48	447	3	281	235.9	474.0	.85	283.5	8	8	.89	2.5	68.4	2.8	15.85	28.09	.1058	.2577	601.7	2413.5
48	459	3	281	204.1	442.3	.85	274.0	9	9	.76	3.0	76.1	2.3	15.57	29.26	.1140	.2775	648.3	2598.6
48	510	3	281	188.2	442.3	.90	256.3	8	8	1.52	3.0	74.2	3.0	15.53	29.44	.1089	.2651	619.3	2482.5
48	535	3	281	244.9	528.4	1.01	303.0	12	10	.51	2.5	72.3	2.4	15.65	28.92	.1138	.2894	646.9	2710.7
34	402	4	260	260.8	503.5	.93	309.4	7	7	1.40	3.5	80.0	3.1	15.55	29.37	.1167	.3202	663.6	2998.9
34	410	4	260	242.7	471.7	.88	284.0	10	10	1.78	3.0	71.6	3.6	14.03	35.81	.0868	.3915	493.6	3666.8
34	415	4	260	220.0	480.8	1.00	284.0	9	9	1.52	2.5	61.3	3.8	14.65	33.17	.1097	.3640	623.4	3408.9
34	452	4	260	208.7	433.2	.86	264.0	8	8	.51	2.5	83.2	1.5	15.93	27.72	.1160	.2619	659.3	2452.5
34	485	4	260	263.1	526.2	1.01	318.0	9	9	1.78	3.0	69.0	4.0	14.58	33.48	.1086	.3995	617.2	3741.4
34	486	4	260	233.6	474.0	.92	284.0	7	7	1.40	3.0	69.7	3.3	15.23	30.70	.1083	.3195	615.7	2991.8
34	530	4	260	229.1	469.5	.92	296.2	9	9	1.40	3.0	72.9	3.3	15.19	30.87	.1211	.3425	688.5	3207.7
37	358	4	281	242.7	499.0	.91	279.4	8	8	1.52	2.5	59.4	3.8	13.33	38.76	.0691	.3959	392.7	3708.1
37	448	4	281	217.7	499.0	1.00	309.8	7	7	1.52	3.0	82.6	3.0	13.97	36.04	.1141	.4193	648.4	3926.7
37	467	4	281	229.1	474.0	.87	273.1	7	7	1.78	3.0	69.7	3.6	14.82	32.46	.0898	.3071	510.6	2876.3
37	480	4	281	279.0	582.9	1.08	347.5	7	7	1.52	2.5	71.6	3.8	15.02	31.61	.1199	.3738	681.7	3501.1
37	488	4	281	208.7	471.7	.94	283.5	9	9	2.51	3.5	63.9	4.9	14.11	35.44	.1017	.3737	578.1	3499.6
37	500	4	281	183.7	430.9	.88	258.1	7	7	1.52	3.0	64.5	3.5	17.93	19.27	.1394	.1400	792.3	1310.9
37	528	4	281	235.9	483.1	.88	298.5	10	10	1.78	3.0	77.4	3.5	14.79	32.59	.1048	.3417	595.8	3200.1

[a]Marbling score: Slight° = 8; Slight$^+$ = 9; Small$^-$ = 10.

[b]Quality grade: Average good = 8; High good = 9; Low choice = 10.

Table A.10. --Continued

Pen no.	Steer no.	Treat-ment no.	Days on feed	Initial wt, kg	Final wt, kg	ADG, kg	Hot carcass wt, kg	Marb.[a]	Qual.[b] grade	Fat thick cm	KPH fat %	Rib eye area, cm	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain, kg	Daily fat gain, kg	Daily energy gain protein, kcal	Daily energy gain fat, kcal
35	395	5	260	208.7	435.5	.87	264.4	14	11	.76	3.5	77.4	2.7	14.63	33.26	.1008	.3409	572.9	3192.2
35	403	5	260	222.3	442.3	.85	274.9	5	6	.76	2.5	78.1	2.1	16.75	24.27	.1269	.2185	721.3	2046.3
35	417	5	260	247.2	483.1	.91	291.2	12	10	1.27	3.0	78.1	2.9	15.04	31.53	.1030	.3356	585.7	3142.9
35	489	5	260	276.7	578.3	1.16	332.9	7	7	1.27	2.5	76.8	3.2	15.66	28.88	.1282	.3357	728.8	3143.7
35	492	5	260	238.1	494.4	.99	298.9	15	11	1.91	3.5	60.0	4.6	13.69	37.25	.0973	.4424	553.0	4143.5
35	495	5	260	235.9	503.5	1.03	306.6	8	8	.76	3.0	78.7	2.5	15.45	29.79	.1291	.3364	733.7	3150.4
35	523	5	260	220.0	467.2	.95	282.6	8	8	.76	3.5	85.2	2.0	15.05	31.47	.1137	.3365	646.2	3151.5
38	411	5	260	297.1	589.7	1.13	347.9	8	8	.89	3.5	74.2	3.3	14.99	31.72	.1174	.3969	667.9	3717.0
38	478	5	260	240.4	535.2	1.13	320.7	9	9	.76	3.5	78.7	2.7	15.10	31.26	.1334	.3789	758.4	3548.8
38	481	5	260	197.3	394.6	.76	240.4	--	--	--	--	--	--	17.12	22.67	.1159	.1721	658.8	1611.7
38	484	5	260	208.7	428.7	.85	255.8	7	7	1.40	2.5	71.0	2.9	16.28	26.26	.1128	.2313	641.5	2166.3
38	498	5	260	256.3	512.6	.99	318.4	11	11	.89	3.0	92.9	2.0	15.81	28.26	.1311	.3168	745.0	2966.7
38	507	5	260	224.5	451.3	.87	274.4	7	7	1.78	3.0	79.4	3.2	14.06	35.66	.0917	.3832	521.2	3589.0
38	511	5	260	231.3	469.5	.92	271.7	8	8	.51	3.0	76.8	2.0	16.69	24.53	.1174	.2139	667.6	2003.2
36	399	6	281	224.5	453.6	.82	272.6	10	10	1.27	3.0	66.5	3.3	15.12	31.17	.0955	.2912	542.8	2726.7
36	438	6	281	201.9	435.5	.83	253.6	9	9	1.27	2.5	71.0	2.8	15.23	30.71	.0954	.2708	542.2	2535.7
36	446	6	281	231.3	514.8	1.01	323.0	11	10	2.29	2.5	71.6	4.4	13.95	36.13	.1151	.4345	654.4	4069.0
36	460	6	281	210.9	494.4	1.01	288.5	13	10	1.52	2.5	60.6	3.9	15.25	30.61	.1178	.3120	669.5	2921.7
36	469	6	281	263.1	521.6	.92	306.2	8	8	.89	3.0	78.7	2.6	15.52	29.48	.1036	.2926	589.2	2740.5
36	482	6	281	206.4	446.8	.86	275.8	9	9	1.65	3.0	71.6	3.4	14.07	35.61	.0969	.3651	551.0	3419.7
36	534	6	281	242.7	526.2	1.01	325.7	11	10	2.51	3.0	69.7	4.8	13.23	39.18	.1008	.4820	573.3	4514.2
39	394	6	281	263.1	567.0	1.08	346.6	7	7	1.27	3.5	89.7	2.9	15.04	31.53	.1289	.3791	732.9	3550.6
39	401	6	281	204.1	378.8	.62	212.3	4	5	.25	2.5	58.1	2.1	16.21	26.53	.0704	.1693	400.2	1585.9
39	419	6	281	229.1	505.8	.98	291.2	8	8	.64	3.0	65.8	2.9	14.72	32.86	.1025	.3385	582.7	3170.6
39	449	6	281	197.3	435.5	.85	262.6	9	9	1.40	3.0	75.5	2.9	14.74	32.80	.0998	.3122	567.5	2923.6
39	490	6	281	240.4	517.1	.98	310.7	8	8	.76	3.0	78.1	2.5	15.13	31.13	.1161	.3350	660.0	3137.1
39	497	6	281	254.0	546.6	1.04	336.1	11	10	2.03	3.0	90.3	3.4	14.60	33.37	.1203	.3992	683.7	3738.9
39	515	6	281	210.9	474.0	.94	287.6	8	8	1.52	3.0	75.5	3.2	15.25	30.61	.1170	.3105	665.0	2907.8
40	370	7	260	201.9	462.7	1.00	277.6	8	8	1.02	2.5	71.0	2.8	15.41	29.93	.1259	.3159	715.5	2958.6
40	423	7	260	217.7	455.9	.92	284.9	13	11	.76	3.0	81.9	2.1	15.94	27.70	.1285	.2831	730.8	2660.8
40	440	7	260	240.4	523.9	1.09	330.7	7	7	2.51	3.0	84.5	4.1	13.15	39.55	.1130	.5378	642.5	5036.7
40	463	7	260	285.8	557.9	1.05	338.4	8	8	1.78	3.0	83.2	3.5	14.65	33.16	.1119	.4145	636.2	3881.7
40	466	7	260	199.6	401.4	.78	246.8	8	8	1.65	3.0	63.2	3.6	15.02	31.58	.0966	.2957	549.3	2769.4
40	472	7	260	238.1	501.2	1.01	318.0	7	7	2.16	3.0	76.8	4.0	14.44	34.06	.1229	.4227	698.7	3959.1
40	504	7	260	249.5	548.9	1.15	338.8	16	12	2.29	3.0	85.2	3.9	13.68	37.29	.1213	.5079	689.8	4757.0

[a]Marbling score: Slight° = 8; Slight^{+} = 9; Small^{-} = 10.

[b]Quality grade: Average good = 8; High good = 9; Low choice = 10.

Table A.10.--Continued

Pen no.	Steer no.	Treat-ment no.	Days on feed	Initial wt, kg	Final wt, kg	ADG, kg	Hot carcass wt, kg	Marb.[a]	Qual.[b] grade	Fat thick cm	KPH fat %	Rib eye area, cm²	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain, kg	Daily fat gain, kg	Daily energy gain protein, kcal	Daily energy gain fat, kcal
43	363	7	281	192.8	362.9	.61	216.4	6	6	.76	2.5	67.7	2.2	16.47	25.47	.0829	.1681	471.2	1573.9
43	396	7	281	210.9	430.9	.78	266.3	7	7	1.65	2.5	78.7	2.9	16.24	26.43	.1112	.2271	632.1	2126.7
43	407	7	281	256.3	551.1	1.05	339.7	7	7	1.40	3.5	81.9	3.3	14.80	32.51	.1245	.3894	707.8	3647.2
43	431	7	281	288.0	601.0	1.11	375.1	14	11	1.65	3.0	75.5	4.1	13.52	37.94	.1129	.5225	641.9	4892.9
43	434	7	281	206.4	469.5	.94	304.4	10	10	1.27	3.0	67.1	3.5	14.48	33.91	.1233	.3846	701.0	3602.2
43	451	7	281	231.3	517.1	1.02	332.9	11	10	1.52	3.0	79.4	3.4	14.60	33.39	.1314	.4062	747.2	3804.0
43	475	7	281	224.5	476.3	.90	282.6	5	4	1.40	3.0	75.5	3.0	15.35	30.18	.1060	.2911	602.5	2726.1
41	398	8	260	226.8	462.7	.91	269.9	8	8	1.27	3.0	73.5	2.9	15.05	31.47	.0985	.3138	560.1	2938.7
41	413	8	260	217.7	485.4	1.03	297.1	11	11	1.78	3.5	70.3	3.9	14.01	35.90	.1136	.4292	646.1	4019.8
41	426	8	260	208.7	440.0	.89	263.1	5	6	.89	3.0	65.8	2.9	15.19	30.88	.1064	.3054	604.9	2860.2
41	436	8	260	215.5	483.1	1.03	294.4	10	10	1.27	2.5	75.5	2.9	15.08	31.33	.1273	.3545	723.5	3320.4
41	509	8	260	242.7	519.4	1.06	325.7	9	9	1.78	3.5	76.8	3.8	14.82	32.43	.1321	.4054	751.2	3796.3
41	521	8	260	197.3	437.7	.92	271.3	8	8	1.65	3.5	70.3	3.6	14.12	35.43	.1076	.3890	611.5	3643.2
41	525	8	260	249.5	508.0	.99	316.2	8	8	1.52	3.5	80.6	3.3	14.54	33.65	.1155	.4070	656.9	3811.8
44	397	8	260	231.3	469.5	.92	294.4	8	8	1.14	3.5	76.8	2.9	14.75	32.73	.1124	.3679	639.0	3445.3
44	443	8	260	251.7	537.5	1.10	318.0	8	8	1.78	3.5	85.8	3.3	14.77	32.66	.1188	.3919	675.5	3670.2
44	450	8	260	195.0	430.9	.91	241.8	8	8	1.40	3.0	63.2	3.3	14.24	34.92	.0867	.3341	492.6	3129.0
44	455	8	260	288.0	546.6	.99	336.6	14	11	1.65	3.0	81.9	3.4	13.72	37.10	.0949	.4796	539.3	4491.8
44	494	8	260	210.9	496.7	1.10	299.8	7	7	1.52	3.5	76.1	3.4	14.82	32.45	.1312	.3826	745.8	3583.3
44	513	8	260	242.7	560.2	1.22	329.3	8	8	1.52	3.5	76.1	3.6	14.67	33.09	.1330	.4224	756.1	3956.1
44	532	8	260	217.7	517.1	1.15	314.8	8	8	2.29	3.0	75.5	4.2	14.18	35.15	.1303	.4469	740.6	4185.3
42	390	9	260	210.9	464.9	.98	273.5	7	7	1.65	3.0	78.7	3.1	14.86	32.27	.1097	.3394	623.5	3178.9
42	427	9	260	265.4	517.1	.97	311.6	7	7	1.40	3.5	72.9	3.5	15.54	29.38	.1153	.3209	655.6	3005.3
42	435	9	260	217.7	476.3	.99	285.3	8	8	1.65	3.0	65.8	3.8	14.55	33.60	.1110	.3738	630.8	3500.3
42	454	9	260	242.7	453.6	.81	270.3	7	7	.76	3.5	82.6	2.1	15.33	30.28	.0918	.2887	521.9	2704.0
42	464	9	260	213.2	489.9	1.06	304.8	13	11	.38	2.5	81.3	1.8	15.45	29.79	.1424	.3464	809.8	3244.5
42	514	9	260	233.6	496.7	1.01	299.4	8	8	1.40	3.0	67.7	3.6	15.24	30.66	.1216	.3416	691.6	3198.9
42	522	9	260	226.8	469.5	.93	285.8	13	11	1.78	3.0	89.0	2.8	12.47	42.42	.0788	.5037	447.9	4717.4
45	369	9	281	215.5	483.1	.95	298.0	7	7	1.78	2.5	78.1	3.3	14.34	34.49	.1113	.3792	632.8	3551.4
45	457	9	281	235.9	526.2	1.03	323.4	11	10	2.41	3.0	76.8	4.3	14.18	35.17	.1159	.4182	658.7	3916.5
45	493	9	281	260.8	514.8	.90	318.9	7	7	1.40	3.0	65.2	3.9	15.02	31.60	.1085	.3431	617.0	3213.7
45	503	9	281	215.5	485.4	.96	288.0	12	10	1.65	3.0	72.3	3.5	14.54	33.62	.1063	.3517	604.4	3293.7
45	506	9	281	197.3	451.3	.90	277.1	8	8	2.29	3.0	71.6	4.1	13.90	36.35	.1014	.3818	576.3	3575.5
45	512	9	281	208.7	474.0	.94	283.0	9	9	1.78	3.0	75.5	3.4	15.35	30.21	.1161	.3003	660.1	2812.6
45	524	9	281	222.3	483.1	.93	298.5	8	8	1.52	3.0	71.6	3.5	13.97	36.05	.1029	.3992	585.2	3738.3

[a]Marbling score: Slight° = 8; Slight⁺ = 9; Small⁻ = 10.

[b]Quality grade: Average good = 8; High good = 9; Low choice = 10.

Table A.11.-- Calculation of Net Energy Values for Growing Ration (Trial 2)

	0 g AN/KGCSDM			7.90 g AN/KGCSDM			15.70 g AN/KGCSDM		
	Level of monensin in ration DM								
	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm
Treatment no.	1	2	3	4	5	6	7	8	9
Initial wt, lb	503.000	505.000	499.000	505.500	509.000	503.500	507.000	506.000	503.000
Initial empty body protein, %	18.590	18.590	18.590	18.590	18.590	18.590	18.590	18.590	18.590
Final empty body protein, %	17.420	18.360	17.770	17.985	17.870	17.540	17.580	17.925	18.170
Initial empty body fat, %	15.330	15.330	15.330	15.330	15.330	15.330	15.330	15.330	15.330
Final empty body fat, %	22.060	17.380	20.320	19.265	19.850	21.460	21.270	19.520	18.310
Final empty body wt, lb	722.000	712.000	723.000	737.500	731.000	708.500	726.000	721.500	687.500
Days on feed	190.000	190.000	190.000	188.000	188.000	190.000	169.000	169.000	169.000
Average daily DM intake, lb[a]	12.660	12.290	11.940	12.595	11.940	11.835	12.570	12.380	11.970
Initial empty body weight, lb	459.893	461.722	456.236	462.179	465.379	460.350	463.550	462.636	459.893
Protein gain, lb	40.278	44.889	43.663	46.751	44.091	38.684	41.360	43.328	39.418
Energy gain protein, Mcal	103.865	115.755	112.593	120.555	113.697	99.754	106.654	111.729	101.646
Fat gain, lb	88.772	52.964	76.973	71.076	73.884	81.511	83.840	69.900	55.415
Energy gain fat, Mcal	377.108	224.994	326.985	301.934	313.864	346.263	356.157	296.940	235.405
Daily NE req. for maintenance, Mcal	5.100	5.074	5.092	5.158	5.147	5.058	5.125	5.108	4.988
Daily NE expended for maint. + gain, Mcal	7.632	6.867	7.405	7.405	7.421	7.405	7.863	7.526	6.983
Ration ME value, Mcal/lb	.603	.559	.820	.588	.622	.626	.625	.608	.583
Daily ME intake, Mcal	14.407	13.986	13.576	14.251	13.504	13.385	14.229	14.814	13.550
Daily ME intake/unit met. wt, Kcal/kg	217.506	212.251	205.302	212.756	202.033	203.770	213.725	211.274	209.164
Daily heat prod./unit met. wt, Kcal/kg	179.288	185.034	170.315	179.183	168.035	168.035	172.681	174.816	178.387
Daily ME intake req. for energy equil., Kcal	125.299	133.844	124.719	128.192	124.782	123.906	122.561	125.582	129.623
NE value of ration for maint., Mcal/lb	.699	.655	.702	.680	.699	.704	.712	.696	.673
NE value of ration for gain, Mcal/lb	.472	.395	.494	.447	.496	.503	.506	.477	.438
Efficiency of ME use for production, %	41.448	34.712	43.418	39.527	43.855	44.487	44.661	42.165	38.657
Energy req. for maintenance, Mcal	1576.909	1675.709	1566.961	1614.570	1567.799	1546.450	1377.906	1407.804	1419.047

[a]Corn silage dry matter intakes were not corrected for loss of volatiles during dry matter determination.

Table A.12.--Calculation of Net Energy Values for Finishing Ration (Trial 2)

	0 g AN/KGCSDM			7.90 g AN/KGCSDM			15.70 g AN/KGCSDM		
	Level of monensin in ration DM								
	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm
Treatment no.	1	2	3	4	5	6	7	8	9
Initial wt, lb	798.571	815.000	792.143	783.571	784.643	808.571	817.143	811.429	790.000
Initial empty body protein, %	17.420	18.360	17.770	17.980	17.860	17.540	17.580	17.930	18.170
Final empty body protein, %	16.383	16.377	16.294	16.041	16.450	15.981	15.961	15.747	15.790
Initial empty body fat, %	22.070	17.380	20.320	19.260	19.845	21.460	21.275	19.520	18.315
Final empty body fat, %	27.250	27.280	27.690	28.952	26.907	29.250	29.343	30.424	30.202
Final empty body wt, lb	945.000	958.143	919.000	943.714	942.000	944.357	978.714	961.643	949.929
Days on feed	91.000	91.000	91.000	82.500	72.000	91.000	101.500	91.000	101.500
Average daily DM intake, lb[a]	19.780	18.940	18.740	19.800	20.300	20.280	19.120	20.085	19.150
Initial empty body weight, lb	717.197	706.034	713.087	671.622	682.607	703.573	734.262	718.620	675.860
Protein gain, lb	29.720	27.036	22.981	30.081	32.570	27.209	26.482	22.413	27.246
Energy gain protein, Mcal	76.635	69.717	59.260	77.570	83.987	70.162	68.289	57.797	70.258
Fat gain, lb	100.031	139.934	109.815	146.586	120.373	126.735	134.220	153.144	162.835
Energy gain fat, Mcal	424.937	594.450	466.502	622.707	511.355	538.380	570.177	650.565	691.737
Daily NE req. for maintenance, Mcal	6.578	6.588	6.494	6.440	6.466	6.535	6.725	6.635	6.476
Daily NE expended for maint. + gain, Mcal	12.090	13.887	12.271	14.973	14.734	13.222	13.017	14.420	13.981
Ration ME value, Mcal/lb	.611	.733	.655	.756	.726	.653	.681	.717	.730
Daily ME intake, Mcal	27.692	26.497	26.217	27.631	28.278	28.461	26.634	27.938	26.676
Daily ME intake/unit met. wt, Kcal/kg	326.707	311.028	311.846	332.913	339.772	338.411	308.358	325.548	317.740
Daily heat prod./unit met. wt, Kcal/kg	262.335	226.078	243.280	227.851	236.956	259.994	237.537	235.532	228.374
Daily ME intake req. for energy equil., Kcal	121.341	114.053	119.710	111.713	113.269	116.900	117.569	113.662	113.609
NE value of ration for maint., Mcal/lb	.892	.546	.901	.970	.965	.927	.915	.944	.945
NE value of ration for gain, Mcal/lb	.444	.610	.501	.640	.595	.508	.538	.595	.610
Efficiency of ME use for production, %	31.709	43.622	35.836	45.895	42.740	36.206	38.632	42.753	43.781
Energy req. for maintenance, Mcal	943.510	886.475	918.555	771.156	688.091	902.346	1035.594	890.083	969.516

[a]High moisture corn and corn silage dry matter intakes were not corrected for loss of volatiles during dry matter determination.

Table A.13.--Calculation of Net Energy Values for Entire Feeding Period (Trial 2)

	0 g AN/KGCSDM			7.90 g AN/KGCSDM			15.70 g AN/KGCSDM		
	Level of monensin in ration DM								
	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm	0 ppm	16.5 ppm	33.0 ppm
Treatment no.	1	2	3	4	5	6	7	8	9
Initial wt, lb	492.857	499.286	495.000	512.500	520.357	500.714	510.714	503.214	498.571
Initial empty body protein, %	18.590	18.590	18.590	18.590	18.590	18.590	18.590	18.590	18.590
Final empty body protein, %	16.383	16.377	16.294	16.041	16.450	15.981	15.961	15.747	15.790
Initial empty body fat, %	15.330	15.330	15.330	15.330	15.330	15.330	15.330	15.330	15.330
Final empty body fat, %	27.250	27.280	27.690	28.952	26.907	29.250	29.343	30.424	30.202
Final empty body wt, lb	945.000	958.143	919.000	943.714	942.000	944.357	978.714	961.643	949.929
Days on feed	281.000	281.000	281.000	270.500	260.000	281.000	270.500	260.000	270.500
Average daily DM intake, lb[a]	14.870	14.870	13.700	14.250	14.180	14.255	14.900	14.805	14.115
Initial empty body weight, lb	450.619	456.497	452.579	468.579	475.763	457.803	466.946	460.089	455.844
Protein gain, lb	70.886	71.801	65.562	64.099	66.271	65.494	68.635	65.848	65.291
Energy gain protein, Mcal	182.792	185.152	169.063	165.291	170.892	168.888	176.988	169.800	168.364
Fat gain, lb	189.236	192.662	185.334	202.279	181.746	207.619	219.474	222.308	216.828
Energy gain fat, Mcal	803.888	818.442	787.312	859.294	772.071	881.981	932.343	944.382	921.101
Daily NE req. for maintenance, Mcal	5.772	5.833	5.700	5.826	5.841	5.792	5.924	5.854	5.807
Daily NE expended for maint. + gain, Mcal	9.283	9.404	9.103	9.615	9.468	9.532	10.035	10.140	9.834
Ration ME value, Mcal/lb	.624	.632	.664	.675	.668	.669	.673	.685	.697
Daily ME intake, Mcal	18.513	18.513	17.098	17.634	17.434	17.797	18.659	18.499	17.765
Daily ME intake/unit met. wt, Kcal/kg	248.439	245.346	231.743	233.865	231.063	238.045	244.717	244.261	235.915
Daily heat prod./unit met. wt, Kcal/kg	201.821	198.299	185.755	183.933	183.457	188.657	191.949	187.981	182.463
Daily ME intake req. for energy equil., Kcal	124.545	124.090	122.504	120.396	121.183	121.133	119.914	118.506	118.972
NE value of ration for maint., Mcal/lb	.772	.774	.785	.793	.784	.796	.808	.813	.815
NE value of ration for gain, Mcal/lb	.477	.488	.530	.549	.540	.538	.545	.565	.576
Efficiency of ME use for production, %	38.287	39.190	42.438	44.410	43.912	43.073	43.551	45.236	45.756
Energy req. for maintenance, Mcal	2616.850	2637.261	2544.971	2459.162	2382.313	2551.484	2481.410	2338.681	2426.969

[a]High moisture corn and corn silage dry matter intakes were not corrected for loss of volatiles during dry matter determination.

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