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1997 Beef Cattle Report

NEBRASKA

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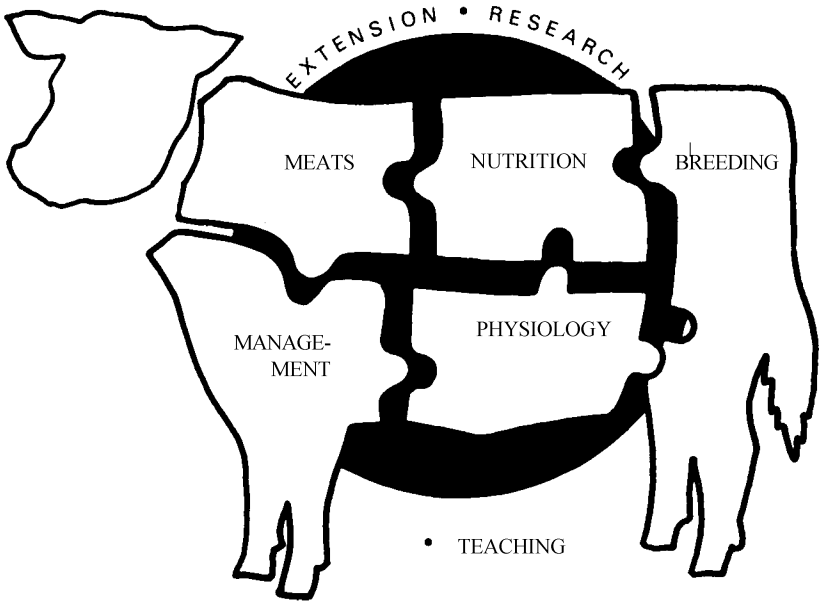

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Darrell W. Nelson, Director

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Seasonal Changes in Protein Degradabilities of Sandhills Native Range and Subirrigated Meadow Diets and Application of a Metabolizable Protein System

Greg Lardy
Don Adams
Terry Klopfenstein
Dick Clark
Jim Lamb[1]

Meadow and range diets increased in digestibility, crude protein, and escape protein during periods of active growth.

Summary

Diet samples from native range and subirrigated meadows were collected with esophageally-fistulated cows and analyzed for CP, IVDMD, in situ protein degradability, and fiber components. Escape protein (EP) and degradable intake protein (DIP) of the samples were calculated. Native range and subirrigated meadow samples were higher in CP, IVDMD and escape protein during periods of active growth. For spring calving cows, the metabolizable protein system, in general, predicted during gestation that degradable protein was more deficient than metabolizable protein. However, during lactation, metabolizable and degradable protein were deficient when cows were fed meadow hay or grazed dormant forage.

Introduction

The Nebraska Sandhills have two distinctly different forage resources; native upland range and subirrigated meadow. Upland range and subirrigated meadow have different grass species and different plant growth characteristics. Familiarity with the nutritional composition of cattle diets from upland range and subirrigated meadow can be a valuable management tool for cattle producers. Cattle select a diet higher in nutritive value than what would be obtained from clipped samples of the same pasture. Samples collected from esophageally-fistulated cattle give a reliable estimate of the animal's diet.

The latest NRC beef cattle requirements (NRC, 1996) uses a metabolizable protein system to express protein requirements on a degradable intake protein (DIP) and a metabolizable protein (MP) basis. Degradable intake protein is the protein degradable in the rumen and available to the microorganisms present in the rumen. Metabolizable protein is the sum of the digestible microbial protein flowing to the small intestine and the digestible escape protein flowing to the small intestine. Metabolizable protein is the protein the animal uses for maintenance, growth, lactation, and gestation.

For the metabolizable protein system to be most effective, precise values for protein degradability of feedstuffs are necessary. Presently, diets throughout the year on upland range and subirrigated meadow have not been adequately characterized for DIP and EP.

The objectives of this research were to characterize the seasonal changes in forage quality and protein degradability of upland range and subirrigated meadow diets and to use a metabolizable protein system to calculate energy, degradable protein, and metabolizable protein status of cows grazing upland range or subirrigated meadow or consuming subirrigated meadow hay.

Procedure

Throughout 1992 and 1994 diets were collected using esophageally-fistulated

(Continued on next page)

cows from both subirrigated meadows and native range at the University of Nebraska's Gudmundsen Sandhills Laboratory. Subirrigated meadow hay used in the NRC model calculations was average in quality and values were based on the work of Villalobos (1994 Beef Cattle Report, p. 5). Samples were freeze-dried, ground, and analyzed for CP, IVDMD, NDF, ADF, neutral detergent insoluble nitrogen (NDIN), in situ protein degradability, and acid detergent insoluble nitrogen (ADIN). From these values, rumen escape protein and rumen degradable protein of the samples were calculated.

In 1992, precipitation during April and May was 1.8 and 2.8 inches below normal, respectively. Total precipitation for the 1992 calendar year was four inches below normal. Average high temperatures in June, July and August were 7 to 10°F below normal. In late May, two consecutive days of below freezing overnight lows (30 and 20°F) were recorded which likely influenced grass growth and quality patterns. During 1994, temperatures and precipitation were average.

When laboratory analysis was completed, the metabolizable protein system (NRC, 1985) was used to predict dietary deficiencies in net energy for maintenance (NE_m), MP, and DIP. Estimates of grazed dry matter intake were based on previous research conducted at the Gudmundsen Sandhills Laboratory. **All requirements calculated in Tables 3-5 were obtained using thermoneutral conditions. Under conditions of cold stress, requirements for energy increase.** No supplement was included in the calculations of nutrient balances. Degradable protein requirements were based on a 13 percent efficiency value for conversion of TDN to bacterial CP. This value may be lower on dormant forages. The consequence of a lower efficiency would be a reduction in the amount of DIP required for the microorganisms. Therefore these should only be used as guidelines.

Assumptions were as follows:

1. Mature cow body weight = 1100 lb
2. Milk production = 18 lb per day
3. Calving Date = March 1 for spring calving cows
4. Weaning Date = October 15 for spring calving cows
5. Meadow hay was assumed to be of average quality (8% CP, 56% TDN)
6. No supplement was included in any calculations.
7. DIP requirement equals IVDMD x .13.
8. Estimates of dry matter intake were based on previous research conducted at the Gudmundsen Sandhills Laboratory (Hollingsworth-Jenkins, 1995 and 1996 Beef Cattle Reports).

Results

Seasonal changes in chemical composition and digestibility for diet samples collected from the subirrigated meadows in 1992 and 1994 are shown in Table 1. Because the subirrigated meadows at Gudmundsen Sandhills Laboratory are made up predominantly of cool season species, CP and IVDMD increased rapidly in the spring and then declined over the summer before increasing again during the fall as regrowth occurred. Meadows were hayed in July of each year, values reported for August through December would represent meadow regrowth. Neutral detergent fiber and ADF values were lower during periods of active growth and higher during periods of dormancy. The diet samples collected on the subirrigated meadow were also relatively high in IVDMD as only the January and December samples were appreciably below 60 percent IVDMD. Escape protein of the meadow diet samples ranged from .9 to 3.6 percent of dry matter. The highest EP values were noted in April.

Seasonal changes in chemical composition and digestibility of diet samples collected from native upland range are shown in Table 2. On the native upland range, CP increased later relative to the subirrigated meadows since the upland sites contain more warm season grass species. Grass growth on upland range started in late April as shown by the increasing CP content of the diet. The cool season species present on upland range initiate growth earlier than the warm season species and the CP content was higher than expected in April. However, forage quantity produced at this time would be quite low. Crude protein values for the diet samples re-

Table 1. Laboratory analysis of meadow diet samples collected at Gudmundsen Sandhills Laboratory in 1992 and 1994, DM Basis.

Sample Date	# OBS[a]	CP	NDFIP[a]	ADFIP[a]	Escape protein	Degradable protein	NDF	ADF	IVDMD
JAN	1	10.3	4.0	.6	1.2	9.1	65.4	42.6	51.1
MAR	1	14.1	4.8	1.1	1.0	13.1	56.6	35.9	61.3
APR	1	25.3	4.9	.1	3.6	21.7	42.3	23.4	71.9
MAY	1	15.3	5.9	.9	2.7	12.6	63.5	36.8	67.9
JUNE	3	14.9	4.0	.7	2.0	12.9	59.0	33.8	67.9
JULY	3	10.9	3.7	.7	1.8	9.2	63.6	36.8	64.3
AUG	2	14.9	3.4	.4	2.0	12.9	54.6	38.4	62.7
SEPT	3	13.1	3.6	.8	1.5	11.6	59.3	36.7	59.6
OCT	1	12.0	3.4	.7	1.0	11.0	51.6	35.7	60.2
NOV	1	7.8	2.6	1.3	1.0	6.8	67.5	46.2	47.9
DEC	2	6.7	2.5	1.0	.9	5.9	69.3	46.6	53.5

[a]# OBS, number of diets analyzed for a given month; NDFIP, Neutral Detergent Insoluble Protein (NDIN * 6.25); ADFIP, Acid Detergent Insoluble Protein (ADIN *6.25).

Table 2. Laboratory analysis of range diet samples collected at Gudmundsen Sandhills Laboratory in 1992 and 1994, DM basis.

Sample Date	#OBS[a]	CP	NDFIP[a]	ADFIP[a]	Escape protein	Degradable protein	NDF	ADF	IVDMD
JAN	1	5.5	2.4	.8	.7	4.8	72.9	45.7	55.7
MAR	2	5.2	2.6	.5	.8	4.3	71.4	46.1	52.1
APR	2	10.1	4.4	.6	1.1	9.1	68.5	38.2	61.4
JUNE	3	12.4	4.8	.6	2.3	10.2	65.1	36.5	68.2
JULY	4	10.9	5.0	.8	2.0	8.9	70.6	38.5	67.1
AUG	3	10.0	4.4	.9	1.6	8.4	69.4	41.3	63.5
SEPT	2	6.6	2.9	.6	.9	5.7	70.5	43.2	59.2
NOV	1	5.2	2.1	1.5	.6	4.6	74.5	49.5	48.9
DEC	2	5.6	2.1	.7	1.0	4.6	73.8	46.8	51.3

[a]# OBS, number of diets analyzed for a given month; NDFIP, Neutral Detergent Insoluble Protein (NDIN * 6.25); ADFIP, Acid Detergent Insoluble Protein (ADIN *6.25).

Table 3. Daily nutrient balances for a spring calving cow as predicted by the metabolizable protein system (NRC, 1996).

Diet	Meadow hay		Meadow Grazing		Range				Meadow		Range		Meadow hay	
Item	April	May	May	June	June	July	August	Sept.	Sept.	Oct.	Dec.	Jan.	Feb.	March
NEm balance, Mcal	-1.7	-2.7	3.1	3.7	3.8	5.9	4.0	.6	3.3	5.1	-.6	-1.0	-.8	-2.4
MP available, g	687	687	932	874	902	928	787	566	737	670	504	457	625	625
MP requirement, g	755	828	828	788	788	714	639	577	577	412	441	423	522	602
MP balance, g	-68	-141	103	85	114	214	148	-11	160	257	64	35	103	23
DIP available, g	659	659	1514	1538	1208	1160	1005	565	1390	1259	461	455	599	599
DIP requirement, g	799	799	1057	1057	1062	1132	989	768	928	898	666	180	727	727
DIP balance, g	-141	-141	457	481	146	28	16	-203	462	361	-205	-180	-128	-128
DM Intake, lb	24.2	24.2	26.4	26.4	26.4	28.6	26.4	22	26.4	25.3	22	22	22	22

mained between 10 and 12 percent for the duration of the summer before declining to 6 percent by late September. In vitro dry matter digestibility was highest during the summer months (the period of active growth). Cows selected a diet containing greater than 5 percent CP throughout the winter months. Escape protein of the range diet was highest during the summer months (1.6 to 2.3% of DM).

Table 3 shows the nutrient balances for a mature spring calving cow. When cows were fed meadow hay during lactation (April and May), they were in negative energy balance, had a MP deficit, and were deficient in DIP. A DIP deficiency also occurred when cows grazed native range in September, December, and January. The MP system predicted a DIP deficiency of about 200 g/d for gestating cows grazing dormant winter range.

In general, the metabolizable protein system predicted that when lactating cows were fed meadow hay or grazed dormant forage, they were deficient in DIP, MP, and energy. For gestating cows which were not lactating, the metabolizable protein system predicted that only DIP was deficient.

Protein supplements differ in the proportion of DIP and EP. Examples of sources high in DIP (as a % of CP) would be sunflower meal, alfalfa hay, corn steep liquor, urea, and biuret. Sources which contain both degradable and escape protein would be soybean meal and cottonseed meal. Sources which are high in escape protein but contain very little DIP would be blood meal and feather meal.

For the gestating cow, a supplement high in DIP is adequate because she is not deficient in MP. For the lactating cow, which needs both DIP and MP, a supplement which contains both degradable and escape protein is necessary.

Use of the metabolizable protein system should allow producers to more accurately predict the type and amount of supplements necessary to maintain the cow herd year long. By feeding the correct type of supplement at the proper time, overall cost of supplementation could be reduced and performance either maintained or improved over traditional supplementation programs.

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[1]Greg Lardy, research technician, Animal Science, Lincoln. Don Adams, Professor, Animal Science, West Central Research and Extension Center, North Platte. Terry Klopfenstein, Professor, Animal Science, Lincoln. Jim Lamb, research technician, Animal Science, West Central Research and Extension Center, North Platte.

First Limiting Nutrient of Native Range for Summer Calving Cows During the Breeding Season and Late Lactation

Greg Lardy
Terry Klopfenstein
Don Adams
Jim Lamb
Dick Clark[1]

Rumen degradable and escape protein are co-limiting for summer calving cows during the breeding season and late lactation.

Summary

Trials were conducted to determine the first limiting nutrient of native range for summer calving cows during the breeding season and late lactation. Treatments were 1) control, no supplement; 2) isocaloric energy control; 3) rumen degradable protein supplement and 4) rumen degradable and undegradable protein supplement. During the breeding season, cows receiving rumen degradable and escape protein gained more weight than cows on other treatments. Cows receiving supplemental protein gave more milk and nursed faster gaining calves than other treatments. Rumen degradable protein and escape protein appear to be co-limiting for summer calving cows during the breeding season and late lactation.

Introduction

Limited information is available about supplementation needs for summer calving cows during the breeding season and late lactation. Most supplementation research has focused on the gestating spring calving cow during the winter months or the lactating fall calving cow during the winter. A summer calving cow herd has been developed at the Gudmundsen Sandhills Laboratory (GSL) as part of a larger systems study.

In general, the cow's requirements for energy and crude protein are fairly well defined (NRC, 1984). However, for the summer calving cow grazing native Sandhills range, the breeding season and late lactation periods coincide with a period when forage quality is declining as the warm season grass goes dormant. During this time the cow must rebreed and maintain body condition for the coming winter, while still providing nutrients for her nursing calf. The lactating cow has increased needs for all nutrients compared to the dry cow. Laboratory analysis conducted with esophageal diet samples collected at the GSL showed that both crude protein and digestibility of range forage are declining during late summer and fall (August through October).

The objectives of these trials were to determine the first limiting nutrient for summer calving cows grazing native range during September and October (breeding season) and during November and December (late lactation) for this herd.

Procedure

Breeding Season Trial

Forty-eight lactating summer calving cows (beginning calving date = June 18) were used in each of two years to determine the first limiting nutrient for summer calving cows grazing native range during a 50 day breeding season beginning September 7. Treatments were 1) control (CON), no supplement; 2) isocaloric energy control supplement (ENG); 3) rumen degradable protein supplement (RDP); 4) rumen degradable + escape protein supplement (RDP+EP). Supplement composition amounts fed are shown in Table 1. The energy control supplement was based on a 90:10 blend of soyhulls and tallow. The energy supplement was not intended to fully meet the cow's requirement for net energy during this time but only to be an isocaloric control for the protein supplements. The rumen degradable protein supplement was based largely on corn steep liquor that supplies protein, peptides, and amino acids that are totally rumen degradable. The escape protein supplement used was an 80:20 blend of SBM treated with sulfite liquor and feather meal. The daily amount of supplements fed was purposely kept small to avoid confounding the responses measured with exceedingly large energy intakes.

Eight pastures were used in the trial, two pastures per treatment. Cows were group fed supplements in each pasture six days per week. Cows used in the late lactation trial remained on the same treatment to which they were assigned for the breeding season trial.

Cows were weighed and body condition score (BCS) was estimated by palpating the ribs and thoracic vertebrae at the beginning and end of the trial. Calves were also weighed at the beginning and end of the trial. During September and October of 1995, a 16-hour weigh-suckle-weigh procedure was performed to estimate milk production. Six cow/calf pairs from each treatment were randomly chosen for this measurement. At each weigh-suckle-weigh, pairs were separated at approximately noon each day and calves were allowed to nurse at 4:00 p.m. Following nursing,

Table 1. Supplement composition for lactating summer calving cows during the breeding season.

	Treatment[a]			
	CON	ENG	RDP	RDP+ EP
Ingredient		lbs DM/day		
Soyhulls	—	0.90	0.30	—
Tallow	—	0.10	0.03	—
Corn Steep Liquor	—	—	0.70	—
Sulfite Liquor Treated SBM	—	—	—	1.00
Feather Meal	—	—	—	0.26
Nutrient		Supplemental Nutrient Intakes (lbs/day)		
NE_m (Mcals)	—	1.1	1.1	1.1
Rumen Degradable Protein (lb)	—	0.11	0.31	0.30
Escape Protein (lb)	—	0.03	0.01	0.33

[a]Con = control, Eng = energy control, RDP = rumen degradable protein, RDP + EP = rumen degradable protein and escape protein.

Table 2. Supplement composition for lactating summer calving cows during late lactation.

	Treatment[a]			
	CON	ENG	RDP	RDP+ EP
Ingredient		lbs DM/day		
Soyhulls	—	0.90	—	0.57
Tallow	—	0.10	—	0.06
Corn Steep Liquor	—	—	1.06	—
Sulfite Liquor Treated SBM	—	—	—	0.37
Feather Meal	—	—	—	0.09
Nutrient		Supplemental Nutrient Intakes (lbs/day)		
NE_m (Mcals)	—	1.1	1.1	1.1
Rumen Degradable Protein (lb)	—	0.11	0.42	0.18
Escape Protein (lb)	—	0.03	0.00	0.14

[a]Con = control, ENG = energy control, RDP = rumen degradable protein, RDP + EP = rumen degradable and escape protein.

Table 3. Crude protein, rumen degradable protein, escape protein, IVDMD, NDF, and ADF of esophageally collected range diets.

Date	CP	EP	RDP	NDF	ADF	IVDMD
9/17/94	6.9	.7	6.2	71.7	44.5	58.6
11/3/94	5.2	.6	4.6	74.5	49.5	48.9
12/12/94	5.3	.9	4.5	76.5	48.7	48.9

pairs were separated again. At 8 a.m. the following morning, calves were weighed and allowed to nurse and then weighed again. The difference in weight was estimated to be the 16-hour milk production. When milk production is presented in this paper, it is expressed on a 24-hour basis. Cows were rectally palpated to determine pregnancy approximately 70 days after the end of the breeding season.

Late Lactation Trial

Forty lactating summer calving cows were used in each of two years to determine the first limiting nutrient for summer calving cows grazing native range during late lactation (November and December). Supplement treatments and data collection procedures were similar to those used during the breeding season trial (Table 2). A 16-hour weigh-suckle-weigh was also performed in December of 1995, following a similar procedure as described in the breeding season trial.

Diet samples were collected using esophageally-fistulated cows to estimate diet quality in September, November, and December. Samples were freeze dried and analyzed for CP, NDF, ADF, IVDMD, and in situ protein degradability.

Results

Diet quality (Table 3) in 1994 declined from September to December. Crude protein declined to approximately 5% by early November. In addition, IVDMD for samples collected in November and December were quite low (less than 50%).

During the breeding season, CON cows lost more weight and body condition than cows receiving supplements (Table 3). Cows supplemented with either RDP or RDP+EP also gained more weight than cows receiving ENG supplement. Cows fed RDP+EP also gained more weight than cows fed RDP. Calves nursing cows which received supplements also gained more weight than calves nursing CON cows. Pregnancy rate was not affected by supplement treatment. Cows receiving supplements gave more milk than CON cows, and cows receiving supplemental protein gave more milk than cows receiving ENG supplement. This may partially explain the increased weight gain of calves nursing cows receiving supplemental protein.

There were no significant differences in cow weight change, calf weight

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Table 4. Production of summer calving cows fed energy, rumen degradable protein, or rumen degradable plus escape protein during the breeding season.

	Treatment				
	CON	ENG	RDP	RDP+ EP	Contrast[a]
Cow weight change (lb)	6.7	-28.4	-9.5	9.5	1, 2, 3
Calf weight change (lb)	119.2	126.1	142.1	139.3	1, 2
Cow BCS change	-0.75	-0.52	-0.40	-0.35	1
Pregnancy rate (%)	91.5	95.8	95.8	95.8	NS
Milk production (lb)	14.3	15.0	18.7	19.4	1, 2

[a]Contrasts: 1 = CON vs supplements; 2 = ENG vs RDP + RDP+EP; 3 = RDP vs RDP+EP. Significant at P = .06.

Table 5. Production of summer calving cows fed energy, rumen degradable protein, or rumen degradable plus escape protein during late lactation.

	Treatment				
	CON	ENG	RDP+ RDP	EP	Contrast[a]
Cow weight change (lb)	-161.5	-141.0	-109.1	-134.7	NS
Calf weight change (lb)	52.1	60.7	62.0	66.9	NS
Cow BCS change[b]					
Year 1	-0.9	-0.7	-0.9	-0.4	NS
Year 2	-0.5	-0.6	-0.4	-0.8	NS
Milk production (lb)	7.0	8.6	9.2	13.2	NS

[a]Contrasts: 1 = CON vs supplements; 2 = ENG vs RDP + RDP+EP; 3 = RDP vs RDP+EP. Significant at P = .06.
[b]Significant year*treatment interaction, data are presented by year.

change, cow BCS change, or milk production during late lactation. During late lactation, cows lost large amounts of weight and calf gains were lower compared to the breeding season. However, cows receiving RDP+EP produced more milk and their calves gained more weight than the other treatments, even though differences were not significant. The fact cows receiving RDP+EP gave almost twice the amount of milk that CON cows did may explain why the RDP+EP cows did not respond as they did during the breeding season. Cows appear to need more supplemental energy than was fed during late lactation (as indicated by the large weight losses).

We believe that rumen degradable and escape protein may be co-first limiting nutrients for summer calving cows during the breeding season and late lactation. As the warm season species on the upland sites in the Sandhills decline in quality, supplementation is necessary. Energy does not appear to be limiting during the breeding season. This work indicates, especially during the breeding season, a small amount of a strategic input can help cows maintain body weight and condition while still producing adequate milk for acceptable calf gains. The supplemental needs of the summer calving cow at this time would probably best be met by using a source of protein that contained both rumen degradable and escape protein in approximately equal proportions. Sources that supply this are cottonseed meal, sulfite liquor treated or heat treated soybean meal, pork meat and bone meals, or a blend of high and low degradability sources such as sunflower meal to supply rumen degradable protein and blood meal or feather meal to supply escape protein.

Rumen Degradable Protein Requirement of Gestating Summer Calving Beef Cows Grazing Dormant Native Sandhills Range

Greg Lardy
Terry Klopfenstein
Don Adams
Jim Lamb
Dick Clark[1]

Summer calving cows require small amounts of rumen degradable protein supplementation to meet their requirement during late winter.

Summary

Sixty-three summer calving cows were used to determine the rumen degradable protein requirement during

[1]Greg Lardy, graduate student; Terry Klopfenstein, Professor, Animal Science, Lincoln; Don Adams, Professor, Jim Lamb, former research technician, Dick Clark, Professor, West Central Research and Extension Center, North Platte.

late winter (March-April). Treatments were 1) Control, no supplemental rumen degradable protein; 2) 29%; 3) 65%; 4) 100%, or 5) 139% of the estimated supplemental rumen degradable protein requirement. Supplements were based on combinations of corn steep liquor and soyhulls. Control cows lost more weight and consumed less forage than cows receiving supplemental rumen degradable protein. Body condition score change and in vivo digestibility of range forage were not different. Summer calving cows require between .2 and .4 lb of supplemental rumen degradable protein to meet their daily requirement of 1.0 to 1.3 lb of rumen degradable protein.

Introduction

A common practice in most range areas in the United States is supplementing gestating spring calving cows with protein during the winter. Supplemental protein may be overfed in many situations because the actual rumen degradable protein requirement and the proportion of forage protein which is degraded are unknown. Many factors, including selectivity, weather, rate of passage, stage of production, previous grazing treatment, and degree of weathering may play a role in determining degradability of protein in a particular forage. If the actual rumen degradable protein requirement were more precisely defined, producers may be able to reduce supplementation costs.

Rumen degradable protein is degraded in the rumen and available to the rumen microorganisms for use in microbial growth and protein synthesis. Undegradable protein escapes degradation in the rumen and is available to the host animal at the small intestine. Metabolizable protein is the sum of the digestible microbial protein and the digestible escape protein. Metabolizable protein is the protein that the animal can use for maintenance, growth, lactation, and fetal development.

Very little is known about how the nutrient requirements of summer calving cows (June 15-Aug 15 calving season) interact with the nutrient supply from forage. Hollingsworth-Jenkins et al. (1996 Beef Cattle Report, p. 14) reported research on the supplemental rumen degradable protein requirement for gestating spring calving cows. No research data are available regarding the requirement for supplemental rumen degradable protein in the summer calving cow during late winter. Therefore, the objective of this trial was to determine the supplemental rumen degradable protein requirement for gestating summer calving beef cows grazing dormant native Sandhills Range.

Procedures

Sixty-three MARC II (1/4 Hereford, 1/4 Angus, 1/4 Simmental, 1/4 Gelbvieh) gestating summer calving cows were assigned randomly to one of five treatments: 1) control, no supplement; 2) 29%, 3) 65%, 4) 100%, 5) 139% of the estimated supplemental rumen degradable protein requirement. Supplements were based on combinations of corn steep liquor and soyhulls to provide varying levels of rumen degradable protein while providing all supplemented cows with isocaloric supplements (Table 1). Corn steep liquor is a byproduct of the corn wet milling industry and is a source of protein, peptides, and amino acids and is 100 percent rumen degradable. The estimated daily rumen degradable protein requirement was 1.28 lb of which .8 lb was supplied by the forage. Cows were fed daily, in groups of 7, from March through mid April (2 pastures per treatment, except for the 139 percent treatment which only had one pasture). Forage intake was estimated on six cows per treatment in late March. Cows were dosed with a Captec chromium bolus that releases chromium at a steady rate into the rumen. Cows were individually fed during the fecal collection period. Fecal output was determined by dividing the amount of chromium released by the Captec device by the chromium concentration in the feces. Forage intake was determined by dividing the fecal output by the indigestibility of the range diet. Diet samples were collected in March and April using six to eight esophageally-cannulated cows to determine rumen degradable protein, escape protein, ADF, NDF, and digestibility of the diets. Weights were taken on two consecutive days at the beginning and the end of the trial and on one day about midway through the trial. Body condition score (BCS) was determined at the beginning and the end of the trial by palpating the ribs and thoracic vertebrae.

Results

Cows receiving no supplemental rumen degradable protein lost more weight than cows receiving supplemental rumen degradable protein (Table 2).

Table 1. Supplement composition for gestating summer calving cows grazing dormant Sandhills native range.

	Treatment				
	CON	29%	65%	100%	125%
Soyhulls, lbs	0	1.7	1.2	.62	0
Corn steep liquor, lbs	0	0	.57	1.1	1.7

Table 2. Weight and body condition score (BCS) change of gestating beef cows grazing winter Sandhills range.

	Treatment				
	CON	29%	65%	100%	125%
Weight change, lbs[a]	-49.1	1.7	5.9	-7.1	1.5
BCS change[b]	-.4	-.7	-.2	-.4	-.1

[a]Control vs. supplemented cattle, P = .0001.
[b]Cubic effect, level of rumen degradable protein, P = .03.

Table 3. Crude, escape, and rumen degradable protein, acid and neutral detergent fiber, and in vitro OM disappearance of Sandhills winter range.

	Date	
	March 22	April 8
	---------- % DM ----------	
Crude protein, %	5.0	8.4
Escape protein, %	.9	1.0
Rumen degradable protein,%	4.1	7.4
ADIN, %	.1	.1
NDIN,%	.3	.6
NDF, %	71.4	69.9
ADF, %	46.4	43.4
IVOMD,%	53.5	57.7

Table 4. In vivo organic matter digestibility (%) and organic matter intake of native Sandhills range as affected by rumen degradable protein supplementation.

	Treatment				
	CON	29%	65%	100%	125%
In Vivo OM Digestibility	59.5	59.3	58.0	58.3	57.2
Forage OM Intake (lbs)[ab]	16.3	17.5	22.8	22.9	27.9
Cow Weight	1179.1	1167.4	1186.0	1200.1	1178.5
Forage OM Intake (% of BW)[ab]	1.39	1.51	1.91	1.91	2.38
Supplement RDP Intake, lb	0	.23	.36	.51	.65
Forage RDP Intake, lb[ab]	.68	.73	.95	.95	1.16
Total RDP Intake, lb[ab]	.68	.96	1.31	1.46	1.81

[a]Control vs. supplemented cows, $P < .001$.
[b]Linear effect, level of rumen degradable protein, $P < .0001$.

No differences in body weight change were detected among cows receiving supplemental rumen degradable protein. Body condition score change increased cubically for cows receiving supplemental rumen degradable protein, but was not different for cows receiving supplement compared to unsupplemented cows. It is difficult to explain the cubic response in body condition score change.

Esophageally-fistulated cows were able to select diets high in CP and rumen degradable protein in early April (Table 3). However, because no estimates of total quantity of forage available for grazing at this time were made and esophageal diets were not collected over an extended period of time, it is not clear that cows would be able to select diets this high in quality continually in early spring. Diets selected in March were typical of dormant winter range samples previously collected at the Gudmundsen Sandhills Laboratory.

Cows supplemented with rumen degradable protein consumed more forage organic matter than did cows that did not receive a supplement (Table 4). It is not known why the high level of steep liquor stimulated an increase in intake, above the other supplements. Intakes averaged 1.8% of body weight in this study, while Hollingsworth-Jenkins et al. (1996 Beef Cattle Report, p. 14) reported an average intake of 2.1% of body weight in two years of work with spring calving cows. Unlike Hollingsworth-Jenkins et al., in vivo digestibility of the range diets consumed was not different among treatments.

This trial demonstrated that summer calving cows require small amounts of rumen degradable protein to maintain weight in late winter. The results of this research suggest that the summer calving cow has a requirement for supplemental rumen degradable protein similar to the spring calving cow. The requirement for rumen degradable protein appears to be between 9 and 10 percent of the digestible OM intake.

With respect to rumen degradable protein requirement, it is apparent that the summer calving cow has a need for a small amount of supplemental rumen degradable protein during late winter. This requirement is best met using protein sources that are highly degradable such as sunflower meal, corn steep liquor, or some combination of natural protein and NPN. A producer could use .9 lb (as fed basis) cottonseed meal to meet this requirement. However, cottonseed meal is 40% escape/60% degradable, so excess escape protein is fed which adds unnecessary cost to the supplementation program. This requirement could be met with approximately 1 lb of sunflower meal that is 80 percent degradable. Since all the protein in corn steep liquor is rumen degradable, 1.4 lb (as fed basis) could be used to meet the requirement. Wheat midds could also be fed with 1.6 lb meeting the requirement.

[1]Greg Lardy, graduate student; Terry Klopfenstein, Professor, Animal Science, Lincoln; Don Adams, Professor, Jim Lamb, former research technician, Dick Clark, Professor, West Central Research and Extension Center, North Platte.

Supplemental Protein on Performance of Lactating Beef Heifers

Gene Deutscher
Don Adams
Duane Farthing
Jim Lamb
Dave Colburn
Merlyn Nielsen[1]

Feeding supplement with meadow hay increased weights and rebreeding performance of lactating 2-year-old heifers. Exposing non-cycling heifers to bulls two weeks before normal breeding and flushing on green grass stimulated cycling.

Summary

A three-year study investigated effects of feeding a supplement (37.5% CP) with meadow hay (7.5% CP) after calving on hay intake and performance of two-year-old heifers (n = 243). Heifers were individually fed supplement from March 11 to May 15. Hay intake and digestibility were similar for supplemented and non-supplemented heifers, but lower than expected, resulting in energy and protein deficient diets. Heifers in supplement group and their calves were heavier on May 15 than those in non-supplement group. Only 6% of all heifers were cycling at beginning of breeding, but 87 percent became pregnant. Heifers in the supplement group calved nine days earlier with their second calf.

Introduction

A major challenge for beef producers is to obtain high rebreeding performance of two-year-old heifers after calving. Proper management is particularly important when heifers are raised under range conditions on low quality forage.

Nutritional status of first-calf heifers has a major impact on reproductive performance. Heifers deficient in protein intake after calving have longer postpartum intervals and decreased conception rates. Protein supplements may also influence energy consumption by increasing intake of low to medium quality hay.

In the Nebraska Sandhills, heifers are generally calved in late February-early March and fed subirrigated meadow hay until native range can be grazed in mid-May. Both protein and energy are potentially limiting, depending on hay quality and intake. Little information is available on intake and digestibility of subirrigated meadow hay by lactating heifers and its effect on performance.

This study was conducted to determine the effects of feeding a supplement (35 to 40% CP) with subirrigated meadow hay on hay intake, weight change, reproduction, and productivity of two-year-old heifers after calving.

Procedure

The study was conducted over three years using 243 MARC II (1/4 Angus, 1/4 Hereford, 1/4 Simmental, 1/4 Gelbvieh) two-year-old heifers and their calves. The heifers originated from the MARC II cow herd at the Gudmundsen Sandhills Laboratory (GSL) near Whitman, NE. They were developed and bred by AI as yearlings to black Angus bulls to calve beginning Feb. 15. In 1991, the study was conducted at GSL where the heifers (n = 80) were calved. In 1992 (n = 81) and 1993 (n = 82), the heifers were transported before calving to the West Central Research and Extension Center at North Platte to conduct the study.

After calving, all heifers with calves shared a common drylot and were fed ad libitum subirrigated meadow hay produced at GSL. Hay samples ranged from 7.0 to 8.0 percent CP each year. Heifers had free access to dical and salt. On March 11, heifers were randomly assigned by calving date to either a supplement (Supp) or a non-supplement control group (Non-supp). The heifers receiving the supplement were individually fed supplement twice weekly until May 15. The supplement consisted of 70% soybean meal (SBM) and 30% wheat in a pellet and was fed each year with the meadow hay to meet the NRC (1984) recommendations.

In 1992 and 1993, the heifers and calves were transported to GSL on May 15; in all three years, cows and calves were placed on native range for summer grazing on May 15. MARC II bulls were placed with the heifers on May 16 each year to begin the 75-day breeding season. Calves were weaned on September 11. Calving dates were obtained the following year.

Weights and body condition scores of heifers and weights of calves were taken in March at the beginning of the supplementation period, in mid-May at the end of supplementation, and in September at weaning. Milk production was estimated on 40 heifers (20 per treatment) in early May each year by the 12-hour weigh-suckle-weigh method. Blood samples were obtained

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before the breeding season in 1991 and 1992 to ascertain cyclicity of heifers.

Twenty-four heifers each year (12 per treatment) were randomly selected to measure hay intake in 1991 and 1992. Intake was determined from fecal output and forage indigestibility. Fecal output was determined using a continuous release chromium-oxide (Cr) bolus. Heifers were dosed with the bolus five days before fecal collection, and rectal fecal samples were taken on day 6 through 10.

Digestion trials were conducted using 1991 and 1992 meadow hay with eight steers (four/treatment each year) to validate digestibility of hay determined with indigestible NDF (INDF) used as a marker. Steers were given a continuous release Cr bolus which was checked and adjusted for release rate by measuring Cr in daily total fecal output. Steers were placed in individual pens and received either subirrigated meadow hay or hay and supplement.

Data were analyzed by analysis of variance using the GLM procedure of SAS with treatment, year, and treatment by year in the model. For heifer and calf weights and heifer body condition scores, beginning (March) weight and body condition score were used as covariates to standardize variation. Pregnancy and estrous cycling data were analyzed using Chi-Square procedures.

Results

Hay digestibility and hay intake by heifers are reported in Table 1. No differences were found between treatments for any of the traits. Year effects (P<.01) occurred for all traits measured. Hay digestibility averaged 48.9 percent and 40.2 percent for 1991 and 1992, respectively. The markers used for determination may have underestimated the digestibility in 1992 due to the lower CP in the hay. Forage intake was 2.3 and 1.8 percent of body weight for 1991 and 1992, respectively. Total intake (meadow hay + supplement) was 2.4 lb/100 lb body weight in 1991 and 1.9 lb/100 lb in 1992.

Hay digestibility and hay intake of heifers were lower than expected. This resulted in both energy and protein deficiencies. NRC recommendations were 2.2 lb CP and 12.1 Mcal NE_m per day. In 1991, Non-supp and Supp heifers were deficient in daily NE_m by 3.8 and 2.3 Mcal NE_m, respectively. The Non-supp heifers in 1991 were .35 lb deficient for CP, but Supp heifers were not deficient. In 1992, Non-supp heifers were deficient .84 lb CP and 7.7 Mcal NE_m per day; and Supp heifers were deficient .29 lb CP and 5.7 Mcal NE_m.

Low forage digestibility probably reduced passage of forage through the animal and resulted in reduced forage intake. Supplemental protein did not increase forage digestibility in this study. The protein supplement was high (78%) in rumen degradable protein and low (22%) in escape protein (NRC, 1996). Previous Nebraska results showed rumen degradable protein enhanced digestibility and intake of native range hay (<6% CP). However, other research has shown no increase in forage digestibility and intake due to protein supplementation when forages contained 8 to 10 percent CP. The hay in our study ranged from 7.0 to 8.0 percent CP.

Hay digestibility and hay intake data by steers indicated that marker estimated and actual hay digestibility were less than 10 percent different. Therefore, INDF was used as an internal marker to determine digestibility for the heifers.

Heifer weights and body condition scores are reported in Table 2. Year effects were statistically removed to compare treatment effects. The Supp heifers were 18 lb heavier (P<.05) in mid-May (prebreeding) than the Non-supp heifers. No difference was found in body condition scores. Heifers in both treatments gained weight and condition from mid-May to weaning in September but no treatment differences were observed.

Weight change during the feeding period (March to mid-May) was positive for the Supp and negative for the Non-supp heifers. Body condition decreased for both groups during this period indicating a nutritional deficiency.

Calves of the Supp heifers were heavier (P<.05) in mid-May than those of the Non-supp heifers. At weaning, calves of the Supp heifers were nine pounds heavier, but were not statistically different from those of the Non-supp heifers. The difference of calf weights in mid-May suggested that milk production was increased in the Supp

Table 1. Intake and digestibility of meadow hay by two-year-old heifers during 1991 and 1992

	Treatment		Year	
Trait	Supp	Non-supp	1991	1992
No. of heifers	23	22	21	24
Hay digestibility, %	44.6	44.5	48.9**	40.2
Hay intake, lb/day	18.5	17.6	20.5**	15.6
Hay intake, % body wt.	2.1	2.0	2.3**	1.8
Intake, hay + supplement, lb/day	19.6	17.6	20.9**	16.3
Intake, hay + supplement, % body wt.	2.3	2.0	2.4**	1.9

** Means within a category in same row are different (P<.01).

Table 2. Two-year-old heifer weights, condition scores and calf weights by treatment groups over three years.

	Groups	
Traits	Supp	Non-supp
No. of animals	123	120
Heifers		
March wt[a], lb	869	869
March body condition[a]	5.4	5.4
Mid-May wt, lb	876*	858
Mid-May body condition	4.8	4.7
September wt, lb	968	955
September body condition	5.3	5.3
Calves		
March wt[a], lb	117	117
Mid-May wt, lb	182*	172
September wt, lb	436	427

[a] March means were adjusted and used in covariate analyses of subsequent data.
* Means differ between treatments (P<.05).

Table 3. Heifer milk production and reproduction by treatment groups over three years

Traits	Groups	
	Supp	Non-supp
No. of heifers	123	120
12-hour milk production[a], lb	7.0	6.9
Cycling before breeding[b], %	8.6†	2.5
Pregnant in 75 days breeding, %	88.6	86.7
Birth date of second calf, day	Mar. 22*	Mar. 31

[a] Data collected on only half of heifers each year.
[b] Data available for only first 2 years.
* Means differ between treatments (P<.05).
† Means differ between treatments (P<.10).

heifers. However, no difference (P>.10) in estimates of milk production was detected (Table 3). The weigh-suckle-weigh procedure may not have been sensitive enough to detect small differences.

Only 5.6 percent of all heifers cycled before the breeding season began (Table 3). Although a greater percentage (P<.10) of Supp heifers cycled (8.6%) compared to Non-supp heifers (2.5%). These very low percentages are indicative of a nutritional deficiency which is predicted by the intake data.

Pregnancy rates were similar between the treatment groups. Heifers were expected to have lower pregnancy rates due to both protein and energy deficiencies. The 75-day breeding season was longer than normal (60 days) which helped increase pregnancy rates. It is believed that starting the breeding season two weeks earlier than normal allowed the bulls to stimulate earlier estrous cycles in the heifers. Only a small percentage of heifers conceived during the first two weeks of the breeding season, but the average conception date was within the first 35 days of breeding. The Supp heifers calved 9 days earlier (P<.05) than the Non-supp heifers.

Nebraska research has shown that exposure to bulls will shorten postpartum anestrous intervals in cows and heifers. Bull exposure appears to have more pronounced effects on thin cows similar to the heifers in this study. The management practice of placing bulls with thin two-year-old cows about two weeks before the normal breeding season to stimulate estrous cycles may be quite beneficial. Also, cows in this study were placed on range with abundant green grass at the beginning of the breeding season which provided a flush of nutrients that would help induce cycling.

In conclusion, supplemental protein did not affect intake and digestibility of subirrigated meadow hay in lactating two-year-old heifers. However, supplementation did increase heifer and calf weights before the breeding season, and the supplemented heifers conceived and calved earlier for the second calf than the non-supplemented heifers. Diets for both treatments were deficient in protein and energy, but pregnancy rates were only slightly below normal, probably because of early bull exposure, lush green pastures, and a longer breeding season.

[1]Gene Deutscher, Don Adams, Professors, Animal Science; Duane Farthing, former graduate student; Jim Lamb, former research technician/graduate student; David Colburn, research technician/graduate student; West Central Research and Extension Center, North Platte; Merlyn Nielsen, Professor, Animal Science, Lincoln

Evaluation of Feather Meal for Cows Grazing Cornstalks

D. J. Jordon
Terry Klopfenstein
Mark Klemesrud
Drew Shain[1]

Replacing soybean meal with sunflower/feather meal is an effective alternative when supplementing cows and heifers grazing corn residue while saving about $50 per ton in ingredient cost.

Summary

Two grazing trials during the fall of 1994 and 1995 were conducted to determine the feeding value of a sunflower/feather meal supplement relative to soybean meal in cows and heifers grazing cornstalks. Cattle on either supplement had similar gains. Replacing soybean meal with a sunflower/feather meal supplement is effective and economical for cows and heifers grazing corn residue.

Introduction

Grazing cornstalks is an economical and efficient way to maintain or increase weight and body condition score in cows and heifers during fall and winter months. However, cattle may require supplementation to meet their protein requirement; especially younger cows. Feather meal is an excellent source of undegraded intake protein (UIP) for ruminants while sunflower meal con-

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tains mostly degraded intake protein (DIP). To minimize possible palatability problems associated with feather meal, sunflower meal can be used as both a carrier and a source of DIP. Blood meal may also be used as a source of UIP, as it complements the amino acid profile of feather meal. A supplemental mixture using these proteins is less expensive and should show similar gains when compared to a more traditional supplement such as soybean meal. Several studies have shown that feather meal can replace up to half of the soybean meal in ruminant diets without adversely affecting animal performance. However, few studies have been conducted to evaluate the response of cows and heifers grazing cornstalks supplemented with sunflower/feather meal.

The objective of this trial was to evaluate the feeding value of sunflower/feather meal relative to that of soybean meal in cows and heifers grazing cornstalks.

Procedure

Eighty-six yearling heifers and two-year-old cows were used in two trials over two consecutive years. In year one, forty heifers and cows were assigned randomly to one of four dryland fields with equal numbers of heifers and cows in each field. In year two, forty-six yearling heifers and two-year-old cows were assigned randomly to one of four dryland fields, with equal numbers of heifers and cows in each field. Two fields contained ten cows in each , while the remaining two fields contained thirteen cows in each. In each year, two fields received the soybean meal supplement with the remaining two fields receiving the sunflower/feather meal supplement. Supplements were formulated to contain equal amounts of metabolizable protein and UIP and were fed at 1.5 lb/hd/day (as-is, Table 1) in a pelleted form to reduce wastage.

In situ analysis was performed on each supplement to determine UIP values. One steer, maintained on a grass hay diet, was used. Soybean meal and sunflower/feather meal supplements were ground and incubated in quadruplicate. Incubation time for all samples was 12 hours. After incubation, bags were rinsed with warm tap water until the rinse water was clear, dried for 48 hours at 140°F and weighed. Residue was then analyzed for N using a nitrogen analyzer.

Stocking rates were 0.5 hd per acre for both treatments. These were determined by previous work at the University of Nebraska with cows grazing dryland corn residue and based on lb of available leaf and husk material per acre.

Animal performance was measured in terms of ADG. Initial and final weights were determined by taking the average of two consecutive day weights. Animals were removed from fields when, based on visual appraisal, the amount of remaining residue became limited to maintain weight gains.

Table 1. Supplement compositions.

	Supplement, %DM	
Ingredient	SBM[a]	SFM/FM[a]
SBM[a]	91.4	—
FM[a]	—	11.2
SFM[a]	—	81.2
BM[a]	—	2.1
Dical	3.3	1.6
Vit. premix	.08	.08
Trace min. premix	.26	.26
Selenium	.18	.18
Pellet binder	1.36	—
Salt	3.27	3.27
Rumensin 80	.14	.14

[a]SBM = soybean meal; FM = feather meal; SFM = sunflower meal; BM = blood meal.

Table 2. Pooled cow and heifer performance from 1994-1995 and 1995-1996.

	Soybean meal	Sunflower/ feather meal
Initial weight, lb	1061	1059
Final weight, lb	1181	1174
ADG, lb	1.74	1.68

Results

Statistical analysis showed no year x treatment interaction, therefore data were pooled across years. Weight gains were similar for either supplement ($P > .15$). Visual observation showed no apparent differences in supplement palatability. Cattle on both treatments were initially slow to the bunk while available residue was plentiful, but as the trial progressed they quickly came up to consume their supplement.

Gains were greater than expected in year two (2.38 lb/day). This was likely a result of limited grass in pastures preceding stalk grazing, excellent stalk quality, and relatively little mud or snowfall during the trial. Cows were in poorer condition due to high milk production demands while grazing poor summer pasture. Pastures were slow in growing due to little rainfall. This contributed to higher gains as cows tried to replenish lost body reserves, while heifers experienced compensatory gain following low summer gains. Gains in year 1 were closer to what might be expected from cows and heifers grazing fall cornstalks (1 lb/day); however, gains in year two raised the average of pooled weights. *In situ* analysis showed soybean meal to be slightly greater in escape protein (30.0%) than the sunflower/feather meal (24.1%).

Statistical analysis was also performed on pooled data to determine animal performance by age. Average daily gain of cows (1.81 lb/day) was greater ($P < .05$) than for heifers (1.65 lb/day). This was probably due to milk production. Heifers had not raised a calf over the previous summer, thereby allowing them to start the trials in better condition; cows were in poorer condition following milk production demands.

Economic analysis of supplements showed the sunflower/feather meal supplement to be $52 less per ton than soybean meal. This resulted in a savings of $0.04/hd/day and a total savings over 70 days of $2.80/hd

[1]D. J. Jordon, graduate student; Terry Klopfenstein, Professor; Mark Klemesrud and Drew Shain, research technicians, Animal Science, Lincoln.

Effects of Supplementing High Levels of Cu, Co, Mn, and Zn After Calving on Productivity of Two-Year-Old Cows

Pete Olson
Dennis Brink
Gene Deutscher
Mike Carlson
Dave Hickok
Norm Schneider
Dave Colburn[1]

When cow management, health and nutrition are adequate, supplementation of trace minerals at high levels is not beneficial and may in fact be detrimental to reproductive performance.

Summary

A two-year study evaluated effects of supplementing Cu, Co, Mn and Zn at levels above NRC recommendations on reproduction and trace minerals in liver of two-year-old cows. Cows (n=236) were assigned to one of three treatments at calving: (1) no supplemental trace minerals, (2) organic complex (4-Plex®) and (3) inorganic. Minerals were supplemented at the same level for both supplemental treatments. Supplemental treatments increased the number of open cows compared to controls. The organic treatment increased days to conception in 1994, but not in 1995. Calf performance was not different among treatments. Liver Cu levels increased for both supplemental treatments.

Introduction

Trace mineral research and feed industry recommendations in the past five years have been directed toward feeding higher levels of trace minerals because of pharmacological responses observed in feedlot receiving cattle studies. Furthermore the response has been greater for organic sources when compared to inorganic sources of the minerals. The two-year-old cow with her nutritional stresses from calving to breeding may respond to pharmacological levels of trace minerals. Therefore, the objective of this study was to determine if a combination of Cu, Co, Mn and Zn in an organic or inorganic form fed only from calving to breeding at higher than NRC recommendations alters: pregnancy rate, subsequent calving date, calf performance, and liver biopsy and serum concentrations of trace minerals.

Procedure

A study was conducted at the University of Nebraska, West Central Research and Extension Center (WCREC), North Platte over two years using 236 (127 in 1994, 109 in 1995) crossbred two-year-old MARC II cows (1/4 Angus x 1/4 Herford x 1/4 Simmental x 1/4 Gelbvieh). Each year cows were developed as yearlings in drylot and fed ground alfalfa hay, corn silage, and dry rolled corn to reach a target weight of 650 lb before a 40-day breeding season. The bred heifers grazed native range during the summer and fall. They were fed grass and alfalfa hay plus dicalcium phosphate and salt during the winter until calving.

The calving season started in early February and lasted until the end of March. After calving the cows were randomly assigned to one of three mineral-protein treatments. The three treatments investigated were: (1) control (no supplemental trace minerals), (2) organic complex (4-Plex®) and (3) inorganic trace minerals. The control supplement consisted of soybean meal and dicalcium phosphate. The organic supplement consisted of the control plus (4-Plex®): copper lysine, cobalt glucoheptonate, manganese methionine, and zinc methionine. The inorganic supplement consisted of the control plus copper sulfate, cobalt carbonate, manganese sulfate and zinc sulfate. Supplemental elements were fed at the same daily level for organic and inorganic treatments: Cu (125 mg), Co(25 mg), Mn (200 mg) and Zn (360 mg). The heifers were tagged for identification of treatment groups and weighed approximately 48 hours after calving. Cows and calves were moved to a small pasture (with sparse grass). Cows had ad libitum access to grass hay (8% CP) from calving to breeding. All cows were individually fed the mineral-protein or protein supplement with corn twice a week to meet protein and energy requirements (NRC 1984). Cows received 3.5 lb of cracked corn and 3.5 lb of supplement at each feeding. The control cows received corn and soybean-meal supplement. Cows in the organic and inorganic treatments received corn, soybean-meal and mineral supplement.

Table 1. Trace elements consumed in the diet.

Element	Control[a]	Org & Inorg[b]	NRC[c]
		mg/day	
Cu	51	176	80
Co	8	33	0.8
Mn	945	1,145	320
Zn	165	525	240

[a] Trace element intake based on analysis of hay samples and dry matter intake of 17.6 lb/day estimated by indigestive markers plus amount provided by base supplement (Cu=7, Co=.45, Mn=57, Zn=21 mg/day).
[b]Org=Organic source of elements and Inorg= inorganic source of elements formulated to contain equal amounts of elements.
[c]NRC=National Research Council (1996) recommendations based on 17.6 lb DM intake.

Table 1 shows the trace elements consumed in the diets of the treatments. The mean concentration of elements in the hay was: Cu 5 mg/kg, Co 0.8 mg/kg, Mn 111 mg/kg and Zn 18 mg/kg. A random sample of cows

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was used each year to determine intakes of hay using chromium oxide boluses. Intakes were calculated and averaged 17.6 lbs of dry matter per day. The soybean meal supplement in the control diet contained a base amount of the four trace minerals. The mineral supplements added higher levels of trace elements to the diet. Cows in the control treatment received a total of 51 mg of Cu, 8 mg of Co, 945 mg of Mn and 165 mg of Zn per day from the hay and soybean meal supplement. Cows in the organic and inorganic supplement received a total of 176 mg of Cu, 33 mg of Co, 1,145 mg of Mn and 525 mg of Zn. Table 1 shows the intake of trace minerals relative to NRC recommendations based upon 17.6 lb of dry matter intake per day. The average feeding period per cow was 60 days.

Liver biopsies were performed to obtain liver samples for trace element analysis. Blood was also collected to compare concentration of trace elements in serum verses liver tissue. Liver biopsies were taken at four times: two weeks before calving (Feb. 5), after calving (start of feeding period), end of feeding period (May 15), and mid summer (July 7). The four biopsy times evaluated change of liver stores over the feeding period. Fifteen cows per treatment per year were randomly selected and biopsies taken on the same cows on all collection dates. Liver, serum, and feed samples were analyzed at the University Veterinary Diagnostic Center for trace minerals. The analysis of mineral concentrations in liver biopsies, serum and feeds was determined with simultaneous/sequential ICP/AES interfaced with an ultrasonic nebulizer.

On May 15, cows and calves were moved to the Gudmundsen Sandhills Laboratory for summer pasture. On May 20, bulls with chin ball markers were placed with the cows and breeding dates were recorded for the first 40 days of the 70-day breeding season. Cows were examined for pregnancy on August 31 and October 5 to determine fetal age and day of conception. Day of conception was calculated by breeding dates, two pregnancy exams, and subsequent calving dates.

Health records were recorded for the calves and cows for the entire year. Cow and calf weights and condition scores on cows were taken at calving, April 4, May 15, and August 31 (weaning).

Table 2. Reproduction of 2-Year-Old Cows on Trace Mineral Supplementation.[a]

	Treatment		
Year	Control	Organic	Inorganic
1994			
No. of cows	43	42	42
No. open after 70 days breeding	0	6	5
Day of conception[b]	June 10[d]	June 21[c]	June 7[d]
(Second Calving date)	(March 22)	(April 1)	(March 19)
1995			
No. of cows	37	36	36
No. open after 70 days breeding	0	5	6
Day of conception[b]	June 18	June 17	June 23
(Second Calving date)	(March 30)	(March 29)	(April 4)
Pooled over years			
No. of cows	80	78	78
No. open	0[e]	11[f]	11[f]
Calf gain (April-May)	54 lb.	53 lb.	52 lb.
Calf wt. at weaning	405 lb.	405 lb.	401 lb.

[a]Treatment by year interaction for mean day of conception (P<.001).
[b]Day of conception estimated by two palpations and confirmed by calving date.
[c,d,e,f]Means with unlike superscripts within a row differ (P<.01).

Results

Mineral treatments increased (P<.01) number of open cows (Table 2). Treatment affected number of open cows (P<.01). Over the two years there were 11 cows open in each mineral supplemented groups. Number of open cows was not different for mineral sources. There was a treatment by year interaction for day of conception (Table 2). The cows in 1994 bred earlier than the cows in 1995. The control and the inorganic cows conceived earlier than the cows fed organic mineral (P<.01) in 1994. However in 1995 there was no difference in day of conception among treatment groups (P>.05).

There were no differences in calf gain from April to May. Calves in each treatment gained about 53 lbs and there were no differences in calf health. Weaning weights were similar among treatments. There were no differences for cow weights or condition scores among treatments.

The trace mineral concentrations in the liver were different between treatments for Cu (P<.01) with organic and inorganic being greater than the control (Table 3). The organic and inorganic groups were not different from each other at any biopsy date (P>.05). The Cu level for the control cows was higher initially at the start of supplementation. The reason the control cows were higher in liver Cu was because of the random allocation of cows to that treatment. At the end of the feeding period, cows fed minerals had increased their liver Cu level nearly three times (P<.01). A fourth biopsy was taken at mid summer to determine the pasture affects on the trace element levels in the liver. The control cows had higher liver Cu in July than the May 15 biopsy date (P<.01). The organic and inorganic cow's liver Cu decreased for the July 7 biopsy (P<.01). Source of mineral did not influence Cu concentrations in liver biopsy samples. Serum Cu concentrations did not differ for treatment or at any of the collection dates. Therefore, serum is a poor indicator of Cu status. The data suggest that organic sources are not advantageous when protein and energy nutrition is adequate.

Liver Mn was not different by treatment or biopsy time. Liver Zn levels were highest after calving (start of

Table 3. Least square means for liver trace element analysis by biopsy time.

ppm	Start Supp March 15	End Supp May 17	Mid Summer July 7
Cu[a]			
Control	67[c]	75[c]	91[c]
Organic	48[b]	184[b]	144[b]
Inorganic	43[b]	174[b]	144[b]
Zn[d]			
Control	131	98	96
Organic	137	112	107
Inorganic	134	102	99
Mn			
Control	10	11	9
Organic	12	10	9
Inorganic	11	10	10

[a]Biopsy treatment by time interaction.
[b,c]Means with unlike superscripts within a column differ (P<.01).
[d]Biopsy time (P<.01).

supplementation) and decreased significantly by May. This was interesting that liver Zn was lower in May after the feeding period. Zinc may not have been used by the animal because it was tied up with another trace element in the diet such as Cu. Zinc is stored in other tissues such as the pancreas at higher levels than liver. This might explain why there were no differences for Zn by treatment time. Manganese liver levels did not differ after supplementation or after the cows went to grass. The levels in the liver are in the normal range. The liver is not a good storage site for Mn. Bone stores more Mn than liver, therefore, it is possible that the sampling technique failed to give an accurate measurement of Mn in the cow. There is no data for liver Co because of the analysis techniques used. Cobalt could not be detected in the liver tissue.

Mineral supplementation increased the number of open cows. The cows were not deficient for Cu, Zn, Mn or Co as evidence by excellent reproductive performance for the control cows. Trace elements in excess may cause sub-clinical toxicities, such as reduced reproductive performance. Therefore, since the base forage contained adequate levels of trace minerals, the additional levels fed may have caused the reduction in reproductive performance.

The study suggests that with the imposed management and nutrition, the combinations of trace elements fed at high levels reduced reproductive performance in beef cows. Trace mineral supplementation should be looked at as a function of health management and nutrient intake. When nutritional management and nutrient intakes are low a response may be seen to feeding higher levels of trace minerals. However, when nutrition and health are closely watched a positive response to higher trace mineral levels probably will not be seen. The trace minerals supplemented individually may not have caused a decrease in reproduction. Based upon hay analysis and amounts of minerals in supplement, elements were not overfed according to NRC maximum tolerable levels. Cobalt was the only element close to reaching the maximum tolerable level of 50 mg/day. Cobalt in the mineral supplement groups was fed at a level of 33 mg/day. Therefore additional research is needed to identify specific elements, levels, and biological mechanisms involved so reduced performance caused by overfeeding trace minerals can be avoided.

[1]Pete Olson, graduate student, Animal Science, Dennis Brink, Professor, Animal Science, Mike Carlson, research technician, Veterinary Diagnostic Center, Dave Hickok, graduate student, Animal Science, Norm Schneider, Associate Professor, Veterinary Diagnostic Center, Lincoln, Gene Deutscher, Professor, Dave Colburn, graduate student, West Central Research and Extension Center, North Platte.

Effects of Copper and Selenium Injections on Cow Productivity and Concentration of Copper in Liver Biopsy Samples

Jerre Johnson
David Hickok
Dennis Brink
Pete Olson[1]

In the conditions of the study when additional copper and selenium were provided, cow reproduction and calf performance were not improved.

Summary

A study with 100 cows in four treatment groups was conducted at the Gudmundsen Sandhills Laboratory. The treatment groups were: 1) Control, no additional Cu or Se, 2) 120 mg Cu, 3) 25 mg Se, or 4) 120 mg Cu and 25 mg of Se. In 1993, treated cows received Cu by injection and Se supplementation by bolus in January and June. In 1994, Se was provided by injection instead of Se bolus in the same months. In 1995, injections of Cu and Se were given in January only. Reproductive performance and calf performance were not influenced by treatment.

(Continued on next page)

Introduction

Copper and Se are trace elements important in several aspects of normal body function; therefore, a diet deficient in these elements may impair productivity in the cow herd. The purpose of the following study was to determine if providing additional Cu and/or Se by injection at manufacturer's recommended levels two times during the year improves cow productivity and changes concentration of Cu in liver biopsy samples of cows or their calves.

Procedure

One-hundred 4- to 6-year-old MARC II cows were randomly assigned to one of four groups. The study was conducted at the Gudmundsen Sandhills Laboratory at Whitman, NE. One of the following treatments was assigned to a group of cows for three years: 1) control untreated, 2) Cu injection, 3) Se bolus/injection, and 4) combination of Cu and Se. Treated cows received Cu by injection and Se supplementation by bolus (MolyCu® and DuraSe® boluses; Schering-Plough) in January and June, 1993. In the same months in 1994 Cu was again injected, but Se was supplemented by injection (Mu-Se®; Schering-Plough) instead of the DuraSe® boluses. Dosage was according to field recommendations; 2 cc of MolyCu® (400 mg of cupric glycinate) was the equivalent of 120 mg Cu. The DuraSe®-120 bolus contained the equivalent of 360 mg Se as sodium selenite and was manufactured to deliver a controlled amount of 3 mg/Se/day for four months. Mu-Se® was injected at 1 ml/200 lb body weight. Each ml contained 10.95 mg sodium selenite (equivalent to 5 mg selenium). Cows received treatments in January, but not June of the third year (1995). The cows were managed as a single herd with energy and protein supplementation provided as needed to maintain moderate body condition scores at calving.

In January and June (1993 and 1994), ten cows from each group were liver

Table 1. Reproductive performance data by treatment group within years (least square means)

	Calving rate (number of cows calving)			
	Control	Cu	Se	Cu & Se
1993	25	25	24	25
1994	22	25	23	23
1995	20	22	20	22
	Calving date[a]			
	Control	Cu	Se	Cu & Se
1993	86	89	92	87
1994	87	87	91	84
1995	82	88	87	85
	Calving interval (mean days)			
	Control	Cu	Se	Cu & Se
1994	367	364	365	365
1995	358	368	361	365

[a]Julian days where 1 = January 1 and 90 = March 31.

Table 2. 205 day adjusted weaning weights (lb) by treatment group with year (least square means)

Item	1993	1994	1995	SEM
Control	557	578	478	22
Cu	563	583	435	22
Se	574	563	495	21
Cu & Se	527	555	475	22

Table 3. Least square means for cow liver Cu by treatment group with year (ppm, dry basis)

Biopsy date[a]	Control	Cu	Se	Cu & Se	SEM
January, 1993	107[bc]	112[bc]	138[b]	94[c]	15
June, 1993	86[bc]	108[b]	89[bc]	74[c]	11
January, 1994	110	108	111	101	11
June, 1994	85	95	82	74	11
March/April, 1995	51[bc]	74[b]	47[c]	54[bc]	11

[a]Biopsy date (P<.01); Treatment (P<.10); Treatment * Biopsy date (P<.75).
[b,c]Means within rows with different superscripts are different (P<.10).

Table 4. Calf liver biopsy (ppm, dry basis) data (least square means)

Element	Control	Cu	Se	Cu & Se	SEM
Mo	1.5	1.4	1.3	1.5	.1
Cu	200	216	179	271	31
Zn	165	156	155	199	30
Mn	7.5	7.5	7.0	7.1	.5

Table 5. Gudmundsen Sandhills Laboratory hay analysis by harvest date

	Cu (ppm)				Mo (ppm)				Zn (ppm)				Mn (ppm)			
Year	High	Low	Mean	# of samples	High	Low	Mean	# of samples	High	Low	Mean	# of samples	High	Low	Mean	# of samples
1992	8.8	2.8	5.9	18	10.1	2.9	5.9	18	23.6	16.4	19.8	18	412.5	41.9	142.7	18
1993	8.8	3.5	6.2	23	10.6	2.6	5.9	23	25.4	14.8	19.5	23	206.3	39.5	118.1	23
1994	10.1	2.4	6.6	23	9.9	1.7	5.4	23	30.0	13.1	19.4	23	645.5	64.0	174.3	23

biopsied and blood serum was collected. Cow weight and body condition score were recorded in January, June, and October. Calves were weighed and serum samples taken at birth. Calves were weighed in May and October. In March/April 1995, calves (average age = 23 days) from liver biopsied cows were liver biopsied at the same time as the cows. Serum and liver biopsy tissue were analyzed for macro and micro-elements using an inductively coupled argon plasma atomic emission spectrometer.

Samples of hay harvested from pastures on the ranch were collected each year and analyzed for mineral elements by x-ray diffraction.

Results

Pregnancy rate, calving date, and calving interval were not affected by treatment or year (Table 1). No differences were observed in calf birth weight or calf weight among treatments. There was a significant year effect on weaning weight (Table 2) with weaning weights being lower for 1995 ($P<.01$).

Tables 3 and 4 show the cow and calf liver biopsy data, respectively. Liver biopsy Cu concentrations were significantly lower in the March/April 1995 samples. The difference may be due to date and that it immediately followed calving. Cows provide Cu to the fetus during the last weeks of pregnancy. Copper concentrations in liver biopsy samples from cows injected with Cu were higher than other groups at several biopsy dates, including March/April 1995. However, increases in concentration of Cu in the liver biopsy samples did not alter reproductive or calf performance. The combination of Cu and Se did not increase Cu in liver biopsy samples. There is limited research suggesting that Se is an antagonist to Cu absorption.

No treatment effects on trace element percentages in calf liver biopsy samples were observed (Table 4). The concentration of Cu was higher in calf liver biopsy samples than cow liver biopsy samples: a relationship between concentration of Cu in calf liver biopsy samples and cow liver biopsy samples was not observed. Cows with high concentrations of Cu in liver biopsy samples did not have calves with higher or lower Cu in their liver biopsy samples as indicated by non-significant correlation coefficients. Calf liver biopsy samples were taken only in year three, so year and treatment by year interactions were not available.

The analysis of hay samples suggest the mean Cu content of the forages consumed by cows during this study contained between 5.9 and 6.6 pm Cu (Table 5). Actual intake of Cu was not available, because samples representative of the forage the cows were consuming during the grazing season were not collected. Based on data reported in the 1994 Nebraska Beef Report, p. 9, the forage the cows consumed during the grazing season should have had greater than 6 ppm Cu, because forages in the early stages of physiological growth tend to have higher concentrations of Cu. The mean molybdenum content of hay samples varied by year between 5.4 and 6.0 ppm (Table 5); however, variability in molybdenum analysis was large in hay samples from pasture to pasture. Analytical methods for Mo are complex and may explain a large portion of the variability.

In this study injections of Cu and Se did not affect reproductive performance or calf performance through weaning. The relationship of lower calf performance and lower Cu concentration in their dam's liver biopsy samples observed in 1995 warrants further study with more closely monitored Cu consumption and additional liver biopsy samples from cows and calves. Furthermore, the Cu-Se interaction suggested by lower Cu concentration in liver biopsy samples from cows given both Cu and Se compared to other treatments may require additional study.

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[1] Jerre Johnson, Professor and Pathologist, West Central Research and Extension Center, North Platte, David Hickok and Pete Olson, graduate students, Dennis Brink, Professor, Animal Science, Lincoln.

Effects of Sire EPD, Dam Traits and Calf Traits on Calving Difficulty and Subsequent Reproduction of Two-Year-Old Heifers

Dave Colburn
Gene Deutscher
Merlyn Nielsen
Don Adams
Pete Olson[1]

Calving difficulty can be reduced by selecting low birth weight EPD sires, culling yearling heifers with large birth weights and small pelvic sizes, and producing calves with moderate bone size and birth weights.

Summary

A three-year study evaluated effects of sire birth weight EPD, heifer and calf traits on calving difficulty and subsequent rebreeding of two-year-old cows. MARC II yearling heifers (n=550) were assigned for breeding to one of four Angus sires with birth weight EPD of -2.1, -1.8, +6.3 and +5.9 lb. Of all heifer weights, only dam birth weight affected calving difficulty score. Heifers requiring caesareans had smallest pelvic areas. Calving difficulty increased as calf birth weight and external measurements increased. Low EPD sires produced calves with smaller head and foot circumferences and less dystocia. Degree of calving difficulty did not affect subsequent pregnancy rates, but did delay rebreeding conception date.

Introduction

Calving difficulty (dystocia) is one of the most important production problems of the beef industry. It has been recognized as a major cause of early calf mortality, reduced calf crop at weaning and decreased reproductive performance. The national annual loss from dystocia is estimated at $750 million.

Many factors are known to contribute to dystocia and are interrelated. The major cause reported in two-year-old heifers is a disproportion between calf birth weight and dam's pelvic area. Other factors involved are: calf sire, sex of calf, shape of calf, heifer weight and body condition, heifer nutrition and geographic location.

Therefore, a study was designed to evaluate the effects of a combination of factors: sire birth weight EPD, calf birth weight and shape, various heifer measurements and climatic conditions on dystocia and subsequent rebreeding of two-year-old heifers. Two methods of measuring dystocia: 1) pounds of delivery pressure and 2) the standard five-point subjective scoring system were evaluated. Also, the effects of dystocia on calf growth from birth to slaughter were investigated.

Procedure

This study was conducted at the University of Nebraska, West Central Research and Extension Center (WCREC), North Platte over three years using 550 MARC II heifers (1/4 Angus x 1/4 Hereford x 1/4 Simmental x 1/4 Gelbveih). Heifer calves were born in March and April at the Gudmundsen Sandhills Laboratory (GSL), Whitman, NE.

Using a standardized procedure each year, yearling heifers were assigned to 50-lb weight blocks, ranked on pelvic area from smallest to largest within weight blocks and then randomly allotted to one of four Angus sires (ABS Global, Inc., DeForest, WI). Two low and two high birth weight EPD Angus sires were used (-2.1, -1.8, +6.3, and +5.9 lb, respectively). All sires had accuracies greater than .95 for birth weight EPD.

Growth traits measured at 12, 18 and 22 months of age were heifer weight, body condition score, hip height, and internal pelvic width, height, and area. Internal pelvic measurements of width and height were obtained using a Krautman Bovine Pelvic Meter and the pelvic area was calculated by multiplying width and height. Body condition scores were given on a visual scale of 1 to 9, where 1=emaciated; 5=moderate; and 9=extremely fat.

The breeding season began May 10 each year and lasted for 42 days. Approximately 12 hours after standing estrus, heifers were artificially inseminated with semen from their assigned sire. The same four sires were used each year.

During the calving season, which began in early February, heifers were checked every two hours for signs of parturition. When heifers needed assistance, a pressure gauge was attached to the calf puller to determine the maximum pounds of pressure required to deliver the calf. Heifers were scored on a calving difficulty scale (CDS) of 1 to 5 for degree of dystocia, with 1=no

assistance, 2=easy pull, 3=mechanical pull, 4=hard mechanical pull, 5=caesarean. The range of pressures for each CDS were: 73-123 lb, 124-618 lb, 619-800 lb, and 850 lb, for CDS 2, 3, 4, and 5, respectively. Since calves experiencing a caesarean birth could not be delivered with a puller, a maximum pressure was assigned (850).

Calving traits recorded immediately after parturition included: calf sex, calving date, calving difficulty score, and delivery pressure. Calf vigor scores were recorded on a scale of 1 to 5, with 1=nursed unassisted within 30 min; 2=nursed unassisted within 30 to 60 min; 3=nursed unassisted within 60 to 75 min; 4= didn't nurse within 75 min and was assisted; and 5=dead at birth. Calf traits recorded within 12 hours of birth included: birth weight, head and foot circumference, width of shoulders and hips, and depth of chest. Pelvic measurements of the heifer were also obtained at 12 hours postpartum.

Circumference of the head was measured by placing the measuring tape over the calf's poll and under the jaw bone giving the largest circumference. The foot circumference was determined by placing the measuring tape around the coronary band of the left front foot. With the calf standing, width of shoulders was measured at the widest point. The width of hips was measured at the widest dimension over the femur joints. The depth of chest was the distance between the crops and the chest floor (sternum).

Reproductive traits of the young cows obtained after calving included: cycling before the breeding season, pregnancy during breeding, and day of conception. Cycling was determined by palpation of the ovaries for corpora lutea; and blood samples were obtained and assayed for progesterone level. Cows were exposed to MARC II bulls in multiple-sire groups for a 75-day breeding season beginning May 19 at GSL each year. Breeding dates were recorded with the aid of chin-ball markers on bulls. Two pregnancy exams were performed via rectal palpation at 30-day intervals for fetal aging. Day of conception was determined using breeding dates, palpation data, and subsequent calving dates.

Traits measured at weaning in early September included: cow weight and body condition score and calf weaning weights. After weaning, calves were placed in a feedlot and fed growing and finishing rations until ready for slaughter the following May. Calf gain was obtained from weaning to slaughter.

Data were analyzed by analysis of variance for a randomized complete-block design with main effects of year and sire. Calf birth weight and sex were included in the model as covariables for calf shape measurement analyses. Percentage data were analyzed by Chi-square procedures. Significant year effects were found and removed statistically to determine causes of dystocia pooled over years. No year x sire interactions were found so they were deleted from the model. For presentation purposes, variables were fitted to a model with CDS to derive means by CDS classes.

Table 1. Means for heifer growth traits and calf measurements by calving difficulty score[a]

	Calving Difficulty Scores[b]				
Traits	1	2	3	4	5
Heifer					
No. of heifers	197	25	104	33	30
Weights,lb					
Birth	88^{e}	90^{efg}	90^{ef}	93^{fg}	95^{g}
12 mo	651^{e}	669^{ef}	653^{ef}	673^{f}	664^{ef}
22 mo	957^{e}	999^{f}	968^{ef}	992^{f}	979^{ef}
Pelvic Area,cm^2					
12 mo	172^{e}	175^{e}	170^{e}	174^{e}	165^{f}
22 mo	245^{e}	247^{e}	244^{e}	245^{e}	235^{f}
25 mo	269^{e}	269^{ef}	267^{ef}	266^{ef}	261^{f}
Calf Traits					
No. of calves	197	25	104	33	30
Delivery pressure,lb	——	103^{e}	457^{f}	671^{g}	850^{h}
Birth weight,lb	72^{e}	76^{f}	79^{g}	83^{h}	88^{i}
Head circumference[c].,cm	45.7^{ef}	45.4^{e}	45.5^{ef}	45.6^{ef}	46.0^{f}
Foot circumference[c].,cm	17.1^{e}	17.2^{fg}	17.1^{eg}	17.0^{eg}	17.3^{f}
Width of shoulders[c],cm	20.4^{e}	20.6^{ef}	20.6^{ef}	20.6^{ef}	20.9^{f}
Width of hips[c],cm	22.4	22.1	22.1	22.1	22.2
Depth of chest[c],cm	29.1^{ef}	29.6^{e}	29.1^{fg}	29.2^{eg}	29.2^{eg}
Vigor score[d]	2.8^{e}	3.2^{fg}	3.1^{f}	3.6^{g}	2.9^{ef}

[a]Values pooled over three years, with year and sire effects removed.
[b]Scoring system 1 to 5, 1=hand pull, 3=mechanical pull, 5=Caesarean.
[c]Calf values had sex of calf and birth weight removed.
[d]Scoring system 1 to 5, 1=nursed unassisted within 30 min, 3=nursed unassisted within 75 min, 5=dead at birth.
[efghi]Means within rows with unlike superscripts differ (P<.05).

Results and Discussion

The effects of climatic conditions during the three years of this study on calf birth weight and dystocia were summarized and reported in the 1996 Nebraska Beef Cattle Report, MP 66-A pp. 23-25.

The pressure system detected only slightly larger amounts (2% to 3%) of variation affecting dystocia than the standard five-point scoring system. The standard CDS system appears adequate in describing the degree of dystocia; and measuring delivery pressure is not necessary. Therefore, the data in this study are presented only by CDS classes.

Heifer Traits

Heifer weights and measurements at various ages and calf measurements by CDS are reported in Table 1. Differences were found between CDS 1 and 5

(Continued on next page)

for dam birth weight (88 vs 95 lb, respectively). This indicates heifers that were heavier at birth experienced more calving difficulty as two-yr-olds. They had heavier birth weight calves, which was probably due to genetics. In general, heifer weights at 12 and 22 months of age did not significantly affect degree of calving difficulty, indicating selecting the heaviest heifers as yearlings may not reduce the degree of dystocia at calving.

In general, no differences were found in hip height and heifer body condition at 12 or 22 mo of age among CDS.

Heifer pelvic area significantly affected CDS only for heifers requiring caesareans (CDS 5). These heifers had smaller pelvic area measurements at 12 and 22 months of age than heifers in all other CDS groups. These results indicate yearling pelvic measurements would have been useful in detecting heifers requiring caesarean deliveries. Heifer pelvic areas at calving (25 months) showed the same significant differences between CDS as at 12 and 22 months.

Yearling pelvic area was highly correlated (.78) to precalving pelvic area, indicating that yearling pelvic area accounted for 61% of the variation in precalving pelvic area and could be used as an indicator for precalving pelvic area.

Calf Traits

As expected, the delivery pressure increased as CDS increased (Table 1). Pounds of pressure required for each CDS were 103, 457, 671, and 850 for scores 2, 3, 4, and 5, respectively. This pressure directly measured the severity of calving difficulty.

Calf birth weight increased as CDS increased and was the most important factor determining CDS. Calf birth weight accounted for 36.5% of the variation in delivery pressure.

Differences were found for calf head and foot circumferences and width of shoulders among CDS. Calf head circumference was larger for CDS 5 than CDS 2. Score 5 had calves with larger foot circumference and width of shoulders compared to CDS 1. Depth of chest results were inconsistent across CDS, with no differences found for width of hips. The results on width of hips may be due to the procedure used in handling calves during parturition. During delivery, calves were rotated to reduce the possibility of hip lock and avoid causing further stress to the calf and heifer. Of the calf measurements, head circumference and width of shoulder measurements appear to be the most important indicators of degree of dystocia in our data set.

Calf birth weight was found to be highly correlated to foot circumference (.79) and accounted for 62% of the variation, indicating that foot circumference may be a good indicator of birth weight.

Calf vigor score increased ($P<.05$) as CDS increased up to CDS 4 meaning less vigorous calves with the more difficult births. Score 5 was not different from CDS 1 indicating calves born with a caesarean did not experience any more stress, and were as vigorous as calves born unassisted.

Sire Effects

Means for heifer and calf measurements by sire are reported in Table 2. There were no differences for heifer yearling weight and pelvic area among the sires due to the heifer allotment procedure. Calf birth weight was different between sire EPD groups, 73 vs 80 lb, low vs high, respectively. The difference in birth weight EPD between the two sire groups was 8 lb, indicating that sire birth weight EPD was a good predictor of average calf birth weight. However, the range of birth weights for a single sire was 60 to 100 lb. Predictability of calf birth weight for a single calf can be low, due to genetic effects from the dam and sire causing a wide range of birth weights and more dystocia than expected.

Calf head and foot circumferences were different between the low and high EPD sires even when calf birth weight was held constant. Differences were also found between the two low birth weight EPD sires for head and foot circumferences: 45.2 vs 45.6 cm, and 16.9 vs 17.0 cm, respectively. Also, there were differences between the two high EPD sires for foot circumference. However, Sires 2 and 4 were not different for head and foot circumferences. These results suggest there were differences between sires within birth weight EPD groups. Also, there were similari-

Table 2. Means for heifer and calf measurements by sire[a]

	Low Sire[b]		High Sire[b]	
Traits	1	2	3	4
No. of heifers	139	137	137	136
12-mo heifer weight, lb	653	653	656	655
12-mo heifer pelvic area, cm^2	171	170	171	171
No. of calves	106	93	94	96
Calf birth weight, lb	72[f]	73[f]	79[g]	80[g]
Head circumference[c], cm	45.2[f]	45.6[h]	46.0[g]	45.7[gh]
Foot circumference[c], cm	16.9[f]	17.0[h]	17.4[g]	17.1[h]
Width of shoulders[c], cm	20.6	20.5	20.4	20.6
Width of hips[c], cm	22.3	22.3	22.2	22.3
Depth of chest[c], cm	29.1	29.2	29.3	29.1
Delivery pressure, lb	246[f]	230[f]	363[g]	298[fg]
Calving difficulty[d]., %	41[fh]	33[f]	52[g]	46[gh]
Calving difficulty score	2.0[fh]	1.9[f]	2.5[g]	2.2[gh]
Caesarean, %	3[f]	5[f]	16[g]	7[f]
Vigor score[e]	2.7[f]	3.0[fh]	3.2[gh]	3.3[g]

[a]Values pooled over three years, with year effects removed.
[b]Sire BWT EPD:1= -2.1, 2= -1.8, 3= +6.3, 4= +5.9 lb.
[c]Values pooled over three years, with year and calf birth weight removed.
[d]Calving difficulty scores 3 to 5.
[e]Scoring system 1 to 5, 1=nursed unassisted within 30 min, 3=nursed unassisted within 75 min, 5=dead at birth.
[fgh]Means within rows with unlike superscripts differ ($P<.05$).

ties between sires of each birth weight EPD group. No differences were found for width of shoulders, width of hips or depth of chest among sires.

Calving difficulty percentage was lower for heifers bred to the low birth weight EPD sires. However, Sire 1 (birth weight EPD -2.1) was not significantly different from Sire 4 (birth weight EPD +5.9), even though they were significantly different for birth weight. A significant difference was found between the two high sires for percent caesareans: 16% for Sire 3 and 7% for Sire 4. This difference is not explained by the small difference in birth weight. The difference may be due to larger bone per unit of calf birth weight for Sire 3, thus causing more dystocia. Sire 3 had a larger foot circumference (larger bone) compared to Sire 4, (Table 2).

There were differences in calf vigor score among sires. Sire 1 was significantly different from Sire 4. These two sires are of interest because they were significantly different for calf birth weight but not CDS. This indicates that heavier calves are less vigorous and slower to nurse.

Table 3. Means for heifer reproductive traits after calving and weaning and post-weaning growth traits of calves by calving difficulty score

	Calving difficulty scores[a]				
Traits	1	2	3	4	5
No. of heifers (2-yr-old)[b]	195	25	107	29	30
Cycling,(%)	44	42	37	40	25
Conception date	June 13[f]	June 16[fg]	June 18[g]	June 24[g]	June 15[fg]
Pregnancy 75d,%	90	84	93	90	80
No. of heifers (3-yr-old)[b]	159	20	94	20	21
Second calf birth wt.,lb	85[f]	87[fg]	87[fg]	92[g]	87[fg]
Calving difficulty,%	6[f]	10[fg]	9[f]	30[g]	10[fg]
Calf Growth Traits[c]					
Weaning Wt[d]., lb	480[f]	480[f]	480[f]	471[fg]	460[g]
Slaughter Wt[e]., lb	1129[f]	1190[g]	1170[g]	1177[g]	1184[g]
Gain[e]	702[f]	761[g]	739[g]	744[g]	761[g]
ADG[e], lb/d	2.6[f]	2.9[g]	2.9[g]	2.9[g]	3.1[g]

[a]Scoring system 1 to 5, 1=no assistance, 3=mechanical pull, 5=Caesarean.
[b]Values pooled over three years, with year and sire effects removed.
[c]Values pooled over three years.
[d]Year, sire, sex of calf, birth weight and birth date effects removed.
[e]Year, sire, and sex of calf effects removed. Gain was calculated from weaning to slaughter.
[fg]Means within rows with unlike superscripts differ (P<.05).

Subsequent Reproduction

Reproductive traits of the cows after calving by CDS are shown in Table 3. No differences were observed in percentage of heifers cycling before the breeding season by CDS. Significant differences were found in conception date between CDS 1 compared to 3 and 4. There was a trend, as CDS increased to 4, conception date increased from June 13 to June 24. Score 5 was not different from the other CDS, but these heifers had the second earliest conception date. These data indicate that heifers requiring caesareans experienced less stress during parturition than CDS 3 and 4 heifers. There were no significant differences for percentage of heifers pregnant among CDS.

Second calf birth weights were similar by CDS; however, the second calves were heavier than the first calves. Differences were found in calving difficulty percentage for three-year-old cows. The heifers in CDS 1 (as two-year-olds) experienced 6% calving difficulty as a three-year-old compared to 30% in the heifers in CDS 4. Heifers in CDS 5 (caesareans) experienced only 10% calving difficulty as three-year-old cows. The only cows that were culled from the study were those that lost calves as a two-year-old, and those that were not pregnant after the breeding season. These results show that heifers experiencing dystocia as two-year-olds will have considerably less difficulty as three-year-olds.

Calf Growth

Table 3 shows the growth of calves from weaning to slaughter by CDS. Calves delivered by caesarean section were significantly lighter at weaning than calves from CDS 1, 2, and 3. No obvious explanation is known as these calves were the heaviest at birth. We theorize that the caesarean surgery may have negatively affected milk production of the heifer which slowed growth of the calf. However, these calves showed compensatory gain in the feedlot and had high slaughter weights. The calves from cows with CDS 1 had slower gains in the feedlot than all other calves. These calves were the smallest at birth and may have had less genetic growth potential. Weaning and slaughter weights of calves were inconsistent across sires.

This research study shows the complexity of dystocia and the many factors influencing it, plus the effects on subsequent cow reproduction and calf growth. These results should be quite useful in helping producers change management practices to reduce calving difficulty. Dystocia and calf losses can be reduced through proper sire selection, heifer selection and calving management.

[1]Dave Colburn, research technician/graduate student; Gene Deutscher, Don Adams, Professors, Animal Science, West Central Research and Extension Center, North Platte; Merlyn Nielsen, Professor; Pete Olson, graduate student, Animal Science, Lincoln.

Cornstalk Grazing in Protected and Unprotected Fields

D. J. Jordon
Terry Klopfenstein
James Brandle
Mark Klemesrud[1]

Calves grazing cornstalks do not require windbreaks during a winter with normal weather. However, it has not been determined if extremely long cold periods would reduce gains of unprotected cattle.

Summary

A grazing trial during the winter of 1995-1996 was conducted to determine if windbreaks could improve calf gains by reducing cold stress. Unprotected cattle gained faster than protected cattle ($P < .05$). Unprotected fields contained more residual corn ($P < .05$) than protected fields that would account for added gains. Unprotected calves also found some shelter using the natural topography of fields. These results agree with previous work where calves grazing grain sorghum residue gained equally with or without protection. Windbreaks do not improve gains in a normal winter; however, during long periods of cold weather, protected cattle may have some advantage.

Introduction

In the upper Midwest and Great Plains region, windbreaks have often been recommended for livestock protection. Cattle performance might be enhanced by decreasing the incidence of cold stress, thereby decreasing heat production for maintenance and increasing feed efficiency. The energy balance of cattle, and thereby their productivity, is a complex interaction between intake, physiological state, and thermal environment. Some of the gross energy consumed by calves is lost in the feces, urine, and gaseous products of digestion. The remaining energy, metabolizable energy, can be used for maintenance and/or production. A portion of this metabolizable energy used for maintenance is converted to heat thereby reducing efficiency of feed:gain.

Grazing of cornstalks by growing calves is a low cost and efficient use of residue remaining in the field. However, weather conditions may affect grazing time and behavior of cattle during extremely cold periods. Windbreaks decrease windflow on both the windward and leeward sides of the barrier. Horizontal extent of the windbreak effects upwind and downwind airflow and is assumed to be proportional to the height. Protection from wind can extend up to 10-12 times the height of the windbreak on the leeward side and 3-5 times the height on the windward side. A well-placed windbreak should then greatly benefit young grazing animals by helping to reduce cold stress, allowing for more total grazing time, and benefit the producer economically through increased animal gains and feed efficiency.

The objective of this trial was to evaluate if windbreaks would reduce cold stress on calves grazing corn residues resulting in increased weight gains.

Procedure

One hundred fourteen weaned crossbred steer calves were assigned randomly to one of seven corn fields. Three fields were protected by established conifer windbreaks, while the remaining four fields offered animals little protection only through the natural topography of the field. Protected fields had north:south 40 ft conifer windbreaks on the east, west, or both sides. The east protected field was relatively flat with slight depressions on the north end and a windbreak on the west side. The middle protected field was very similar to the east field with windbreaks on both the east and west sides. Topography of the west protected field was more rolling with wind protection only on the east side of the field. Protected fields were fenced to prevent animal access to the trees. Of the four unprotected fields, two were adjacent fields, separated by an electric fence and so, topography was very similar with slight depressions. The third unprotected field was flat with the southern end containing a grassy area in a relatively large depression. The fourth unprotected field had rolling hills with a few large ditches running through it.

Cattle were weighed on two consecutive days at the beginning and end of the trial after being limit fed for a period of three days to standardize fill differences. Cattle performance was measured in terms of ADG. All fields were stocked at one animal per acre. This stocking rate was determined through past research with calves grazing dryland corn residue at the University of Nebraska. Residual corn from each field was sampled in random locations by taking four 250 x 2.5 ft strips. Only whole and partial ears were collected. All ears were shelled to determine bushels per acre of residual corn. Each protected field had three anemometers placed in the middle and spaced equally apart. Two unprotected fields also contained three anemometers in the same fashion. However, due to a lack of anemometers, the two unprotected fields that were adjacent to each other contained only two anemometers that were placed one in each field. Each individual anemometer was protected from cattle by a 256 sq ft cage. A protein supplement containing 36 per-

Table 1. Calf performance, wind speed measurements, and field data.

	Protected	Unprotected
Initial weight, lb	497	496
Final weight, lb[a]	577	588
ADG, lb[a]	1.22	1.40
Wind speed, mph (With west field)	5.8	6.8
Wind speed, mph[a] (Without west field)	5.06	6.75
Yield, bu/acre[c]	80.0	75.6
Residual corn, bu/acre[bc]	3.13	4.54

[a]Protected < unprotected (P < .05).
[b]Protected < unprotected (P < .10).
[c]Includes 15% moisture.

cent CP was fed at 1.5 lb/hd/day (as-is) to each treatment. Cattle were placed in fields on December 5, 1995 and removed on February 1, 1996. Anemometers were monitored throughout the trial. Observations of cattle were made during the trial, especially during periods of extremely cold and windy conditions to determine grazing behavior and bedding areas of calves.

Results

Average daily gains of calves on unprotected fields were greater (P < .05) than calves in protected fields (Table 1). The most likely explanation for this is found in the residual corn values for each treatment. Residual corn was greater (P < .10) in unprotected fields (Table 1). When broken down into lb of residual corn DM/hd/day, the added energy supplied by corn to calves in unprotected fields would have accounted for the added gains. Also, upon observation of animals during periods of extreme cold, unprotected calves appeared to find shelter using the natural topography of the land. Cattle huddled in slight depressions and ditches to find shelter. It is also possible that cornstalks provided some protection to the animals when they were lying down. Windbreaks used in this trial ran north to south, but over half of the winds were out of the north (27%) and northwest (25%). Perhaps east:west windbreaks would have benefitted protected cattle more, thereby affecting gains. Typical wind speed reductions from east:west barriers are approximately 40 percent, whereas reductions from the north:south barriers used in this trial were only 25 percent.

Wind speed measurements taken by anemometers at a height of 10 feet in each field showed that protected fields had wind speeds which were less (P < .05) than those in unprotected fields. Table 1 shows two wind speed values for each treatment. One set of values are with the west protected field included, while the other values are with the west protected field removed from the data set. This was done because of unusually high wind speed measurements recorded in the west field. The west field had protection only on the east side, thereby only offering protection close to the tree line. Anemometers were placed in the middle of the field and apparently did not receive any wind reduction from the trees in the west field. In fact, anemometers in the west field recorded higher wind speeds than in any other field. Twenty-seven percent of the winds during the trial were out of the northwest, explaining why the west field had higher wind speeds than the other two protected fields. A line of deciduous trees which lines a small stream lies 200-300 feet to the west of the field, possibly causing a more turbulent airflow by the time air reached the anemometers. This could explain why the west field had the highest wind speeds of all fields. Because the windbreak would have offered cattle some protection next to the trees, anemometer readings may not have represented the protection cattle actually received.

Table 2 presents correlation coefficients for variables measured in the trial. Both final weight and ADG were positively correlated with the amount of residual corn in the field (P < .05). Residual corn and wind speed were positively correlated (P < .10). Although not significant, ADG and final weight were negatively correlated with corn yield indicating that as yields declined, cattle gains increased, possibly because more corn remained in the field. While the added residual corn in unprotected fields does not entirely account for differences in yields between the treatments, 1.5 bu per acre added to unprotected field yields does make yields among fields more similar.

Table 2. Correlation coefficients.

	Residual corn, lb/acre	Yield, bu/acre
Final weight, lb	.862[a]	-.588
ADG, lb	.785[a]	-.607
Wind speed, mph	.730[b]	.129

[a]Significant (P < .05).
[b]Significant (P < .10).

The average temperature for the 66 days of the trial was 20.8°F which is below the critical temperature for cattle with a winter coat. The 30-year average temperature for the same period in eastern Nebraska is 22.7°F showing that cattle were exposed to similar or slightly colder than normal temperatures. Average wind speed during the trial as measured by the University weather station at Mead, NE was 8.8 mph compared to 11.1 mph which is the 30-year average for the area. So even though temperatures were slightly colder, wind speeds were below normal possibly offsetting each other in terms of cold stress to the animals. There were two days during the trial that were particularly cold and windy with significant amounts of snowfall. On each day, snowfall totaled 3.5 inches. For the most part, cattle were not exposed to extreme conditions for extended periods which might have significantly affected performance.

Data in the present study help to support data in a similar trial conducted at the University of Nebraska in the fall and winter of 1994-1995 where cattle grazed grain sorghum residue (1996 Nebraska Beef Report, pp. 44-45). Average daily gains for protected and unprotected cattle were equal at 0.59 lb per day. Weather conditions over the period of the trial were slightly milder than the 30-year average and, as in the present study, cattle were never exposed to extended periods of cold weather.

[1]D. J. Jordon, graduate student; Terry Klopfenstein, Professor; Mark Klemesrud, research technician, Animal Science, Lincoln; James Brandle, Associate Professor, Forestry, Fisheries & Wildlife, Lincoln.

Comparative Grazing of Corn and Soybean Residue

D. J. Jordon
Terry Klopfenstein
Mark Klemesrud
Drew Shain[1]

Cattle gain faster on cornstalks than on a combination of soybean stubble and cornstalks.

Summary

A grazing trial was conducted in the fall and winter of 1995-1996 to determine the feeding value of soybean stubble relative to corn residue. Cattle on the corn residue gained faster (P < .05) than calves on corn residue plus soybean stubble. Residual corn and soybean estimates between treatments were not different. Characterization of irrigated and dryland soybean plant components showed no difference in in vitro organic matter disappearance; however, crude protein values in the irrigated components were higher.

Introduction

Many producers use corn residue as a source of low cost winter feed for calves. Many times cattle are also allowed access to bean stubble adjacent to the corn field and animals often spend a considerable amount of time foraging in soybean residue. It is not known what nutritive value animals gain from this highly lignified bean stubble. While the nutritive value of soybeans as a standing crop is relatively high, onset of maturity drastically increases cell wall constituents and lignin. At harvest, soybean stubble contains predominantly stem and pod material and is a highly lignified forage product. A few studies have been conducted to evaluate soybean straw as a feed source; however, no studies have been done which allow cattle to graze stubble. Therefore, the objective of this research sought to evaluate the feeding value of grazing soybean residue relative to corn residue as determined by animal gains.

Procedure

Fifty-three weaned crossbred steer calves were assigned randomly to one of four fields. Two 11-acre fields of only corn residue contained 13 head each. One field had six acres of corn residue and 12.5 acres of soybean stubble and contained 13 head. The remaining field had six acres of corn residue and 15 acres of soybean stubble and contained 14 head. All corn fields, as well as one of the bean fields, were irrigated; however, due to irrigation constraints, one of the bean fields was dryland. Soybean fields were equally stocked based on lb of available pod DM per acre. An assumption was made that the only available DM in the soybean stubble available to calves would be the pods. Beans would have been harvested, leaves would most likely have decayed, and stems would not be selected by the animal. Stocking rates for corn fields were determined based on previous irrigated corn residue grazing studies conducted at the University of Nebraska. These stocking rates were based on lb of available husk and leaf DM material. The two fields consisting of only corn residue were stocked at 1.2 animals per acre. The two fields consisting of corn residue and soybean stubble were stocked at 1.2 animals per acre to account for corn, and at 0.5 animal per acre to account for soybean stubble.

Whole bean plant samples were collected before harvest in four random 15 x 2.5 ft strips. Plants were then separated into leaf, stem, and pod components to determine crude protein (CP) content and *in vitro* organic matter disappearance (IVOMD). Crude protein was determined using a nitrogen analyzer. *In vitro* organic matter disappearance was determined using the Tilley-Terry method. Samples were digested for 48 hours *in vitro*, followed by a 24-hour pepsin digestion. Samples were then ashed to determine IVOMD. After harvest, but before cattle were placed in the fields, samples of residual grain were taken in one random 250 x 2.5 ft strip in each corn field. Whole and partial ears were collected to determine bu of residual corn per head. Four random 50 ft strips were sampled in each bean field to remove any beans and pods left on the stems which were missed by the combine head. Beans were removed from pods to determine bushels of residual beans per head. Calves were supplemented with a 36% CP supplement at 1.5 lb/hd/day (as-is). Cattle were turned out on December 5, 1995 and removed on February 1, 1996 due to a heavy snowfall.

Results

Cattle grazing soy/corn residue gained less (P < .05) than cattle grazing only corn residue (Table 1). Observa-

Table 1. Cattle performance and residual grain.

	Corn	Soy/corn
Initial weight, lb	492	498
Final weight, lb	569	564
ADG, lb[a]	1.17	1.00
Residual corn, bu/head[b]	3.54	2.07
Residual beans, bu/head[b]	——	1.13
Residual grain, bu/head[b]	3.54	3.20

[a]Corn > soy/corn (P < .05).
[b]Includes 15% moisture.

Table 2. IVOMD[a] and CP[a] content of irrigated and dryland bean components.

	Crude Protein, %DM		IVOMD[a]	
	IR[a]	DL[a]	IR[a]	DL[a]
Pods	7.13	5.73	64.8	63.5
Stems	6.03	5.67	38.7	41.5
Leaves	12.75	11.94	38.7	39.6

[a]IVOMD = in vitro organic matter disappearance; CP = crude protein; IR = irrigated; DL = dryland.

tions throughout the trial showed that initially, calves spent considerable time in bean fields eating residual beans off of stems. As time progressed, cattle began to spend more time in corn fields. Even though calves were allowed an adaptation period before the beginning of the trial to acclimate themselves to grazing cornstalks, it is likely that the beans were more readily available initially, therefore calves removed the soybeans first. Residual corn values (Table 1) showed calves grazing only corn had slightly more corn per head compared to cattle on the soy/corn; however, due to sampling variation there was no statistical difference. Corn fields in both treatments should have been relatively equal in terms of downed corn. Cornfields for both treatments were actually one large field divided by an electric fence. Residual bean values showed that calves on the soy/corn treatment had access to soybeans to make the overall residual grain values closer; however, the soybeans did not entirely make up the difference.

Table 2 shows the characterization of soybean material from irrigated and dryland fields. Components from the irrigated fields were consistently higher in CP than dryland components. Higher CP values typically correspond to higher intakes depending on diet; however, because calves also had access to corn residue, it is doubtful there were any intake differences between bean fields. Excluding pods, IVOMD for dryland soybean plant components were greater than those of the irrigated. Irrigated stems and leaves may have been less digestible because of irrigation, thereby lowering IVOMD values. Legumes are known to deposit more structural carbohydrates during periods of adequate water in contrast to periods of moisture stress. The summer preceding the trial was relatively dry, causing a water deficit in the dryland beans compared to irrigated beans. *In vitro* organic matter disappearance for the leaves was lower than values for other components. This finding was surprising; however, it may have been due to weathering that occurred after the leaves had dropped from the plant.

The assumption made about the bean fields was that calves would only consume pod material. Even though pod CP values were low, IVOMD values for both dryland and irrigated beans support the idea that cattle would benefit from this highly digestible material.

Comparison of IVOMD values for both corn plant components and soybean plant components show them to be similar. Corn husks are much like pods with an IVOMD of roughly 70 percent. Corn leaves compare to bean stems and leaves with an IVOMD of approximately 42 percent. While values are similar, the corn residue would supply more lb of available DM per acre.

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[1]D. J. Jordon, graduate student; Terry Klopfenstein, Professor; Mark Klemesrud and Drew Shain, research technicians, Animal Science, Lincoln.

Grazing Corn Residues in Conventional and Ridge-Till Planting Systems

D. J. Jordon
Terry Klopfenstein
Mark Klemesrud
Gary Lesoing[1]

Cattle perform similarly on either tillage practice; however, yearly circumstances may affect overall performance. Calves grazing winter stalks will not adversely affect corn yields.

Summary

A grazing trial was conducted in the fall and winter of 1995-1996 to compare how conventional and ridge-till systems would affect animal performance. Calves on each treatment performed similarly showing no differences in gains. These results closely follow three previous years of data that show cattle can be expected to gain equally on each tillage practice. A year x treatment interaction (P < .05) was detected when data from all four years

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were pooled, indicating that gains may be slightly affected in each practice, depending on specific yearly circumstances such as precipitation or weed infestations. Yield data over the past four years has shown that grazing stalks will not adversely affect corn yields on either tillage practice.

Introduction

Cornstalks provide a low cost and efficient source of winter feed for cows and calves to reduce wintering costs. Calf gains are often low resulting in a compensatory gain period in the spring when cattle are placed on pasture or put into the feedlot. To truly evaluate costs and benefits of grazing cornstalks, cattle gains on different tillage methods, as well as subsequent effects on crop yields, must be evaluated. Since the fall of 1992, studies at the University of Nebraska have been conducted to determine cattle performance and subsequent crop yields in ridge-till and conventional disk plant irrigated corn production systems. In the ridge-till production system, residual corn material settles into the furrows. Under snowy and/or muddy conditions, available forage may be covered or trampled, as cattle tend to walk in the furrows.

Objectives of this trial were to continue to build on previous work comparing cattle performance and grain yields on conventional and ridge-till fields.

Procedure

Experiments were conducted during the fall and winters of 1992-1993, 1993-1994, 1994-1995, and 1995-1996 to evaluate performance of calves grazing cornstalks on conventional and ridge-till fields. A 100-acre irrigated corn field under a linear move irrigation system was divided into six fields allowing three fields for each tillage practice. One-hundred-nineteen, 117, 117, and 104 weaned crossbred steers were assigned randomly to one of six fields in 1992-1993, 1993-1994,1994-1995, and 1995-1996, respectively. Cattle were weighed on two consecutive days at the beginning and end of each trial after being limit fed for a period of three days to standardize differences in gut fill. Corn fields were stocked at 1.2 animals per acre according to previous irrigated corn residue work done at the University of Nebraska. Stocking rates were based on lbs of available husk and leaf DM material per acre.

Before cattle placement on stalks, each field was sampled in four random 250 x 2.5 ft strips to determine amount of residual corn. Full and partial ears were collected and shelled to determine bushels per acre of residual corn in each field. No residual corn estimates were collected before the 1992-1993 trial. Calves in all fields were supplemented with a 36% CP supplement at 1.5 lb/hd/day (as-is). To determine impact of grazing, yields were measured by machine harvest the following fall from grazed and ungrazed areas of each tillage method. Ungrazed areas were maintained each year. Calves were placed on stalks approximately December 1 and removed approximately February 1 in each year.

Results

Cattle performance for the 1995-1996 trial are shown in Table 1. Calves on conventional fields outperformed cattle on ridge-till fields; however, there were no statistical differences in gains. Precipitation events during the trial were minor, with only two measurable snowfalls occurring, each totaling 3.5 in. Snow in each instance was gone within two to three days. Temperatures during the trial were slightly below normal for the period when compared against the local 30-year average (22.7°F). The lower temperatures tended to keep the ground frozen and available forage from being trampled in mud between ridges.

Residual corn estimates for the trial are also shown in Table 1. There was no difference between conventional and ridge-till fields for the 1995-1996 trial; however, high sampling variation existed. More samples should have been collected in each field to make the estimates more reliable.

Table 2 shows cattle gains over four years of grazing. Only during the 1993-1994 trial was a difference seen in gains between conventional and ridge-till fields ($P < .10$). Gains in 1995-1996 were greater than in previous years; however, there were no treatment differences. Added gains in 1995-1996 were likely a result of the dry summer which preceded the trial. Previous trials at the University of Nebraska have shown that cattle gains tend to be greater on stalks following a dry summer due to an increase in residue quality. Increased quality combined with a cold and dry grazing period allowed for excellent calf gains. Performance data over all four years were pooled to find overall averages comparing conventional and ridge-till fields. Averages showed similar gains. A year x treatment interaction ($P < .05$) was detected in the pooled data set. This can be explained by environmental differences which occurred in each year. In 1992-1993, muddy conditions resulted in calves on conventional fields having higher gains. Calves on ridge-till fields trampled available forage which had collected in the furrows where they tend to walk. In 1993-1994, a grassy weed infestation and lower plant populations in conventional fields resulted in low DM production and lower animal gains compared to ridge-till fields. Also, grazing conditions in the ridge-till fields were excellent with

Table 1. 1995-1996 cattle performance.

	Conventional	Ridge-till
Initial weight, lb	497	496
Final weight, lb	576	574
ADG, lb	1.19	1.17
Residual corn, bu/acre[a]	2.7	4.3

[a]Includes 15% moisture.

Table 2. ADG of cattle grazing conventional or ridge-till production systems.

	ADG, lb/hd/day	
	Conventional	Ridge-till
1992-1993	.63	.53
1993-1994	.41[a]	.63[b]
1994-1995	.47	.52
1995-1996	1.19	1.17
1992-1996 Average	.66	.70

[a,b]Means within a row with unlike superscripts differ ($P < .10$).

Table 3. Machine harvested yields for grazed and ungrazed areas and residual corn estimates.

	Yield, bu/acre				Residual corn, bu/acre	
Year	GR[a]	UGR[a]	GC[a]	UGC[a]	Conventional	Ridge-till
1993	86.0	101.0	78.0	78.0	2.3[b]	5.8[c]
1994	124.0	120.0	119.0	127.0	2.7	2.2
1995	79.0	82.0	90.0	89.0	2.7	4.3

[a]GR=grazed ridge-till; UGR=ungrazed ridge-till; GC=grazed conventional; UGC=ungrazed conventional.
[b,c]Means within a row with unlike superscripts differ (P < .05).

frozen ground and little mud. This trial also showed a difference in residual corn estimates which partially accounted for the increased gains seen in the ridge-till fields.

Table 3 shows machine harvested yields and residual corn estimates broken down by year. No residual corn samples were collected before the 1992-1993 trial. Yields were measured in the fall following grazing in the previous year. Yields for both grazed and ungrazed areas were variable from year to year showing no definitive trends. Residual corn estimates were different (P < .05) only in 1993, the same year in which a difference was found in cattle gains indicating that gains are somewhat dependent on residual corn. In 1994 and 1995, residual corn estimates were much closer as were cattle gains.

[1]D. J. Jordon, graduate student; Terry Klopfenstein, Professor; Mark Klemesrud, research technician, Animal Science, Lincoln; Gary Lesoing, Research Assistant Professor, Center for Sustainable Agricultural Systems, Lincoln.

Continuous vs Rotational Stocking of Warm-Season Grasses at Three Stocking Rates

Bruce Anderson
Mike Trammell
Terry Klopfenstein[1]

Continuous stocking changes species composition of grass stands and may affect long-term productivity. Rotational stocking lengthens the grazing season but may not increase total gains.

Summary

Pastures containing big and little bluestem, indiangrass, sideoats grama, and switchgrass were stocked with 2.1, 2.7, and 3.3 yearling steers/acre from June to August. Continuous stocking and six-paddock rotations were used. Grazing terminated early on most continuously stocked pastures due to low herbage mass. As stocking rate increased, ADG declined; continuous stocking produced highest (1.6 lbs) and lowest (.69 lbs) ADG. Gain/acre was unaffected by stocking rate using rotational stocking (224 lbs/acre) but declined from 250 to 133 lbs/acre as stocking rate increased using continuous stocking. Continuous stocking caused big bluestem to replace little bluestem and indiangrass and caused a slight decrease in stands.

Introduction

Many studies have shown that grazing systems including warm-season grass pastures are more productive than grazing only cool-season grasses. In addition, numerous reports extol the benefits of rotational stocking, but research comparisons rarely have found large differences in animal gains between continuous and rotational stocking. Stocking rate is the most important controllable factor influencing animal and pasture performance, regardless of the grass grazed. Despite their importance, few studies have evaluated either stocking rate or grazing methods of warm-season grasses.

Stocking rate and grazing methods influence animal and pasture performance several ways. Gain per animal remains constant at stocking rates below a critical level and decrease above that level. Gain per acre increases with stocking rate until gain per animal becomes so low that gain per acre declines rapidly with further increases in stocking rate. Plant species differ in their response to grazing so botanical composition may change under various stocking rates and combinations of grazing and rest.

This study examined botanical changes in mixed stands of warm-season grasses and measured yearling cattle gains as influenced by continuous or rotational stocking at three stocking rates.

Procedure

Eighteen seeded pastures containing a mixture of big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), sideoats grama (*Bouteloua curtipendula*), little bluestem (*Schizachyrium scoparium*), and switchgrass (*Panicum virgatum*) were grazed at the Agricultural Research and Development Center near Ithaca, NE during 1993-1995.

Pastures contained about 3.3 acres and were grazed as a 3 x 3 factorial with 2.1, 2.7, and 3.3 yearling steers per acre. Continuous stocking and six-paddock rotations with either fixed (5-day graze, 25-day rest) or variable graze/rest periods were the grazing methods. Variable graze/rest periods were

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adjusted to match rotation and plant growth rates; animals generally were moved to the next paddock when one-half of the herbage mass in the medium stocking rate paddocks had disappeared according to visual estimates. A split-plot arrangement was used, with stocking rate as whole plots and grazing method as sub-plots. Whole plots were allocated in a completely randomized design with two replications. Pastures were fertilized annually in late May or early June with 80 lbs N/acre.

Yearling beef steers (620 lb) grazed corn stalks during winter and smooth bromegrass for 20 to 40 days during spring before starting the trials. Steers were blocked according to size and performance during winter grazing before starting to graze warm-season grasses in early June. Grazing was terminated early each year on most continuously stocked pastures when herbage mass dropped below 500 lbs/acre. Initial and final weights were the average of two weights taken on consecutive days following a 6-to 10-day feeding of a 50 percent alfalfa hay and 50 percent corn silage diet (DM basis), with intake limited to 2 percent of body weight. Data were analyzed as a split-plot in time with year as the sub-plot. In 1995 (year 3), after grazing warm-season grasses for 30 days, cattle from all pastures were moved back to smooth bromegrass pastures for 14 days and then returned to warm-season grasses for the remainder of the summer grazing season. This modification permitted longer rest periods for the warm-season grasses and used smooth bromegrass residue and regrowth that would have had poor feed value if left unused until after summer warm-season grazing was complete. Average daily gain data for 1995 include this bromegrass grazing.

Before grazing each year, basal plant cover and relative species composition were determined in each pasture using a modified single step-point method with over 400 points per pasture.

Results

Gain/acre was not affected by stocking rate when rotationally stocked (ave. 224 lbs/acre). However, it declined from 250 to 133 lbs/acre as stocking rate increased from 2.1 to 3.3 steers/acre using continuous stocking (Table 1). The ADG declined linearly across all grazing methods as stocking rate increased. The decline was greatest with continuous stocking, which produced both the highest (1.6 lbs) and lowest (.69 lbs) ADG among all treatments. Reported gains of steers continuously stocked at 2.7 or 3.3 head/acre probably were underestimated due to severe shortages of forage mass available late in the grazing season. Intermediate full weights (data not shown) taken periodically during years one and two suggest that steers on these pastures lost almost one lb/day during the last 20 days of grazing.

Table 1. Gain/acre and average daily gains of steers grazing mixed stands of warm-season grasses for three years in eastern Nebraska.

Grazing method	Steers/acre 2.1	2.7	3.3
	------- Gain/acre (lb) --------		
Continuous stocking	250^{w}	173^{y}	133^{z}
Fixed rotation	217^{x}	221^{x}	227^{x}
Variable rotation	237^{wx}	219^{x}	226^{x}
	---- Average daily gain (lb) ----		
Continuous stocking	1.60^{a}	1.03^{d}	0.69^{e}
Fixed rotation	1.35^{bc}	1.10^{cd}	1.02^{d}
Variable rotation	1.47^{ab}	1.10^{cd}	0.98^{de}

^{a,b,c,d,e,w,x,y,z}Values with different superscripts are different (P<.05).

Table 2. Change in basal cover of a mixed stand of warm-season grasses following two seasons of grazing in eastern Nebraska.

Grazing method	Steers/acre 2.1	2.7	3.3
	------ Percentage units ------		
Continuous stocking	-4.8^{a}	-2.2^{b}	-3.5^{ab}
Fixed rotation	-4.7^{a}	0.1^{c}	0.2^{c}
Variable rotation	-2.2^{b}	1.1^{c}	-0.3^{c}

Initial basal cover prior to 1993 grazing averaged 7.3%; basal density prior to 1995 averaged 5.6%.
^{a,b,c}Values with different superscripts are different (P<.05).

Stand basal cover declined after two years of continuous stocking and at the lower stocking rate (Table 2). Rotational stocking at higher stocking rates caused no significant changes in overall basal cover. Lower stand cover at low stocking rates may have occurred because some plants were grazed repeatedly. This repeated grazing combined with competition from adjacent ungrazed plants probably killed some of the grazed plants.

Relative species composition was affected by stocking rate and grazing method (Table 3). Big bluestem increased compared to other grasses at all stocking rates and also with continuous and fixed rotational stocking. Change in species composition of pastures was least when variable rotational stocking was used and at the medium stocking rate. If lower stand basal cover and less species diversity cause poorer animal performance, long-term declines in productivity may occur with continuous stocking.

Big bluestem and indiangrass changed in relative species composition with each other and with little bluestem and switchgrass, respectively (Table 4). At heavier stocking rates under the variable stocking method, relative species composition of indiangrass increased as big bluestem decreased (Table 3). However, continuous stocking at the medium and higher stocking rates caused big bluestem to replace the other grass species.

The relatively short grazing season (about 70 days) used with these warm-season grasses may have limited the usefulness of rotational stocking to increase animal production. Also, small paddocks used in research prevent factors such as distance from water, topography, and shade from influencing grazing distribution.

Nonetheless, rotational stocking extended the grazing season when stock-

Table 3. Change in relative species composition of five warm-season grass species following two seasons of grazing in eastern Nebraska.

Grazing	Big bluestem	Switchgrass	Indiangrass	Sideoats grama	Little bluestem
	---------- Percentage Units ----------				
Steers/acre					
2.1	+14.98[a]	+0.96[b]	-10.40[c]	-2.63[b]	-2.91[b]
2.7	+ 7.08[a]	-0.64[b]	-1.84[b]	-0.72[b]	-3.88[b]
3.3	+15.52[a]	-2.05[bc]	-6.01[c]	-0.63[b]	-6.83[c]
Grazing method					
Continuous	+20.14[a]	+1.30[b]	-14.70[d]	-2.14[bc]	-4.58[c]
Rotation					
Fixed	+18.05[a]	+0.02[b]	-7.40[c]	-2.62[b]	-8.04[c]
Variable	-0.61[ab]	-3.05[b]	+ 3.86[a]	+0.80[ab]	-1.00[ab]

[a,b,c,d]Values within a row with different superscripts are different (P<.05).

Table 4. Partial correlation coefficients relating relative species composition of five warm-season grass species following two seasons of grazing in eastern Nebraska.

	Big bluestem	Indiangrass	Little bluestem	Sideoats grama
Switchgrass	0.05	-0.47*	0.22	-0.01
Big bluestem		-0.80**	-0.59**	-0.02
Indiangrass			0.21	-0.24
Little bluestem				-0.31

*, ** Significant at 0.05 and 0.01, respectively.

ing rate was relatively high and it maintained comparatively higher ADG and gain/acre than continuous stocking as stocking rate increased. In addition, continuous stocking caused greater changes in botanical composition, which may affect long-term production. Grazing will continue at least two more years to try and document the importance of these changes.

Rest periods in this study were too short (< 30 days) for warm-season grasses to recover from grazing, even when growing rapidly. Observations suggest that 40 to 45 days are needed. As this study continues during the next two years, a brief mid-summer grazing (14 to 21 days) of smooth bromegrass will be used to provide more recovery time for grazed plants and to utilize smooth bromegrass more effectively in the grazing system.

[1]Bruce Anderson, Professor; Mike Trammell, research technologist, Agronomy, Lincoln; Terry Klopfenstein, Professor, Animal Science, Lincoln

Cover Crops in Crop/Livestock Production Systems

Gary Lesoing
Terry Klopfenstein
Martin Williams
David Mortensen
D. J. Jordon[1,2]

Cover crops may provide a spring forage source for beef producers. Early spring grazing may reduce the need for harvested or purchased feed and reduce labor costs.

Summary

The use of cover crops in integrated crop/livestock production systems was evaluated. Spring small grains over seeded into soybeans in late summer provided cover, but not sufficient forage for fall grazing. Winter small grains over seeded into soybeans were established in late summer with sufficient rainfall or irrigation, but were susceptible to winterkill. Rye was the most productive and winter hardy, producing 2.25 tons/acre of dry matter in the spring. Rye no-till drilled following corn silage production provided winter cover and an average of two tons/acre of spring dry matter production. Rye was stocked at 1.1 head/acre for one month during the spring.

Introduction

Cover crops have the potential for several uses in integrated crop and livestock production systems. Cover crops can provide early spring grazing for beef producers. This may reduce the need for harvested or purchased protein and energy feeds, and decrease labor costs. While cover crops may potentially benefit the beef producer, the influence on subsequent crop production is uncertain. Cover crops may also be used for hay, erosion control, as a source of nitrogen for subsequent cereal crops, as scavenger crops to remove excess nitrogen from the soil profile, and as weed suppressants. Experiments at the University of Nebraska Agricultural Research and Development Center's Integrated Farm investigated cover crops for these purposes and their effect on subsequent crop production.

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Procedure

Experiment 1

In late summer of 1993, Sharp spring wheat, Ogle oats, Hazen spring barley, and annual ryegrass were over-seeded into either Dunbar (Group III, indeterminate) or Hobbit 87 (Group III, determinate) soybeans on August 25, September 3, and September 13. These normally spring-seeded forages were used to eliminate the need for chemical burndown the following spring. Winter small grains would need to be killed by tillage or chemical in the spring. Forages were seeded at the rate of 100 lbs/acre with a hand seeder in 20 x 100-foot plots, replicated twice for each planting date. Different planting dates were evaluated to determine the effects on forage dry matter production and of soybean canopy on forage stands. Forage dry matter yields were measured following the first killing frost in early October.

Experiment 2

Based on the results of Experiment 1, a second experiment was initiated in 1994 to evaluate the over-seeding of winter small grains into soybeans with methods and dates similar to those used in the 1993 experiment (August 26, September 6, September 16). Arapahoe winter wheat, Newcale triticale, Perkins barley, and VNS rye were over seeded into Holt (Group II, indeterminate) or Hobbit 87. During the spring of 1995 forage yields were measured (May 11). Following yield measurements, forages were mowed and corn was no-till planted in the Holt soybean field, while grain sorghum was planted following disking in the Hobbit 87 field. The effect of these cover crops on subsequent crop yields was measured in the fall of 1995.

This experiment was repeated in the late summer of 1995 with winter small grains over seeded into either Colfax (Group II, indeterminate) or Dunbar soybeans. A very dry summer and fall, plus an infestation of grasshoppers in some plots, limited establishment of forages in the fall. A cold, dry winter with limited snow cover in 1995-96 resulted in severe winterkill for all forages except rye. Rye forage yields were measured on May 23.

Experiment 3

A third experiment was initiated in 1994 to evaluate the seeding of cover crops following corn silage harvest. The same winter wheat, triticale, barley, and rye varieties were no-till drilled into corn silage stubble at the rate of 80 lbs/acre on September 7 in plots 15 x 100-foot, replicated three times. Redroot pigweed and common waterhemp were also overseeded April 21, 1995 at .51 lbs/acre to see if cover crops reduced emergence and suppressed growth of these weeds. Forage dry matter yields were taken June 5, 1995. Plots were burned down with Roundup herbicide on June 6, and soybeans planted June 7. During the summer of 1995, one half of each plot was irrigated while the other half was dryland. Soybean yields were measured for the different treatments in the fall of 1995. This experiment was repeated at a different location in 1995. Forage dry matter yields of winter wheat, triticale, and rye were measured on May 8. Winterkill of barley was greater than 75 percent.

Experiment 4

In the fall of 1995 an experiment was initiated to evaluate the use of rye as a cover crop in a crop/livestock production system on a larger scale. On September 18, 1995 VNS rye was over seeded with an airplane at the rate of 115 lbs/acre in corn and soybean strips on 13 acres irrigated by a center pivot system. Following over seeding we received approximately one inch of rain that evening, and did not need to use the irrigation system to establish the rye cover crop. During the fall and winter, the field was grazed primarily for corn and soybean residue, but also for any rye forage growth. Cattle were removed from the field in February.

The field was divided into two comparably sized fields for spring rye grazing. A 20-foot wide ungrazed strip over the length of the fields was left between the two grazed fields to assess the effect of grazing. On April 2, 1996 seven head of calves averaging 561 lbs went on each field through April 30, 1996 (28 days). Measurements taken on grazed and ungrazed plots, and rye and no rye plots included: soil bulk density, soil moisture, percent of residue cover, and water infiltration rates. Observations were made following intense rainfall as to the effect of a rye cover crop on erosion compared to no cover crop. Percent tracking was estimated on the grazed strips.

Results and Discussion

Experiment 1

Soybeans were late in 1993, so light penetration was limited to 10 and 33 percent for Dunbar and Hobbit 87 soybeans, respectively, for the first planting date. We received several inches of rainfall after seeding to help establish the cover crops. At the second and third planting dates, light penetration was 50 and 75 percent, respectively, for Hobbit 87, and 10-20 percent for Dunbar. Due to considerable rainfall during this period, there was an excellent stand of all forages seeded for each planting date. Plant growth was limited before the first killing frost. Forage yields were low, with oats and annual ryegrass yielding 545 lbs/acre dry matter for the first planting date. All other forages and planting dates evaluated had considerably lower yields. The dry matter production from these spring forages would not be a feasible forage source if planted in late August or early to mid-September. They may have potential as forages if seeded following wheat or oat harvest in late July.

Experiment 2

In 1994, soybeans were much earlier, with leaf drop 25 to 50 percent completed in Holt and Hobbit 87 soybeans at the first planting date. By the second planting date, leaf drop was 95 to 100 percent complete for Holt and 50 percent complete in Hobbit 87 soybeans. Holt was harvested before the final planting date and Hobbit 87 leaf drop was 95-98 percent complete. Ob-

Table 1. Cover crop forage dry matter yields. (ton/acre; spring, 1995)

	Soybean Variety	
	Holt	Hobbit 87
Forage		
Rye	1.9	2.25
Wheat	1.25	1.00
Triticale	1.4	1.5
Barley	.13	.25

servations from this study indicate it is advantageous to over seed cover crops before soybeans are harvested, unless the cover crop is seeded with a drill. If over seeding is done after soybean harvest, soybean residue on the soil surface will reduce seed to soil contact and consequently, cover crop establishment. We received sufficient rainfall after planting to establish the forages at each planting date. Fall dry matter production was limited, although forages provided excellent ground cover for control of erosion. During the spring of 1995, rainfall throughout the spring delayed harvest until May 11. Average forage dry matter yields of cover crops in the two soybean varieties are shown in Table 1. The effect of planting date on forage yields was inconsistent among forages. Rye, triticale, and wheat consistently yielded much higher than barley due to winterkill of the barley. Following the very hot, dry growing season of 1995, yields of crops were substantially reduced following cover crops. Corn yields were reduced 63 percent, from 54 to 20 bu/acre following cover crops compared to corn following soybeans without a cover crop. Grain sorghum, which is more drought tolerant, had a yield reduction of 27 percent, from 91 to 66 bu/acre following cover crops. Results of this study indicate soil moisture is a critical factor in cover crop systems. Earlier destruction of the cover crop to limit soil moisture depletion, or the availability of irrigation may reduce negative effects of cover crops on subsequent crop yields.

In 1995, soybeans were late in maturing with no leaf drop before the first two forage seeding dates into either soybean variety. At the third seeding date, leaf drop was 20 to 40 percent complete in Colfax (Group II) soybeans and 5 to 25 percent complete in the Dunbar (Group III maturity) variety. Observations from this experiment indicate that in dry years, when grasshoppers are a problem and rainfall is limited, such as in 1995, the successful establishment of cover crops under dryland conditions may be difficult. The dry climatic conditions may also severely limit dry matter production of the cover crop as a forage and adversely affect productivity of the subsequent crop. In Dunbar soybeans, cover crop establishment was poor on the first planting date as a result of a grasshopper infestation. On the other planting dates, establishment was also poorer in Dunbar, probably due to more canopy cover later into the fall. In both soybean varieties, cover crop dry matter production was limited for all planting dates and soil moisture was depleted going into the winter. Rye was the only cover crop winter-hardy enough to survive. Rye dry matter yields measured on May 23 averaged 2,743 and 699 lbs/acre in the Colfax and Dunbar soybean stubble, respectively. The large differences in dry matter yields were a result of the poorer rye establishment in the Dunbar soybean stubble. Grain yields of subsequent grain sorghum in the Colfax and corn in the Dunbar fields will be measured in the fall of 1996 to determine effect of rye on crop yields.

Experiment 3

Stands were much more uniform with the drill compared to over seeding. Dry matter yields were 3.2, 3.0, 2.8, and 1.4 tons/acre for triticale, wheat, rye, and barley, respectively. These high yields were the result of the cool, wet spring and the delay in killing the cover crops. Results of this study showed no difference in subsequent soybean yield of the bare ground control vs the cover crop under irrigation (32 bu/acre). Under dryland conditions, control yields were 29 bu/acre. Yields following the barley, rye, triticale, and wheat cover crops were 16, 17, 21, and 23 bu/acre, respectively. Barley appeared to reduce final density and early-season growth of pigweed compared to the bare soil control, even though it produced the least amount of dry matter.

Cover crop forage dry matter yields in 1996 were considerably lower than 1995, primarily due to the dry soil conditions and cold temperatures in the 1996 spring. Yet, precipitation in late April and early May, accompanied by warmer temperatures stimulated late growth of the cover crops. Rye was the only cover crop without substantial winterkill, whereas triticale and wheat loss was as high as 50 percent in some plots. Cover crop dry matter yields were 1.3, .34, and .43 tons/acre for rye, triticale, and wheat, respectively.

Experiment 4

Cost of over seeding rye with an airplane was $17/acre. The rye provided almost one month of spring grazing at a stocking rate of 1.1 hd/acre. Cold temperatures limited rye growth in the spring, which delayed grazing. Rye stands were much better in the soybean residue compared to the corn stalks. This was attributed to a better stand establishment and growth during the previous fall due to greater light penetration in the soybean strips. In the spring, periods of significant rainfall created muddy conditions and caused significant tracking in the fields. Bulk density measurements to evaluate surface compaction (0 to 6") were taken following grazing of the rye. Results indicated a 5% increase in bulk density following spring grazing (1.51 gm/cm^3) compared to ungrazed plots (1.44 gm/cm^3). Measurements in the grazed plots were taken in cattle hoof tracks, while measurements in ungrazed plots were in untracked areas. This will provide an indication of the surface compaction that is occurring due to tracking. Transect measurements on the grazed rye fields indicate 52 percent of the field was tracked on both corn and soybean residue. The increase in bulk density is insignificant due to spatial variability in soil type and landscape position, but water infiltration rates were significantly reduced in the tracked areas of the grazed rye field. After one inch of water application, infiltration rates averaged only .25"/hr on the grazed

rye plots compared to 2.66"/hr on the ungrazed rye plots. With approximately 50 percent of the field tracked, the average infiltration rate was 1.41"/hr. This is important because historical climatic records indicate a one year frequency of a one inch per half hour rainfall occurrence. Fields with infiltration rates similar to the grazed rye plots may be subject to significant runoff and erosion problems during an intense storm. Residue cover measurements following grazing in soybean residue with rye were 65 percent, compared to only 51 percent for soybean residue without rye, a 27 percent increase in residue cover. This provided significant protection from erosion during intense rainfall in the spring. Observations made following the storm indicated that although runoff occurred in the grazed rye fields, soil was held in place much better compared to soybean residue alone.

Although significant rainfall replenished the soil water profile considerably during and following rye grazing, the soil water content at the beginning of the experiment was quite low. Under dryland conditions this may cause severe water limiting problems for the subsequent crop, as in 1995. Soil moisture measurements in 1996, following rye grazing were similar for grazed and ungrazed, and rye and no rye plots. Crop yields of soybeans and corn will be measured on grazed and ungrazed plots in 1996.

Conclusion

Results of these studies indicate cover crops can be established in the fall if rainfall is sufficient or if irrigation is available. If the previous summer is dry, the potential for establishment of cover crops is marginal without irrigation. Cover crops should be seeded from late August until mid-September for best results in eastern Nebraska, earlier in other parts of the state. If the cover crop is over-seeded into soybeans, it should be planted during early leaf drop to get maximum seed to soil contact. When over-seeding was done with the airplane, establishment was much better on soybean compared to corn residue. Of the cover crops evaluated, rye appears to be the most versatile. It has excellent dry matter yield potential and is the most winter hardy of the winter small grains evaluated. Cover crops may have a negative impact on subsequent crops. In 1995, following cover crops, corn yields were reduced as much as 63 percent, while grain sorghum yields were reduced 27 percent.

Grazing of cover crops during the spring may provide a month of grazing per head/acre. More grazing could be provided if cover crops were established following corn silage, wheat, or high moisture corn, and a crop other than corn, such as soybeans or grain sorghum planted later in the spring. Forage production may be as high as 3 tons/acre. On grazed rye fields in tracked areas, water infiltration rates were reduced to .25"/hr for 1" of water application. Infiltration rates were decreased over ten fold compared to ungrazed plots. Rye increased spring residue cover and provided protection from soil erosion during intense spring rainfall occurrences.

Ideally the use of cover crops in integrated crop/livestock production systems will provide numerous benefits, such as increased livestock feed and erosion control, which outweigh any negative effects on subsequent crop production. Research will continue to evaluate cover crops in integrated crop and livestock production systems with the goal of developing cropping and grazing strategies which maximize whole-farm profits.

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[1]Gary Lesoing, Research Assistant Professor, Center for Sustainable Agricultural Systems; Terry Klopfenstein, Professor, Animal Science; Martin Williams, graduate research assistant, Agronomy; David Mortensen, Associate Professor, Agronomy; D. J. Jordon, graduate assistant, Animal Science.

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Effect of Crop Residue Grazing on Crop Production-Update of Research Activities

Gary Lesoing
D. J. Jordon
Terry Klopfenstein[1,2]

Crop residues provide an inexpensive feed source during the winter months. Cattle grazing them during this period will not impact subsequent crop yields if managed carefully.

Summary

Three years of data indicate no significant effect from fall and winter grazing on subsequent crop yields. Residue cover was significantly reduced from grazing compared to ungrazed plots.

Soil bulk density has increased in tracked areas in the top (0 to 6") depth of soil following grazing for many years. In a ridge-till system, the ridge height has been maintained following grazing for corn residues for four years. Spring grazing of corn stalks showed a significant decrease in water infiltration rates in tracked areas following grazing compared to ungrazed areas. Residue cover was reduced while soil bulk density increased.

Introduction

In the *1996 Beef Cattle Report,* research results were reported on experiments conducted to evaluate the effect of cattle grazing crop residues on crop production. This is long-term research that was initiated on the Integrated Crop/Livestock Farm at the Agricultural Research and Development Center. This research is being continued to evaluate long-term effects of grazing on crop productivity and soil characteristics. Previous research conducted on the Integrated Farm has shown no significant effect on crop yields from fall and winter grazing of crop residues. Information on the spring grazing of crop residues and the subsequent effect on crop yields and soil compaction is limited. Research was initiated in 1996 to investigate these issues further.

Procedure

Research was continued on established crop residue grazing experiments in 1995 and 1996. Specific information on these experiments was reported in the *1996 Beef Report*. In these crop residue grazing experiments, calf stocking rate generally ranged from 1 to 1.2 head/acre for a 60-day grazing period from December to February, depending upon residual forage and grain. Stocking rate for beef cows was approximately .7 head/acre. In 1995, crop yields were recorded following grazing in the fall and winter of 1994-95. In the spring of 1996, % residue cover and bulk density measurements were taken on the crop residue grazing experiments. A brief summary of the experimental procedure of each crop residue grazing experiment is listed below.

Experiment 1

Cows grazed corn residue under 1/4 of a center pivot irrigation system in December and January of 1994-95. This was compared to 1/4 of the center pivot that was ungrazed. This experiment was replicated on an adjacent center pivot. Irrigated soybeans were planted in the spring of 1995 and yields measured on the grazed and ungrazed fields in the fall of 1995.

Experiment 2

Calves grazed irrigated corn stalks under a ridge-till or conventional (disk-plant) tillage system for 58 days, from December 5, 1995 through February 1, 1996. In the fall of 1995, corn yields were recorded on grazed and ungrazed plots of both tillage systems. Any differences in yields between grazed and ungrazed plots were a result of previous years' grazing, which in 1994-95 was 78 days, from December 12, 1994 through February 27, 1995. Prior to and following grazing in the winter of 1995-96, soil bulk density and % residue cover were measured. Ridge heights were measured following grazing in the spring of 1996. Cattle performance was also measured and is reported in another article in this report.

Experiment 3

This experiment was reported in an additional article in the *1996 Beef Report* on winter calf grazing and windbreaks. In the winter of 1994-95, exclosures were erected to enclose anemometers to measure wind speed on the three protected fields and two unprotected fields. In the spring of 1995, bulk density measurements were taken in grazed areas in cattle hoof tracks and in ungrazed exclosures for comparisons. Percent tracking was also recorded in these fields by using the line-transect methods as described by Shelton et al., NebGuide G92-1133. Cattle tracks were measured instead of residue cover. In the fall of 1995, corn yields were recorded by hand harvesting 2-15' rows in paired grazed and ungrazed plots in the protected and unprotected fields.

This experiment was continued in the winter of 1995-96 in three corn fields protected by windbreaks and four unprotected corn fields. Calves grazed cornstalks for 58 days, from December 5, 1995 through February 1, 1996. Percent residue cover and soil bulk density were measured following grazing. Cattle performance is reported in a corresponding article of this report.

Experiment 4

This experiment was initiated in 1992 on a 27-acre strip-cropped field of corn, grain sorghum, and soybeans. Four replications of four grazing exclosures, (4 ft. × 5 ft.) were placed in strips of each crop. These plots have been ungrazed since 1992. Cattle graze the crop residue periodically from late November until late February or early March when the forage residue is gone or conditions are too muddy. In the fall of 1995, crop yields were measured in two to five foot rows of paired grazed and ungrazed comparisons for each crop. In the spring of 1996 following grazing of the crop residues, % residue cover, soil bulk density, and % tracking were recorded on these plots.

Experiment 5

This is a continuation of experiments initiated to evaluate the effect of grazing under irrigated conditions. Exclosures have been placed on irrigated continuous corn strips to compare grazed and ungrazed plots on a sandy loam site. Corn yields were measured in the fall of 1995, with harvest procedures similar to those described in Experiment 4. Cattle were allowed to graze this area throughout the winter and were removed in February in 1996. Following grazing, similar measurements were taken as in Experiment 4.

(Continued on next page)

Experiment 6

A new experiment was initiated in 1996 to evaluate the effect of late winter and early spring stalk grazing on crop production. Three head of cattle grazed three acres for 55 days, from February 26, 1996 through April 20, 1996. Five sets of exclosures were placed in different positions on the hill, to provide a good representation of the different soil types. Measurements taken following grazing on the grazed and ungrazed plots included: soil bulk density, water infiltration rates, and % residue cover. Percent tracking was also recorded in the grazed areas. In the fall of 1996, crop yields will also be measured in the grazed and ungrazed plots.

Results

Experiment 1

Results of experiment 1 indicate no effect on soybean yields from grazing corn stalks during the fall and winter of 1994 and 1995. Soybean yields were 51 bu/acre for both grazed and ungrazed fields. For the three years of the experiment, soybean yields were similar for grazed and ungrazed fields, averaging 55 bu/acre for both.

Experiment 2

Corn yields in 1995 were 79, 82, 90, and 89 bu/acre for grazed ridge-till, ungrazed ridge-till, grazed conventional, and ungrazed conventional treatments, respectively. Grazing had no effect on corn yields in 1995. The lower yields on the ridge-till compared to the conventional tillage may be a result of greater phosphorus availability from feedlot manure compost applied to both treatments in a separate study. Compost was applied 10 tons/acre during the winter of 1994-95 and disked in prior to planting in the spring, while compost on the ridge-till treatment was just top dressed on the surface. Phosphorus soil tests were low to very low (3 to 10 ppm) for this field. Yield results of check strips which received no compost compared to strips where compost was applied on the two tillage systems showed only a 3% yield response on the ridge-till and a 19% yield increase on the conventional system.

The three-year yield averages (1993-1995) for these systems show little difference between treatments. Corn yields averaged 96, 101, 96, and 98 bu/acre for grazed ridge-till, ungrazed ridge-till, grazed conventional, and ungrazed conventional, respectively. Corn yields will continue to be measured on these grazed and ungrazed strips in subsequent years with these tillage systems to determine if any long-term effects on crop yields are occurring.

Results reported in the *1996 Beef Report* showed higher bulk densities in the 0 to 3" depth for the inter-row of the grazed ridge-till system compared to the row, probably due to compaction caused by cattle walking in the inter-row during muddy conditions. Measurements taken in both the fall of 1995 and spring of 1996 show this relationship is still true, but is not changing significantly. Bulk densities were (1.23 vs 1.07 gm/cm^3) and (1.28 vs 1.17 gm/cm^3) for the ridge-till grazed inter-row and row in the fall of 1995 prior to grazing, and the spring of 1996 following grazing, respectively. Differences in bulk densities between the fall and spring are due to seasonal variability.

Percent residue cover measurements taken in the fall prior to grazing and the spring following grazing on the ridge-till system showed a 17% reduction in residue cover for the grazed ridge-till system compared to a 4% reduction on the ungrazed ridge-till, indicating a 13% reduction due to grazing. The conventional system showed a 7% reduction for the grazed system, with no reduction in residue cover for the ungrazed. Over the three-year period from 1993-1995, residue cover was reduced an average of 13 and 7% from grazing for the ridge-till and conventional tillage systems, respectively. The higher residue cover reduction on the ridge-till is attributed to most of the corn stalks falling in the furrow, and the ridges being left bare except for the corn stubble. The reduction in residue cover from grazing in this experiment is generally lower than for the other experiments. This is due to this field being in continuous corn for several years, being under irrigation, and the cattle not grazing on the stalks as long as some of the other experiments.

Ridge height measurements taken in the spring of 1996 following grazing were (6.5 and 6.8") for the grazed and ungrazed treatments, respectively. This is consistent with previously reported results and confirms that ridges can be maintained following crop residue grazing. This field has been grazed for four years and corn was planted on the ridges in the spring of 1996 without difficulty.

Experiment 3

In the spring of 1995 following grazing, bulk densities were similar for the top (0 to 6") depth for grazed and ungrazed plots (1.38 vs 1.35 gm/cm^3). Percent tracking measurements indicated that cattle tracks covered 37% of the field as a result of grazing. This was not biologically important though as corn yield measurements taken in the fall of 1995 showed no difference between grazed and ungrazed plots (109 vs 110 bu/acre).

Percent residue cover measurements taken following grazing in the spring of 1996 showed an 11% reduction in residue cover on grazed compared to ungrazed plots (77 vs 87%). Bulk density measurements (0-6") taken in the spring of 1996 following grazing were similar for grazed and ungrazed plots (1.38 vs 1.34 gm/cm^3). Crop yields will be measured in the fall of 1996 on these plots to continue to evaluate the effect of grazing crop residues on subsequent crop yields over time.

Experiment 4

Effect of grazing crop residues on subsequent crop yields for 1995 and the three-year average (1993-95), plus % residue cover and soil bulk density (0-6") for 1996 are shown in Table 1. It was very dry throughout the 1995 growing season with approximately 4.2 inches of precipitation from early June through mid-September. Despite muddy condi-

Table 1. Effect of grazing crop residues on subsequent crop yields, % residue cover, and soil bulk density.

Treatment	Crop	Yield (bu/acre) 1995	Yield (bu/acre) 3-year av.	Residue cover[a] %	Bulk density (gm/cm^3)
Grazed	Soybean	27	39	43	1.33
Ungrazed	Soybean	33	42	65	1.23
Grazed	Grain sorghum	103	106	78	1.44
Ungrazed	Grain sorghum	108	107	98	1.29
Grazed	Corn	148	185	56	1.33
Ungrazed	Corn	135	175	68	1.26

[a]Residue cover was measured using the line-transect method as described by Shelton et al., NebGuide G92-1133.

tions during the winter grazing season of 1994-95, and the dry conditions of the summer, yields were similar in grazed and ungrazed plots. The three-year crop yield average was similar for grazed and ungrazed crops. Residue cover measurements for the spring of 1996 were reduced 18% (68 vs 56%), 20% (98 vs 78), and 34% (65 vs 43%) for grazed corn, grain sorghum, and soybeans, respectively. Corn residue cover reduction was similar to 1995, while grain sorghum and soybeans were significantly higher in 1996 compared to 1995. This may be a result of the lower crop yields in 1995 compared to 1994. Soybeans yielded only 49%, and grain sorghum only 71% of 1994 yields. Soil bulk density measurements were 6,12, and 8% higher in tracks from grazed corn, grain sorghum, and soybean residue, respectively. The bulk density on the grain sorghum residue plots may be higher because they have not been treated with a subsoiler yet, while corn and soybean were treated in previous years. Percent tracking for corn, soybean, and grain sorghum were 34, 31, and 39%, respectively.

Experiment 5

Irrigated continuous corn yields in 1995 were not affected by corn residue grazing during the winter of 1994-95. Corn yields were 223 bu/acre for grazed compared to 209 bu/acre for ungrazed plots. Percent residue cover measurements taken following grazing in the spring of 1996 showed a 19% reduction due to grazing (98 vs 79%). Soil bulk density measurements (0-6") taken in the spring of 1996 on this sandy site showed no difference between grazed and ungrazed plots (1.58 vs 1.56 gm/cm^3). Percent tracking was similar to other corn plots at 33%.

Experiment 6

Soil types in the spring cornstalk grazing study ranged from sandy loam to a clay loam soil. Following grazing, soil bulk density measurements (0 to 6") in cattle tracks were increased 7% (1.58 vs 1.48 gm/cm^3) compared to ungrazed plots. Average percent tracking in this field was 49%, which was over 40% greater than the average for winter stalk grazing. Water infiltration rate measurements, taken following grazing in cattle hoof prints compared to ungrazed plots, showed an 89% decrease in water infiltration rate following one inch of water applied (.94"/hr vs 8.39"/hr). With approximately 50% of the field tracked, the average infiltration rate was 4.74"/hr on the grazed plots. Residue cover measurements following grazing showed a reduction in residue cover of 24% (90 vs 68%) compared to ungrazed plots. Corn yield comparisons between grazed and ungrazed plots in the fall of 1996 will show if there is an impact of this spring stalk grazing on crop production. While observations indicated considerable runoff following an intense spring rainfall occurrence, the high density of corn stalks minimized soil erosion substantially.

Conclusion

Under the conditions of the past three years at the Integrated Crop/Livestock Farm, grazing has had no significant effects on crop yields compared to ungrazed areas. Corn, soybean, or grain sorghum yields were not adversely affected following the grazing of the previous crop. Residue cover was significantly reduced from grazing compared to ungrazed plots. In no-till cropping systems, additional tillage was not required following fall and winter grazing of crop residues. In the ridge-till system, grazing of cornstalks did not adversely affect the integrity of the ridges, but soil bulk density in the top (0 to 3") depth was increased in the inter-row following grazing under muddy conditions. Other measurements showed soil bulk density may increase in tracked areas following grazing. Spring grazing indicated a significant decrease in water infiltration rate compared to ungrazed areas. Spring grazing of stalks also showed a decrease in residue cover and increase in bulk density.

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[1]Gary Lesoing, Research Assistant Professor, Center for Sustainable Agricultural Systems; D. J. Jordon, graduate student, Terry Klopfenstein, Professor, Animal Science, Lincoln.

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Estimating In Situ Degradability of Protein in Forages

Ryan Mass
Greg Lardy
Terry Klopfenstein[1]

In situ neutral detergent fiber nitrogen is an effective method of estimating undegraded intake protein in forages. The information obtained allows for more accurate protein formulation of ruminant diets.

Summary

A method was developed for measuring undegraded intake protein (UIP) in forages. Neutral detergent fiber nitrogen (NDFN) was assumed to be the potential ruminally-undegradable fraction. In situ incubations were completed on eight forages to determine rates of digestion and rates of passage were used to calculate UIP. When compared to in situ UIP values determined by both uncorrected and microbial-corrected nitrogen, values found using NDFN were not different from the purine method and were more precise. Furthermore, NDFN gave values for four of the samples that were highly correlated to in vivo values determined for those forages.

Introduction

Current applications of beef cattle nutrition such as the newly-revised National Research Council's nutrient requirements of beef cattle use a metabolizable protein system to calculate animal requirements because the protein needs of ruminants are met by both microbial protein and undegraded intake protein (UIP). A metabolizable protein system describes the total amount of protein absorbed by the small intestine from these two sources and is superior to expressing requirements only as crude protein in the diet.

To take advantage of such a system, accurate information about the degradability of protein in the diet is required. Degradability information is used to calculate the amount of UIP that contributes to the metabolizable protein pool.

Many methods currently exist for measuring protein degradability of feedstuffs. The in vivo method is accepted as the standard because it provides an actual UIP value for the feedstuff. Animals are fed the diet in question and digesta samples are obtained. Laboratory analyses are conducted to measure what proportion of the total protein reaching the small intestine is UIP.

However, there are many disadvantages to the in vivo method. Animals with the ruminal and intestinal fistulas are needed. Flow rate and microbial markers are used to calculate what proportion of the metabolizable protein pool originates from the diet, microbes, or the animal itself. These markers add considerably to the time and expense required to complete this measurement and may be inaccurate. Therefore this method is not practical as it is neither inexpensive nor simple for a commercial laboratory to perform.

Attempts have been made to develop a simple laboratory method that could measure feed protein degradability. Commercially-produced enzymes have been tested and some success has been reported. Such methods are simple, rapid, and do not require the use of an animal. However, degradability estimates obtained using commercial enzymes may not correlate well with the accepted in vivo estimates.

Another method used is the in situ dacron bag. Samples are incubated in a ruminally-fistulated animal and the amount of UIP can be determined. However, different estimates of degradability may be obtained from this method depending on whether or not attached microbial protein is measured. While the use of such microbial markers as purines is a standard practice, such methods are labor intensive.

Previous researchers stated that feed protein that is insoluble in neutral detergent solution makes up the potential UIP fraction and is partially digestible in the rumen.

The objective of this experiment was to determine if neutral detergent fiber nitrogen (NDFN) of forages incubated in situ was an effective estimate of UIP when compared to in situ values (both uncorrected for microbial protein and corrected with purines) and in vivo values for those forages.

Procedure

The standardized method for in situ incubation was used. Five grams of sample were placed in dacron bags and those bags were placed into several mesh bags. These mesh bags were placed into the rumen for incubation. The mesh bags were then washed thoroughly in warm water and the bags and residue were then dried.

Samples tested included two alfalfa hays, two Sandhills meadow hays, one brome hay, one prairie hay, and two range samples. They were incubated in a ruminally-fistulated steer that was fed brome hay containing 8 percent CP

Table 1. Undegraded intake protein values (% DM).

Sample	CP	UNCORR[a]	PUR	NDFN
Brome hay	14.4	5.04	3.54	3.57
Prairie hay	6.8	3.77	3.14	3.14
Alfalfa hay #1	20.3	4.02	3.19	2.87
Alfalfa hay #2	30.0	5.34	4.25	3.65
Meadow hay #1	16.2	3.54	2.20	2.28
Meadow hay #2	7.7	2.45	1.38	1.68
Range diet #1	12.0	4.87	3.50	3.15
Range diet #2	5.6	1.74	0.84	1.24
Mean UIP	——	3.84[b]	2.75[c]	2.70[c]
SE[d]	——	0.14	0.10	0.07

[a] UNCORR uses total in situ N to calculate UIP.
PUR uses total in situ N corrected for microbial N.
NDFN uses in situ N that is insoluble in neutral detergent.
[b,c] Means with unlike superscripts differ (P<.05).
[d] Standard error for each method.

Table 2. Correlation coefficients of methods.

METHOD[a]	UNCORR	PUR	NDFN	IN VIVO
UNCORR	——	.821	.812	.685
PUR	.821	——	.921	.893
NDFN	.812	.921	——	.954
IN VIVO	.685	.893	.954	——

[a] UNCORR uses total in situ N to calculate UIP.
PUR uses total in situ N corrected for microbial N.
NDFN uses in situ N that is insoluble in neutral detergent.
IN VIVO is considered the standard UIP value for a forage.

(DM basis). The five vegetative samples were incubated for 4, 10, and 16 hours and the dormant samples were incubated for 8, 16, and 24 hours. Incubations were replicated three times on consecutive days.

The residue in each bag was analyzed for nitrogen, purine, and NDFN. A separate experiment was conducted to determine the purine to nitrogen ratio for our experimental protocol. In situ residue was analyzed for purine and nitrogen content before and after the NDF procedure.

Rates of digestion (Kd) for potential UIP were calculated using residual nitrogen alone (UNCORR), residual nitrogen corrected for microbial nitrogen as determined by the purine method (PUR), and NDFN. Rates of passage (Kp) of 5%/hour for vegetative samples and 2%/hour for dormant samples were used. The potential UIP pool for each method was calculated using the y-intercept of the rate of digestion equation.

The following equation was used to calculate UIP on a dry matter basis:

$$\text{UIP} = \frac{Kp}{Kp + Kd} * \text{potential UIP pool} * 6.25$$

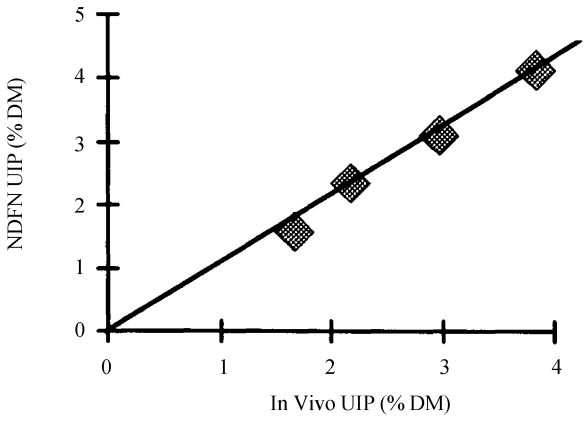

Figure 1. Correlation between NDFN and In vivo.

Results

The UIP values for UNCORR were higher than either PUR or NDFN (P<.05, Table 1). When the purine to nitrogen ratio determined herein (.14) was applied, PUR was not different than NDFN (P>.05). The standard error for mean NDFN was lowest, indicating that it is the most precise method. These results support our hypothesis that NDFN is equal to or more accurate than PUR, which is currently an accepted method for correcting in situ residue for microbial nitrogen. Additionally, the necessity of an accurate purine to nitrogen ratio when estimating PUR UIP illustrates one of the disadvantages of that method.

A correlation analysis was conducted to compare combinations of the four UIP methods (Table 2). NDFN and PUR were highly correlated (r=.921), showing that the two procedures ranked the samples similarly.

In vivo UIP values for four of the samples were correlated with each laboratory procedure (Table 2). Individual NDFN values were ranked similarly in respect to in vivo values (Figure 1). NDFN yielded the highest correlation coefficient with in vivo values of all the in situ methods (r=.954), indicating that it is the most accurate laboratory procedure.

In summary, in situ NDFN is an accurate and precise way to measure UIP in forages when compared to either not correcting for microbial nitrogen or using the purine method as a correction. NDFN eliminates the need for a purine to nitrogen ratio and is simpler to perform than PUR. However, it does require a ruminally-fistulated animal.

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[1]Ryan Mass, Greg Lardy, research technicians, Terry Klopfenstein, Professor, Animal Science, Lincoln.

Ammonia (NPN) Utilization by *Prevotella ruminicola* is Affected by the Availability of Peptides

Zezhang Wen
Mark Morrison[1]

Ammonia (NPN) utilization by a predominant ruminal bacterium is rapidly decreased, once peptides are available in sufficient quantities.

Summary

*In **Prevotella ruminicola**, a predominant proteolytic ruminal bacterium, the NAD(P)H-utilizing glutamate dehydrogenase (GDH) seems to be a primary enzyme involved with ammonia utilization. This enzyme activity is affected by ammonia concentration, and by the availability of peptides. Different strains can be distinguished from each other by their respective enzyme activity patterns in non-denaturing polyacrylamide gels. Specifically, strain GA33 appears to produce a second, NAD(H)-utilizing enzyme, which is probably involved with amino acid breakdown. Greater attention needs to be directed towards ruminal peptide concentrations in addition to ammonia concentrations, when assessing nitrogen requirements that maximize microbial protein synthesis.*

Introduction

Bacteria currently classified as *Prevotella ruminicola* are probably the most numerous species of bacteria inhabiting the rumens of both forage- and concentrate-fed cattle. Therefore, the capacity of these bacteria to degrade feed protein, and resynthesize bacterial protein from either ammonia and(or) amino acids, has a major impact upon the efficiency of nitrogen utilization in cattle.

Although ruminant nutritionists have invested considerable effort in determining "optimal" ruminal nitrogen requirements, there is still great variation in the efficiencies of microbial protein synthesis in animals fed seemingly similar rations. Indeed, little is known about whether and how ammonia utilization by ruminal bacteria is affected by N-source (i.e. NPN:DIP) and availability. A better understanding of how feed and ruminal factors affect the utilization of different nitrogen sources by *P. ruminicola* should help to better define rumen microbial nitrogen requirements. Glutamate dehydrogenase is a key enzyme involved with ammonia utilization and microbial protein synthesis. We report here some of the features of GDH activities in two strains of *P. ruminicola:* strain 23 (subsp. *ruminicola*) and strain GA33 (subsp. *brevis*), and show that NPN utilization by these bacteria is reduced once peptides are also available for growth.

Procedure

GDH activity and its response to nitrogen source

P. ruminicola strains 23 and GA33 were grown using a glucose minimal medium prepared to contain either 1 mM or 10 mM ammonium chloride, or with 1.5% (w/v) trypticase peptides, as

Table 1. Glutamae dehydrogenase activity in three strains of *Prevotella ruminicola* in response to ammonia concentration and nitrogen source.[a]

Nitrogen source	Glutamate dehydrogenase specific activity					
	Strain B_14		Strain 23		Strain GA33	
	NADPH	NADH	NADPH	NADH	NADPH	NADH
1 mM NH_4Cl	1262.5 ± 114.3[a]	<10[a]	557.8 ± 4.6[a]	27.0 ± 3.4[a]	370.1 ± 65.0[a]	20.9 ± 7.3[a]
10 mM NH_4Cl	714.9 ± 62.5[b]	<10[a]	216.7 ± 37.0[b]	22.4 ± 4.7[a]	299.5 ± 28.0[b]	19.1 ± 4.5[a]
1.5% peptides	165.00 ± 3.1[c]	<10[a]	26.1 ± 0.5[c]	32.0 ± 5.8[a]	99.0 ± 8.6[c]	66.3 ± 21.1[b]

[a] NADPH, NADH are NADPH-, NADH-dependent activity expressed as nanomols of NAD(P)H oxidized $minute^{-1}$ mg $protein^{-1}$, respectively. Data presented in this table are the results when 0.2 M KCl was included in the reaction mixture and represent means (± SD) of no less than 4 separate observations from two different experiments. Values within columns, with unlike superscripts differ ($P < 0.1$).

Table 2. Effect of peptide shock on the glutamate dehydrogenase activity in three strains of *Prevotella ruminicola.*[a]

Treatment	Glutamate dehydrogenase specific activity					
	Strain B_14		Strain 23		Strain GA33	
	NADPH	NADH	NADPH	NADH	NADPH	NADH
Control	558.2 ± 48.8[a]	<10[a]	214.0 ± 52.9[a]	15.3 ± 3.2[a]	281.7 ± 4.3[a]	28.8 ± 5.3[a]
20 minutes	452.0 ± 35.5[a]	<10[a]	88.9 ± 25.9[b]	29.5 ± 6.1[b]	32.4 ± 3.1[b]	37.7 ± 5.0[a]
One doubling	304.0 ± 13.3[b]	<10[a]	88.9 ± 18.1[b]	64.4 ± 19.5[c]	40.3 ± 2.7[b]	73.0 ± 10.5[b]

[a]Abbreviations are the same as those in Table 1. Data presented in this table are the results when 0.2 M KCl was included in the reaction mixture and represent means (± SD) of no less than 4 separate observations from two different experiments. Values within columns, with unlike superscripts differ ($P < 0.1$).

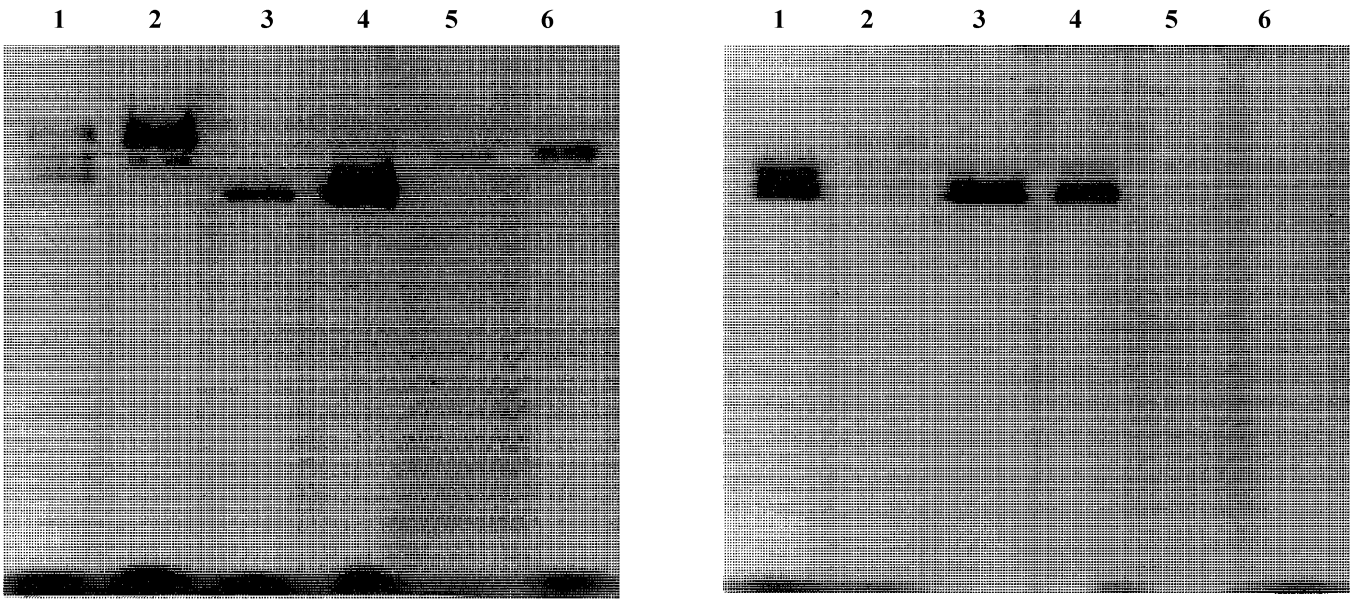

Figure 1. Electrophoretic mobility of the GDH enzymes from three representative strains of *P. ruminicola*. Lanes 1 and 2 contain cellular proteins from strain GA33, lanes 3 and 4 contain cellular proteins from strain 23; and lanes 5 and 6 contain proteins from strain $B_1$4. Extracts prepared from peptide-grown cultures are loaded in lanes 1, 3, and 5; while extracts from ammonia-grown cells are loaded in lanes 2, 4, and 6.

sole nitrogen source. Cells were harvested at mid-log phase of growth and assayed for GDH activity using NAD(P)H as cofactor, with or without the addition of 0.2 M KCl in the reaction mixtures.

To find out how rapidly ammonia utilization is blocked once peptides are also available, *P. ruminicola* strains $B_1$4, 23 and GA33 were first grown on ammonia, then "shocked" by the addition of a solution of peptides (trypticase) to give 1.5% (w/v) of initial peptide concentration. The cultures were reincubated for either 15 or 80 minutes, and then harvested for GDH assay. Control cultures received anaerobic water in place of trypticase.

GDH protein staining

GDH protein profiles in polyacrylamide gels can show whether the production of the enzyme is altered in response to growth conditions. Such information is critical to the development of strategies designed to optimize ammonia utilization by ruminal bacteria. The three *P. ruminicola* strains were harvested at mid-log phase, following growth with either 10 mM ammonium chloride or 1.5% (w/v) peptides as sole nitrogen source. The enzymes were released by three passages through a French pressure cell, and unbroken cells and large debris were removed by low speed centrifugation. Aliquots of the resulting cell free extract (20 μg total protein) were then subjected to non-denaturing, polyacrylamide gel electrophoresis. GDH proteins were visualized by immersing the gel in a staining mixture, which is specifically reactive with GDH enzymes. Different enzymes could be detected either by their cofactor requirement (NAD^+ vs $NADP^+$) and(or), the distance of migration of protein into the gel slab. The total amount of enzyme is positively correlated with the intensity of the region which is stained within the gel. Therefore, changes in the position and(or) stain intensity indicate changes in enzyme production.

Results

As previously shown for *P. ruminicola* $B_1$4, both *P. ruminicola* 23 and *P. ruminicola* GA33 possess measurable NADH- and NADPH-utilizing GDH activities (Table 1). The highest NADPH-utilizing activities were obtained from ammonia-limited cultures (1 mM), and peptide nitrogen resulted in a marked reduction in NADPH-utilizing specific activity in all three strains. NADH-utilizing GDH activity also decreased in strain 23 and $B_1$4 following growth on peptides, but interestingly, NADH-utilizing GDH activity was consistently higher in strain GA33 following growth with peptides (Table 1).

Addition of peptides (1.5%, w/v) to cultures already growing on ammonia resulted in significant reduction in NADPH-utilizing GDH activity (Table 2). However, the time required for a reduction in enzyme activity was different among strains. In strain $B_1$4 significant reductions were observed after one doubling time (~72 minutes). In contrast, NADPH-utilizing GDH specific activity decreased 60% and 90% in strains 23 and GA33, respectively, within 20 minutes of the addition of peptides. This rapid response suggests that GDH enzyme activity is subject to feedback inhibition by amino acids. Feedback inhibition by reversible binding of the end product is one of the major mechanisms that regulates the biosynthesis of amino acids. Similar to results shown in Table 1, NADH-utilizing GDH activity in strain GA33

(Continued on nexg page)

seemed to increase in response to addition of peptides, but this required the cells to grow for one generation.

The results of the activity gels are similar to the results of the enzyme assays (Table 1, Figure 1). However, the migration pattern of the GDH proteins for each strain was distinct. The $NAD(P)^+$-utilizing activity in strains $B_1$4 and 23 appears to be catalyzed by only one protein, while strain GA33 produces additional proteins with NAD^+-utilizing activity when the cells are grown with peptides, which are smaller in size.

Conclusions

The strains used here are considered to be representative of the three major subdivisions of *P. ruminicola*, and collectively, they can account for as much as 60 percent of the culturable bacteria present in the rumen. Our results show that ammonia utilization by these bacteria is rapidly decreased, once peptides are available in sufficient quantities. Therefore, a decrease in GDH activity in *Prevotella* sp. may be relevant in increasing propionate (energy) production relative to the cells' need to produce amino acids, and this would help explain why rumen bacterial growth is stimulated when peptides rather than ammonia is provided as a nitrogen source. However, temporarily high ruminal peptide concentrations reduces the production of enzymes needed for the utilization of ammonia by a large proportion of ruminal bacteria. Any delay in ammonia utilization after peptide-nitrogen is depleted probably results in a decrease in the efficiency of microbial protein synthesis. For these reasons, it is important to determine the variation in ruminal peptide concentrations in addition to ammonia concentrations.

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[1]Zezhang Wen, graduate student and recipient of a Center for Biotechnology Graduate Research Associateship; Mark Morrison, assistant professor of Animal Science Department and the Center for Biotechnology, Lincoln.

Mutants of *Prevotella ruminicola* Defective in Peptidase Activity: Impact on Ammonia Production

Humberto Madeira
Lansha Peng
Mark Morrison[1]

An enzyme from a predominant ruminal bacterium that degrades peptides has a significant impact on ammonia production, and its manipulation could increase efficiency of nitrogen retention in forage-fed animals.

Summary

*Two **P. ruminicola** mutants defective in peptidase activity were obtained using a method of chemical mutagenesis, and the relevance of this activity in terms of ruminal ammonia production was demonstrated by co-culture experiments. The 25 percent decrease in ammonia production when Gly-Arg-MNAse is absent illustrates the interspecies association regarding degradation of protein sources in the rumen. These mutants will be useful for future studies of this activity, and also demonstrate how molecular biology techniques can be applied in the quest to improve efficiency of beef production.*

Introduction

Considering that up to 25 percent of the feed protein fed to ruminants may be wasted by excessive ammonia production in the rumen, manipulation of ruminal protein digestion could have a positive effect on nitrogen retention efficiency in ruminants, as well as decrease nitrogen losses via animal waste. Much effort has been directed towards identifying and evaluating sources of bypass (escape) protein, as well as identifying which microorganisms are involved with protein digestion and ammonia production. Little information is available about the characteristics and contribution of

protein-degrading enzymes present in ruminal contents. Such information is critical to the development of new, improved strategies to control the rate of forage protein digestion. Molecular biology techniques provide the tools to achieve such a goal. For instance, the mutational analysis of an enzyme can effectively show the relevance of that enzyme related to nutrient utilization, growth and development of the microorganism. With specific emphasis upon ruminal ammonia production, the dipeptidyl peptidase activity of *P. ruminicola* described in the adjoining paper is considered to be the predominant peptidase activity in the rumen. This enzyme is thought to have a major role in controlling protein digestion to small peptides and amino acids that are subsequently broken down to ammonia and VFA by other ruminal bacteria. By removing such activity from this predominant ruminal bacterium the rate and(or) extent of ammonia production from various protein sources should be reduced. Following is a description of how such a hypothesis was tested, and the conclusions we obtained from these experiments.

Procedure

Mutagenesis of ***P. ruminicola***

P. ruminicola strain $B_1$4 was cultured overnight in rich medium, and then diluted 1:20 into defined medium. The mutagen ethylmethylsulfonate (EMS) was added to a final concentration of 0.05% (v/v) and the broths were incubated at 37°C for 5, 10, 15, 30, 45 and 60 minutes. Treated and control cultures (no EMS added) were centrifuged and the cell pellets were washed twice with sterile defined medium to remove residual mutagen. The mutagenized cells were then resuspended in defined medium, and aliquots were taken for serial dilutions and plate counts to determine the number of viable cells remaining following mutagenesis. The remaining cell suspension was then incubated overnight at 37°C.

After overnight growth, the mutagenized cultures were plated again to quantify the rate of mutagenesis. This was done by spreading serial dilutions of the cultures on plates of rich agar medium with or without 20 μg ml^{-1} rifampicin added.

Selection of mutants

To identify mutants lacking dipeptidyl aminopeptidase-like activity, plates inoculated with 200-300 mutagenized colonies were overlaid with a soft-agar solution containing 2 mM glycyl-argininyl-methylnapthylamide (Gly-Arg-MNA). The MNA group is attached to the Gly-Arg dipeptide via a peptide bond. Therefore, only those enzymes capable of cleaving a peptide bond, and allowing Gly-Arg to bind to it, will degrade this substrate. As such, Gly-Arg-MNA is a very specific substrate for the peptidase we are studying. The agar overlay was allowed to solidify and then the plates were left protected from light in the incubator at 37°C. After 30 minutes, the plates were positioned under a long wave ultraviolet lamp. Mutant colonies were not expected to produce the fluorescent "halo" indicative of cleavage and release of free-MNA from the dipeptide conjugate. Putative mutants isolated by this method were quantitatively assayed for the loss of Gly-Arg-MNAse activity using a standardized method (see adjoining paper) to confirm the phenotype.

Characterization of mutants

The impact of the mutation(s) on growth of wild type (WT, i.e. still possessing Gly-Arg-MNAse) and mutant strains (GM4 and GM6, i.e. deficient in Gly-Arg MNAse activity) was measured by growing them in defined medium prepared to contain different nitrogen sources: either 10 mM ammonia, peptides (1.25% w/v Trypticase), or ammonia plus peptides (10 mM ammonia and 1.25% Trypticase), all in the presence of 0.4% glucose. Growth was assessed by optical density (OD_{600})using a spectrophotometer.

Co-cultures of ***P. ruminicola*** *wild type and Gly-Arg-MNAse mutants with ammonia-producing organisms*

To demonstrate the relevance of this peptidase activity in the ruminal environment, co-cultures of the wild type and mutants, along with two ruminal isolates that are known to possess high rates of ammonia production from amino acids or small peptides, were established in a medium containing clarified rumen fluid (5%) and large quantities of peptides from two sources: Trypticase and Gelatin hydrolyzate. Before inoculation with strain C (*Peptostreptococcus anaerobius*) or strain F (*Clostridium aminophilum*), tubes were inoculated with anaerobically harvested *P. ruminicola* cells (wild type and mutants), to a final concentration of 400 mg protein/liter. Monocultures of all organisms were established under the same conditions provided for the co-cultures. Results presented are the average of two independent experiments, with duplicate incubations of each treatment per experiment. A second set of experiments was also conducted with the same number of experimental observations but with the inclusion of 0.1% glucose in the medium. Co-cultures were incubated at 37°C. Samples (1.2 ml) were collected anaerobically at time 0, 12, 24, 48, and 72 hours for ammonia analysis. Ammonia was determined colorimetrically using the phenol-hypochlorite method on an AutoAnalyzer II.

Results

Mutagenesis of ***P. ruminicola*** *and characterization of mutants*

The broth containing cells incubated for 45 minutes in the presence of the mutagenic compound EMS was chosen to be screened for the mutants defective in the peptidase activity, based on the adequate survival (50%), and highest frequency of mutation, as measured by the acquired resistance to the antibiotic rifampicin (data not shown). Approximately 6,000 colonies were screened

(Continued on next page)

Table 1. Gly-Arg-MNAse activity of *P. ruminicola* B_14 wild type and mutants, expressed in nmol/min/mg protein. Values in parentheses represent generation time expressed in minutes.[1]

	Nitrogen Source		
	10 mM ammonia	1.25% peptides	Ammonia plus peptides
Wild type	6.7(65)	9.3(67)	7.0 (68)
Mutant GM4	0.7(68)	0.7(69)	0.6 (67)
Mutant GM6	0.7(67)	0.8(69)	0.7 (66)

[1] Results are average of four observations.

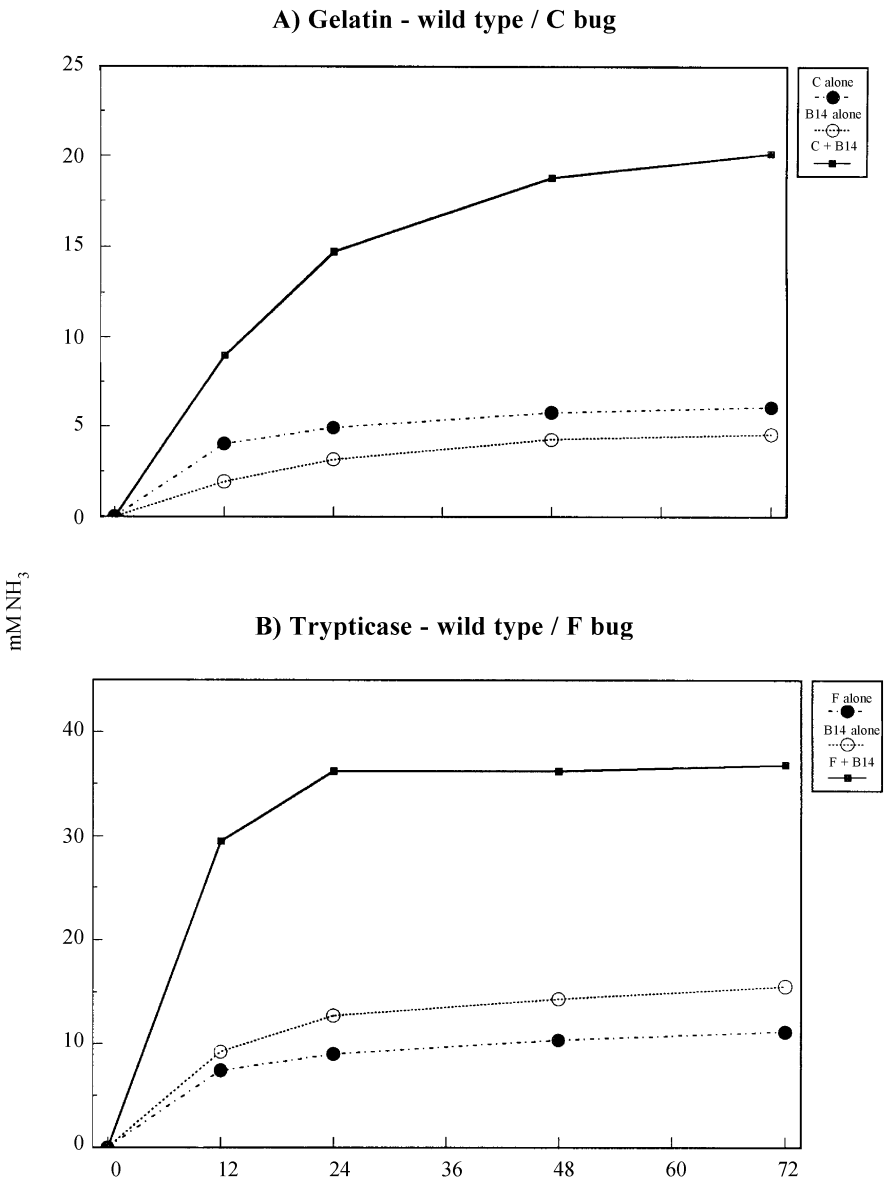

Figure 1. Ammonia production by *Prevotella ruminicola* wild type growing on gelatin hydrolyzate or Trypticase, and by strains C (on gelatin) and F (on Trypticase), growing as monocultures and co-cultures. Results are average of two experiments, with two observations per time incubation time.

and two mutants were confirmed to be defective in peptidase activity, and are identified as GM4 and GM6.

Characterization of mutants

Mutants possessed approximately 10 percent of the peptidase activity measurable from the wild type (Table 1). Little activity was found in the cell-free supernatants, and values were similar for WT, GM4 and GM6. The total activity of the mutants, when measured using cell fragments, was also decreased by 10 times the activity of the wild type (data not shown). These results confirm the mutant strains truly are deficient in Gly-Arg-MNAse activity, rather than a change in the location of enzyme activity. Growth rates of both mutants in media containing either 10 mM ammonia, 1.25% Trypticase peptides, and ammonia plus peptides were similar to those obtained with the wild type under the same conditions (Table 1). In addition, total cell yield of mutants did not differ greatly from that for the wild type, reflected in similar final OD_{600} values in all cultures. Such findings are promising, because they suggest that if Gly-Arg-MNAse could be inhibited, ammonia production might be changed, but the growth and useful activities of *P. ruminicola* in the rumen might still be retained.

Ammonia production by co-cultures

Ammonia production by co-cultures of the wild type *P. ruminicola* strain with either ammonia-producing strain C or strain F showed a more than additive effect when compared to the monocultures (Figure 1), supporting the role of *P. ruminicola* in providing the substrate for strains C and F to produce ammonia. Co-cultures of strains C and F with mutants defective in Gly-Arg-MNAse activity showed a significant (approximately 25%) decrease in ammonia production when compared with incubations in the presence of the wild type (Figure 2). Incubations in the presence of glucose showed a slightly higher rate and extent of ammonia production,

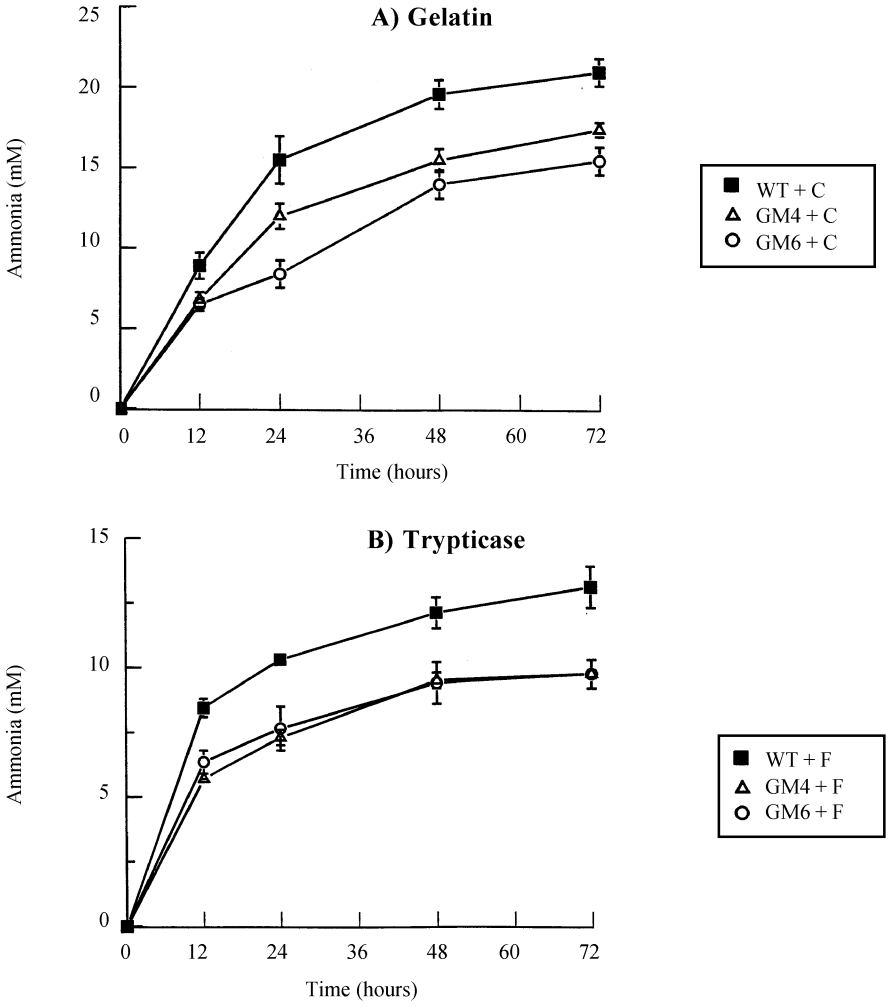

Figure 2. Ammonia production of co-cultures of *P. ruminicola* wild type and mutants (GM4, GM6) with either strain C on gelatin hydrolyzate, or strain F on Trypticase. Results are average of two experiments, with two observations per incubation time.

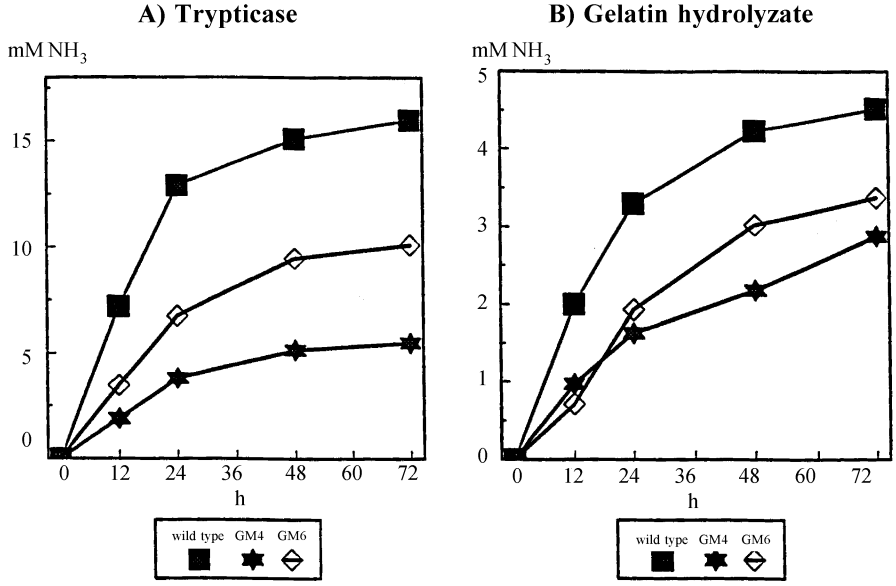

Figure 3. Ammonia production by *P. ruminicola* wild type and mutants (GM4, GM6) on gelatin hydrolyzate or Trypticase. Results are average of two experiments, with two observations per incubation time.

but the degree of contribution of the mutants to the patterns of ammonia production by the co-cultures was similar to that observed in the absence of glucose.

Interestingly, *P. ruminicola* mutants defective in Gly-Arg-MNAse showed decreased rate and extent of ammonia production, a decrease ranging from 35% (gelatin hydrolyzate) to 60% (Trypticase), when compared to the wild type (Figure 3). Further research is needed to demonstrate whether the mutation(s) imposed also affected genetic material coding for deaminase(s), or if the reduced ammonia production is a function of the reduced supply of substrate for deamination.

Conclusions

The generation of two mutants of *P. ruminicola* $B_1 4$ defective in peptidase activity was successfully achieved using a chemical mutagenesis protocol. The ecological relevance of this is demonstrated by its impact on ammonia production by the ammonia-producing ruminal bacteria *Peptostreptococcus anaerobius* and *Clostridium aminophilum*, when co-cultured with mutants of *P. ruminicola*. Co-cultures with the mutants showed a 25 percent decrease in ammonia production when compared to the wild type. The development of inhibitors specific for Gly-Arg-MNAse activity should positively affect the nitrogen balance of beef animals: either by increasing the escape value of forage protein, or reducing the losses of ammonia in animal waste.

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[1]Humberto Madeira, graduate student; Lansha Peng, graduate student; Mark Morrison, Assistant Professor, Animal Science.

Biochemical Characterization of a Peptidase Enzyme from the Ruminal Bacterium *Prevotella ruminicola*

Humberto Madeira
Mark Morrison[1]

The characterization by molecular biology techniques of a bacterial enzyme involved with ruminal protein digestion brings new insights and strategies which seek to optimize protein nutrition of beef cattle.

Summary

The dipeptidyl aminopeptidase activity of the rumen bacteria ***Prevotella ruminicola*** *is localized in the cell periplasm/cytoplasm, possesses pH optimum of 7.5, is inhibited by cysteine protease inhibitors, and is calcium-dependant. The production of this enzyme is not affected by different nitrogen sources or stage of growth. These results provide relevant information on how this enzyme is affected by ruminal environment (pH) and on possible use and design of specific inhibitors. Additionally, the studies show how the techniques of molecular biology provide understanding of the structure function and expression of enzymes, and how this information is the first step in developing new approaches to optimize protein nutrition of beef cattle.*

Introduction

An important step in the ruminal degradation of feed proteins is the conversion of peptides, generated by the proteolytic activity of the microflora, into amino acids. *Prevotella ruminicola*, besides being a predominant proteolytic species, is also considered to be one of the most active bacteria involved with the degradation of peptides. Recent attention has been directed towards a dipeptidyl aminopeptidase enzyme characterized by its cleavage of the diagnostic substrate Glycyl-Arginyl-4-methoxy-β-naphthylamide (Gly-Arg-MNA) to Gly-Arg, and free-MNA. This enzyme is thought to be the predominant peptidase in the rumen and we have shown that its inactivation could reduce ammonia production by as much as 25 percent (see article by Madeira, Peng, and Morrison, in this Beef Report). Although such findings offer the potential for productive alterations in protein nutrition of beef cattle, such potential is unlikely to be achieved unless the methods of controlling enzyme activity are highly selective, with minimal negative effects upon other enzymes, microorganisms, and the beef animal. For these reasons it is critical to understand the structure and function of this enzyme, and molecular biology techniques provide the tools necessary to obtain such knowledge. We describe here some of the knowledge we have obtained about this peptidase enzyme and explain how this knowledge provides new insights for our goal of improving protein nutrition.

Procedure

Effect of pH, rumen fluid, nitrogen sources, and stage of growth on peptidase activity

Overnight cultures of *P. ruminicola* strain B_14 were grown on a defined medium (1995 Beef Report, p. 13). Peptidase activity was determined anaerobically by incubating cells with the diagnostic substrate Gly-Arg-MNA. Upon the action of the peptidase on the substrate, the fluorescent compound MNA is released and is quantified using a fluorescence spectrophotometer. Specific activity is expressed as nmols of MNA released/min/mg protein. To test the effect of pH on enzyme activity, cells were resuspended in buffers with pH values of 6.0, 6.5, 7.0, 7.5, and 8.0 before peptidase assays. To test the effects of rumen fluid and nitrogen sources, cultures receiving either 5 percent (v/v) rumen fluid or no rumen fluid were incubated in the presence of two levels of ammonia (ammonium chloride, 1 mM and 10 mM), gelatin (porcine skin gelatin) and peptides (Trypticase) to a final concentration of 10 mM as nitrogen equivalents. Peptidase activity of cultures harvested at different stages of growth was also tested; the same nitrogen sources described above were used, with cultures harvested at either mid-log phase (5 h), or stationary phase of growth (14 h).

Effect of Inhibitors on Peptidase activity

Much can be learned about how a peptidase enzyme cleaves its substrate by first treating the enzyme with specific chemicals. If enzyme activity is lost, then the chemical is diagnostic for the presence of a certain structure, critical to protein digestion. Treatments comprised of additions of 1 mM of either the serine protease inhibitor phenylmethylsulfonylfluoride (PMSF), the cysteine protease inhibitors para-hydroxy-mercuribenzoic acid (pCMB) and iodoacetate (IAA), or the metal-binding compounds ethylenediaminetetracetic acid (EDTA) and ethyleneglycol-bis-tetracetic acid (EGTA) to the assay mixture. For the EDTA and EGTA treatments, the requirement for either Ca^{++} or Mg^{++} ions was assessed by adding either 5 mM calcium chloride or magnesium chloride to the assay buffer. The effect of reduced sulfhydryl groups was tested by the addition of the reducing agent dithiothreitol (DTT) at 5 mM. The effect of oxygen on enzyme activity was also assessed by harvesting the cells and conducting the enzyme assays aerobically.

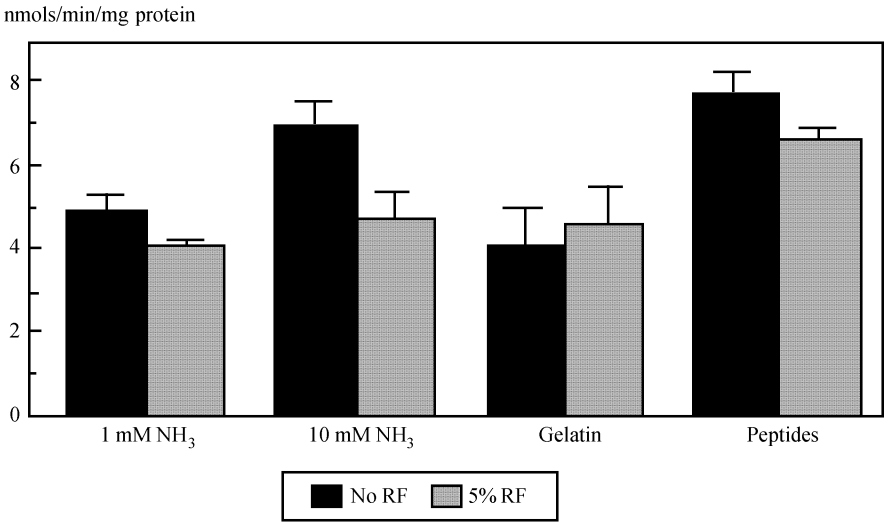

Figure 1. Effect of nitrogen sources and rumen fluid (RF) on peptidase activity of *P. ruminicola* (n=4, error bars represent standard deviations).

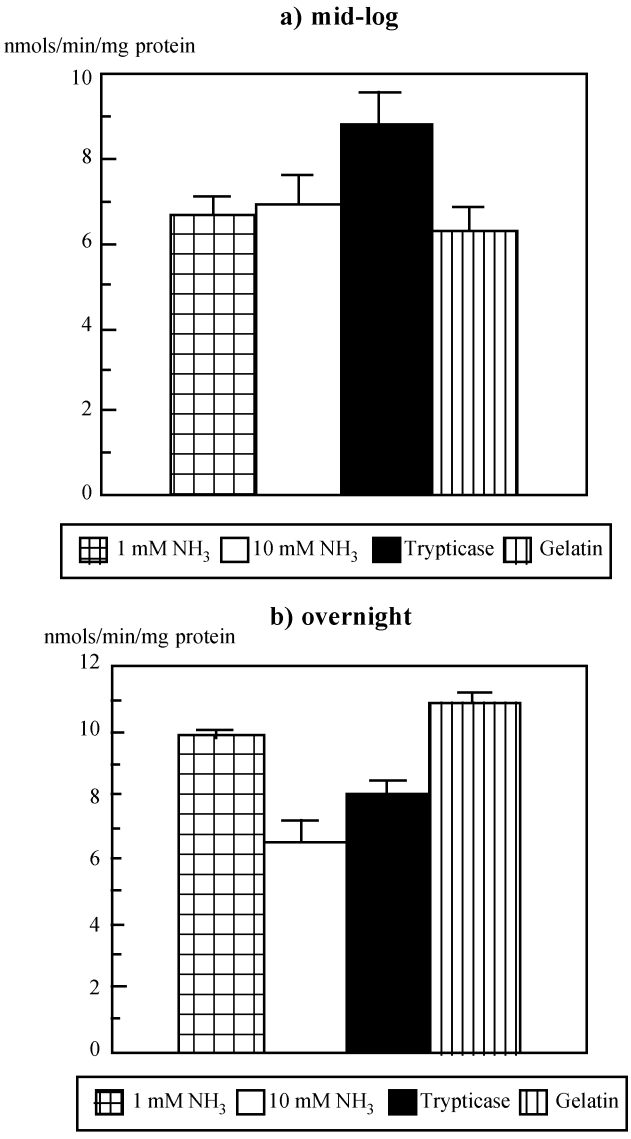

Figure 2. Effective of stage of growth on peptidase activity of *P. ruminicola* cultures growing on different nitrogen sources (n=4, error bars represent standard deviations).

Localization of Peptidase Activity

Localization of enzyme activity - whether it is extracellular, membrane associated or intracellular - needs to be determined, so that inhibitory compounds "reach" their target. To determine the location of the peptidase enzyme, fifty ml cultures were harvested and resuspended in one-tenth of the original volume in phosphate buffer, pH 7.5. These resuspended cells were broken using a French pressure cell under a flux of nitrogen gas because oxygen was found to inhibit the enzyme (see Figure 3). Following cell disruption, a low spin centrifugation was applied to remove any unbroken cells, and the remaining suspension was then recentrifuged at 80,000 rpm for 30 min. The supernatant liquid contains any intracellular proteins while the pellet contains membrane-bound proteins. After resuspending the membrane proteins in phosphate buffer, the cell fractions were stored in liquid nitrogen (-80°C) until analyzed for peptidase activity using Gly-Arg-MNA as a substrate.

Results

Effect of pH, rumen fluid, nitrogen sources, and stage of growth on peptidase activity

Enzyme activity was maximal at pH 7.5 and therefore, all subsequent assays were conducted at this pH. Enzyme activity decreased markedly (~40%) at a pH of 6.0. *P. ruminicola* is recognized as being one of the more acid-tolerant ruminal bacteria. However, buffer pHs typical of those seen in animals receiving high-concentrate diets decreased Gly-Arg-MNAse (peptidase) specific activity. Therefore, it seems possible that the peptidase activity may be affected by diet and(or) ruminal pH.

Addition of rumen fluid had little impact on peptidase activity (Figure 1), suggesting that there are no requirements for nutrients or co-factors that could be present in ruminal fluid. Similarly, enzyme activity did not appear to be modulated in response to nitrogen source (Figure 1) or stage of growth

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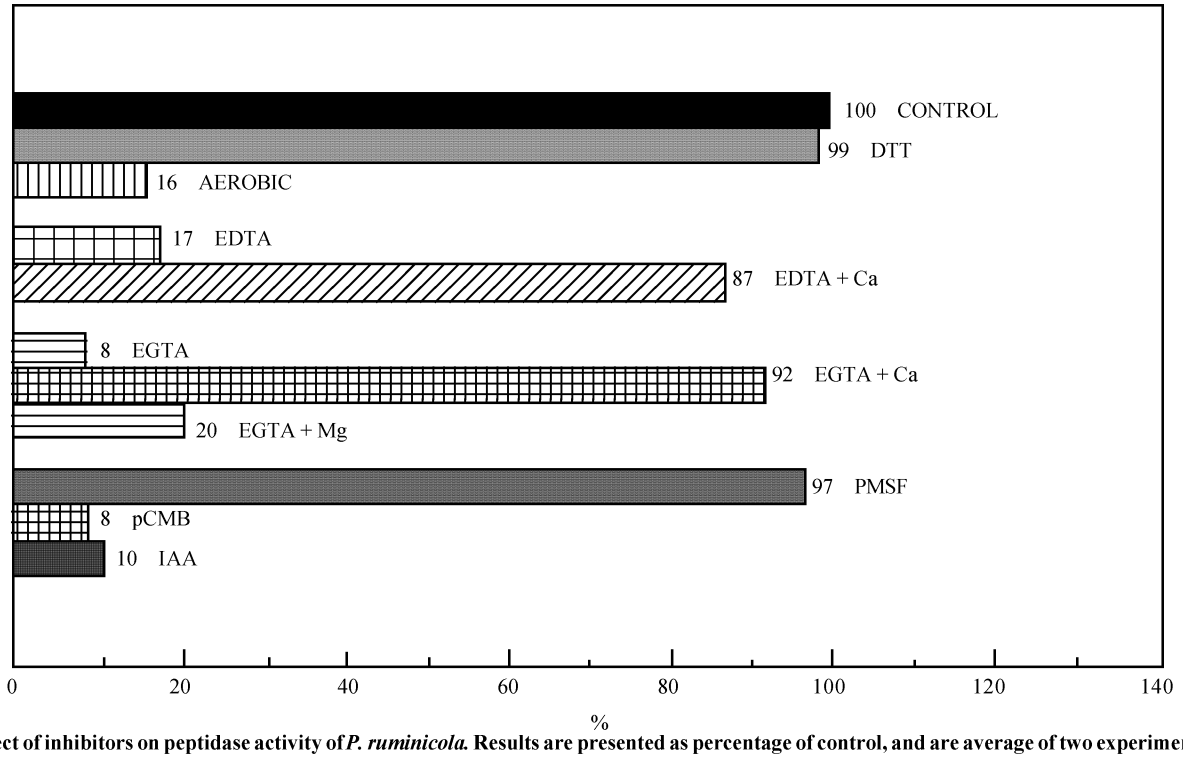

Figure 3. Effect of inhibitors on peptidase activity of *P. ruminicola*. Results are presented as percentage of control, and are average of two experiments, with four replicates per treatment.

(Figure 2), suggesting that this enzyme activity is always produced by *P. ruminicola*.

Effect of Inhibitors on Peptidase activity

Although the serine protease inhibitor, PMSF, as well as the reducing agent, DTT, had no effect on enzyme activity (Figure 3), cysteine protease inhibitors (pCMB and IAA) reduced activity drastically. The enzyme activity is also very sensitive to oxygen because enzyme activity was decreased by approximately 80 percent when the incubation was conducted aerobically. The metal-binding compounds EDTA and EGTA also caused a decrease in enzyme activity, which indicates the enzyme must contain divalent cations for maximal enzyme activity. The more pronounced effect of EGTA suggested a requirement for calcium ions, and this was confirmed by the addition of excess calcium ions (Figure 3), that reverted the inhibition caused by EGTA and EDTA. However, magnesium could not replace calcium in restoring enzyme activity, suggesting that the divalent cation requirement for enzyme activity is quite specific for calcium. Cell-free assays conducted with the cytoplasmic/periplasmic fraction resulted in a similar inhibition profile (data not shown).

Localization of Peptidase Activity

More than 90 percent of the peptidase activity under investigation is present in the intracellular fraction. Little activity was found in the cell-free supernatant (3%), showing that it is not extracellular. These findings determine that an inhibitor specific for this enzyme will only be effective if it is capable of crossing the bacterial cell wall. Therefore, the design of any inhibitory compound must ensure it is compatible with those structures involved with the transport of nutrients into the bacterium.

Conclusions

The dipeptidyl aminopeptidase produced by *P. ruminicola*, which degrades the diagnostic substrate Gly-Arg-MNA is produced in similar amounts irrespective of the nitrogen source used for growth, other nutritional factors, or stage of growth. Therefore, manipulation of the diet is unlikely to result in measurable changes in enzyme activity. Enzyme activity however is decreased by low pH, removal of calcium ions, and by chemicals which bind to a cysteine residue which is critical to the cleavage of the dietary protein. Because the enzyme appears to be located inside the bacterium, the peptides present in ruminal fluid must first be transported across the bacterial cell wall before they can be degraded to amino acids, ammonia, and VFA. These molecular details now provide at least two new strategies which may control ruminal ammonia production: inhibitors which irreversibly bind to the peptidase enzyme, or compounds which irreversibly bind to the bacterium's peptide transporter.

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[1] Humberto Madeira is a graduate student; and Mark Morrison is Assistant Professor, Animal Science.

Effect of Rumensin and Feed Intake Variation on Ruminal pH

Rob Cooper
Terry Klopfenstein
Rick Stock
Cal Parrott
Dan Herold[1]

Steers receiving Rumensin had reduced acidosis as indicated by elevated ruminal pH and reduced area of ruminal pH below 5.6. Therefore, Rumensin can be used as a management tool to aid in reducing acidosis and thereby increasing feedlot performance.

Summary

Six ruminally-fistulated steers were used to evaluate the effect of Rumensin and feed intake variation on ruminal pH. Steers were adapted to a 92.5 percent concentrate diet and then subjected to three levels of intake variation: ad libitum, intake variation of 2 lb/day, and intake variation of 4 lb/day. Feed intakes and ruminal pH were monitored continuously throughout the entire trial. Results indicate that Rumensin reduced acidosis by elevating average ruminal pH and decreasing area of ruminal pH below 5.6. In addition, Rumensin stabilized rate of intake and daily ruminal pH fluctuation at the high level of intake variation.

Introduction

Changes in dry matter intake by cattle fed high-concentrate diets can negatively influence feedlot gain and efficiency as well as predispose digestive disorders such as acidosis. Subacute acidosis increases variation in feed intake and decreases dry matter intake of cattle consuming high-grain diets. During acidosis, cattle will reduce feed intake until ruminal pH increases to approximately 5.6. Thus, ruminal pH must affect feed intake. On the other hand, it is not totally clear whether ruminal pH causes feed intake variation or whether feed intake variation changes ruminal pH, and how these factors are controlled in cattle. Rumensin is an ionophore widely used in the feedlot industry to increase feed efficiency. It has been widely observed and recently shown that Rumensin reduces feed intake variation and may reduce digestive disturbances and death loss. This effect of Rumensin and its mechanism have been difficult to measure and explain. Therefore, a system of continuous acquisition of feed intake and ruminal pH data was developed so that a more complete understanding of the interactions between ruminal pH and feed intake variation would be possible. The objectives of this trial were to evaluate the effects of Rumensin and feed intake variation on ruminal pH through continuous data acquisition.

Procedure

Six ruminally-fistulated steers (860 lb) were used in a 111-day metabolism finishing trial. To have the steers used in this trial respond in intake and performance similar to yearling cattle coming off grass and going to the feedlot in early fall, the steers were cannulated in the spring at approximately one year of age and then summered on grass until the start of the trial in mid-October.

Table 1. Composition of finishing diet.

Item	% of DM
Dry-rolled corn	81.95
Alfalfa hay	7.50
Molasses-urea supplement	6.36
Dry supplement[a]	4.19

[a]Contained minerals, vitamins, and Tylan, with or without Rumensin.

Steers were then allotted randomly to one of two dietary treatments, a 92.5 percent concentrate diet with or without Rumensin at 25 g/ton (Table 1). Steers were adapted to the finishing diet through a 20-day, four step grain adaptation period. Each step was fed for a 5-day period and consisted of 45, 35, 25, and 15% (DM basis) alfalfa hay in place of dry-rolled corn for steps one through 4, respectively. All steers were then subjected to three levels of intake variation: ad libitum intake with no controlled intake variation on days 21-47 and 60-98 (NV), low daily intake variation of 2 lb/day of dry matter on days 48-53 and 99-104 (LV), and high daily intake variation of 4 lb/day of dry matter on days 54-59 and 106-111 (HV). Dietary treatments were switched on day 78, with the three steers receiving Rumensin going to the control diet and the three steers already on the control diet going to the Rumensin treatment.

Throughout the entire trial, steers were tethered in individual metabolism stalls. Feed intakes were monitored continuously with individual feed bunks that were suspended from load cells. Ruminal pH was also monitored continuously with submersible pH electrodes suspended through the plugs of the rumen cannulas of each steer. Each pH electrode was encased in a weighted four-wire metal shroud to keep the electrode in a stationary position approximately five to ten inches above the ventral floor of the rumen, while allowing rumen contents to flow freely through it. Load cells and pH electrodes were linked directly to a computer allowing data acquisition software to record both feed weight and ruminal pH every minute for each steer over the entire feeding period.

Analysis included DM intake, rate of DM intake, average ruminal pH, area of ruminal pH below 5.6, daily magni-

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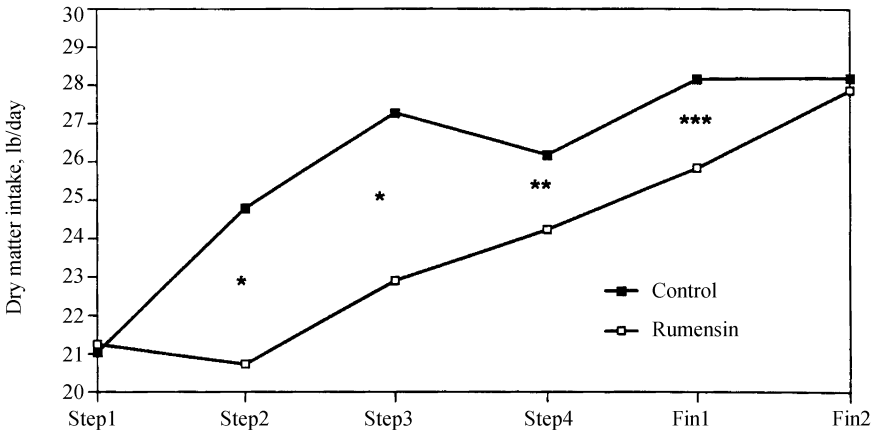
Table 2. Effect of Rumensin during grain adaptation period.

Item	Control	Rumensin
DM intake, lb/day[a]	25.94	23.81
Rate of intake, % of daily intake/min	.77	.79
Ruminal pH	5.79	5.78
Area below 5.6[b]	134.21	98.16
pHDIFF[c]	1.16	1.11
pHVAR[d]	.093	.072

[a]Means differ (P < .10).
[b]Area = ruminal pH units below 5.6 by minute.
[c]Magnitude of daily ruminal pH change.
[d]Variance of daily ruminal pH.

tude of ruminal pH change (pHDIFF), and daily variance of ruminal pH (pHVAR). Rate of intake was calculated as a first-order reaction with units of percent of daily intake per minute. Area of ruminal pH below 5.6 was calculated as time (minutes) by the units of ruminal pH below 5.6. Since it has been shown that on average cattle will reduce intakes at a ruminal pH below 5.6, the area of the ruminal pH curve below 5.6 should provide a measurement of subacute acidosis. Both pHDIFF and pHVAR indicate the degree to which the ruminal pH is changing or fluctuating within a day, where pHDIFF is calculated as the difference between the maximum and the minimum ruminal pH for a steer in a day.



* Control vs Rumensin (P<.01).
** Control vs Rumensin (P=.15).
*** Control vs Rumensin (P<.10).
Step 1 through Step 4 are the 5 day average of each respective step-up diet.
Fin1 and Fin2 are the first and second 5 days of finisher, respectively.

Figure 1. Dry matter intakes during grain adaptation period.

Table 3. Effect of step-up diet during grain adaptation period.

	Diet[a]					
Item	Step1	Step2	Step3	Step4	Fin1	Fin2
DM intake, lb/day	21.15[b]	22.76[c]	25.09[d]	25.21[d]	27.0[e]	28.04[e]
Rate of intake, % of daily intake/min	.72[bc]	.50[b]	.81[bcd]	.82[bcd]	.91[cd]	.94[d]
Ruminal pH	5.89[b]	5.80[bc]	5.88[b]	5.92[b]	5.73[c]	5.50[d]
Area below 5.6[f]	64.88[b]	93.41[b]	83.23[b]	54.40[b]	139.50[b]	261.66[c]
pHDIFF[g]	.99[b]	1.08[bc]	1.36[d]	1.21[c]	1.18[c]	1.0[b]
pHVAR[h]	.058[bc]	.073[bcd]	.130[e]	.094[d]	.088[cd]	.050[b]

[a]Step1 through Step4 are the 5 day average of each respective step-up diet. Fin1 and Fin2 are the first and second 5 days of finisher, respectively.
[b,c,d,e]Means differ (P < .10).
[f]Area = ruminal pH units below 5.6 by minute.
[g]Magnitude of daily ruminal pH change.
[h]Variance of daily ruminal pH.

Results

Dry matter intakes and daily gains were typical of yearling feedlot cattle. Dry matter intakes during the finishing period averaged 28.0 lb per day and ADG for the six steers during the trial was 4.0 lb.

Grain Adaptation Period

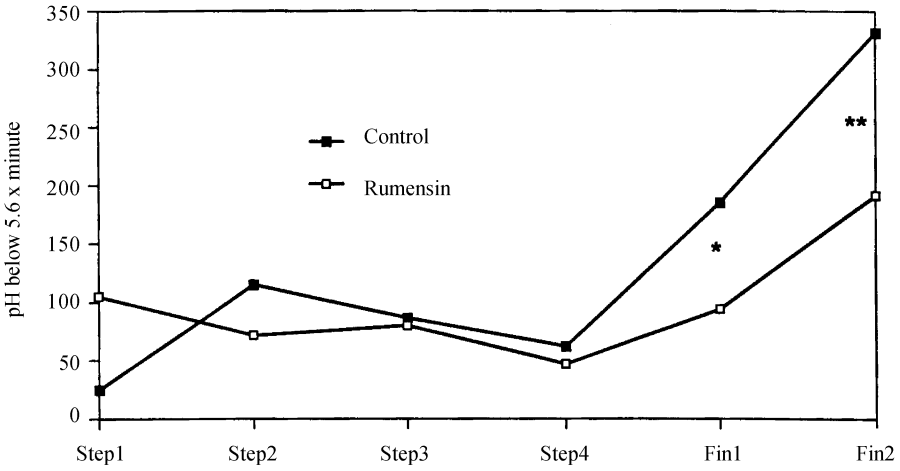
Analysis of the grain adaptation period included the 5-day average for each step-up diet (1 through 4) plus the average of the first and second five days on the finisher. Steers receiving Rumensin consumed less feed over the grain adaptation period (P < .05) (Table 2), reaching the level of the controls by the second five days on finisher (Figure 1). Dry matter intakes on step one were similar for the steers on the control and Rumensin treatments. On steps two and three, steers receiving Rumensin consumed approximately 16 percent less feed than the controls (P < .01). During step four and the first five days on finisher, steers on the Rumensin treatment tended to consume eight percent less feed than the controls (P < .16). By the second five days on finisher, DM intakes were not different. During the grain adaptation period, rate of DM intake was not affected by dietary treatment or step-up diet.

Average daily ruminal pH was not affected by Rumensin, although it was affected by step-up diet (Table 3). Ruminal pH was relatively constant from step one through step four, averaging 5.87. During the first five days on finisher, average ruminal pH dropped to 5.73 (P < .05, from step 4). During the second five days on finisher, average ruminal pH dropped to 5.50 (P < .05, from first 5 days on finisher). Area of ruminal pH below 5.6 followed the same pattern as average ruminal pH. Steps one through four were not different from each other and averaged 73.90 across dietary treatments. Area of rumi-

Table 4. Effect of Rumensin during finishing period.

Item	Control	Rumensin
DM intake, lb/day	28.34	27.61
Rate of intake, % of daily intake/min	.61	.55
Ruminal pH[a]	5.59	5.73
Area below 5.6[bc]	216.09	98.18
pHDIFF[d]	1.10	1.07
pHVAR[e]	.063	.055

[a]Means differ (P = .11).
[b]Area = ruminal pH units below 5.6 by minute.
[c]Means differ (P < .10).
[d]Magnitude of daily ruminal pH change.



*Control vs Rumensin (P=.25).
**Control vs Rumensin (P=.08).
Step1 through Step4 are the 5 day average of each respective step-up diet.
Fin1 and Fin2 are the first and second 5 days of finisher, respectively.

Figure 2. Area of ruminal pH below 5.6 during grain adaptation period.

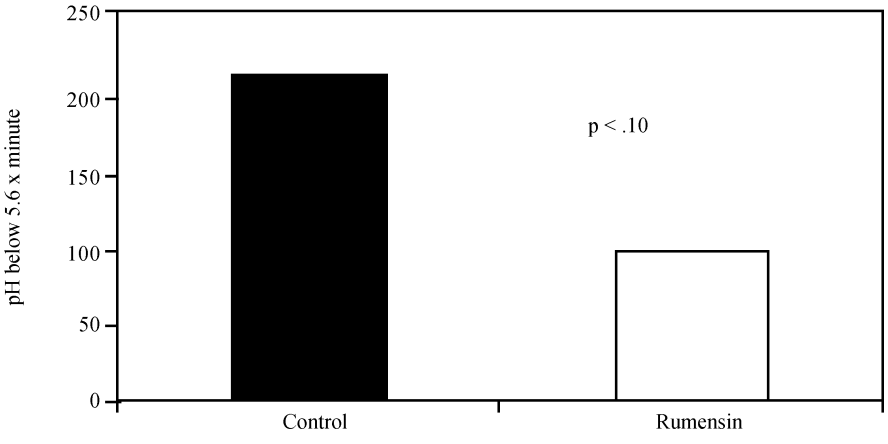


Figure 3. Area of ruminal pH below 5.6 during finishing period.

nal pH below 5.6 tended (P = .16, from step 4) to increase during the first five days on finisher to an average of 139.50. Area again increased during the second five days of finisher to an average of 261.66 (P < .05, from first 5 days on finisher). For steers on the Rumensin treatment, area of ruminal pH below 5.6 was numerically lower (P = .25) during the first five days on finisher and was significantly lower (P = .08) during the second five days on finisher compared to the controls (Figure 2).

Daily magnitude of ruminal pH change was not affected by Rumensin. However, pHVAR tended (P = .14) to be lower for the Rumensin treatment compared to the control (Table 2). Both pHDIFF and pHVAR had significant (P < .01) quadratic responses to step-up diet (Table 3). Both started low on step one, were highest on step three, and returned to levels similar to step one by the second five days on finisher.

Therefore, results of the grain adaptation period indicate that Rumensin caused steers to move on feed more gradually, but did not affect DM intake by the second five days on finisher. In addition, Rumensin reduced area of ruminal pH below 5.6 for the first and second five days on finisher, indicating less acidosis while adapting to the final diet.

Finishing period

Analysis of the finishing period included the average of the last two days on each level of intake variation. Dry matter intake was not affected by dietary treatment or level of intake variation and averaged 28.0 lb per day for the finishing period. Rate of intake increased linearly (P < .05) with level of intake variation on the control diet, but was not affected by level of intake variation on the Rumensin diet (data not shown).

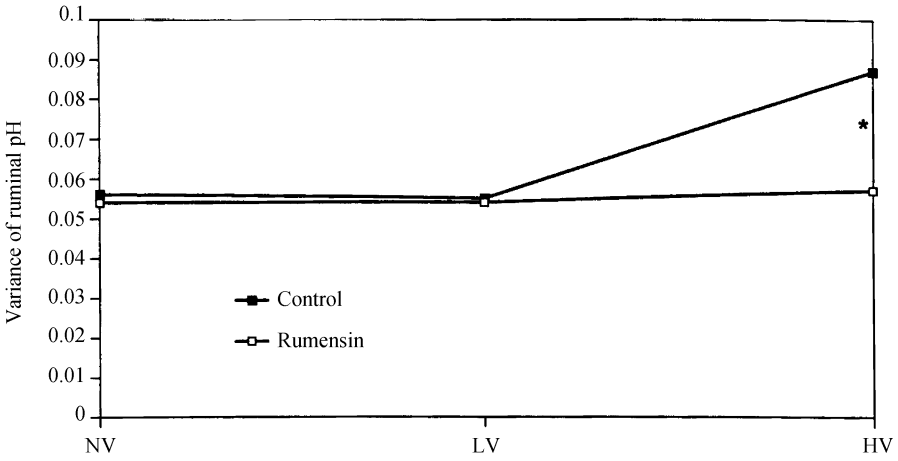
Average daily ruminal pH tended (P = .11) to be higher for the steers on Rumensin than the controls across all three levels of intake variation (Table 4). Average daily ruminal pH increased (P < .05, linear) with increasing level of intake variation

(Continued on next page)

Table 5. Effect of level of intake variation during finishing period.

Item	Level of intake variation[a]		
	No variation	Low variation	High variation
DM intake, lb/day	28.16	27.85	27.92
Rate of intake, % of daily intake/min[b]	.52	.62	.59
Ruminal pH	5.52[c]	5.69[d]	5.76[d]
Area below 5.6[e]	234.03[c]	142.72[d]	94.67[d]
pHDIFF[f]	1.03[c]	1.07[cd]	1.15[d]
pHVAR[g]	.050[c]	.055[c]	.072[d]

[a]No Variation = Ad libitum. Low Variation = 2 lb/day intake variation. High Variation = 4 lb/day intake variation (DM basis).
[b]Significant interaction detected (P = .08). Overall means presented but not statistically analyzed.
[c,d]Means differ (P < .10).
[e]Area = ruminal pH units below 5.6 by minute.
[f]Magnitude of daily ruminal pH change.
[g]Variance of daily ruminal pH.



*Control vs Rumensin (P<.05).
NV = Ad libitum, no controlled intake variation.
LV = Low intake variation.
HV = High intake variation.

Figure 4. Variance of daily ruminal pH during finishing period.

(Table 5). Area of ruminal pH below 5.6 was significantly greater (P = .07) for the steers on control than on Rumensin, indicating more subacute acidosis with the controls (Figure 3). Area of ruminal pH below 5.6 linearly decreased (P < .05) with increasing level of intake variation (Table 5). The reason average ruminal pH increased and area below 5.6 decreased with increasing level of intake variation is unclear.

Daily magnitude of ruminal pH change (pHDIFF) and pHVAR were relatively constant and not affected by dietary treatment across NV and LV. However, with high intake variation, both pHDIFF and pHVAR significantly increased (P < .05) for the control, while remaining constant for the Rumensin treatment (Figure 4).

Therefore, results of the finishing period indicate that the use of Rumensin elevates average ruminal pH and decreases area of ruminal pH below 5.6, while stabilizing rate of intake and daily ruminal pH fluctuation at high levels of feed intake variation.

[1]Rob Cooper, graduate student; Terry Klopfenstein, Professor, Animal Science, Lincoln; Rick Stock, Former Professor, Animal Science, Lincoln; Cal Parrott, Lilly Research Laboratories, Greenfield, IN.; Dan Herold, research technician, Animal Science, Lincoln.

Evaluating Breakeven for Various Management Systems for Different Breed Types from Weaning to Slaughter

Cynthia Hayden
Ivan Rush
Burt Weichenthal
Brad Van Pelt[1]

Maximizing summer pasture gain after utilizing cornstalk grazing resulted in lower overall cost of production.

Summary

Two hundred twenty-four medium framed, weaned British-breed steer calves (509 lb) and 139 weaned continental-breed steer calves (542 lb) were used in two consecutive years (1994, 1995; 2 finishing pens/treatment/yr) to evaluate the effects of winter gain and length of summer grazing season on subsequent finishing performance and overall system breakeven within two different breed types.

Calves were wintered at two rates of gain: <.75 lb/day (Slow) and approximately 2 lb/day (Fast). Calves from each wintering treatment group grazed either native range or crested wheat grass. The grazing period was from May to July (61 days; Short) or September (120 days; Long). All steers were finished on a 90% concentrate finishing diet for 131 d (Short) and 118 d (Long). Winter gain and breed type

affected overall systems breakeven differently.

Introduction

As cattle frame size has increased through crossbreeding and through selection within breeds, an increasing percentage of large framed calves is now available at weaning. Producers have the option of buying medium or large framed calves, and are interested in differences in performance and cost of production when managed in various growing and finishing systems. Because of the many ways to feed and manage cattle from weaning to slaughter, economics of production systems will help producers develop management and marketing strategies for beef feeding systems.

Total efficiency (energy utilization) for a growing and a finishing period depends on the length of time of low energy feeding, level of energy restriction, level of nutrition during the compensatory period, and composition of the animal when compensatory growth is ended. Because cattle have compensatory gain potential, it allows the use of low quality economical feeds in at least part of the growing process.

The objectives of this research were to 1) evaluate the effect of winter management and length of summer grazing on subsequent finishing performance with medium framed and large framed steers, and 2) evaluate breakeven costs of production for various systems of production.

Experimental Procedures

Animals

During year one, 66 large-framed Continental cross steers (initial weight 522 lb) were compared with 128 medium-framed British cross steers (initial weight 503 lb). During year two, 73 large framed Continental cross steers (initial weight 562 lb) and 96 medium framed British cross steers (initial weight 516 lb) were subjected to the various systems. The steers were managed in a $2 \times 2 \times 2$ factorial arrangement. Factors included: breed type (British cross or Continental cross), winter rate of gain (Slow at <.75 lb/day, or Fast at 2 lb/day), and summer grazing season (Short 58 days, year one and 63 days, year two; Long 121 days, year one and 119 days, year two). All steers were finished on a common high concentrate ration.

Initial weight and summer grazing weights (initial and final) were an average of two consecutive days' weights. Final finishing weight was a full weight that was shrunk 4 percent. All steers were implanted with Synovex S® at the beginning of the summer grazing season and were reimplanted at the beginning of the finishing phase. During the wintering and finishing phases in the feedlot, cattle were fed in two pens per treatment in both years. During the winter on cornstalks and during the summer grazing phase, all cattle were grazed together.

Winter Period

The wintering period averaged 145 days with the Slow treatment grazing cornstalks (supplemented with alfalfa hay) approximately 82 days followed by limit feeding the following diet. The winter diets for both years and for both the Slow and Fast treatments consisted of 34% dry rolled corn, 32% corn silage, 32% haylage, and 2% supplement (DM basis) and was formulated (DM basis) to contain 12.5% CP, .7% calcium, .3% phosphorus, 25 g/ton Rumensin, and 10 g/ton Tylan.

Summer Period

Wintering groups were randomly assigned by pen to either a Short or Long grazing season (2 pens per treatment). One pen (replicate) was randomly assigned to graze predominately crested wheat grass (*Agropyron cristatum* Gaertn.) pastures at the High Plains Agriculture Laboratory (HPAL) in Sidney, NE. The other pen was assigned to graze at the University of Nebraska, Panhandle Experiment Range (UNPER) in Sioux County, NE which was primarily native grass consisting of blue grama (*Bouteloua gracilis* (H.B.K). Lag. Ex Steud.), threadleaf sedge (*Carex filifolia* Nutt.), needleandthread (*Stipa comala* Trin. and Rupr.), and prairie sandreed (*Calamovilfa longifolia* (Hook.) Scribn.). Half of each wintering group was either grazed Short or Long season at each summer pasture location. The grazing period was from mid-May to mid-July for the early removal treatment or from mid-May to mid-September for the late removal treatment. The starting date for cattle being turned out to grass depended on the amount of forage left from the previous year of grazing, the precipitation for the current year and amount of forage growth in the current year.

Stocking rate averaged for the two locations was .31 and .28 AUM/acre for both years one and two, respectively. A mineral supplement was provided free choice for the steers grazing pasture.

Rumen fill differences after both the short and late grazing seasons were minimized by feeding a common diet of 50% corn silage and 50% haylage (DM basis) at 1.5% BW for 5 days before weighing. Weights were taken for two consecutive days before feeding in the morning.

Finishing Period

Steers were fed a common finishing diet for 137 days (Short) and 118 days (Long) for year one and 125 days (Short) and 118 days (Long) for year two until it was estimated that 70 percent of the steers had reached the Choice grade. The finishing diet for both years was a high concentrate corn diet which contained 10% DM from corn silage. The rations were formulated to contain (DM basis) 12.5% CP, .6% calcium, .3% phosphorus, 25 g/ton Rumensin, and 10 g/ton Tylan. Three step up diets were utilized which contained 50%, 28%, and 13% roughage (DM basis) with each step up ration fed for approximately 5-7 days. Carcass data were collected for both years after a 24 hour chill (Table 2).

Economics

Economic analysis for each system included standardized costs for both years for all inputs. Breakeven prices

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were used to evaluate the comparative economic costs of each system. The charges used for both years were: feedlot yardage, $.25/day; purchase price, $95/cwt; interest rate, 9%; feed cost for the Fast winter group, $.45/day; feed cost for the Slow group, cornstalks for 3 months at $.15/day and limit fed for 2 months, $.45/day; summer grass, $.33/day; and feed cost for finishing, $.05/lb.

Statistical Analysis

Data within in each trial were analyzed by analysis of variance using the General Linear Models procedure (SAS, 1985). The data for the economic analysis were evaluated for differences in mean values by use of Duncan's multiple range test for years one and two. Experimental design was a completely randomized design with a 2 × 2 × 2 factorial treatment arrangement, with finishing pen as the experimental unit. It was not possible to pool the two years because of a treatment x year interaction (P<.10).

Results

Cattle wintered at a Slow rate of gain compensated during the summer grazing period, as would be expected, and gained more than those wintered at a faster rate (P<.01;Table 1). The Continental cross cattle gained more on pasture regardless of previous winter gain the first year (P<.10), however summer gains were similar in both breed types the second year. The winter gain was slightly higher the second year for both the British cross and the Continental cross, and perhaps the Continental cross were near the same body condition as the British in year two when going to grass. Also the summer gain in year two tended to be higher than in year one for both breed groups. The differences in physiological maturity of the Continental and British cross cattle may not have been as great as in the previous year.

When nutrients are not restricted, perhaps the larger-framed cattle can continue to take advantage of their growth potential. Even though grass consumption was not measured, it is probable that the larger compensating cattle consumed considerably more forage.

During the finishing phase there was not a consistent carryover effect of winter gain in both years. Finishing dry matter intake for both years shows the Continental cattle consumed more than the British cattle regardless of winter or grazing treatments. In year two, cattle that were wintered at a Slow rate gained faster and were more efficient than those that were wintered at a faster rate. Because there was a lack of compensatory growth difference exhibited between the two breed types during the summer grazing period, perhaps these differences were exhibited during the finishing phase. Finishing ADG was higher for steers that finished after the Long grazing season compared with those grazed for the Short season for both breed types during year one. For both years, hot carcass weights and rib-eye areas were higher for Continental cattle, regardless of winter gain or grazing season.

Finishing feed to gain ratios (Table 2, year one) were higher (P<.10) for the Short grazing season than the Long for both breed types. For year one, the combination of both winter gains with Long season grazing resulted in the lowest finishing feed to gain ratio for both British and Continental cattle.

The most desirable breakeven for year one was for Continental cattle wintered Fast and summer grazed the Short season, and for year two it was for British cattle grazing cornstalks for the winter and summer grazed for the Short period (Figure 1). The letters used to identify boxes in Figure 1 are in the order of breed type, winter gain, and grazing season defined in Tables 1 and

Table 1. Steer performance for winter and summer management systems.

Breed type:	Brit	Brit	Brit	Brit	Cont	Cont	Cont	Cont	
Winter gain:	Slow	Slow	Fast	Fast	Slow	Slow	Fast	Fast	
Grazing season:	Short	Long	Short	Long	Short	Long	Short	Long	SEM
Year 1:									
No. of Steers	31	33	32	32	16	18	14	18	
Initial wt, lb[a]	501	505	507	498	531	546	516	497	4.56
Winter									
Total gain, lb[bc]	84	75	210	225	76	63	242	205	5.02
ADG, lb/[bc]	.55	.50	1.40	1.50	.50	.42	1.60	.62	.03
Summer									
Total gain, lb[cde]	130	210	78	134	143	229	97	161	6.46
ADG, lb/d[cde]	2.24	1.74	1.35	1.11	2.47	1.89	1.67	1.33	
Year 2:									
No. of Steers	26	23	24	23	19	17	18	19	
Initial wt, lb[b]	516	513	527	510	550	575	563	561	2.03
Winter									
Total gain, lb[af]	85	97	255	251	91	93	246	227	3.37
ADG, lb/[da]	.61	.70	1.85	1.82	.66	.67	1.78	1.64	.02
Summer									
Total gain, lb[ce]	167	239	99	150	177	258	114	181	9.69
ADG, lb/d[ce]	2.65	2.00	1.57	1.57	1.26	2.80	1.80	1.52	.13

[a]Breed type × Winter gain (P<.10). [b]Breed type × Grazing season (P<.10). [c]Winter gain (P<.01). [d]Breed type (P<.10). [e]Grazing season (P<.10). [f]Winter gain x Grazing season (P<.10).

Table 2. Steer performance during finishing phase of systems.

Breed type:	Brit	Brit	Brit	Brit	Cont	Cont	Cont	Cont	
Winter gain:	Slow	Slow	Fast	Fast	Slow	Slow	Fast	Fast	
Grazing season:	Short	Long	Short	Long	Short	Long	Short	Long	SEM
Year 1:									
Finishing data									
Gain, lb,[a]	481	424	444	442	483	464	509	509	16.80
F/G[ac]	6.58	6.44	7.37	6.48	7.30	6.18	6.84	6.47	.01
ADG, lb/d[a]	3.51	3.59	3.24	3.74	3.52	3.92	3.72	3.80	.13
DMI, lb[b]	23.10	23.10	23.85	24.25	25.75	24.30	24.45	24.45	.48
Final wt, lb[a]	1195	1213	1242	1298	1233	1302	1364	1310	11.66
Carcass data									
Hot carcass weight, lb[a]	748	730	788	792	782	813	884	821	12.88
Rib eye area, sq in[a]	14.4	12.6	13.3	13.9	11.9	13.9	13.6	14.3	.65
Year 2:									
Finishing data									
Gain, lb[bde]	565	455	387	404	446	439	370	429	24.39
F/G[bcde]	5.03	6.02	7.30	6.69	6.58	6.35	7.77	6.85	.01
ADG, lb/d[bde]	4.52	3.86	3.09	3.42	3.57	3.72	2.96	3.64	.20
DMI, lb[f]	22.75	23.25	22.60	22.90	23.50	23.70	23.00	24.80	.57
Final wt, lb[g]	1333	1303	1268	1314	1263	1365	1292	1398	20.01
Carcass data									
Hot carcass weight, lb[f]	781	812	842	834	830	864	853	896	28.59
Rib eye area, sq in[f]	14.4	12.8	15.1	12.9	15.9	13.5	16.0	13.7	.71

[a]Breed type × Winter gain × Grazing season (P<.10). [b]Breed type × Grazing season (P<.10). [c]Feed/gain was analyzed as gain/feed. Gain/feed is the reciprocal of feed/gain. [d]Breed type × Winter gain (P<.10). [e]Winter gain × Grazing season (P<.10). [f] Breed type (P<.10). [g]Grazing season (P<.10). [h]Winter gain (P<.10).

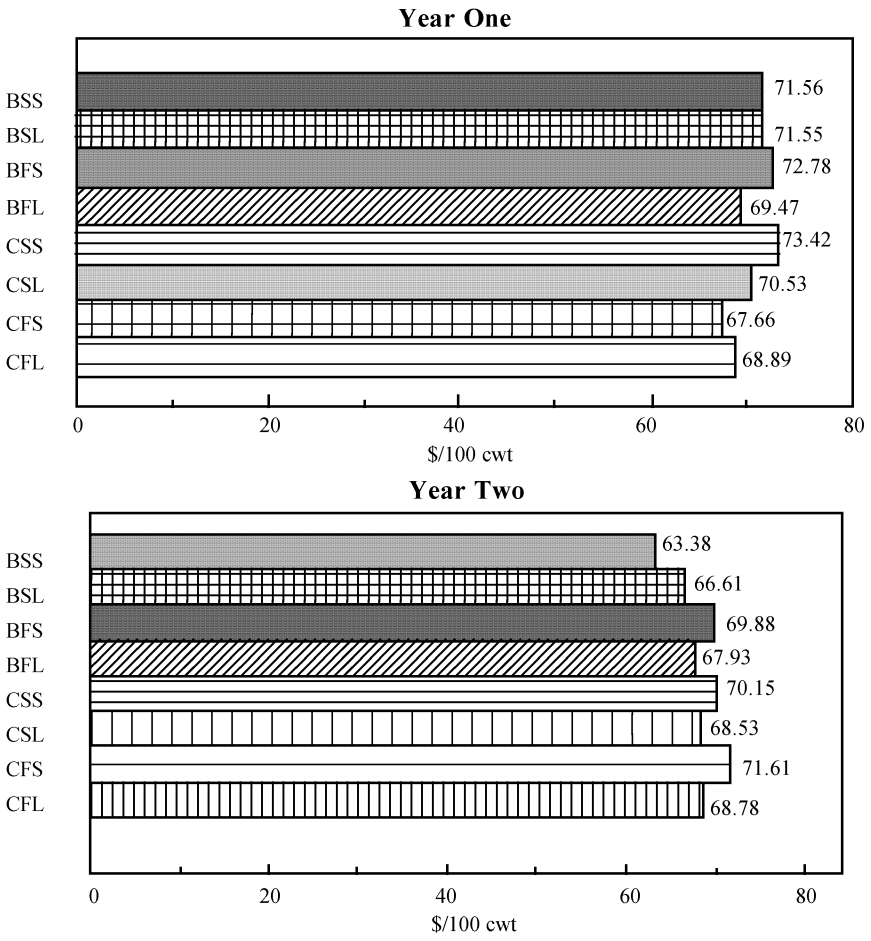

Figure 1. Breakeven analysis of management systems, coded from top three lines, Table 2.

2. In year two, Continental cross cattle that grazed cornstalks in the winter and grazed in the summer for the Long season had the highest breakeven. The difference in the two years may be explained by the biological differences in the cattle and the summer forage available.

Total costs for year two were lower for the Short summer grazing group than the Long season group. Total costs for year one were lower for the British cross cattle compared to the Continental cattle when both grazed cornstalks during wintering. Breakeven analysis was considerably different between years. Year one had a Continental group with the lowest breakeven which was the highest the following year. Since the two years of results were so different in the analysis, it shows that more research is needed to find out which management system may be the best in particular years.

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[1]Cynthia Hayden, former graduate student; Ivan Rush and Burt Weichenthal, Professors, Animal Science, Brad Van Pelt, research technician, Panhandle Research and Extension Center, Scottsbluff.

Forage Combinations for Summer and Fall Grazing

Drew Shain
Terry Klopfenstein
Rick Stock
Mark Klemesrud[1]

Beef production costs and slaughter breakeven values can be reduced by grazing forages that maximize summer grazing gain when production costs are fixed.

Summary

One hundred ninety-two medium framed, British-breed steers were used to evaluate combinations of forages grazed during the summer and fall of 1995, and subsequent finishing performance. Treatments consisted of steers grazing different combinations of bromegrass, warm-season grasses, native Sandhills range, or red clover interseeded in bromegrass. Following grazing, steers were finished on a 93 percent concentrate diet. Systems using native Sandhills range had the greatest daily summer gains and the lowest slaughter breakeven costs. Maximizing grazed forage gain, while cost of gain is low, reduces overall breakeven costs of forage systems.

Introduction

Cool-season grasses grazed during May, June, and September are commonly used to obtain daily gains up to two pounds in grazing beef cattle. However, growth and quality of cool-season grasses decline during July and August resulting in lower weight gains. Grazing cool-season then warm-season grasses optimizes forage quality by rotating to warm-season grasses during July and August. Using the native grass resources available in the Nebraska Sandhills to provide a mix of warm-season grasses may be an alternative to establishing both cool- and warm-season grass pastures at one location. However, the cost of transportation, weight loss, and stress associated with transportation needs evaluation. Following a winter and spring period of limited animal growth, grazing combinations of cool- and warm-season grasses to optimize both quality and quantity of grasses available during the summer, should result in animal weight gains up to two pounds per day, while reducing cost of gain.

Objectives of this research were to evaluate the influence of different forage combinations on summer and fall livestock gains and to evaluate the effect of each of these combinations on the economics of the entire growing/finishing system.

Procedure

One hundred ninety-two medium-framed, British-breed steers (473 lb) were purchased in the fall, processed and allowed a 28-day weaning and acclimation period. Steers were then assigned to a low-input wintering system consisting of grazing irrigated cornstalks from November 18, 1994 to February 17, 1995. Following cornstalk grazing, steers were fed alfalfa hay and a mineral supplement ad libitum until May 5, 1995. This diet allowed for some growth (.86 lb/day) and maintained animal health while keeping costs to a minimum.

On May 5, 1995, steers were implanted with Compudose, and randomly assigned to one of eight forage grazing systems (Table 1): (1) continuous bromegrass until August 10, (2) rotational bromegrass until August 10, (3) rotational red clover inter-seeded in bromegrass until August 10, (4) bromegrass or warm-season grasses until August 25, (5) bromegrass or native Sandhills range until September 13, (6) native Sandhills range until September 7, (7) bromegrass or native Sandhills range until September 7 with bromegrass, rye or cornstalk grazing until November 17, (8) bromegrass until September 7 with bromegrass, rye or cornstalk grazing until November 17. Bromegrass, warm-season grass, rye, and cornstalk pastures were located at the University of Nebraska Agricultural Research and Development Center near Ithaca NE.. Native Sandhills range pasture was located approximately 20 miles north of North Platte, Nebraska. Days of grazing and assigned acres for each system are listed in Table 1.

Cattle in the red clover/bromegrass system (5) grazed a seven-paddock rotation. Six paddocks were in their first year following red clover seeding. The seventh paddock, a monoculture of bromegrass, was twice the size of the other paddocks, and was used as an area for animals to graze while allowing appropriate regrowth of the red clover/bromegrass paddocks. Cattle were rotated among paddocks every five days. Cattle in the rotational bromegrass system (2) served as the control group for the red clover/bromegrass system with paddock size, paddock number and rotation time the same as the red clover/bromegrass system.

Cattle in systems using a combination of forages (excluding red clover/bromegrass) were rotated based upon forage quality and quantity to assure optimum forage availability at all times. Warm-season grass pastures were a mix of big and little bluestem, Indian grass, switchgrass, and sideoats grama. Grazing of warm-season grass pastures be-

Table 1. Summer systems grazing acreage.

Forage system	Treatment #	Total acre/head	Acres	Days grazed
September Removal				
Continuous Bromegrass	1	1	24	97
Rotational Bromegrass	2	1	24	97
Red Clover/Bromegrass	3	.75	18	97
Bromegrass rest		.25	6	
Bromegrass	4	.4	9.6	38
Warm- Season grasses		.55	13.2	74
Bromegrass	5	.4	9.6	31
Sandhills Range		4.95	119	94
Sandhills Range	6	6.9	166	125
November Removal				
Bromegrass	7	.6	14.4	31
Sandhills range		4.95	119	94
Rye grass or cornstalks		.62	14.9	68
Bromegrass	8	1.2	29	125
Rye grass or cornstalks		.62	14.9	68

gan on June 12, 1995. Rye was drilled into wheat stubble in early August. Cornstalks were made available following the harvest of high-moisture corn. Cattle grazing cornstalks received 1.75 lb/head/day of a protein supplement. Grazing of rye and cornstalks began on October 12.

Following grazing, steers were implanted with Revalor and fed a 93 percent concentrate diet during the finishing period. Length of feeding periods averaged 107, 79, and 61 days for grazing treatments ending in August, September, and November, respectively. Steers were adjusted to the final diet using four adaptation diets containing 45, 35, 25, and 15 percent (DM basis) forage (alfalfa hay and corn silage mixture) and were fed for 3, 4, 7, and 7 days, respectively. The final diet contained 52.5% dry rolled corn, 35% corn gluten feed, 5% supplement and 7.5% alfalfa hay, and it was formulated (DM basis) to contain 12% CP, .7% calcium, .35% phosphorus, .7% potassium, 25 g/ton Rumensin, and 10 g/ton Tylan. Cattle from each forage system were fed in two pens of 12 head each.

Initial and final weights for each stage of the system were the average of two weights taken on consecutive days following a three-day feeding of a 50% alfalfa hay and 50% corn silage diet (DM basis). Intakes during these periods were limited to 2 percent (DM) of body weight. Final weights were estimated from hot carcass weight using a 62 percent dressing percentage. Carcass measurements included hot carcass weight, liver abscess score, fat thickness, quality grade, and yield grade.

Breakeven cost was used as the measure of success of each system and included all input costs. Feedlot pen was used as the observation unit for statistical analysis. Breakeven correlation coefficients (r) for amount of gain achieved during the summer grazing, combined summer and fall grazing, and finishing periods were determined to evaluate which period, within each system, had the most influence on breakeven cost.

Results

Winter Period

Calves grazed cornstalks for 91 days and were fed alfalfa hay for an additional 77 days. Gain during the winter period was .86 lb/day.

Summer Period

The amount of red clover in the red clover/bromegrass paddocks was low. Germination of red clover was slow due to a cool, wet spring; therefore, cattle grazed the bromegrass rest paddock for the first 10 days of the grazing season, to allow more time for red clover to establish. After one rotation of cattle through the red clover/bromegrass paddocks, subsequent regrowth of red clover did not occur. Therefore, for the 97-day grazing period, cattle were grazing a combination of red clover and bromegrass for only 30 days.

Gains for cattle grazing bromegrass and Sandhills range or only Sandhills range were higher ($P < .05$, Table 2) than cattle grazing other treatments. No difference in daily gain was noted among cattle grazing bromegrass, either rotational or continuous, the red clover/bromegrass combination or for cattle grazing the bromegrass and warm- season grass pastures. Gains for cattle grazing continuous bromegrass in the November removal group were the lowest ($P < .05$) for all treatments.

In systems grazing combinations of cool- and warm-season grasses, we estimate that 40 percent of a 120-day grazing period is spent grazing cool-season pastures with 60 percent of the grazing season spent grazing warm-season pastures. However, no measurable rainfall occurred during the months of June and July at the ARDC location. Therefore, available moisture for grass growth was limited for both the bromegrass and warm-season grasses which resulted in cattle being removed from pastures approximately 30 days earlier than predicted. However, cattle in the treatment grazing a combination of bromegrass and warm-season grass spent 66 percent of the grazing period grazing warm-season pastures and 34 percent grazing cool-season pastures. Calculating pasture value for both cool- and warm-season pastures indicates that the warm-season pasture was able to maintain its grazing value during the summer drought.

(Continued on next page)

Table 2. Total system performance for steers grazing different forage combinations.

Forage System:	September/August Removal						November Removal	
Item Treatment:	Continuous bromegrass 1	Rotational bromegrass 2	Red Clover bromegrass 3	Brome-grass, warm-season 4	Bromegrass Sandhills 5	Sandhills 6	Brome-grass, Sandhills Rye/stalks 7	Continuous Bromegrass Rye/stalks 8
Weight, lb								
May 5	633	633	635	617	628	627	617	632
Aug., 10	782	772	777					
Aug., 25				796				
Sept., 7					897	895	874	768
Nov., 17							1034	939
Final[a]	1265[b]	1261[b]	1254[b]	1261[b]	1268[b]	1249[b]	1265[b]	1169[c]
Daily gain, lb								
Summer[d]	1.53[e]	1.43[e]	1.46[e]	1.60[e]	2.15[f]	2.14[f]	2.06[f]	1.09[g]
Fall[j]							2.35	2.52
Total grazing	1.53[e]	1.43[e]	1.46[e]	1.60[e]	2.15[f]	2.14[f]	2.16[f]	1.59[e]
Finishing performance								
DMI, lb/d	30.49[eg]	30.36[eg]	29.95[ef]	29.39[f]	31.05[ghi]	30.22[e]	30.53[eh]	31.49[i]
Daily gain, lb	4.51[e]	4.58[e]	4.46[e]	4.38[e]	4.64[e]	4.41[e]	3.79[f]	3.77[f]
Feed/gain[k]	6.76[e]	6.64[e]	6.72[e]	6.71[e]	6.69[e]	6.85[e]	8.05[f]	8.35[f]
Carcass data								
Fat, in	.49[e]	.51[e]	.48[ef]	.47[ef]	.42[ef]	.47[ef]	.42[ef]	.40[f]
Yield grade	2.6[e]	2.6[e]	2.6[e]	2.5[ef]	2.2[ef]	2.5[ef]	2.3[ef]	2.1[f]
% Choice	62.5[efg]	79.2[e]	62.5[efg]	79.2[ef]	54.2[fg]	30.4[g]	50.0[efg]	43.5[gh]

[a]Calculated from carcass weight adjusted for 62% dressing percentage.
[bc]Means in row with unlike superscripts differ (P < .05).
[d]Grazing = May 5 to Aug. 10, Treatments 1, 2, & 3; May 5 to Aug. 25, Treatment 4; May 5 to September 7, treatments 5, 6, 7, & 8.
[efghi]Means in rows with unlike superscripts differ (P<.05).
[j]Fall grazing = September 8 to November 17.
[k]Feed/gain was analyzed as gain/feed. Gain/feed is the reciprocal of feed/gain.

Fall Period

No difference in daily gain was noted in cattle grazing rye and cornstalks due to previous summer grazing treatments (Table 2).

Finishing Period

Differences among treatments for dry matter intake varied (Table 2). No difference in daily gain or feed efficiency was noted among cattle in the September/August removal treatments. However, cattle in the September/August removal treatments gained faster and more efficiently (P < .05) than cattle in the November removal treatments possibly due to environmental differences between groups. Cattle in the September/August removal treatments were slaughtered in mid-December and experienced less severe winter weather compared with November removal cattle that were slaughtered the end on January. No differences in daily gain or feed efficiency were noted among groups in the November removal treatments. No differences in fat thickness or yield grade were noted among cattle in the September/August removal treatments. However, cattle in the continuous bromegrass, November removal group (treatment 8) had a lighter final weight which resulted in less (P < .05) fat, measured at the 12th rib, and a greater (P < .05) yield grade than cattle in the continuous or rotational bromegrass, September/August removal groups. Differences in the percentage of Choice carcasses varied among treatments and is probably related to the number of days in the finishing period. Cattle in the August removal groups (treatments 1, 2, 3, and 4) were fed an average of 107 days compared with cattle in the September or November removal groups which were fed an average of 79 and 61 days, respectively.

Economics

Cattle grazing Sandhills range, either in combination with bromegrass or only Sandhills range (treatments 5, 6, & 7), had the most desirable breakeven costs (Table 3). No difference in breakeven costs were noted among the remaining treatments (treatments 1, 2, 3, 4, 8). Cattle grazing continuous bromegrass in the November removal group (treatment 8), numerically, had the least desirable breakeven cost. Breakeven cost correlation coefficients (r) for summer gain, the combined summer and fall gain, and feedlot gain were -.91 (P

Table 3. Total system economics of steers grazing different forage combinations.

Forage System:	September/August Removal						November Removal	
Item Treatment:	Continuous bromegrass 1	Rotational bromegrass 2	Red Clover season 3	Brome-grass, warm-Sandhills 4	Bromegrass Sandhills 5	Rye/stalks 6	Brome-grass, Sandhills Rye/stalks 7	Continuous Bromegrass 8
Steer cost,$[a]	440.41	433.90	436.96	432.75	431.17	439.80	429.18	439.61
Interest[b]	47.92	47.21	47.55	48.71	46.92	47.86	52.45	53.73
Health[c]	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Winter costs,$								
Feed[d]	83.76	83.76	83.76	83.76	83.76	83.76	83.76	83.76
Supplement[e]	20.88	20.88	20.88	20.88	20.88	20.88	20.88	20.88
Summer & Fall costs,$								
Grazing[f]	33.95	33.95	33.95	39.20	43.75	43.75	84.55	84.55
Finishing costs,$								
Yardage[g]	32.10	32.10	32.10	31.80	23.70	23.70	18.30	18.30
Feed[h]	168.82	168.14	165.99	162.42	129.18	125.98	103.86	106.74
Total costs, $[i]	830.44	822.53	823.80	822.14	782.31	788.71	795.85	810.42
Final weight, lb[j]	1265	1261	1254	1261	1268	1249	1265	1169
Slaughter Breakeven,								
$/100 lb[kl]	65.68[m]	65.22[m]	65.69[m]	65.21[m]	61.71[n]	63.17[n]	62.93[n]	69.31[m]
$/100 lb[p]	75.26[m]	74.78[m]	75.17[m]	74.39[m]	68.90[n]	70.27[n]	68.42[n]	75.44[m]

[a]Initial weight x $92/100 lb.
[b]9% interest rate.
[c]Health costs = implants, fly tags, antibiotics, etc.
[d]Receiving = 28 days at $.74/day; stalk grazing = 98 days at $.12/day; alfalfa = 76 days at $.3/day; yardage = 174 days at $.10/day.
[e]Supplement = 174 days at $.12/day; 1.5 lb/day (as fed).
[f]Grazing costs = $.35/hd/day summer pasture; $.35/hd/day fall pasture & $.25/day supplement.
[g]Yardage cost $.30/hd/day.
[h]Average diet cost = $.0467/day (DM) and 9% interest for 1/2 of feed.
[i]Total costs includes 2% death loss for each system.
[j]Calculated from hot carcass weight adjusted for 62% dressing percentage.
[k]Trucking cost to Sandhills range would increase breakeven ($/100 lb) by $.0019/mile.
[l]Breakeven calculated using five year average corn price = $2.36/bu.
[mn]Means in the same row with different superscripts differ (P < .05).
[p]Breakeven calculated using 1996 corn price = $4.50/bu.

< .0001), -.53 (P < .05), and .27 (P > .30), respectively, indicating summer grazing gain or combined summer and fall grazing gain had the most effect on breakeven cost.

Gains for cattle on the red clover/ bromegrass and bromegrass, warm- season grass treatments were lower than anticipated. Previous research (1996 Nebraska Beef Report, pp 48-51) indicated summer grazing gains can be improved when cattle have access to alternative forages, such as inter-seeded red clover or warm- season grasses, during July and August when the quality and quantity of bromegrass is low. However, in the current trial, the loss of red clover plants in the bromegrass pasture combined with inadequate moisture for warm-season grasses probably reduced gains.

Transporting cattle to warm-season grasses to optimize forage quality, rather than developing warm-season pastures, is economical as evidenced by the Sandhills range treatments (Treatments 5, 6 & 7). The stress and body weight shrink associated with transporting the steers did not negatively influence weight gain. The transportation costs associated with the Sandhills range treatments would increase breakeven cost by $.95/100 lb resulting in no change in ranking of breakeven costs among treatments.

Breakeven values at slaughter reflect the final weight in each system. Further, the final weight for each system was influenced by the amount of gain achieved during the summer grazing period. Systems with a higher gain during the summer grazing period maintained a high rate of gain during the finishing period. Forages that maximize summer grazing gain, when grazing cost is fixed, result in a lower cost of gain. Therefore, cattle entering the feedlot at a heavier weight and having achieved a low summer cost of gain maintained their weight advantage through the finishing period, resulting in heavier final weights and lower breakeven values.

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[1]Drew Shain, Mark Klemesrud, research technicians, Terry Klopfenstein, Professor, Rick Stock, former Professor, Animal Science, Lincoln,

Synchronizing Micotil Treatment with Time of Sickness in Newly Received Calves

Mark Klemesrud
Michelle Apfel
Terry Klopfenstein
Gene White[1]

Mass treatment with Micotil® 300 of newly received feeder cattle susceptible to bovine respiratory disease can be an effective means of reducing animal morbidity and increasing animal intakes and gains.

Summary

A trial was conducted to evaluate treatment with Micotil® 300 on health and performance of newly received feeder cattle. Treatments included an untreated control, mass Micotil® treatment on arrival, mass Micotil® treatment on day six, and Micotil® treatment on day six based on internal body temperature. Calves mass treated with Micotil® either on arrival or day six had greater dry matter intakes, greater average daily gains, and reduced incidence of bovine respiratory disease. Treating animals on day six based on body temperature identified a greater incidence of sickness than visual observation alone.

Introduction

Bovine Respiratory Disease Complex (BRD) is the most commonly occurring disease problem in feedlot cattle. Stress factors, such as weaning, castration, dehorning, transportation, processing, feed changes, and weather changes create situations where cattle, especially calves, are susceptible to viral and bacterial organisms associated with BRD.

Direct losses due to BRD include those associated with morbidity and mortality. However, indirect losses, including reduced performance, are equally important. While reducing stress factors may aid in managing BRD problems, antibiotic therapy is often necessary to combat BRD. Micotil® 300 is an effective antibiotic treatment for BRD.

Treatment with Micotil® 300 has been shown to be effective in reducing the incidence of BRD in newly received feedlot cattle, but mass treatment of all calves may not be cost effective (1995 Nebraska Beef Report, pp.38-41.). Additionally, calves may not become sick at arrival but at some point after arrival. Thus, the timing of antibiotic administration may be equally important in the control of BRD.

The objective of this research was to synchronize Micotil® treatment with time of sickness in newly received calves. Additionally, determining sickness of animals based on internal body temperature was evaluated as an alternative to mass treatment.

Procedure

Nine hundred fifty-two steer calves (495 lb) received at the Agricultural Research and Development Center (ARDC) Ithaca, NE during the fall of 1995 were blocked by load into 14 replications. Calves were obtained both directly from ranches and from sale barns and represented those typically available to Nebraska cattle feeders.

Calves received in the morning were processed upon arrival without access to feed or water. Calves received in the afternoon were given access to grass hay and water overnight and processed the following morning. When processed, all calves were vaccinated for IBR, BVD, PI_3, BRSV, and Haemophilus Somnus, treated for internal parasites, and tagged with two identification ear tags. In addition, the weight of each animal was recorded.

Calves were assigned randomly to treatment at processing; every fourth calf through the chute was assigned the same treatment. The four treatments included an untreated control, mass Micotil® treatment on arrival, mass Micotil® treatment on day six, and Micotil® treatment on day six based on an internal body temperature greater than 103.5°F. Mass treated calves received 8 ml Micotil® 300.

Six groups of calves representing 546 total head were penned by treatment for determination of dry matter intake. Due to a limited number of pens, the remaining eight groups of calves were penned by combining the untreated control calves with calves mass treated on arrival, and calves mass treated on day six with calves that were treated on day six based on body temperature. Dry matter intake for combined treatments could not be determined.

All calves were observed daily for sickness. Those suspected of illness were pulled and checked for fever via rectal thermometer. Animals were treated if their internal body temperature exceeded 103.5°F. Animals treated

Table 1. Effect of Micotil® 300 treatments on receiving health and performance.

Item	Treatment			
	Control	Mass Day-0	Mass Day-6	Temp Day-6
Total head/treatment	251	248	228	225
Daily gain, lb	1.62[c]	1.80[d]	1.81[d]	1.62[c]
Feed intake, lb/day[a]	10.78[c]	11.14[d]	11.20[d]	11.07[cd]
Number of cattle treated[b]	56[d]	32[c]	32[c]	80[e]
Number of dead cattle	3	1	2	1

[a]Feed intakes are for 6 of the 14 replications.
[b]Temp D-6 includes 41 animals treated due to elevated temperature on day 6.
[c,d,e]Means within a row with unlike superscripts differ (P<.10).

received Micotil® 300 (1.5ml/100 lb body weight) once every three days until body temperature was restored to normal. If health was restored, animals treated with Micotil® from treatments three and four were not remedicated on day six..

Calves were fed a receiving diet containing (DM basis) 50% forage and 50% concentrate for the first ten days of the trial. Following day ten, diets were changed to 65% concentrate, which included 25% corn gluten feed. The receiving trial lasted an average of 24 days. The last five days on trial, animals were limit fed at 2% of estimated body weight for each replication to reduce differences in weight due to fill. Final weights were determined as the average weight of two consecutive days at the completion of the receiving period. Average daily gain, dry matter intake, morbidity, and mortality were the criteria used to evaluate treatments.

Results

Mass treatment with Micotil® 300, either at arrival or on day six, decreased (P<.10) the incidence of BRD in newly received feeder calves (Table 1). This is in agreement with McCoy et al. (1995 Nebraska Beef Cattle Report, pp. 38-41) who found improved health when newly received calves were mass treated with Micotil® 300. Mass treated animals also had improved dry matter intakes (P<.10) and greater daily gains (P<.10) than animals on the Control or Temp Day-6 treatments (Table 1). However, there were no differences between mass treatment at arrival or on day six (P>.40) for average daily gain, dry matter intake, or number of animals treated . Animals treated on day six did have an added labor cost associated with additional processing which animals treated on arrival did not.

Micotil® treatment on day six based on body temperature did not improve dry matter intake or average daily gain compared to the untreated controls. However, treating animals on day six based on internal body temperature did identify more animals with an elevated temperature than visual observation alone (P<.10). While animals were treated if their internal body temperature exceeded 103.5°F, some elevated temperatures may have been due to factors other than BRD. Of the 225 animals from treatment four, 80 required treatment; however, only 41 of them were treated due to an elevated temperature on day six. Visual observation of the 251 control animals identified 56 animals that required treatment.

These results show that mass treatment with Micotil® 300 improved dry matter intake and average daily gain, and effectively reduced the incidence of morbidity due to bovine respiratory disease in newly received calves. Mass treatment at arrival is just as effective as treatment on day six. Treating animals based on internal body temperature can reduce medical costs over mass treatment and identify more sick animals than visual observation alone.

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[1]Mark Klemesrud, Michelle Apfel, research technicians; Terry Klopfenstein, Professor, Animal Science, Lincoln. Gene White, Director, Institutional Animal Care Program, Lincoln.

Digestibility of Dry-Rolled Corn, Wet Corn Gluten Feed, and Alfalfa Hay in Receiving and Finishing Diets

Rob McCoy
Chris Richards
Tony Scott
Rick Stock
Terry Klopfenstein
Dan Herold[1]

Crude protein of wet corn gluten feed is degraded extensively in the rumen. Thus, protein supplementation is an important consideration when feeding wet corn gluten feed, especially in receiving diets.

Summary

Six ruminally-fistulated steers were used to evaluate ruminal metabolism and digestibility of dry-rolled corn, wet corn gluten feed, and alfalfa hay in receiving and finishing diets. In the receiving trial, ruminal digestibility of dry matter, crude protein, and starch was greater for wet corn gluten feed than dry-rolled corn. Apparent total tract digestibility of dry matter was greater for wet corn gluten feed diets

(Continued on next page)

compared with the dry-rolled corn diet. In the finishing trial, wet corn gluten feed increased ruminal pH and total tract fiber digestion.

Introduction

Wet corn gluten feed (WCGF) is an excellent energy source in diets for beef cattle. In forage-based growing diets, inclusion of WCGF supports performance superior to that observed when grain is included, presumably due to a reduction in negative associative effects. In finishing diets, reported energy values of WCGF range from 90 to 120 percent that of dry-rolled corn (DRC).

Wet corn gluten feed is comprised primarily of corn fiber (bran) and a liquid fraction. The liquid fraction contains steep liquor and may include condensed solubles from ethanol production. Compared with DRC, WCGF is much lower in starch (26 vs 72%, DM basis). Reducing dietary starch in finishing diets by replacing DRC with WCGF may reduce subacute acidosis, which may partially explain the higher energy value observed with WCGF. Additionally, WCGF is much higher in NDF (44 vs 12%, DM basis) than DRC. However, the NDF of corn bran is degraded rapidly and extensively in vitro. The CP content of WCGF is also higher than DRC (15 to 20 vs 9%, DM basis), but the majority of CP in WCGF is contributed by the liquid fraction and may be degraded extensively in the rumen.

The objective of these trials was to evaluate ruminal metabolism and digestibility of DRC, WCGF, and alfalfa hay in steers fed receiving and finishing diets.

Procedure

Receiving Trial

Six ruminally-fistulated steers (2 steers/treatment/period; 3 periods) were fed dietary treatments based on concentrate energy source (DRC or WCGF). Two sources of WCGF (WCGF1, Minnesota Corn Processors, Columbus, NE and WCGF2, Cargill, Eddyville, IA) were evaluated. Wet corn gluten feeds differed in the approximate proportions of bran to liquid (WCGF1, 70% bran:30% liquid, DM basis; WCGF2, 50% bran:50% liquid, DM basis). The DRC diet contained (DM basis) 45% alfalfa hay, 47.39% DRC, 6.09% molasses, .73% urea, and .79% vitamins and minerals. The WCGF diets contained (DM basis) 45% alfalfa hay, 54.39% WCGF and .61% vitamins and minerals. Diets were formulated to meet the degradable intake protein requirement (TDN×.13) and for a minimum of .7% Ca, .35% P, and 1.3% K. Steers were fed 12 equal portions daily (2-h intervals) and had ad libitum access to water. Feed allotment was such that feed intake was as close to ad libitum as possible.

Each period was 14 days — day one to nine for diet adaptation and day 10 to 14 for marker dosing, sample collection, and in situ incubation. Samples of ruminal fluid and contents were collected at 0, 4, 8, 16, and 24 hours after dosing. Fecal grab samples were collected at 24, 36, 48, 60, 72, 84, and 96 hours after dosing.

Ruminal fluid samples were analyzed for NH_3-N and VFA. Subsamples of each fecal sample were composited by steer, within period, for total tract digestibility calculations. Ruminal passage rates of DRC, WCGF1, WCGF2, and alfalfa hay were estimated from marker concentrations. Dry-rolled corn, WCGF1, and WCGF2 were marked with ytterbium and alfalfa hay was marked with erbium.

For in situ incubation, DRC was sieved to remove whole kernels and fine particles. Alfalfa hay was ground to pass through a 2-mm screen. Wet corn gluten feeds were incubated in the same form as they were fed. Approximately 5 g (DM basis) of material was placed into each polyester in situ bag. Bags were incubated for 0, 4, 8, 16, 24, 36, and 72 hours. Alfalfa hay was incubated in each steer; DRC and the WCGF were incubated in steers fed their corresponding dietary treatment. Following incubation, bags were removed, rinsed thoroughly, dried, and weighed. Samples were analyzed for CP, NDF, and starch to estimate rate of disappearance and ruminal digestibility. Ruminal digestibility (%) of DM, CP, NDF, and starch for each feedstuff was calculated using the following equation:

$$100 - ((k_p/(k_p + k_d)) \times (\% \text{ of original remaining after 0-hour wash}))$$

where k_p = rate of passage and k_d = rate of disappearance. Estimates were made using rates of passage determined from both ruminal and fecal samples. Diet and fecal samples were used to estimate total tract diet digestibility, with indigestible ADF used as an internal diet flow marker.

Finishing Trial

Steers used in the receiving trial were also used in the finishing trial (2 steers/treatment/period; 3 periods). Dietary treatments were based on concentrate energy source (DRC, DRC/WCGF, or WCGF). Wet corn gluten feed was produced by Minnesota Corn Processors, Columbus, NE. The DRC diet contained 83.08% DRC, 6.09% molasses, 7.5% alfalfa hay, 1.09% urea, and 2.24% vitamins and minerals. The DRC/WCGF diet contained 45.19% each of DRC and WCGF, 7.5% alfalfa hay, and 2.12% vitamins and minerals. The WCGF diet contained 89.89% WCGF, 7.5% alfalfa hay, and 2.61% vitamins and minerals. Diets were formulated to meet the degradable intake protein requirement (TDN × .081) and for a minimum of .7% Ca, .35% P, and .7% K. Diets contained (DM basis) .25% chromic oxide as a dietary flow marker. Feeding protocol was the same as described for the receiving trial.

Each period was 21 days — day one to nine for diet adaptation and day 10 to 21 for marker dosing, sample collection, and in situ incubation. A third week was necessary because DRC and WCGF were labeled with the same marker, thus it was not possible to estimate rate of passage of these feedstuffs simultaneously. Sampling and analysis of rumen fluid, rumen contents, and fecal samples were the same as described for the receiving trial.

In situ incubation protocol was the same as described for the receiving trial. During the second week, DRC was incubated in steers fed DRC, and WCGF was incubated in steers fed DRC/WCGF and WCGF. During the third week, DRC was incubated in steers fed DRC and DRC/WCGF. Sample analysis and calculation of ruminal digestibility were the same as described for the receiving trial. Diet and fecal samples were used to estimate total tract diet digestibility, with Cr used as a diet flow marker.

Results

Receiving Trial

Dry matter intakes were not different ($P > .10$) among treatments (Table 1). Experimental variation associated with ruminal passage estimates was lower with fecal samples compared with ruminal contents samples, thus only estimates using fecal samples are reported. Ruminal passage rates of both WCGF were faster ($P < .05$) than that of DRC. The faster passage rate of WCGF may be attributable to smaller particle size and(or) increased rumination activity in steers fed diets containing WCGF. Ruminal passage rate of alfalfa was slower ($P < .05$) for the DRC treatment than for either WCGF treatment. Again, rumination activity may have been greater in steers fed WCGF, resulting in more rapid particle size reduction and increased rates of passage. Ruminal pH and ruminal concentrations of NH_3-N, acetate, propionate, butyrate, and total VFA were not different ($P > .10$) among treatments (data not shown).

Rate of DM disappearance was faster ($P < .10$) for WCGF2 compared with DRC or WCGF1 (Table 1). Rates of CP and starch disappearance were fastest for WCGF2, intermediate for WCGF1, and slowest for DRC ($P < .10$). Nitrogenous compounds in WCGF are associated primarily with the liquid fraction, rather than the bran. Because the majority of CP in WCGF was solubilized during the 0-hour wash, presence of the soluble fraction cannot explain the more rapid rates of CP disappearance observed with WCGF. However, residual protein or starch associated with the bran fraction may be more susceptible to microbial degradation compared with starch and protein within the starch-protein matrix of corn. This would contribute to a more rapid rate of CP and starch disappearance. Rate of NDF disappearance was not different ($P > .10$) among concentrates. Rates of DM, CP, NDF, and starch disappearance of alfalfa were not different ($P > .10$) among treatments.

Ruminal digestibility of DM, CP, and starch was highest for WCGF2, intermediate for WCGF1, and lowest for DRC ($P < .10$; Table 2). We estimated that approximately 30 and 50 percent of the DM in WCGF1 and WCGF2, respectively, may have originated from the liquid fraction. These

(Continued on next page)

Table 1. Effect of dietary treatment on DMI, ruminal digesta passage, and rates of DM, CP, NDF, and starch disappearance in concentrate or alfalfa - Receiving Trial.

Item	DRC[a]	WCGF1[a]	WCGF2[a]
DMI, lb	21.8	22.5	23.4
Ruminal passage, %/hour			
Concentrate	4.9[b]	6.0[c]	5.8[c]
Alfalfa	3.9[b]	4.5[c]	4.4[c]
DM rate of disappearance, %/hour			
Concentrate	3.71[b]	4.05[b]	5.62[c]
Alfalfa	6.96	6.08	7.41
CP rate of disappearance, %/hour			
Concentrate	3.37[b]	5.55[c]	6.87[d]
Alfalfa	2.96	2.57	2.89
NDF rate of disappearance, %/hour			
Concentrate	3.20	3.07	3.78
Alfalfa	6.48	5.65	6.81
Starch rate of disappearance, %/hour			
Concentrate	4.63[b]	9.19[c]	11.27[d]
Alfalfa	2.58	2.42	2.63

[a]DRC = dry-rolled corn; WCGF1 = Minnesota Corn Processors, Columbus, NE; WCGF2 = Cargill, Eddyville, IA.
[b,c,d]Means within a row with unlike superscripts differ ($P < .05$).

Table 2. Effect of dietary treatment on ruminal digestibility of DM, CP, NDF, and starch in concentrate or alfalfa and apparent total tract digestibility - Receiving Trial.

Item	DRC[a]	WCGF1[a]	WCGF2[a]
Ruminal digestibility, %			
DM			
Concentrate	43.7[b]	59.2[c]	78.1[d]
Alfalfa	73.3[b]	68.2[c]	71.6[bc]
CP			
Concentrate	47.9[b]	81.6[c]	86.7[d]
Alfalfa	67.8[b]	62.8[c]	63.1[c]
NDF			
Concentrate	39.2[b]	33.8[c]	38.7[b]
Alfalfa	62.6[b]	55.9[c]	59.8[bc]
Starch			
Concentrate	43.9[b]	73.6[c]	88.8[d]
Alfalfa	62.1	59.6	62.5
Apparent total tract digestibility, %			
DM	56.0[b]	66.4[c]	64.5[c]
CP	49.5[b]	63.4[c]	59.5[bc]
NDF	65.7[b]	73.3[c]	69.3[bc]
Starch	67.1[b]	89.7[c]	86.5[c]

[a]DRC = dry-rolled corn; WCGF1 = Minnesota Corn Processors, Columbus, NE; WCGF2 = Cargill, Eddyville, IA.
[b,c,d]Means within a row with unlike superscripts differ ($P < .10$).

Table 3. Effect of dietary treatment on DMI, ruminal digesta passage, ruminal pH, and rates of DM, CP, NDF, and starch disappearance in DRC, WCGF, and alfalfa - Finishing Trial.

Item	DRC[a]	DRC/WCGF[a]	WCGF[a]
DMI, lb[bc]	16.3	20.5	18.7
Ruminal passage, %/hour			
DRC[d]	1.9	4.2	--
WCGF	--	5.2	5.4
Alfalfa	2.7	5.7	4.4
Ruminal pH[e]	5.49	5.71	5.77
DM rate of disappearance, %/hour			
DRC[d]	2.73	4.04	--
WCGF	--	2.56	2.71
Alfalfa[c]	2.75	5.03	5.25
CP rate of disappearance, %/hour			
DRC	1.96	2.31	--
WCGF	--	5.25	5.38
Alfalfa[f]	2.22	2.75	1.68
NDF rate of disappearance, %/hour			
DRC[d]	1.25	3.23	--
WCGF	--	1.39	1.56
Alfalfa	3.04	4.25	4.53
Starch rate of disappearance, %/hour			
DRC[d]	3.02	4.54	--
WCGF	--	9.07	8.82
Alfalfa	1.83	2.00	2.05

[a]DRC = dry-rolled corn; WCGF = wet corn gluten feed.
[b]Quadratic effect ($P < .05$).
[c]Linear effect ($P < .10$).
[d] 0 vs 50% ($P < .01$).
[e]Linear effect ($P < .05$).
[f]Quadratic effect ($P < .10$).

Table 4. Effect of dietary treatment on ruminal digestibility of DM, CP, NDF, and starch in DRC, WCGF or alfalfa and apparent total tract digestibility - Finishing Trial.

Item	DRC[a]	DRC/WCGF[a]	WCGF[a]
Ruminal digestibility, %			
DM			
DRC	52.2	49.3	--
WCGF	--	57.7	58.2
Alfalfa	74.5	59.5	66.0
CP			
DRC	40.7	38.8	--
WCGF	--	81.4	83.2
Alfalfa	59.7	54.7	53.2
NDF			
DRC	34.0	40.4	--
WCGF	--	16.6	18.9
Alfalfa	63.5	42.2	49.0
Starch			
DRC	52.2	47.9	--
WCGF	--	NE[b]	79.1
Alfalfa	75.6	66.2	69.7
Apparent total tract digestibility, %			
DM[cd]	83.4	77.7	79.7
CP	73.4	71.6	75.3
NDF[e]	61.8	66.2	73.6
Starch[f]	93.2	87.8	96.1

[a]DRC = dry-rolled corn; WCGF = wet corn gluten feed.
[b]NE = no estimate.
[c]Quadratic effect ($P < .05$).
[d]Linear effect ($P < .10$).
[e]Linear effect ($P < .01$).
[f]Quadratic effect ($P < .01$).

values are similar to the amount of DM solubilized during the 0-hour wash. Because the liquid fraction is soluble, it may be extensively digested in the rumen. Therefore, presence of the liquid fraction may contribute to the higher digestibilities estimated for WCGF. Ruminal digestibility of NDF in concentrate was higher ($P < .10$) for DRC and WCGF2 than for WCGF1. There is no clear explanation for the lower digestibility of NDF in WCGF1 compared with DRC and WCGF2.

Ruminal digestibility of DM in alfalfa was highest for calves fed DRC, intermediate for calves fed WCGF2, and lowest for calves fed WCGF1 ($P < .10$). Ruminal digestibility of NDF in alfalfa was highest for calves fed DRC, intermediate for calves fed WCGF2, and lowest for calves fed WCGF1 ($P < .10$). Ruminal digestibility of CP in alfalfa was higher ($P < .10$) for steers fed DRC compared with steers fed WCGF1 or WCGF2. The explanation for these observations is not clear. Ruminal digestibility of starch in alfalfa was not different ($P > .10$) among treatments.

Apparent total tract digestibility of DM and starch was higher ($P < .10$) for WCGF diets compared with the DRC diet (Table 2). Total tract digestibility of NDF was higher ($P < .10$) for WCGF1 compared with DRC, with NDF digestibility of WCGF2 being intermediate ($P > .10$) to WCGF1 and DRC. Apparent total tract digestibility of CP was higher ($P < .10$) for WCGF1 compared with DRC, with CP digestibility of WCGF2 being intermediate ($P > .10$) to WCGF1 and DRC.

Finishing Trial

Dry matter intake increased (quadratic, $P < .05$; linear, $P < .10$; Table 3) with inclusion of WCGF. Rate of passage for DRC was slower ($P < .01$) for the DRC diet compared with the DRC/WCGF diet. This may be due, in part, to lower DMI. Rates of passage for WCGF and alfalfa were not affected ($P > .10$) by dietary treatment.

Ruminal pH (linear, $P < .05$) increased with inclusion of WCGF. Additionally, concentrations of acetate

(linear, $P < .05$) and butyrate (linear, $P < .01$) increased with inclusion of WCGF, while concentration of propionate decreased (linear, $P < .05$; data not shown). Total VFA concentration and ruminal concentration of NH_3-N were not affected by dietary treatment ($P > .10$; data not shown).

Increasing dietary WCGF had no effect ($P > .10$) on rate of disappearance for DM, CP, NDF, or starch of WCGF (Table 3). Rate of disappearance for DM, NDF, and starch of DRC was faster ($P < .01$) for the DRC/WCGF diet compared with DRC diet. Rate of disappearance for DM of alfalfa increased (linear, $P < .10$) with WCGF. Rate of disappearance for CP of alfalfa responded quadratically ($P < .10$) to WCGF addition. Rates of disappearance for NDF and starch of alfalfa were not affected ($P > .10$) by dietary treatment.

No differences ($P > .10$) in ruminal digestibility of DM, CP, NDF, or starch were observed for DRC, WCGF, or alfalfa (Table 4). Apparent total tract digestibility of DM was 83.4% for the DRC diet, 77.7% for the DRC/WCGF diet, and 79.7% for the WCGF diet (quadratic, $P < .05$; linear, $P < .10$; Table 4). Total tract digestibility of NDF increased (linear, $P < .01$) with WCGF. A quadratic ($P < .01$) response was observed for apparent total tract digestibility of starch. Apparent total tract digestibility of CP was not affected by dietary treatment.

Results of this research indicate that WCGF, whether fed in receiving or finishing diets, is digested extensively in the rumen. With receiving diets, replacing DRC with WCGF may increase total tract digestibility of DM, resulting in improved feed efficiency. In finishing diets, inclusion of WCGF increased ruminal pH. As a result, the efficiency of microbial protein synthesis may increase, potentially offsetting the need for escape protein supplementation when WCGF replaces DRC.

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[1]Rob McCoy, Chris Richards, and Tony Scott, graduate students; Rick Stock, former Professor; Terry Klopfenstein, Professor; Dan Herold, research technician, Animal Science, Lincoln.

Lysine Requirements for Feedlot Cattle

Mark Klemesrud
Terry Klopfenstein
Austin Lewis
Rick Stock[1]

Feedlot diets low in ruminal escape protein may be deficient in metabolizable lysine, especially early in the feeding period. Addition of rumen-protected lysine can improve feedlot gain and efficiency.

Summary

Sixty steer calves individually fed incremental levels of rumen-protected lysine were used to determine the lysine requirement for feedlot cattle. Treatments contained either rumen-protected lysine and methionine, or methionine alone. Addition of lysine and methionine improved gains, intakes and efficiency ($P < .1$) during the first 56 days. There was no response to methionine alone ($P > .3$), suggesting that lysine was the first limiting amino acid. The predicted lysine flow for the control diet was 55.4 g/day. Steers supplemented with 3-4 g/day lysine had the greatest gains, predicting a requirement of 58.4 g/day or 5.58 percent of the metabolizable protein.

Introduction

Many large frame calves are being fed high concentrate finishing diets immediately after weaning without a growing period. These calves are commonly fed for 160 to 200 days before being slaughtered. During this time calves make rapid gains, depositing a high percentage of protein, especially early in the feeding period. Protein requirements early in the feeding period would be expected to be high.

Feeding wet corn gluten feed (WCGF) has markedly increased in the Midwest as corn syrup and ethanol production have increased. Although a good source of crude protein, most is degradable, making WCGF a poor source of escape protein. While the escape value of dry corn protein is high, high moisture corn protein is more degradable, having only two-thirds the escape value of dry corn.

Because of their lower escape protein values, we hypothesize that calves finished on WCGF and/or high moisture corn would be deficient in metabolizable protein. Furthermore, because of the low lysine content in corn protein, we predict lysine to be the first limiting amino acid. Supplementing WCGF/high moisture corn diets with rumen-protected lysine should improve finishing performance of large-framed calves.

Procedure

A calf growth trial was conducted using 60 large frame size crossbred steer calves (522 lb) with a high potential for growth. Calves were individually fed ad libitum once daily using Calan electronic gates. The diet consisted of (DM basis) 45% WCGF, 22.5% high moisture corn, 20% dry rolled corn, 5% corn silage, 5% alfalfa hay, and 2.5% supplement (Table 1). Diets were formulated to contain a minimum of 12% crude protein, 0.7% calcium, 0.35% phosphorus, 0.7% potassium and 7.5% roughage.

Supplements were combined at feeding to achieve our ten treatments, which varied in amount of supplemental rumen-protected lysine and methionine fed. Supplements were fed to supply 0, 1, 2, 3, 4, 6, 8, 10, and 12 grams per day of rumen-protected lysine hydrochloride. The protected lysine, supplied as Smartamine ML™, contained both lysine and methionine. To determine the response due to lysine, a rumen-protected methionine control was

(Continued on next page)

Table 1. Supplement composition (% dry matter basis).

Ingredient	0 g lysine, 0 g methionine[a]	12 g lysine, 3.6 g methionine[a]	0 g lysine, 3.6 g methionine
Limestone	59.52	59.52	59.52
Ground corn	23.72	12.28	21.27
Salt	12.00	12.00	12.00
Trace mineral premix	.80	.80	.80
Vitamin premix	.40	.40	.40
Monensin	.64	.64	.64
Tylosin	.44	.44	.44
Thiamin premix	.24	.24	.24
Copper oxide	.24	.24	.24
Tallow	2.00	2.00	2.00
Smartamine ML™		11.44	
Smartamine M™			2.45

[a]Supplements mixed to supply 0, 1, 2, 3, 4, 6, 8, 10, and 12 of lysine with 0, .3, .6, .9, 1.2, 1.8, 2.4, 3.0, and 3.6 g of methionine, respectively.

Table 2. Performance of finishing steer calves, days 0 - 56

Lysine level	Daily gain, lb[a]	Dry matter intake, lb/day[a]	Feed/gain
0 (control)	4.58	22.0	4.8
1	4.95	21.6	4.4
2	4.80	21.8	4.5
3	5.21	22.9	4.4
4	5.26	24.0	4.6
6	5.10	22.4	4.4
8	5.06	23.1	4.6
10	5.21	23.1	4.4
12	4.51	21.8	4.8
0 (methionine)	4.58	21.3	4.7

[a]Quadratic response to supplemental lysine, P < .10.

Table 3. Performance of finishing steer calves, days 0 - 161.

Lysine level	Daily gain, lb[a]	Dry matter intake, lb/day	Feed/gain
0 (control)	3.85	20.3	5.3
1	3.86	19.6	5.1
2	3.81	19.0	5.0
3	4.23	21.1	5.0
4	4.34	21.9	5.1
6	3.99	21.2	5.3
8	4.04	21.0	5.2
10	4.16	21.5	5.2
12	3.73	19.8	5.3
0 (methionine)	3.82	20.1	5.3

[a]Quadratic response to supplemental lysine, P < .10.

Table 4. Amino acids in abomasal contents, predicted dietary supply and predicted NRC requirements.

Amino acid	Abomasal, % of CP	Supply, g/day[a]	Predicted NRC requirement (g/day)
ARG	5.43	56.7	62.4
HIS	2.27	23.8	23.4
ILE	3.76	39.3	26.9
LEU	9.34	97.6	63.4
LYS	5.30	55.4	60.3
MET	1.54	16.1	18.6
PHE	4.37	45.7	33.4
VAL	4.88	51.0	38.1
THR	4.68	48.9	36.9

[a]Based on a calculated metabolizable protein flow of 1045 g/day.

included. Supplements also supplied 240 mg Rumensin, 80 mg Tylan and 50 mg thiamine daily.

Steers were randomly assigned to treatment, with ten steers assigned to the zero lysine control, ten steers assigned to the methionine control, and five steers assigned to each of the other eight treatments. Before the start of the trial, steers were limit fed 12 lb (dry-matter) daily of a 50% corn silage, 50% alfalfa hay diet to reduce weight differences due to fill. Steers were implanted with Revalor-S at the start of trial and on day 84 of the 161-day trial. Steers were fed the final finishing diet from day 1 of the trial by limit feeding 12 lb/day (dry-matter) of the final diet and increasing the amount offered by 1 lb (dry-matter) daily until animals were offered ad libitum amounts of feed. Feed refusals were collected and weighed every three days to keep feed fresh and bunks clean.

Animals were weighed before feeding on three consecutive days at the beginning of the trial and on days 56, 84, 112, and 161. Average daily gain, dry matter intake and feed/gain were calculated for all periods of the trial and plotted using the slope ratio technique. At the conclusion of the trial animals were slaughtered. Carcass characteristics including fat depth, quality grade, and yield grade were measured.

Metabolizable protein flow for steers on the finishing diet was predicted using the NRC model (1996 Nutrient Requirements of Beef Cattle) for ruminant protein metabolism. Amino acid composition of the metabolizable protein was determined in a separate metabolism trial. Abomasal contents were collected following slaughter of four steers fed the control finishing diet for 14 days. Contents were freeze dried and analyzed for amino acid composition. Flow of metabolizable amino acids was calculated by multiplying the abomasal amino acid composition as a percentage of the protein by the predicted metabolizable protein flow. These calculated supplies of amino acids were compared to requirements estimated using level 2 of the NRC model (1996 Nutrient Requirements of Beef Cattle).

Results

Steers responded to rumen-protected lysine during the first 56 days on feed (Table 2). However, gains, intakes, and feed conversions were equal for the control and the methionine supplemented cattle, suggesting that the response was due to lysine, not methionine. Gains, intakes and feed conversions were all improved in a quadratic manner ($P < .10$). Gains were maximized at the three and four gram supplementation level. Steers supplemented with three grams of lysine had an increased gain above the control of .63 lb per day, or an improvement of 13.7 percent. Higher levels of lysine supplementation were less effective at improving gain and feed efficiency, suggesting a true quadratic response. Non-linear analysis comparing gain to supplemental lysine intake predicted a supplemental lysine requirement of 2.9 g/day to achieve a maximum gain of 5.1 lb.

During no periods following the first 56 days did lysine supplementation improve animal performance. However, for the entire trial, lysine supplementation quadratically improved gain ($P < .10$) over the control (Table 3). Cattle supplemented with three and four grams of lysine gained 37 lb more than the controls during the first 56 days. By the end of the trial, these steers had a weight advantage of 68 lb or a ten percent improvement in gain compared to the controls. Any weight advantage obtained during the first 56 days was more than maintained throughout the feeding period. Carcass characteristics were similar ($P > .3$) for treatments.

The NRC model predicted a daily metabolizable protein flow of 1045 g for steers consuming the control diet and gaining 5.1 lb, the maximum gain determined using non-linear analysis. Based on an abomasal lysine content of 5.30% (Table 4), our predicted lysine flow for the control diet was 55.4 g. Three g of supplemental lysine would increase the lysine flow to 58.4 g which is similar to the NRC calculated requirement of 60.3 g. A lysine flow of 58.4 g would correspond to 5.58 percent of the metabolizable protein. While the predicted flow of lysine, methionine, and arginine was less than their calculated requirement (Table 4), a response to lysine would suggest lysine to be first limiting, and the animals requirement for the other amino acids to be met.

Feedlot diets containing high levels of WCGF and high moisture corn may be deficient in metabolizable lysine. Supplementing rumen escape lysine can improve performance of feedlot cattle, especially early in the feeding period. Our predicted metabolizable lysine requirement for steer calves gaining 5.1 lb/day would be 58.4 g/day or 5.58 percent of the metabolizable protein requirement.

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[1]Mark Klemesrud, research technician; Terry Klopfenstein, Austin Lewis, Professors; Rick Stock, former Professor, Animal Science, Lincoln.

Effect of Dried Poultry Waste on Performance of Finishing Yearling Steers

Daniel Herold
Dale Downs
Terry Klopfenstein
Mark Klemesrud[1]

Feeding dried poultry waste is an effective means of supplementing dry-rolled corn finishing diets by providing a portion of the dietary degradable protein and minerals necessary to meet animal requirements.

Summary

Two trials evaluated dried poultry waste (DPW) as a source of rumen degradable protein for finishing steers. In Trial 1, diets were supplemented with DPW or urea to provide equal amounts of degradable protein. In Trial 2, dietary DPW inclusion was based on its mineral content rather than its degradable protein contribution. In both trials, high levels of dietary DPW diminished ADG and feed efficiency. However, animal performance obtained with lower levels of DPW did not differ from urea or control treatments. Results indicate DPW is an effective means of supplementing both rumen degradable protein and minerals in finishing diets.

Introduction

Dry-rolled corn finishing diets can be deficient in ruminally degradable

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intake protein (DIP), limiting synthesis and growth of rumen bacteria, and diminishing both carbohydrate fermentation and microbial protein flow to the small intestine. Although the protein in corn is known to be extensively digested in the total digestive tract, approximately 60 percent of the CP in dry-rolled corn escapes ruminal degradation in finishing diets. These diets should be supplemented with a source of ruminally available nitrogen, thereby enhancing microbial activity, DM digestibility, and consequently, animal performance.

Supplementation of finishing diets with DIP can be achieved with nonprotein nitrogen. Urea provides ruminally available ammonia for microbial protein synthesis, and constitutes an economical alternative to sources of natural protein. Dried poultry waste (DPW) contains uric acid which can serve as a source of ammonia in a manner similar to urea. Although DPW (4.5% N) is lower in CP than urea (46% N), research indicates that it is a viable alternative to urea for DIP supplementation (1996 Nebraska Beef Report, pp. 31-33).

The objectives of this research were to evaluate DPW as a source of DIP and minerals for finishing cattle, and assess how dietary levels of DPW influence dry matter intake and performance.

Procedure

Trial 1

One hundred sixty yearling steers (725 lb) were used to evaluate DPW as a source of DIP relative to urea in a 155-day finishing trial. Cattle were adapted to grain in 21 days using common adaptation diets containing 7.2% of the DM as DPW. Adaptation diets contained 45, 35, 25, and 15% roughage (DM basis) and were fed for 3, 4, 7, and 7 days, respectively. Following the grain adaptation period, steers were blocked by weight and assigned randomly to one of five treatments in a 2 x 2 plus 1 factorial treatment arrangement. Four pens were used for each treatment, each containing eight steers. Dietary DIP levels varied with additions of urea or DPW to a control diet that contained no supplemental DIP. Treatments consisted of: 1) Control 3.7% DIP, 2) Urea 6.5% DIP, 3) Urea 7.8% DIP, 4) DPW 6.5% DIP, and 5) DPW 7.8% DIP. The DIP requirement was estimated to be about 6.8 percent of diet dry matter. The 6.5 percent level was designed to be below the requirement and the 7.8 percent level was designed to be somewhat in excess of the requirement.

Diet DM consisted of 7.5 percent roughage (50% alfalfa hay, 50% corn silage), and 65 to 75 percent dry-rolled corn depending on DPW inclusion (Table 1). All diets contained 25 g/ton Rumensin, 10 g/ton Tylan, supplemental vitamins A, D, and E, and trace minerals. Dietary CP ranged from 8.0 percent (control) to 12.0 percent (7.8% DIP treatments). Control and urea diets were balanced to provide a minimum of .7% Ca, .35% P, and .7% K. To provide an equal level of supplemental DIP, these mineral levels were exceeded in both the DPW, 6.5% DIP (1.1% Ca, .5% P, .75% K) and DPW, 7.8% DIP (1.5% Ca, .5% P, .85% K) treatments.

Trial 2

One hundred eighty yearling steers (758 lb) were used in this 115-day fin-

Table 1. Composition of diets fed in Trials 1 and 2 (% DM basis).

	Treatment							
	Trial 1					Trial 2		
Item	Control	Urea 6.5% DIP[b]	Urea 7.8% DIP	DPW[a] 6.5% DIP	DPW 7.8% DIP	0% DPW	DPW 3.5% of DM	DPW 7% of DM
Dry-rolled corn	74.9	73.9	72.9	69.2	64.6	73.0	73.0	73.0
Corn silage	5.0	5.0	5.0	5.0	5.0	—	—	—
Alfalfa hay	5.0	5.0	5.0	5.0	5.0	—	—	—
Alfalfa haylage	—	—	—	—	—	10.0	10.0	10.0
Molasses	7.1	7.1	7.1	7.1	7.1	5.0	5.0	5.0
DPW[a]	—	—	—	9.7	14.3	—	3.5	7.0
Urea	—	1.0	1.4	—	—	.5	.2	—
Wheat middlings	—	—	—	—	—	7.8	5.6	2.7
Limestone	1.4	1.3	1.3	—	—	1.3	.4	—
Potassium chloride	.3	.3	.3	—	—	—	—	—
Dicalcium phosphate	.2	.2	.2	—	—	—	—	—
Salt	.2	.2	.2	—	—	.3	.2	.2
Tallow	3.0	3.0	3.0	3.0	3.0	2.0	2.0	2.0
Supplement[c]	2.9	3.0	3.6	1.0	1.0	.1	.1	.1

[a]Dried poultry waste; 30% CP, 9.6% Ca, 2.3% P, 2.5% K, and .63% Na.
[b]Ruminally degradable intake protein.
[c]Contained vitamins, trace minerals, Rumensin 80, and Tylan blended with finely ground corn (Trial 1), or pelleted with wheat middlings (Trial 2).

Table 2. Effect of dried poultry waste and urea supplementation on performance of finishing steers.

	Treatment							
	Trial 1					Trial 2		
Item	Control	Urea 6.5% DIP[b]	Urea 7.8% DIP	DPW[a] 6.5% DIP	DPW 7.8% DIP	0% DPW	DPW 3.5% of DM	DPW 7% of DM
Intake (DM)	25.40	25.22	25.73	24.86	24.81	28.57[c]	28.56[c]	27.43[d]
ADG	3.59[cd]	3.72[cd]	3.80[c]	3.57[d]	3.32[e]	4.40[c]	4.33[c]	4.02[d]
Feed/gain[f]	7.07[c]	6.78[c]	6.77[c]	6.96[c]	7.47[d]	6.49[c]	6.59[cd]	6.82[d]

[a]Dried poultry waste.
[b]Ruminally degradable intake protein.
[c,d,e]Means with unlike superscript within a trial and row differ ($P < .10$).
[f]Analyzed as gain to feed, the reciprocal of feed to gain.

ishing trial. Steers were blocked by weight and assigned randomly, within block, to treatments consisting of 0, 3.5, or 7% DPW (% of diet DM). Six pens provided the mean for each treatment with ten animals per pen. Animals were adapted to grain by the same means used in Trial 1, with the exception that DPW was not included in the adaptation diets. Diets contained (DM basis) 73% dry-rolled corn, 10% alfalfa haylage, and 10% pelleted supplement containing the DPW (Table 1). Wheat middlings were replaced by DPW in the supplement to obtain the desired dietary levels. Diets were balanced to provide 6.9% DIP (12.0% CP), .7% Ca, .35% P, and .7% K, based on contributions from DPW. Urea, limestone, salt, and trace minerals were replaced by nutrients in DPW as dietary levels increased from 0 to 3.5 and 7 percent. In Trial 2, DPW inclusion was based on meeting requirements for both DIP and minerals without contributing excessive ash. Therefore, lower dietary DPW levels were used than in Trial 1, wherein DPW was incorporated to obtain a specific DIP level and provided an excess of Ca, P, and K.

In both Trials 1 and 2, steers were implanted initially with Revalor. Initial weights were the average of two weights obtained on consecutive days before feeding. Final weights were based on hot carcass weights divided by a common 62% dressing percentage. Liver abscess scores and hot carcass weights were taken at slaughter, whereas fat thicknesses at the 12th rib, quality grades, and yield grades were recorded following a 48-hour chill.

Results

In Trial 1, dry matter intake was not significantly different among treatments. However, sorting of the DPW was apparent at the 7.8 percent level of DIP indicating lower diet palatability at high inclusion rates. Cattle assigned to the DPW 7.8 percent DIP treatment exhibited lower ADG ($P < .10$) than those consuming the other four diets (Table 2). However, steers fed the DPW 6.5 percent DIP diet gained similarly to steers fed urea at the same level of DIP. Feed efficiency exhibited by the DPW 7.8 percent DIP treatment was significantly lower than both the control diet and other treatments containing supplemental DIP.

The diminished feed efficiency and ADG associated with the DPW 7.8 percent DIP diet may have resulted from the high level of dietary minerals, especially Ca, contributed by the amount of DPW necessary to reach this level of DIP. Dried poultry waste comprised 14 percent of the diet DM in this treatment, substantially lowering the concentration of dry-rolled corn. Depressed performance may have been due to lower diet NE_g rather than an inability of DPW to sufficiently provide DIP.

In Trial 2, both ADG and dry matter intake were lower when DPW made up 7 percent of the diet DM (Table 2). However, the 3.5 percent DPW treatment was not different than the urea control for either measure ($P > .10$). Feed efficiency was lower at the 7 percent DPW level relative to the control, although the urea control did not differ from the 3.5 percent DPW treatment. Supplements containing DPW were pelleted in this trial to reduce the tendency for sorting that was exhibited in Trial 1. However, orts collected from pens assigned to the 7 percent DPW treatment appeared to have a higher proportion of pellets than was present in the initial diet. Because the pellets were the primary source of dietary DIP, performance of cattle receiving the 7 percent DPW treatment may have been limited by the actual amount of DIP consumed.

Measures of carcass quality, yield, fat depth, and liver abscesses were not negatively influenced by DPW in either of the two trials.

These studies indicate that DPW can be an effective source of both ruminally degraded protein and minerals when included at low levels in dry-rolled corn finishing diets. Supplementing high concentrate diets with DPW to enhance ruminal ammonia concentration may also eliminate the need for some macro-mineral supplementation. When fed at excessive levels, DPW may cause a nutrient imbalance by replacing energy with minerals, diminishing performance and decreasing palatability.

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[1]Daniel Herold and Mark Klemesrud, research technicians; Dale Downs, graduate student; Terry Klopfenstein, Professor, Animal Science, Lincoln.

Wet Corn Gluten Feed as a Source of Rumen Degradable Protein for Finishing Steers

Tony Scott
Terry Klopfenstein
Drew Shain
Mark Klemesrud[1]

Rumen degradable protein supplied by alfalfa, wet corn gluten feed, or corn steep liquor increased efficiency.

Summary

Three hundred twenty steer calves were used to evaluate wet corn gluten feed and steep liquor as degradable intake protein sources relative to soybean meal and to determine the need for rumen degradable protein. The metabolizable protein supplied in the diet was sufficient in all cattle except those fed steep, and all cattle were near or in excess of their degradable protein (includes NPN) requirement. Treatments designed to supply an increasing proportion of degradable intake protein as amino acids and peptides increased efficiency. Wet corn gluten feed provided better daily gain and efficiency than soybean meal. Steep liquor appears to have a higher energy value than corn.

Introduction

Improvements in finishing performance (both daily gain and efficiency) have been reported when high levels (5 to 10% of the diet DM) of soybean meal were fed with low quality roughage as the source of roughages in these high grain diets. According to the 1996 NRC Nutrient Requirements of Beef Cattle, finishing diets containing 5 to 10 % soybean meal contain excess rumen degradable and metabolizable protein. Thus, the response does not appear to be due to a protein deficiency. Replacing dry rolled corn with soybean meal may reduce acidosis resulting in higher feed consumption and greater daily gain. Also, it has been suggested that rumen microbes may require a portion of the degradable intake protein (DIP) in the diet be supplied in the form of amino acids and peptides. This requirement for amino acids and peptides by rumen microbes would not be met by urea or escape protein. Replacing 5 to 10% of the dry-rolled corn with SBM in diets containing urea would supply rumen microbes additional amino acids and peptides in the form of DIP. However, wet corn gluten feed or corn steep liquor may reduce acidosis and supply DIP as amino acids and peptides in the ration at a more economical cost than corn and soybean meal. Additionally, using alfalfa hay as a roughage source was evaluated with the hypothesis that alfalfa would supply more DIP as amino acids and peptides than corncobs. Therefore, the objectives of this research were to determine the need for degradable intake protein in the form of amino acids and peptides in finishing diets and to determine if wet corn gluten feed or corn steep liquor would provide a similar response to soybean meal.

Procedure

Three hundred twenty steer calves (596 lb) were used in a finishing trial. Steers were blocked by weight and randomly assigned, within block, to one of eight pens (10 head/pen). Each pen was randomly assigned to one of eight dietary treatments. Treatments were based on the addition (DM basis) of soybean meal (5.0 or 10.0%), wet corn gluten feed (10.4, 20.8, or 38.2%), or corn steep liquor (10.4%) to a basal diet comprised of dry rolled corn, corncobs, and urea. It should be noted that the steep liquor used in this trial was actually a blend of steep and distiller's solubles. A dry rolled corn diet with alfalfa as the roughage source was also included. Steers were adapted to final finishing diets using four adaptation diets containing (DM basis) 45 (3 days), 35 (7 days), 25 (7 days), and 15% (7 days) roughage.

Diets (Table 1) were formulated to contain a minimum of 11.5% CP, .70% Ca, .30% P, and .65% K, 25 g/ton Rumensin, and 10 g/ton Tylan. Steers were implanted with Revalor-S at the start of the trial and re-implanted with Revalor-S at 90 days. Diets were also formulated to meet the rumen degradable protein requirement (TDN x .081), based on 1996 NRC Nutrient Requirements of Beef Cattle. Steers were finished for an average of 169 days. Final weights were calculated by dividing hot carcass weight by a common dressing percentage (62). Fat thickness at the twelfth rib, quality grade, yield grade, and liver abscess score were recorded.

Results

Treatments designed to supply a higher proportion of DIP as amino acids and peptides tended to increase efficiency (Table 2). All treatments except 5 or 10% soybean meal (SBM) and 10.4% wet corn gluten feed (WCGF) had greater ($P<.10$) daily gains than the control. Feed efficiency was increased ($P<.10$) in all treatments versus the control and 10.4% WCGF, suggesting that amino acids and peptides were deficient in the control diet and as a result limited microbial activity. The 10.4% WCGF diet may not have supplied sufficient amino acids and peptides. Feed efficiency was improved with increasing levels of WCGF in the diet.

Feed efficiency was improved ($P<.10$) by replacing corncobs (DRC/COBS) with alfalfa (DRC/ALF) as the roughage source. However, it can not be determined if the response is solely due to the additional amino acids and peptides supplied by the alfalfa.

Table 1. Diet composition (% DM basis).

	Diet[a]							
Ingredient	DRC/ COBS	DRC/ ALF	5% SBM	10% SBM	10.4% WCGF	20.8% WCGF	38.2% WCGF	10.4% Steep
Dry rolled corn	83.50	83.50	78.50	73.50	73.10	62.70	36.40	78.10
Corncobs	7.50		7.50	7.50	7.50	7.50	7.50	7.50
Alfalfa hay		7.50						
Liquid 32		5.00	5.00	5.00	5.00	5.00	5.00	
Soybean meal			5.00	10.00				
WCGF					10.40	20.80	38.20	
Steep liquor								10.40
Urea	.39	.08	.39	.39	.38	.38		.93
Supplement[b]	3.61	3.92	3.61	3.61	3.62	3.62	4.00	3.07

[a]DRC = dry rolled corn; ALF = alfalfa; SBM = soybean meal; WCGF = wet corn gluten feed.
[b]Includes vitamins, minerals, and feed additives.

Table 2. Effect of DIP source on steer performance.

	Diet[a]							
Item	DRC/ COBS	DRC/ ALF	5% SBM	10% SBM	10.4% WCGF	20.8% WCGF	38.2% WCGF	10.4% Steep
Daily gain, lb	3.36^{b}	3.77^{de}	3.41^{b}	3.49^{bc}	3.49^{bc}	3.78^{de}	3.89^{e}	3.66^{cd}
DM intake, lb/day	19.72^{b}	20.89^{cde}	19.38^{b}	19.58^{b}	20.23^{bc}	21.23^{de}	21.48^{e}	19.55^{b}
Feed/gain[h]	5.88^{b}	5.54^{de}	5.68^{cd}	5.60^{de}	5.80^{bc}	5.61^{de}	5.51^{e}	5.34^{f}
Quality grade[i]	18.5^{de}	18.6^{de}	18.0^{b}	18.2^{bc}	18.8^{ef}	18.4^{cd}	19.0^{fg}	18.6^{de}
Yield grade	2.30^{bc}	2.58^{def}	2.35^{bcd}	2.25^{b}	2.61^{efg}	2.77^{fg}	2.80^{g}	2.51^{cde}
Fat thickness, in	$.43^{b}$	$.49^{cde}$	$.44^{bc}$	$.45^{bc}$	$.51^{de}$	$.52^{de}$	$.53^{e}$	$.47^{bcd}$

[a]DRC = dry rolled corn; ALF = alfalfa; SBM = soybean meal; WCGF = wet corn gluten feed.
[b,c,d,e,f,g]Means within a row with unlike superscripts differ (P<.10).
[h]Feed/gain analyzed as gain/feed. Feed/gain is the reciprocal of gain/feed.
[i]18 = high Select; 19 = low Choice.

Table 3. Protein requirements, supplies, and balances.

	Diet[a]							
Item	DRC/ COBS	DRC/ ALF	5% SBM	10% SBM	10.4% WCGF	20.8% WCGF	38.2% WCGF	10.4% Steep
MP[b] requirement, g/d	729.0	779.0	739.0	751.0	750.0	791.0	809.3	766.8
MP supply, diet g/d	743.8	803.5	767.8	813.8	772.8	821.0	872.3	715.0
DIP balance, g/d[cd]	-2.5	17.5	111.8	260.0	106.0	227.5	0	166.5
Peptide N Balance, g/d	-55.8	-44.8	-33.8	-12.3	-41.0	-24.8	7.3	-28.5

[a]DRC = dry rolled corn; ALF = alfalfa; SBM = soybean meal; WCGF = wet corn gluten feed.
[b] MP = Metabolizable protein.
[c]DIP = Degradable intake protein.
[d]Degradable protein content (% of CP): dry rolled corn = 40%; corncobs = 50%;
alfalfa hay = 72%; liquid 32 = 100%; soybean meal = 60%; wet corn gluten feed = 80%;
steep liquor = 100%; urea = 100%.

Adding steep liquor to the diet produced better (P<.10) feed efficiency than any other treatment. Since steep liquor is high in DIP, the response may be due in part to the additional amino acids and peptides supplied by steep liquor. However, the high feed efficiency of cattle fed steep liquor suggests that the steep has a higher energy value than dry-rolled corn or that it has an associative effect in finishing diets. This is consistent with results in another article within this Beef Cattle Report, titled Evaluation of Corn Bran and Steep Liquor for Finishing Steers.

The metabolizable protein (MP) requirement, MP supply, DIP balance, and peptide nitrogen balance (Table 3) were calculated using the NRC Nutrient Requirements of Beef Cattle 1996 software. The MP supplied in the diet was sufficient in all treatments except steep liquor. The MP balance (MP supplied by the diet - MP requirement) ranged from -51.8 to + 63 g/d for the steep liquor and 38.2% WCGF treatments respectively. Though calculated to be slightly deficient in MP, the superior feed efficiency of cattle fed steep liquor suggests that metabolizable protein was not deficient. We may have either underestimated the amount of MP supplied by the diet or overestimated the MP requirement of the steers. All treatments were near or in excess of DIP balance (0) with ranges from -2.5

to +260 g/d for DRC/COBS and 10% SBM, respectively. Therefore, it is unlikely that DIP supply (ignoring amino acids and peptides) limited microbial growth and subsequently reduced cattle performance in any of the treatments. Steers fed 38.2% WCGF had the highest peptide nitrogen balance at 7.3 g/d followed by 10% SBM at -12.3 g/d. Steers fed DRC/COBS, DRC/ALF, 5 or 10% SBM, 10.4 or 20.8% WCGF or steep had negative peptide nitrogen balances. Alfalfa supplied 11 g/d more amino acids and peptides than corncobs. Increasing levels of WCGF and SBM reduced the negative peptide balance.

When ingredients are substituted into the diet to replace corn, a number of effects may occur. Ingredients lower in starch than corn may reduce acidosis. Some ingredients may have more or less energy than the corn replaced or in the case of alfalfa, more energy than the corncobs replaced. Certainly, there was no clear relationship between peptide balance and feed efficiency. The 11 grams supplied by the alfalfa gave as much response in feed efficiency as 63 grams in the 38.2% WCGF diet. Certainly the other factors mentioned previously are affecting the feed efficiency response.

The NRC model (Level 2) calculates peptide balance assuming that all DIP would be in the form of protein and none as NPN. This explains the negative balances for diets such as the 10.4% steep liquor diet. The steep liquor contains some nonprotein nitrogen (actually non-amino acid nitrogen) in the form of ammonium lactate. While it seems likely that some portion of the DIP should be in the form of amino acids and peptides in finishing diets, it is not clear from these data just what this level should be.

Results from this research indicate that WCGF can elicit equal or superior responses in gain and efficiency when compared with SBM. Cattle fed 20.8 or 38.2 % WCGF gained faster and consumed more feed than those fed SBM (5 or 10%). Steep liquor markedly enhanced efficiency and appears to have a higher energy value than dry-rolled corn. This trial failed to show the increased daily gain and dry matter intake previously indicated when high levels of SBM were fed although feed efficiency was increased. In general, supplying additional degradable intake protein as peptides and amino acids in the diet improved performance.

[1]Tony Scott, graduate student; Terry Klopfenstein, Professor Animal Science, Lincoln; Drew Shain, research technician, Lincoln; Mark Klemesrud, research technician, Lincoln.

Evaluation of Corn Bran and Corn Steep Liquor for Finishing Steers

Tony Scott
Terry Klopfenstein
Rick Stock
Mark Klemesrud[1]

Corn steep liquor has a higher energy value than bran and there is an associative effect between steep and bran when fed in combination.

Summary

Sixty yearling Hereford steers were used to evaluate the effect of replacing of dry rolled corn with various levels of corn bran and/or corn steep liquor in finishing diets. Steers fed 15% bran, 15 or 30% steep liquor or any combination of bran and steep gained faster than steers fed the dry rolled corn diet or the 30% bran diet. A product type x level interaction was observed for feed/gain. The first increment (15%) of bran or steep liquor added to the diet appears to be the most beneficial; steep liquor has a higher energy value than bran and there is an associative effect between steep liquor and bran.

Introduction

The increased production of fructose in Nebraska has resulted in various byproduct feedstuffs from the corn wet milling industry. Many of these byproduct feedstuffs are potential economic alternatives to corn. Corn bran and corn steep liquor are the main byproducts of corn sweetener and ethanol production and are the two major ingredients blended to produce wet corn gluten feed. Previous research has shown that wet corn byproducts are equal to or higher in energy than corn grain. The higher energy value of the byproducts has the potential to increase efficiency. The longer storage life of corn bran and corn steep liquor versus that of wet corn gluten feed may serve as a way to further expand the area to which byproduct feeding is an economically viable alternative to corn grain. Therefore, the objectives of this trial were to determine the feeding values of corn bran and corn steep liquor in finishing diets.

Procedure

Sixty yearling Hereford steers (722 lb) were used in a finishing trial from August 4 to December 15, 1995 (132 days). Steers were assigned randomly to one of nine dietary treatments based on the replacement of dry rolled corn (DRC) with corn bran (B) and/or steep liquor (S). The product referred to as steep liquor in this trial was actually a blend of steep and distiller's solubles. The distillers solubles is the liquid byproduct of alcohol production using yeast fermentation in the wet milling

Table 1. Diet composition (% DM basis).

	Diet[a]								
Item	DRC	15%B	30%B	15%S	30%S	15%B-15%S	15%B-30%S	30%B-15%S	30%B-30%S
Dry rolled corn	85.00	70.00	55.00	70.00	55.00	55.00	40.00	40.00	25.00
Corn bran	——	15.00	30.00	——	——	15.00	15.00	30.00	30.00
Steep liquor	——	——	——	15.00	30.00	15.00	30.00	15.00	30.00
Alfalfa silage	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Supplement[b]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

[a]DRC = dry rolled corn; B = corn bran; S = steep liquor.
[b,c]Includes vitamins, minerals, and feed additives.

Table 2. Effect of corn bran and steep liquor on performance.

	Diet[a]								
Item	DRC	15%B	30%B	15%S	30%S	15%B-15%S	15%B-30%S	30%B-15%S	30%B-30%S
Daily gain, lb	3.24[b]	4.26[c]	3.64[b]	4.35[c]	3.99[c]	4.37[c]	4.37[c]	4.33[c]	4.23[c]
DM intake, lb/day	22.7[d]	25.46[e]	25.99[e]	25.01[e]	23.94[d]	27.54[e]	28.37[e]	27.60[e]	27.23[e]
Feed/gain[hi]	6.99	5.99	7.14	5.75	5.99	6.29	6.49	6.37	6.45
Quality grade[j]	17.0[de]	17.8[defg]	16.9[de]	18.9[g]	17.7[def]	18.0[efg]	18.7[fg]	17.5[def]	16.7[d]
Yield grade	2.1[d]	2.8[ef]	2.6[def]	2.4[de]	2.6[def]	3.0[f]	3.5[g]	3.0[f]	3.0[f]
Fat thickness, in	.34[d]	.48[def]	.41[def]	.38[de]	.44[def]	.53[fg]	.63[g]	.49[efg]	.51[efg]

[a]DRC = dry rolled corn; B = corn bran; S = steep liquor.
[b,c]Means within a row with unlike superscripts differ (P<.01).
[d,e,f,g]Means within a row with unlike superscripts differ (P<.10).
[h]Feed/gain analyzed as gain/feed. Feed/gain is the reciprocal of gain/feed.
[i]Product type x level interaction (P<.01).
[j]17 = average select; 18 = high select; 19 = low choice.

plant. Steep liquor alone is the byproduct when corn sweetener is produced, but both steep liquor and distillers solubles are produced when alcohol is produced. Normally, steep liquor from wet milling plants contains some distillers solubles as does wet corn gluten feed. Corn bran and steep liquor were fed alone or in combination to replace 0, 15, 30, 45, or 60% of the DRC (DM basis). Diets were DRC control, 15% B, 30% B, 15% S, 30% S, 15% B-15% S, 15% B-30% S, 30% B-15% S, and 30% B-30% S.

Diets (Table 1) were formulated to contain (DM basis) a minimum of 13% CP, .70% Ca, and .30% P, and included 25 g/ton Rumensin and 10 g/ton Tylan. Steers were adapted by limit feeding finishing diets until ad libitum intake was reached. Steers were individually fed once daily using Calan gates. Steers were implanted with Revalor-S on day one and re-implanted with Revalor-S on day 69. Steers were housed in covered pens with 15 head per pen. Initial weights were the average of three consecutive weights taken before feeding. Final weights were calculated using hot carcass weight divided by a common dressing percentage (62). Hot carcass weights and liver abscess scores were recorded at slaughter. Fat thickness at the 12th rib, quality grade, and yield grade were recorded after a 48-hour chill.

Results

Steers fed B and/or S gained faster (P<.01) than steers fed DRC except for 30% B fed alone (Table 2). Steers fed 15% B or 30% B consumed more feed (P<.05) than steers fed DRC. Steers fed 15% S consumed more feed (P<.10) than steers fed DRC. Steers fed B and S in combination consumed more feed (P<.01) than steers fed DRC. A product type x level interaction (P<.01) was observed (Figure 1) for feed/gain. While some statistical differences in carcass characteristics were obtained, these differences were likely due to the limited number of observations per treatment and the inherent variation among animals rather than biological differences due to the dietary treatments.

The first increment of B (15%) markedly increased DM intake, daily gain, and efficiency (Figure 1), likely due to reduced acidosis. Steers fed the DRC diet may have experienced mild subacute acidosis. These cattle performed typically for grain fed cattle and it is likely that cattle fed these high grain diets experience some degree of acidosis in the feedlot. Wet milling byproducts have much lower starch content than DRC. Therefore, the inclusion of these byproducts reduces the starch content of the diet and as a result reduces acidosis. This has been clearly demonstrated with the feeding of wet corn gluten feed. The next increment of B (30%) reduced efficiency versus 15% B, suggesting that bran has less energy than the DRC that it replaced and that 15% B was sufficient to reduce acidosis. Feed efficiency for the 30% B diet was still equal to the control diet, likely because of the combination of acidosis control and energy content.

Both 15 and 30% S improved efficiency compared to cattle fed DRC, suggesting a higher energy value for S than for DRC. The first increment of S

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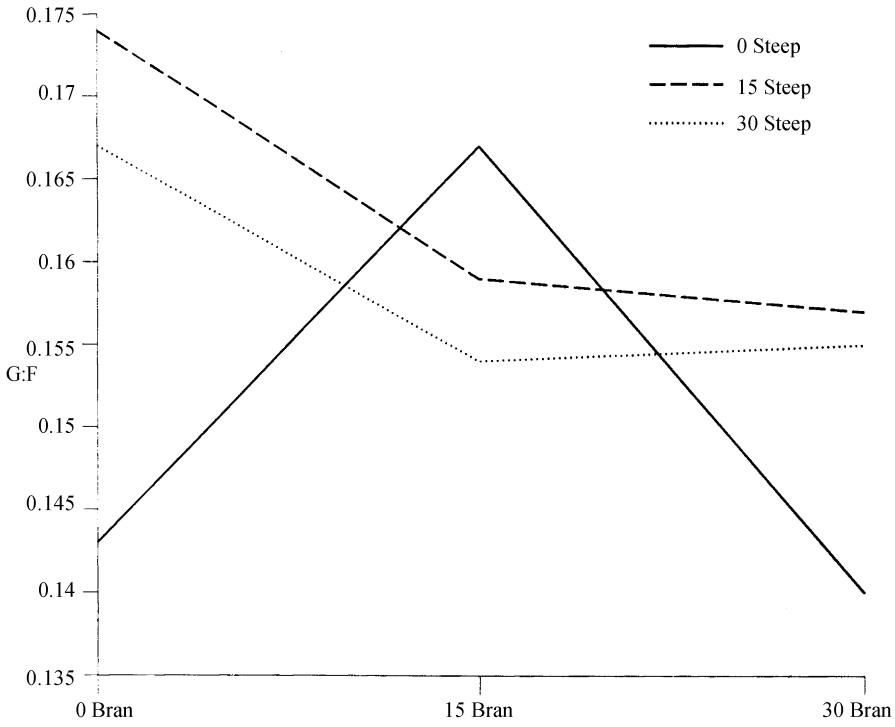

Figure 1. Interaction of level of bran and level of steep on feed efficiency.

(15%) gave as much response in efficiency and daily gain as 30% S, suggesting an effect other than energy content alone. Previous research at the University of Nebraska (1995 Nebraska Beef Report, pp 30-33) has shown increased lactate utilization by rumen microbes in steers fed distiller's solubles. The steep liquor used in this trial contained some distiller's solubles resulting from alcohol production. Thus, S would have reduced the starch content of the diet and may have enhanced lactate utilization by rumen microbes. The resulting net effect may have been reduced subacute acidosis.

Addition of B to diets containing both 15 and 30% S decreased efficiency suggesting lower energy content in B compared to S. The combinations of 15 or 30% S with 15 or 30 percent B resulted in diets similar to those containing 30-60% wet corn gluten feed. These ratios of S to B are probably representative of the range of values seen in the wet milling industry. Efficiencies were better than the control for all combinations of S and B. This is consistent with previous research with wet corn gluten feed especially where subacute acidosis is a factor in the high grain control diet. It is of interest to note that addition of 15% S to 30% B increased efficiency 12% when compared to 30% B fed alone, suggesting an associative effect between the S and B.

Results of this research indicate that replacement of dry rolled corn with corn bran (15 percent of diet DM), corn steep liquor, and corn bran and corn steep liquor in combination improved daily gain. Addition of corn bran, corn steep liquor (15% of diet DM), or corn bran and corn steep liquor in combination also increased DM intake. It appears the greatest efficiency response occurs with the first increment of B or S included in the diet. There may be an associative effect between B and S when fed in combination. This research also suggests that S is higher in energy than the dry-rolled corn it replaced.

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[1]Tony Scott, graduate student; Terry Klopfenstein, Professor Animal Science, Lincoln; Rick Stock, former professor; Mark Klemesrud, research technician, Lincoln.

A Bacterial Preservative for Ensiled High-Moisture Corn

Burt Weichenthal
Ivan Rush
Brad Van Pelt[1]

PRO-MAX bacterial inoculant added to ground high-moisture corn before ensiling can speed up fermentation, lower the pH faster, and increase propionic acid percentage enough to reduce spoilage organism counts.

Summary

High-moisture corn at 26 to 27 percent moisture was ground and ensiled, with or without inoculation with PRO-MAX[2]*, a bacterial preservative designed to stimulate production of lactic and propionic acids during*

fermentation. Laboratory analyses showed lower pH and counts for spoilage organisms at 40 and 80 days after ensiling, along with higher propionic acid than in the control corn. A finishing trial with yearling steers showed similar overall performance and carcass means for the control and the treated corn.

Introduction

High-moisture corn ensiled at 24 to 30 percent moisture normally produces organic acids during fermentation. Preservation is achieved after sufficient acids are produced to lower pH enough to inhibit spoilage organisms. Bacterial inoculants are sometimes added to corn during ensiling to reduce nutrient losses by stimulating mainly lactic acid production to lower the pH rapidly. During feed-out of the ensiled corn, spoilage can occur at exposed surfaces of the ensiled product in storage or in the bunk if the corn remains very long under hot and wet environments. Therefore, one objective of this trial was to treat high-moisture ground corn with a bacterial inoculant that would not only stimulate production of lactic acid, but also propionic acid which would improve storage and bunk-life characteristics of high-moisture corn by reducing spoilage organism counts. Ultimately the objective was to compare yearling cattle performance and carcass characteristics when fed during summer on a finishing diet containing dry rolled corn and ground high-moisture corn that was treated with this preservative or left untreated at ensiling time during fall harvest.

Procedure

High-moisture harvested shelled corn was ground with a hammer mill before packing in two 12-foot-wide concrete bunkers, alternating every three to four loads between the bunkers. The corn averaged 26.4 and 27.4 percent moisture in the control and treatment bunkers, respectively. The inoculant treatment (PRO-MAX) contained *Propionibacterium spp.* fermentation product, *Pediococci acidilacteri* fermentation product and maltodextrin. The treatment rate was 120 grams of inoculant in cold water per 12.5 tons of high-moisture corn, applying 500 thousand colony forming units (cfu) per gram of crop. The dissolved inoculant was sprayed on corn at the unloading auger of the hammer mill through use of a commercial spray tank.

The high-moisture corn ranged in depth from 3 to 4 feet after packing and was covered with black plastic and tires. Samples of both control and inoculated corn were taken at 40, 80, 120, and 180 days post ensiling for microbial (cfu/g) and organic acid (%) analyses.

Eighty Angus crossbred yearling steers averaging 928 pounds initially were randomly allotted by weight groups to eight pens and started on trial on July 11, 1995. After five to seven days on each of three step-up diets, the final diet was reached, which on a dry matter basis contained 45.5 percent dry rolled corn, 37.3 percent ground high-moisture corn, 10 percent corn silage, and 7.2 percent of a pelleted supplement that included 58 percent crude protein with 38 percentage units from NPN. The calculated nutrient contents were 12.5 percent crude protein, 64 Mcal of NEg, .76 percent calcium and .34 percent phosphorus. Rumensin and Tylan were included at 30 and 10 grams per ton of diet dry matter, respectively. The cattle were implanted with Synovex S initially and fed ad libitum once daily during the 105-day finishing trial. Carcass information was collected at slaughter. High-moisture corn was loaded at feeding with a payloader, and the small amounts removed daily from each bunker allowed considerable surface exposure.

Results

High-moisture harvested corn inoculated with the PRO-MAX bacterial preservative at ensiling time did not affect overall performance and carcass comparisons when fed to yearling finishing steers during the following summer and early fall (Table 1). While the cattle on treated high-moisture corn appeared to gain faster during the first and second periods of the 105-day feeding trial, a slightly lower gain during the last period caused overall gains to be similar. There were no statistically significant differences in the comparisons. The slight improvement in feed per unit of gain for the treated high-moisture corn (6.24 vs 6.41) had a statistical P value of .17, which is somewhat weak as an indicator of repeatability.

Table 1. Treated vs untreated high-moisture ensiled corn for finishing yearling steers.

Corn	Control	Treated
No. of pens	4	4
No. of steers	40	40
Initial weight, lb	929	927
Final weight, lb	1320	1325
Daily gain, 28 days	4.21	4.56
Daily gain, 28-64 days	3.67	3.82
Daily gain, 64-105 days	3.84	3.72
Daily gain, 105 days	3.74	3.78
Feed DM intake, lb	24	23.6
Feed/gain ratio	6.41	6.24
Hot carcass weight, lb	788	791
Dressing percent	62.18	62.16
Marbling score[a]	5.54	5.75
Quality grade[b]	19.1	19.4
Fat cover, in	.42	.44
Rib eye area, sq in	13.1	13.8
Yield grade	2.8	2.6

[a]Marbling score of 5.0 = Small.
[b]Quality grade of 19.0 = Choice -.

The results from the laboratory analyses of the stored corn at several times after ensiling are shown in Table 2. Coliform counts were lower in the treated sample taken at 40 days and were low in both treated and untreated samples at later dates. Mold counts were lower in treated corn samples at 40 and 80 days compared to the control. Propionic acid was higher in treated corn samples taken at 40, 80 and 180 days. Differences in lactic and acetic acid were not consistent between treatments. Corn samples taken for the storage analyses were higher in moisture than those taken during ensiling, possibly due to condensation under the plastic cover during storage.

The inoculation of the high-moisture corn with the PRO-MAX preservative lowered pH and the counts of undesirable microorganisms at 40 and 80 days post ensiling. Propionic acid was increased in the treated corn which can be a benefit against spoilage at the

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Table 2. Microbial and organic acid analysis of treated and untreated stored high-moisture corn.

Treatment	Days ensiled	pH	Microbial Analysis (cfu/g) Yeast	Mold	Coliforms	Organic Acid Analysis (%) Lactic	Acetic	Propionic[a]
Control	40	5.0	$5.5x10^5$	$4.8x10^5$	$4.9x10^3$	.9	.7	<.2
Treated	40	4.5	$1.5x10^4$	$1.0x10^4$	<10	.4	.5	.4
Control	80	3.63	$1.5x10^3$	$2.0x10^2$	<10	.4	.4	<.2
Treated	80	3.43	$3.0x10^4$	<100	<10	.2	.5	.4
Control	120	3.6	$1.5x10^7$	$2.0x10^2$	<10	.1	.1	<.2
Treated	120	3.54	$1.8x10^7$	$3.0x10^4$	<10	.2	0	<.2
Control	180	3.3	$2.8x10^4$	$4.5x10^2$	<10	1.1	.3	<.2
Treated	180	3.45	$7.5x10^6$	$3.0x10^2$	<10	.2	.2	.3

[a]Minimum level of propionic acid detectable is .2%.

exposed surface of the stored high-moisture corn as well as in the bunk. There was not enough effect on nutrient quality of the treated corn to affect cattle performance or carcass characteristics with a diet dry matter that contained about 37 percent of the treated corn.

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[1]Ivan Rush and Burt Weichenthal, Professors, Animal Science; Brad Van Pelt, research technician, Panhandle Research and Extension Center, Scottsbluff.

[2]PRO-MAX™ is a high-moisture corn inoculant from AgMaster™ Silage Inoculants and manufactured for Agtech Products, Inc., Waukesha, WI 53186.

A Low Roughage Diet Alternative for Finishing Cattle

Ivan Rush
Burt Weichenthal
Brad Van Pelt[1]

A low roughage diet containing Impact supplement can reduce feed to gain ratio while maintaining daily gain. A relatively high energy level in this diet results in lower ad libitum intake.

Summary

A finishing trial was conducted to compare a high concentrate ration supplemented with Impact (manufactured by Purina Mills Inc.) with a finishing ration containing 10 percent DM from corn silage and a urea containing protein supplement. Steers fed the low roughage diet containing Impact consumed slightly less feed and were 5.4 percent more efficient. Carcass traits were similar for the two treatments except the steers fed Impact had slightly less fat.

Introduction

Optimum levels and types of roughages in finishing cattle diets continue to be questioned. Fiber in roughages adds a safety factor by diluting the energy concentration slightly which diminishes the incidence of acidosis. Roughages also add a "scratch factor" that may improve the motility of the rumen. Fiber is poorly digested in high concentrate rations, offers very little energy to promote gain, and can possibly lower the digestion of concentrates in the diets. Roughage sources are also bulky to handle, and add to manure build up in pens. Because of problems with roughages in finishing rations, many attempts have been made to eliminate roughages; yet it is felt by cattle feeders that with traditional all concentrate programs, the incidence of acidosis is often increased. The increase of acidosis in all concentrate diets is due to considerable variation in daily intake. Purina Mills Inc. has developed a protein supplement, Impact®[2], to aid in controlling the variation in daily feed intake with a high concentrate diet. As a result intake is lowered slightly.

Impact supplement used in this trial contained 58.2 percent crude protein with 36.8 percentage units from NPN. Fat content of the dry matter was 3.7 percent and fiber was 5.2 percent. This supplement contains a combination of ingredients that alters intake patterns and avoids extremely high intakes at any single feeding.

The objective of this trial was to compare the performance and carcass characteristics of steers fed a high concentrate diet containing corn, pressed beet pulp and Impact supplement or corn, corn silage, pressed beet pulp and a urea containing protein supplement.

Procedure

A finishing trial was initiated with 88 Angus and Angus cross yearling steers that had previously grazed summer pasture together for a full grazing season. The average initial weight was 907 lb and they were allotted by weight groups to eight pens of nine and two pens of eight steers. Five pens were fed a control diet and five pens were fed a similar diet containing Purina Impact supplement. Four step-up diets were fed for five to seven days each to reach the final diet, which for the control on a dry matter basis contained 72.7 percent dry rolled corn, 10 percent corn silage, 10.1 percent pressed beet pulp, and 7.2 percent of a protein-mineral supplement. Calculated nutrient contents were 12.6 percent crude protein, 61.6 Mcal

NEg, and 79.6 percent TDN. The final Impact diet dry matter contained 82.9 percent dry rolled corn, 8.5 percent pressed beet pulp, and 8.6 percent Purina Impact supplement. Calculated nutrient contents for this diet were 13.15 percent crude protein, 63.3 Mcal NEg, and 88 percent TDN. Both treatment groups were fed Tylan at 10 grams per ton of diet dry matter, but Rumensin was fed at 30 grams per ton in the control diet and at 25 grams per ton in the Impact diet. The steers were implanted with Synovex S at the start of the trial. The steers were fed once daily during the 104-day trial. Carcass data were collected at slaughter and final weights were calculated by dividing hot carcass weights by a common dressing percentage (62). Statistical analysis of the data was conducted through the use of the general linear model in PC SAS.

Table 1. Steer performance and carcass results with Purina Impact supplement in a finishing diet.

	Control	Impact
No. of steers	44	43
No. of pens	5	5
Initial wt, lb	907	907
Daily gain, lb, 56 days	4.23	4.34
DM intake, lb, 56 days	24.1	23.2
Feed/gain, lb, 56 days	5.70	5.34
Final wt, lb, 104 days[1]	1318	1319
Daily gain, lb, 104 days[1]	3.95	3.96
DM intake, lb, 104 days	24.05	22.85
Feed/gain, 104 days	6.11[a]	5.78[b]
Hot carcass wt, lb	817	818
Dressing %	62.9	63.0
Marbling score[2]	541	526
Fat cover, in	.7[a]	.6[b]
Yield grade	3.1	3.1

[1]Final weight and daily gain adjusted by dividing hot carcass weight by a common dressing percentage (62).
[2]Marbling score of 500 to 599 = Small, equivalent to low Choice quality grade.
[ab]Treatment means in the same row with different superscripts are different (P<.1).

Results

Steer performance and carcass results are shown in Table 1. Although not statistically significant, steers during the first 56 days on the Impact treatment gained slightly faster on slightly less feed, resulting in a feed to gain ratio that was numerically 6.3 percent better than the control. Feed intake by the Impact supplemented cattle appeared to be more affected by management changes than the conventionally fed steers. During the first 56 days, both treatment groups had established a high feed intake that was uniform within each treatment. On day 56 of the trial all cattle were individually weighed and moved to similar but adjacent pens. This disruption of routine caused a significant decline in intake for the Impact cattle for two to three days, however they came back onto full feed without problems. The incidence of liver abscess was very low (less than 5 percent) in the trial. Final weights, adjusted to common dressing percentage (62), and daily gains were similar. Dry matter intake for the Impact treatment, which involved a low roughage diet, was 1.2 lb per day lower than the control. The resulting feed to gain ratios for the 104 day trial favored the Impact treatment by 5.4 percent (P=.10).

Carcass fat cover was less for the Impact treatment (P<.08) but dressing percentages were similar, as were marbling scores and yield grades. Pressed wet beet pulp was the only source of roughage in the Impact diet, and it is highly digestible and palatable roughage that may not provide the typical roughage characteristics needed in the rumen to maintain consistent rumen function and, consequently, consistent feed dry matter intake. The results of this trial indicate that the combination of corn, pressed beet pulp and the Impact supplement can produce comparable gain on less feed than obtained with finishing diets that contain traditional roughages at levels to maintain consistent performance.

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[1]Ivan Rush and Burt Weichenthal, Professors, Animal Science; Brad Van Pelt, research technician, Panhandle Research and Extension Center, Scottsbluff.

[2]Impact is a product name from Purina Mills Inc. The use of this product in no way implies endorsement by the University of Nebraska-Lincoln.

Time of Feeding Influence on Cattle Exposed to Heat

Terry Mader
John Gaughan
Darryl Savage
Bruce Young[1]

Managing heat load through manipulation of feeding regime may be effective in maintaining intake of individually fed feedlot cattle exposed to hot environmental conditions.

Summary

The effects of high temperature and time of daily feeding were examined on six individually fed Hereford steers. In general, pulse rate was more indicative of dry matter intake (DMI) than of heat load. Afternoon feeding was not found to be an effective method of maintaining DMI under hot environmental conditions (HOT). As a percent of body weight, steers fed after noon under HOT had significantly lower metabolizable energy intake than other treatments, while steers fed morning or split fed (30% roughage diet fed at 0800 hr and 6% roughage diet fed at 1600 hr) under HOT were able to maintain DMI at a level equal to or greater than steers fed under thermoneutral

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conditions. For afternoon feeding to be more effective, night-time cooling below a temperature-humidity index of 74 may be needed if cattle experience excessive heat load the previous day.

Introduction

Thermal load causing an increase in maintenance energy requirement and a reduction in growth rate in beef cattle can represent considerable economic loss to the feedlot industry. Unexpected periods of heat load impose serious problems when cattle are not physiologically adapted to hot conditions. High ambient temperature resulting in an increase in internal body temperature will reduce feed intake and change eating patterns. Since ruminal fermentation of most high grain diets generally peaks within a few hours after consumption, daily morning feeding may result in maximum heat from fermentation during the hottest part of the day. This suggests that cattle consuming the highest energy components of their diets during late evening or at night during summer may better cope with heat load and utilize metabolizable energy more efficiently than those fed in the morning immediately before maximum daily heat load.

This study was undertaken to evaluate responses and feed intake under different feeding regimes in cattle exposed to thermoneutral or hot environmental conditions.

Materials and Methods

A metabolism trial was conducted during the summer at the University of Queensland, Gatton College, Department of Animal Production facilities. Six yearling Hereford steers (mean weight = 616 lb) were randomly assigned to individual stalls (9.8 ft x 3.3 ft) in one of two temperature controlled rooms. Each animal was restrained in its stall by a head halter and had previously been accustomed to being led and being tied. The feeding treatments were: 14% roughage diet (Table 1) provided at 0800 hr daily (morning); the same diet as in morning but fed at 1600 hr (afternoon); and a split feeding regime (SP) in which approximately one-third of the dietary intake was provided from a 30% roughage diet fed at 0800 hr with the remaining dietary intake provided from a 6% roughage diet fed at 1600 hr. Total diet consumed in the split feeding group approximated the composition of the 14% roughage diet of the other two treatments. Water was available ad libitum. The trial was replicated over three time periods with each test period three days long.

Before each test period, steers were accustomed to feeding treatment for seven days under thermoneutral conditions. Feed intakes and refusals were recorded daily throughout the trial. During the test periods, the hot room had the capacity to be heated to temperatures in excess of 100°F through supplementary heat, while the thermoneutral room maintained temperatures between 72°F and 88°F. High temperatures were imposed in the hot room beginning at 1000 hr and ending at 1800 hr. Although test room temperatures were imposed during the day, room temperatures were also influenced by and varied with outside conditions, particularly at night. In the hot room, a gradual cool down to thermoneutral conditions was allowed at night to depict normal cyclical daily temperatures. The thermoneutral room peak temperature averaged 88.5°F during the afternoon, and also followed a natural cyclical temperature pattern.

Table 1. Composition of diets.

	Diet roughage level, %		
	6	14	30
Ingredient, % of DM			
Barley	44.5	40.5	32.5
Sorghum	44.5	40.5	32.5
Alfalfa hay	3.0	7.0	15.0
Oat hay	3.0	7.0	15.0
Supplement[a]	5.0	5.0	5.0
Calculated nutrient content, % of DM			
Calcium	.54	.60	.72
Phosphorous	.45	.44	.41
Roughage	6.0	14.0	30.0
Rumensin, g/ton	25.0	25.0	25.0
NEg, mcal/cwt	61.7	58.9	53.1
ME, mcal/cwt	135.7	131.9	124.5

[a]Fed in dry form and contained protein, minerals, vitamins, and Rumensin.

Feed intake (DMI) and metabolizable energy intake (MEI) were determined daily for each steer. During the three-day test periods, respiratory rate (RR) and pulse rate were measured daily at 0900, 1600, and 2000 hr on each steer; body temperature (BT) was recorded, using a data logger, at ten-minute intervals for the duration of the trial, via an 8-inch rectal probe with a thermistor mounted in the tip. Pulse rate was determined via pulse monitor attached to an ear clip sensor.

Results

Mean temperature in the thermoneutral room over the test period was 78.4°F. Mean hourly relative humidity ranged from 61% to 85% (overall mean = 74%). Mean hourly temperature-humidity index (THI) was 75 and ranged between 71 to 81. Mean temperature in the hot room was 86.4°F. Mean hourly relative humidity was 69% and ranged from 50 to 86%. Mean THI was 82 and ranged from 74 to 90. Mean THI between 1200 and 1800 hr averaged 88 in the hot room and 74 in the thermoneutral room. During this period, mean dry bulb temperature in the hot room was 96.3°F.

Mean respiratory rate measured at 1600 and 2000 hr differed ($P < .10$) between steers fed under thermoneutral vs hot conditions (Table 2). Within feeding regime, respiratory rate was not affected. In contrast, pulse rate was significantly influenced by feeding regime at 1600 hr, in which afternoon fed steers had the lowest pulse rate while SP fed steers had the highest pulse rate. At 0900 hr, pulse rate in the thermoneutral treatment was higher than pulse rate in the hot treatment steer group. Steers exposed to hot environmental conditions had greater body temperature at 1600 and 2000 hr; however, environmental conditions by feeding regimen interactions existed at both times. In general, under thermoneutral conditions, body temperature was the least with morning feeding and greatest with SP feeding. An opposite trend tended to be evident under hot conditions. Even though the interaction was not apparent, these same trends were

Table 2. Mean respiratory rate (RR), pulse rate (PR), and body temperature (BT) measured at 900, 1600, and 2000 hr for cattle fed feedlot diets while being exposed to thermoneutral (TNL) or hot (HOT) environmental conditions (ENV).[a]

ENV:	TNL			HOT		
Feeding regime:	AM	PM	SP	AM	PM	SP
RR, breaths/min						
900 hr	68.4	68.8	76.2	88.0	80.1	81.6
1600 hr[b]	72.8	81.0	88.7	136.2	136.2	130.7
2000 hr[b]	87.0	96.8	101.3	113.7	115.7	114.8
PR, beats/min						
900 hr[b]	95.0	97.3	98.6	92.2	90.9	88.7
1600 hr[c]	94.6	90.3	97.4	96.4	93.3	98.4
2000 hr	97.5	92.3	97.6	97.7	101.4	107.3
BT, °F						
900 hr	101.8	101.8	102.2	102.2	102.2	101.8
1600 hr[bd]	101.8	102.2	102.7	103.5	104.5	104.2
2000 hr[bd]	102.6	102.7	103.5	104.7	104.2	104.2

[a]The AM and PM fed diets contained 14% roughage while SP diet contained 30% roughage during morning feeding and 6% roughage during afternoon feeding.
[b]TNL vs HOT, $P < .10$.
[c]Feeding regimens differ $P < .10$.
[d]ENV by feeding regimens interaction, $P < .10$.

Table 3. Mean, maximum (max), minimum (min) and range in body temperature for cattle fed feedlot diets while being exposed to thermoneutral (TNL) or hot (HOT) environmental conditions (ENV).[a]

ENV:	TNL			HOT		
Feeding regime:	AM	PM	SP	AM	PM	SP
Day 1						
Mean[bc]	102.1	102.3	102.9	103.5	103.2	103.1
Max[b]	103.1	103.4	103.9	105.1	104.6	104.4
Min[bc]	101.0	101.3	101.7	102.4	101.8	101.4
Range	2.1	2.1	2.2	2.8	2.8	2.9
Day 2						
Mean[bc]	102.2	102.5	102.9	103.9	103.5	103.3
Max[b]	103.2	103.7	104.3	105.3	104.8	104.9
Min[bc]	101.1	101.3	101.8	102.3	101.8	101.6
Range[b]	2.2	2.3	2.5	3.0	3.0	3.4
Day 3						
Mean[bc]	102.4	102.5	103.1	104.0	103.6	103.4
Max[bc]	103.4	103.9	104.0	105.7	104.9	105.2
Min[c]	101.3	101.9	102.3	102.3	101.7	101.1
Range[b]	2.1	2.0	1.7	3.3	3.1	4.2
Trial						
Mean[bc]	102.2	102.5	103.0	103.8	103.4	103.2
Max[bc]	103.4	104.0	104.3	105.6	105.0	105.2
Min[bc]	101.1	101.1	101.8	102.1	101.7	101.3
Range[b]	2.4	2.9	2.5	3.5	3.3	3.9

[a]The AM and PM fed diets contained 14% roughage while SP diet contained 30% roughage during morning feeding and 6% roughage during afternoon feeding.
[b]TNL vs HOT, $P < .10$.
[c]ENV by feeding regimen interaction, $P < .10$.

evident for 0900 hr pulse rate.

These same trends were also observed in the daily mean, maximum and minimum body temperature values shown in Table 3. The body temperature values were greatest in the hot morning treatment, but least in the thermoneutral morning treatment on most days and over the entire trial. By day three, and over the entire trial, environmental condition by feeding regimen interactions were found for mean, maximum and minimum body temperature. In general, maximum and minimum body temperature values for the thermoneutral split feeding treatments tended to be greater than respective body temperature values of other thermoneutral treatment, while the body temperature values of the hot split feeding treatment tended to be lower than respective body temperature values of the other hot treatments. As expected, the range in body temperature values were greater in the hot treatment than in the thermoneutral treatment. Ranges in body temperature tended to increase from day one to day three in the hot treatment group only.

Under hot conditions, mean body temperature of afternoon-fed steers tended to remain elevated above split feeding program-fed steers, while maximum body temperature tended to be less for afternoon-fed steers (day 2, day 3, and over the entire trial). Under hot conditions, morning- and afternoon-fed steers tended to have consistently greater minimum body temperature (daily and over entire trial) than split-fed steers. The inability to dissipate body heat and return to a state of normalcy most likely impacts post-heat feeding behavior. Feeding after noon tended to reduce maximum body temperature compared to morning and split feeding, but it did not allow for the lower minimum body temperature that was observed in the split feeding program-fed steer group.

Under both environmental conditions split feeding program-fed steers tended to have the greatest DMI and MEI (Table 4). Under thermoneutral conditions, afternoon fed steers maintained equal intakes to split feeding program-fed steers, which tended to be greater than morning fed steers. However, under hot conditions afternoon-fed steers had intakes as a percent of body weight of 12.3% and 13.6%, respectively, lower than the morning and split feeding program-fed steers. Steers that were split fed under hot conditions appeared to be better able to distribute MEI throughout the 24-hour period, thus minimizing heat load by achieving lower mean and minimum body temperature than other steers fed under hot conditions.

Although pulse rate appeared not to

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Table 4. Mean daily dry matter (DMI) and metabolizable energy (MEI) consumed for cattle fed feedlot diets and exposed to thermoneutral (TNL) or hot (HOT) environmental conditions (ENV)[a].

ENV:	TNL			HOT		
Feeding regime:	AM	PM	SP	AM	PM	SP
DMI, lb/day[b]	16.14	16.49	16.49	15.81	14.31	16.67
DMI, % BW[cd]	2.62	2.72	2.72	2.60	2.28	2.64
MEI, mcal/day[b]	21.3	21.8	21.8	20.9	18.9	22.1
MEI, % BW[cd]	3.46	3.59	3.60	3.42	3.00	3.50

[a]The AM and PM fed diets contained 14% roughage while SP diet contained 30% roughage during morning feeding and 6% roughage during afternoon feeding.
[b]Feeding regimens differ, $P < .10$.
[c]Expressed as a % of body weight; TNL vs HOT, $P < .10$.
[d]ENV by feeding regimen interaction, $P < .10$.

be elevated during heat load, the lower pulse rate for the hot group at 0900 h, when the steers were not exposed to heat load, corresponds to the lower DMI (%BW) and MEI (%BW) of the hot group.

Data suggest that under hot conditions, minimum body temperature may have a greater influence on subsequent intake than previous maximum body temperature. Cattle consuming large quantities of feed afternoon may not experience the degree of body temperature reduction normally associated with night-time cooling. In this study, THI in the hot room did not go below 74 (76° F and 80% RH). Nighttime values which are less than these or several hours of conditions near THI of 74 may be needed if cattle are to consume greater portions of their diet at night. By split feeding under hot conditions, DMI tended to be as great or greater than under any thermoneutral diet regimen. Intakes (%BW) were able to be maintained and not reduced, as is usually the case under heat load. Intakes appear to be maintained as a result of lower mean and minimum body temperature. However, additional research is needed regarding split feeding regimen before being considered for use under practical feedlot conditions.

[1]Terry Mader, Professor of Animal Science, Northeast Research and Extension Center, Concord; John Gaughan, Lecturer, Darryl Savage, student, and Bruce Young, Professor and department head, Department of Animal Production, University of Queensland-Gatton (UQG), Gatton, Queensland, Australia.

Effects of Heat Exposure on Adapting Feedlot Cattle to Finishing Diets

Terry Mader
John Gaughan
Bruce Young[1]

Body temperatures increased in individually fed cattle being stepped-up on finishing diets under both thermoneutral and hot conditions.

Summary

Individually fed feedlot cattle were exposed to excessive heat load (HOT) or thermoneutral (TNL) conditions while being stepped-up to a finishing diet by decreasing roughage from 55 percent to 10 percent in the diet. At 10 percent roughage, heat exposure resulted in reduced metabolizable energy intake (MEI), dry matter intake, and pulse rate. However, over the entire trial, pulse rates tended to be influenced more by MEI than environmental conditions. Data indicate that intakes of individually fed cattle were maintained when 40 and 25 percent roughage diets were fed. However, significant declines in intake were found in cattle stepped-up to 10 percent roughage diets when exposed to increasing levels of excessive heat load.

Introduction

Environmental discomfort in the form of excessive heat load (EHL) can represent a sizeable economic loss to cattle feeders through reduced performance and, in extreme cases, death of feedlot animals. Problems in managing cattle exposed to EHL are further complicated if cattle have to cope with other stressors, such as adaptation to high energy (HE) finishing diets. The objectives of this research were to evaluate cattle exposed to EHL while being stepped-up to HE feedlot diets.

Procedure

A metabolism trial was conducted during late spring and early summer at the University of Queensland, Gatton College, Department of Animal Production facilities. Six *Bos taurus* (Hereford) steers were randomly assigned to individual stalls (9.8 ft x 3.3 ft). The metabolism unit had been divided into two separate rooms, each containing

Table 1. Composition of diets.

	Period			
	Pre-trial	1	2	3
Ingredient, % of DM				
Barley	21.0	27.5	35.0	42.5
Sorghum	21.0	27.5	35.0	42.5
Alfalfa hay	11.0	—	5.0	10.0
Oat hay	44.0	40.0	20.0	—
Supplement[a]	3.0	5.0	5.0	5.0
Calculated nutrient content, % of DM				
Dry matter	90.0	90.0	90.0	90.0
Crude protein	13.5	13.4	13.4	13.4
Calcium	.55	.57	.60	.63
Phosphorous	.34	.39	.42	.44
Roughage	55.0	40.0	25.0	10.0
Rumensin, g/ton	15.0	25.0	25.0	25.0
NEg, mcal/cwt	43.6	48.6	54.5	60.5

[a]Fed in dry form and contained protein, minerals, vitamins, and Rumensin.

Table 2. Mean climatic conditions and temperature-humidity index (THI) associated with feedlot cattle fed adaptation diets and exposed to thermoneutral (TNL) or hot (HOT) environments.

Environment:	TNL				HOT			
Diet period[a]:	1	2	3	Mean	1	2	3	Mean
Temperature, °F	76.1	78.1	82.6	79.3	85.3	87.1	92.1	88.7
Relative humidity, %	65.3	69.5	65.9	66.8	52.1	51.4	46.4	49.5
THI	72.6	74.6	77.9	75.4	77.8	79.0	81.8	79.7

[a]Diets fed in periods 1, 2, and 3 contained 40, 25, and 10% roughage, DM basis, and were fed sequentially 5, 5, and 7 days, respectively.

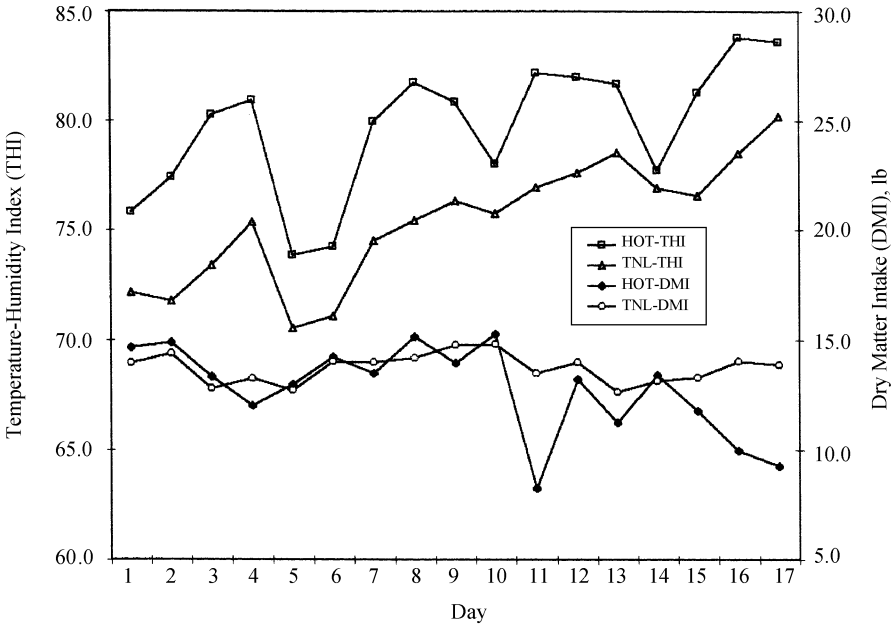

Figure 1. THI and DMI for cattle fed 40% roughage diet (day 1-5), 25% roughage diet (day 6-10), and 10% roughage (day 11-17) when exposed to thermoneutral (TNL) or hot (HOT) environmental conditions.

three stalls. The rooms were separated by an insulated partition. One room had the capability of being heated to temperatures above 100°F (HOT) while the other room could be maintained at or near thermoneutral (TNL) conditions.

Before entering stalls, steers (mean weight = 527 lb) were accustomed to tying over a 30-day period. Steers were brought into stalls and fed a 55 percent roughage diet (Table 1) 10 days before trial initiation. During the trial, steers were fed 40, 25, and 10 percent roughage diets for 5, 5, and 7 days, respectively, over a 17-day period. During that time, the HOT group of steers was exposed to EHL by heating the HOT room from approximately 72°F beginning at 1000 hr, to temperatures around 100°F between 1400 and 1900 hr. Although test room temperature treatments were imposed during the day, room temperatures were also influenced by and varied with outside conditions, particularly at night. A gradual cool-down to TNL conditions was allowed at night to depict normal cyclical daily temperatures. Over the entire study, the TNL room peak temperature averaged 82.4°F during the afternoon, and tended to also follow a natural cyclical temperature pattern.

Steers were fed once daily in the morning. Feed intake (DMI) and metabolizable energy intake (MEI) were determined daily for each steer. Respiratory rate (RR) and pulse rate (PR) were measured daily at 1600 hr on each steer. Body temperature (BT) was obtained via an 8-inch rectal probe with a thermistor mounted in the tip; BT were taken at ten-minute intervals for the duration of the trial using a data logger. Pulse rate was determined via a pulse monitor attached to an ear clip sensor. A baseline PR was determined for each steer by averaging six readings taken over the last four days of the pre-trial period while the steers were on the 55 percent roughage diet.

Results

As a result of changing outside ambient temperatures, mean temperatures (Table 2 and Figure 1) were not able to be maintained throughout the trial, but

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Table 3. Mean dry matter intake (DMI), metabolizable energy intake (MEI), respiratory rate (RR), pulse rate (PR), change from baseline PR (PRCHG), and body temperature (BT) for feedlot cattle fed adaptation diets and exposed to thermoneutral (TNL) or hot (HOT) environmental conditions (ENVCON)[a].

Diet period:	1		2		3	
ENVCON:	TNL	HOT	TNL	HOT	TNL	HOT
DMI, lb/day	13.43[c]	13.56[c]	14.33[d]	14.40[d]	13.47[c]	11.00[b]
MEI, mcal/day	15.98[c]	16.14[c]	18.11[d]	18.20[d]	18.05[d]	14.74[b]
RR, breaths/min	58[b]	109[d]	64[b]	132[e]	80[c]	135[e]
PR, beats/min	87[b]	92[bc]	96[cd]	93[b]	102[d]	86[b]
PRCHG, %	2.9[b]	8.4[bc]	12.0[cd]	10.2[bcd]	18.2[d]	2.7[b]
BT, °F	103.3[b]	103.3[b]	103.8[bc]	104.5[cd]	104.7[d]	105.6[e]

[a]Diets contained 40, 25, and 10% roughage and were fed sequentially for 5, 5, and 7 day periods, respectively.
[bcde]Means in a row with different superscripts differ ($P < .05$).

increased from period one to period three in both TNL and HOT rooms by 6.5 F° and 6.8 F°, respectively. Mean temperature humidity index (THI) was 4.3 (75.4 vs 79.7) units greater in the HOT room. Peak THI averaged 72.4, 75.2, and 79.6 in the TNL room and 83.8, 84.7, and 88.1 in the HOT room in periods 1, 2, and 3, respectively.

During periods 1 and 2 (Table 3 and Figure 1), when steers were fed 40 percent and 25 percent roughage diets, respectively, DMI and MEI were unaffected by EHL. When the 10 percent roughage diet was fed (period 3), DMI and MEI were decreased significantly ($P < .05$) for the steer group in the HOT room even though steers were exposed to EHL for 10 days previously. Respiratory rates increased (periods 1 vs 3) with increases in energy density of the diet fed in both TNL and HOT treatments. However, PR increased only in the TNL treatment; the lowest PR occurred in the HOT treatment when DMI and MEI were the lowest (period 3). Percent change, from a baseline PR, followed a similar pattern. In the TNL treatment, PR tended to increase with each increase in energy density of the diet, while in the HOT treatment, PR tended to be indicative of MEI. As steers moved from lower to higher energy density diets, BT significantly ($P < .05$) increased in both TNL and HOT treatments. As expected, the greatest increase in BT occurred in the HOT treatment. The inability of an animal to dissipate or rapidly acclimate to added heat from the diet most likely contributed to the decline in DMI for cattle fed the 10 percent roughage diet in the HOT treatment.

Pre-trial baseline temperatures, while cattle were fed the 55 percent roughage diet in the stalls, averaged 102.3°F for both HOT and TNL treatments. Normal rectal BT, for the cattle type used, should average 101.5 ±1°F. During the trial, average steer BT ranged between 103.3 to 105.6°F. There was no evidence of ill health in the steers during the trial; intakes (DMI) remained between 2.1 and 2.7 percent of body weight. The increase in ambient temperatures of < .5 F°/day, on the average, during the trial may have also contributed to an

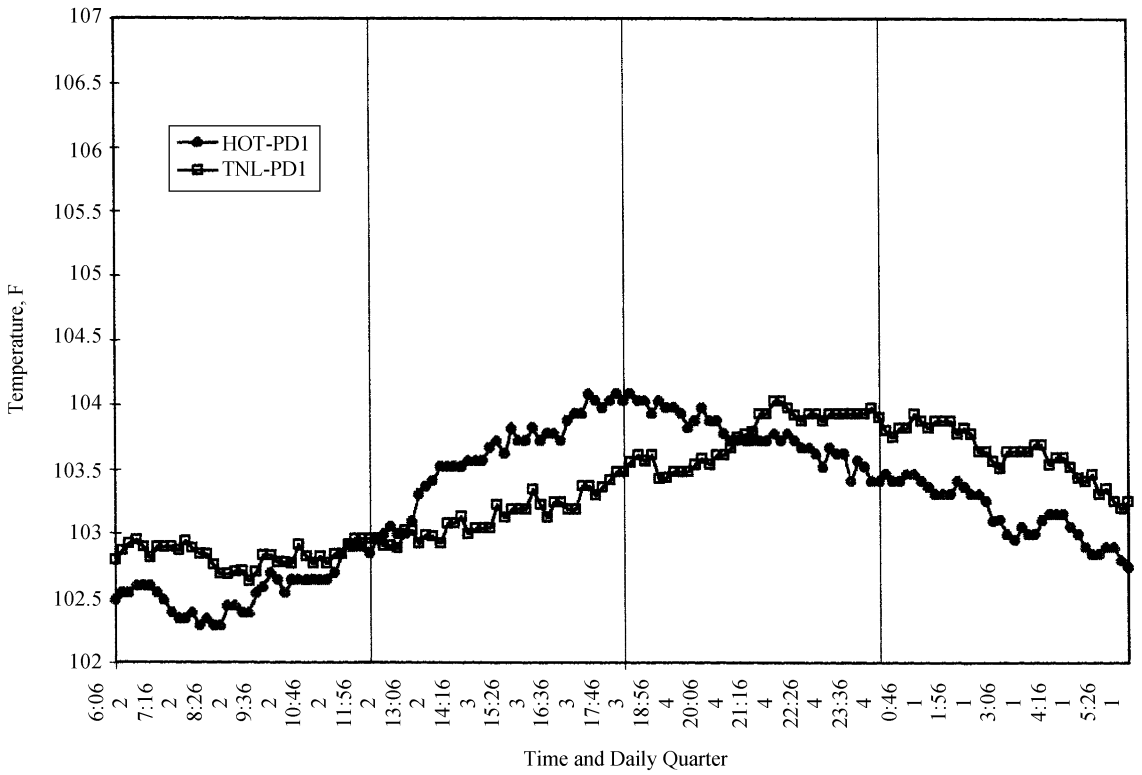

Figure 2. Rectal temperatures for steers fed 40% roughage diet (period 1-day 1 through 5).

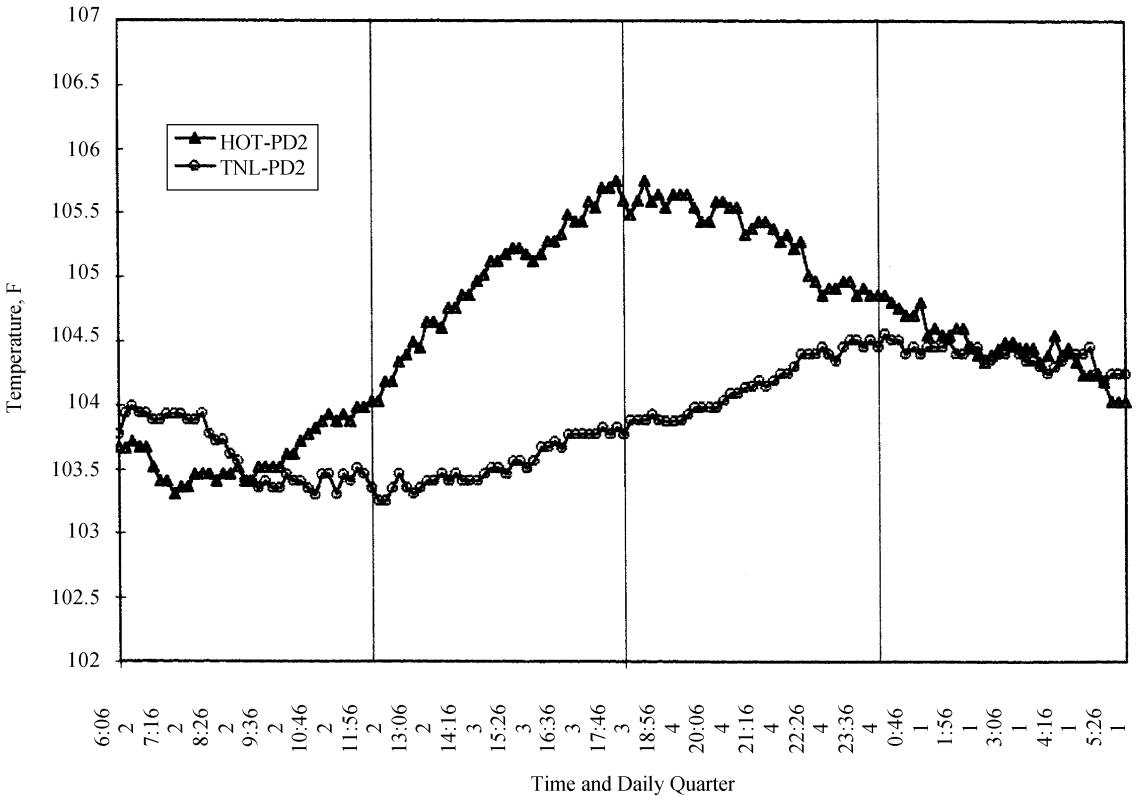

Figure 3. Rectal temperatures for steers fed 25% roughage diet (period 2-day 6 through 10).

increase in BT; although this gradual change in normal ambient temperature should have minimal effect on BT. Increasing dietary energy density, by decreasing roughage level from 55 percent to 10 percent, increased BT over 2 F° (102.3 vs 104.7) in the TNL treatment. The higher roughage diets (≥25% of diet DM) are lower in metabolizable energy density, appear to contribute less to metabolic heat load, and thus appear to allow for lower peak BT. Once cattle are adapted to high energy diets, the extent to which BT returns to previous normal BT is not known. Feeding higher energy diets would appear to make cattle more susceptible to EHL, particularly as they are being stepped-up or adapted to high energy diets.

Figures 2 through 4 display the 24-hr BT pattern associated with cattle exposed to EHL and fed 40 percent, 25 percent and 10 percent roughage diets, respectively. Although THI was similar between periods 1 and 2, dramatic differences are apparent in the relative shape of the BT curves. Ranges and magnitude in BT were similar between TNL and HOT treatments when a 40 percent roughage diet was fed (Figure 2). When 25 percent (Figure 3) and 10 percent (Figure 4) roughage diets were fed, differences ($P < .05$) in maximum and minimum BT were observed between HOT and TNL treatments from 1201 to 1800 hr and 1801 to 2400 hr. Although ranges in BT increased as higher energy density diets were consumed, differences in BT range were not found between TNL and HOT treatments.

The four quarterly periods for the HOT treatment roughly correspond to a transition period (Quarter 2) from nighttime cool-down to day heating, increased BT period associated with heat stress (Quarter 3), transition from daytime heat to nighttime cool-down (Quarter 4), and nighttime cooling (Quarter 1). For the TNL treatment, the periods are similar except Quarter 3 and 4 both represent an increase in BT with no transition prior to nighttime cooling being present. In all feeding periods, lower or nearly equal BT (Quarter 1) were found in the HOT treatment during the initial portion of nighttime cooling compared to the TNL treatment. This may be a result of the overcompensation of physiologic and metabolic processes associated with reducing BT as opposed to the TNL treatment, in which BT during nighttime cooling tended to remain stable from midnight then drop-off beginning around 400 hr, particularly for steers fed 25 percent and 10 percent roughage diets.

In the TNL treatment, continued metabolism of ingested feed, at a time when the steers are lying down (reducing surface area exposure and dissipation of heat), possibly explains the slight rise in or maintenance of BT after midnight. As digestion of ingested feed diminishes, when the animal rises and exposes more body surface area to dissipate heat, and/or environmental temperatures decline, BT begins to decline during the latter part of period 1. For the TNL treatment, BT tended to remain at a low point until mid to late morning (Quarter 2), or approximately 2 to 4 hr post-consumption of the AM feed

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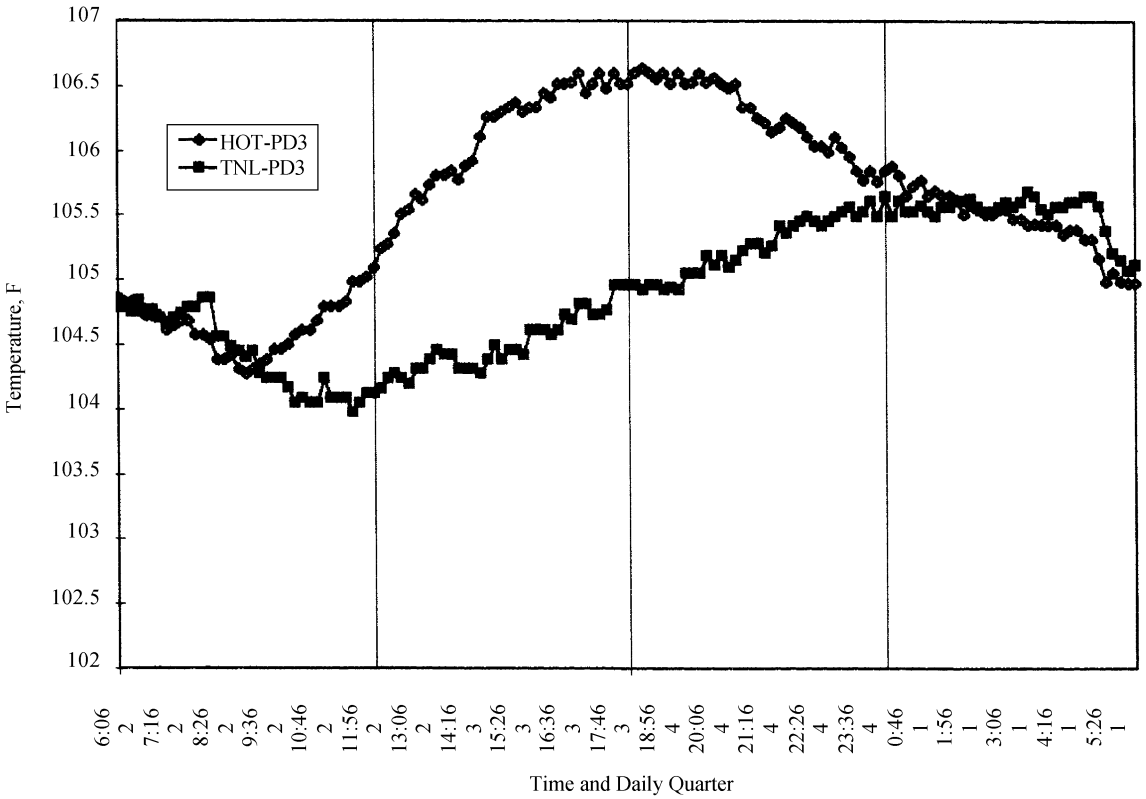

Figure 4. Rectal temperatures for steers fed 10% roughage diet (period 3-day 11 through 17).

(Figures 3 and 4). Also, BT of the HOT treatment group was found to be as low or lower than BT of the TNL treatment group during some portion of quarter 2 in both periods 1 and 2 (figures 2 and 3). This drop in BT in the HOT group to equivalent BT levels was not found in period 3 (figure 4). Obtaining BT levels in quarter 2, which are comparable to those in cattle fed under TNL conditions, may be needed for normal DMI to be obtained in cattle exposed to excessive heat load.

In conclusion, feedlot cattle (individually fed in metabolism units) being adapted from 55 percent to 10 percent roughage diets and exposed to EHL were able to maintain intake up to the 25 percent roughage diet, even though BT was elevated from the heat load. At 10 percent roughage, effects of increased dietary energy density in combination with EHL were sufficient to reduce DMI and MEI. Increases in BT were found in cattle as they were stepped up from 40 to 10 percent roughage diets under both TNL and HOT conditions.

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[1]Terry Mader, Professor of Animal Science, Northeast Research and Extension Center, Concord; John Gaughan, Lecturer and Bruce Young, Professor and Department Head, Department of Animal Production, University of Queensland-Gatton, Gatton, Queensland, Australia.

Effects of Feeding Level and Diet Energy Density on Cattle Exposed to Heat

Terry Mader
John Gaughan
Bruce Young[1]

Under hot environmental conditions, individually fed steers maintained lower body temperatures and greater intakes when limit fed when compared to steers fed the same diet ad libitum.

Summary

Individually-fed feedlot steers were exposed to excessive heat load or thermoneutral conditions and fed a 6% roughage diet (135 ME, Mcal/cwt) ad libitum (HE) or the same diet 90% of ad libitum (LE), or fed a 28% roughage diet (124 ME, Mcal/cwt) ad libitum (HR). Steers fed HE diets had greater (P < .10) respiratory rates than cattle fed HR diets. Also, HE fed cattle had greater (P < .10) pulse rate than LE and HR fed cattle at 0 800 hr but not at 1600 hr. Near the time of peak heat exposure (1600 hr), under hot conditions, HE and LE fed steers had body temperatures 1.5 and 1.0 F° greater (P < .10) than HR fed cattle, although metabolizable energy intake tended to be greater for LE fed steers and lower for HR fed steers when compared to HE fed steers.

Introduction

Factors such as high solar radiation, high air temperature, high humidity, and low wind velocity are conditions that can lead to animal discomfort and lower performance. Although proper feedlot design partially alleviates problems associated with excessive heat load (EHL), it cannot eliminate effects. Management of diet and feeding programs to aid in alleviating problems of EHL may become more crucial during periods of environmental stress. This study was undertaken to evaluate individually-fed feedlot cattle provided diets having different dietary energy levels and densities when subjected to thermoneutral or hot environmental conditions.

Materials and Methods

A metabolism trial was conducted during the late summer and early autumn at the University of Queensland, Gatton College, Department of Animal Production facilities. Six yearling Hereford steers (mean weight = 780 lb) were randomly assigned to individual stalls (9.8 ft × 3.3 ft) in one of two temperature controlled rooms. Each animal was restrained in its stall by a head halter and had previously been accustomed to being led and tied. Three diet treatments were imposed (Table 1). Cattle were fed a 6% roughage diet ad libitum (HE) or the same diet at 90% of ad libitum (LE), or fed ad libitum a 28% roughage diet (HR) such that ME intake of the 28% roughage diet approximated the ME intake of the restricted-fed 6% roughage diet. Water was available ad-libitum. The trial was replicated three times with steers being assigned to a different feeding regime and environmental condition combination each period.

Table 1. Composition of diets.

	Roughage level	
	28%	6%
Ingredient, % of DM		
Barley	34.0	44.8
Sorghum	34.0	44.8
Alfalfa hay	19.0	6.0
Barley straw	9.0	—
Limestone	—	.4
Dry supplement[a]	4.0	4.0
Calculated nutrient content, % of DM		
Dry matter	90.0	90.0
Crude protein	12.8	12.8
Calcium	.69	.64
Phosphorus	.38	.43
Rumensin, g/ton	20.0	20.0
NEg, Mcal/lb	.53	.62
ME, Mcal/lb	1.24	1.35

[a]Contained protein, minerals, vitamins and Rumensin.

Steers were accustomed to feeding treatment over a seven-day period at or near thermoneutral conditions. Feed intakes and refusals were recorded daily throughout the trial. During the test periods (four days each), the hot room was heated to temperatures in excess of 100°F through supplementary heat while temperatures in the thermo neutral room ranged from 62.8°F to

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83.9°F. The test rooms varied in temperature with outside conditions, particularly at night. High temperatures were imposed in the hot room beginning at 1000 hr and ending at 1800 hr. A gradual cool-down to thermoneutral conditions was allowed at night to depict normal cyclical daily temperatures. Temperature in the thermoneutral room was also allowed to follow a normal cyclical pattern.

Feed dry matter intake (DMI) and metabolizable energy intake (MEI) were determined daily for each steer. During the four-day test periods, respiratory rate (RR) and pulse rate (PR) were measured daily at 0800 and 1600 hr on each steer; body temperature (BT) was recorded, using a data logger, at five minute intervals for the duration of the trial via an 8-inch rectal probe with a thermistor mounted in the tip. Pulse rate was determined via a pulse monitor attached to an ear clip sensor.

Data were analyzed for a 2 x 3 factorial design with pre-planned comparisons made for HE vs LE diets, HE vs HR diets, environmental treatment by HE and HR diet interaction, and environmental treatment by HE and LE diet interactions.

Results

Mean temperature in the thermoneutral room (Table 2), over the test period, averaged 74.4°F. Relative humidity (RH) ranged from 39.8% to 94.3% (mean 68.4%). Mean temperature-humidity index (THI) was 71.7 and ranged from 61.5 to 81.0. Mean temperature in the hot room was 86.5°F and ranged from a maximum of 105.3°F to a minimum of 60.1°F. Mean RH was 56.0% and ranged from 13.4 to 93.7%. Mean THI was 79.1 and ranged from 59.6 to 92.1. Mean THI between 1200 and 1800 hr was 85.4 in the hot room and 71.0 in the TNL room. During this time period, temperature in the hot room averaged 98.4°F.

Mean RR (Table 3) was greater ($P < .10$) for cattle in the hot room at both 0800 and 1600 hr. Cattle fed HE diets had greater ($P < .10$) RR than LE fed cattle at 0800 hr only but greater RR than HR fed cattle at both 0800 and 1600 hr. Only at 0800 hr did PR differ; HE fed cattle had greater ($P < .10$) PR than LE and HR fed cattle. Interactions between environmental conditions and diet existed for BT at both times. Near the time of peak heat exposure (1600 hr), HE and LE fed cattle had BT 1.5 and 1.0 F° greater, respectively, than HR fed cattle. Under thermoneutral conditions, BT tended to be similar among diet treatments but with the LE fed steers tending to have the lowest BT. Under hot conditions, BT were greatest for HE fed cattle and the least for HR fed cattle (Table 3, Figure 1, and Figure 2).

Table 2. Mean environmental conditions associated with feedlot cattle exposed to thermoneutral (TNL) or hot (HOT) environments[a].

Environment:	TNL	HOT
Temperature, F°	74.4	86.5
Relative humidity, %	68.4	56.0
THI	71.7	79.1

[a]Cattle were fed ad libitum (HE) or 90% of ad libitum (LE) a 6% roughage diet, or fed ad libitum a 28% roughage diet (HR) such that ME intake of the 28% roughage diet approximated the ME intake of the restricted-fed 6% roughage diet.

In the thermoneutral treatment group (Table 4), DMI of the LE fed steers was 91.5% of that for the HE fed steers and near the designed level of 90%. Environmental condition by diet interactions ($P < .10$) were found for DMI, MEI and mean daily water intake (WTI). In both environmental treatment groups, DMI as a percent of bodyweight (% BW) was similar for HE and HR fed steers. However, LE steers tended to have the lowest DMI under thermoneutral conditions, but tended to have the greatest DMI under hot conditions. This same trend was particularly evident for MEI and MEI (% BW) under hot conditions; whereas under thermoneutral conditions, MEI was similar between LE and HR fed steers but greater than HE fed steers. Under hot conditions, DMI as a % of BW were reduced by a similar amount (.33 units) for the ad libitum fed steer groups (HE and HR) when compared to steers fed under thermoneutral conditions. Lower DMI and MEI found in the HR fed steers would most likely contribute to the lower BT experienced in steers fed under hot conditions, although lower BT was not found for HE fed steers with the reduced intakes experienced under hot conditions.

Water intake was greater ($P < .10$) for LE and HR fed steers when com-

Table 3. Mean respiratory rate (RR), pulse rate (PR), and body temperature (BT) collected at 800 and 1600 hr for cattle fed feedlot diets while being exposed to thermoneutral or hot environmental conditions (Env)[a].

Env:	TNL			HOT		
Diet:	HE	LE	HR	HE	LE	HR
RR, breaths/min						
800 hr[b,c,d,e]	60.9	55.6	56.1	66.4	59.5	60.9
1600 hr[b,c,e]	74.7	70.5	61.3	128.0	125.4	122.7
PR, beats/min						
800 hr[c,d,e]	80.7	77.1	76.2	79.2	75.7	72.4
1600 hr	92.9	92.2	88.7	85.7	93.0	86.8
BT, F[1]						
800 hr[b,c,d,e,f,g,h]	101.6	101.4	101.5	103.1	102.0	101.7
1600 hr[b,c,d,e,f,g,h]	102.1	101.5	102.0	105.0	104.5	103.5

[a]Cattle were fed ad libitum (HE) or 90% of ad libitum (LE) a 6% roughage diet, or fed ad libitum a 28% roughage diet (HR) such that ME intake of the 28% roughage diet approximated the ME intake of the restricted-fed 6% roughage diet.
[b]Env effect ($P < .10$).
[c]Diet effect ($P < .10$).
[d]HE vs LE ($P < .10$).
[e]HE vs HR ($P < .10$).
[f]Env by diet interaction ($P < .10$).
[g]Env by HE and LE interaction ($P < .10$).
[h]Env by HE and HR interaction ($P < .10$).

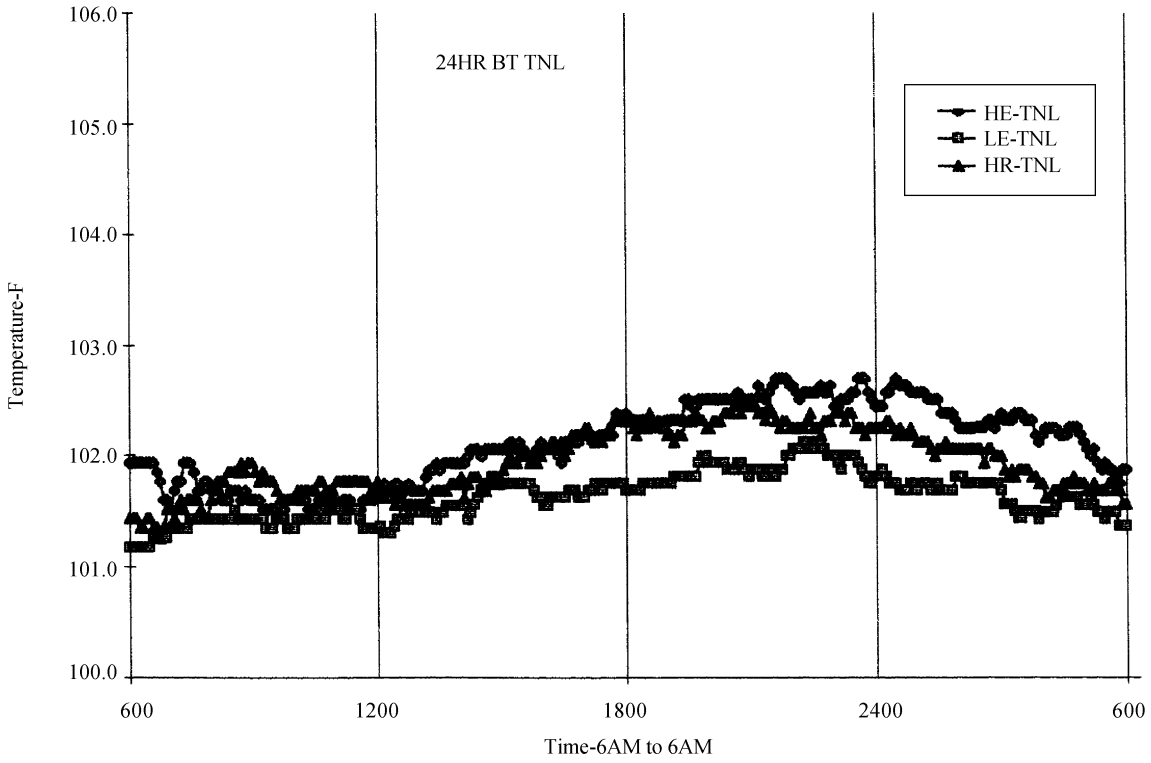

Figure 1. Rectal temperatures for steers fed a high energy diet, ad libitum (HE) or limited (LE), or fed 28% roughage diet (HR) under thermoneutral conditions.

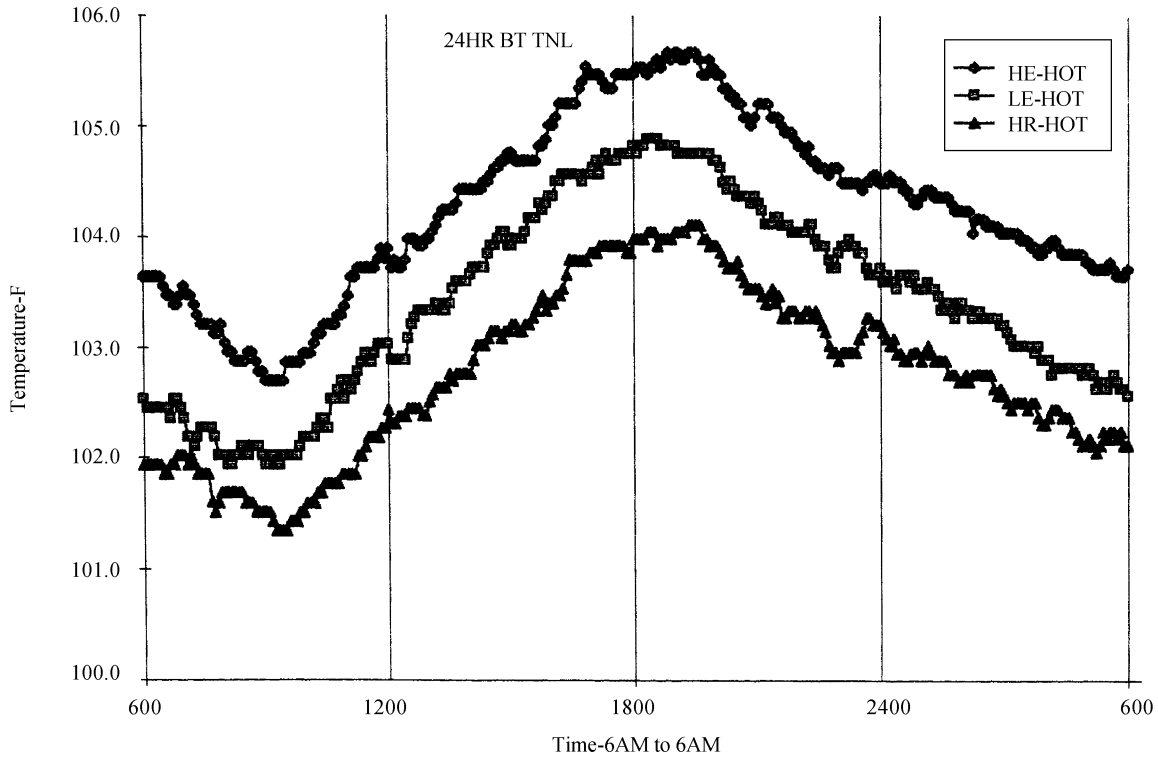

Figure 2. Rectal temperatures for steers fed a high energy diet, ad libitum (HE) or limited (LE), or fed 28% roughage diet (HR) under hot environmental conditions.

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Table 4. Mean daily dry matter (DMI), metabolizable energy (MEI), and water intake (WTI) for cattle fed feedlot diets and exposed to thermoneutral or hot environmental conditions (Env)[a].

Env:	TNL			HOT		
Diet:	HE	LE	HR	HE	LE	HR
DMI, lb/day[b,c,d]	15.71	14.37	15.82	13.36	13.71	12.97
MEI, Mcal/day[b,c,d,e,f,g]	21.30	19.47	19.56	18.11	18.58	16.03
DMI, % BW[b,c,d]	2.00	1.80	1.99	1.67	1.75	1.67
MEI, % BW[b,c,d,e,f,g]	5.98	5.38	5.42	4.99	5.23	4.55
WTI,						
gal[e,f,g]	5.88	7.05	7.10	5.41	7.49	6.83
gal/lb DMI[b,c,e,f,g,h]	.38	.47	.43	.38	.54	.53
gal/Mcal MEI[b,c,e,f,g,h]	.28	.35	.35	.28	.40	.43

[a]Cattle were fed ad libitum (HE) or 90% of ad libitum (LE) a 6% roughage diet, or fed ad libitum a 28% roughage diet (HR) such that ME intake of the 28% roughage diet approximated the ME intake of the restricted-fed 6% roughage diet.
[b]Env effect ($P < .10$).
[c] Env by diet interaction ($P < .10$).
[d] Env by HE and LE diet interaction, ($P < .10$).
[e] Diet effect ($P < .10$).
[f]HE vs HR ($P < .10$).
[g]HE vs LE ($P < .10$).
[h]Env by HE and HR diet interaction ($P < .10$).

pared to HE fed steers; only in the LE fed group did hot conditions enhance WTI, although the interactions between environmental conditions and diet were not found. Expressing WTI per unit of DMI and MEI showed similar trends although environmental conditions by diet (HE vs HR) interactions existed ($P < .10$). Cattle fed HR diets tended to consume more water per lb of DMI and mcal of MEI under hot conditions; effects of hot conditions were not found for HE fed cattle. Data suggest that under hot conditions, LE and HR individually-fed cattle had lower BT than HE fed cattle and that DMI of LE fed cattle was reduced slightly but remained above DMI of HE and HR fed cattle.

[1]Terry Mader, Professor of Animal Science, Northeast Research and Extension Center, Concord; John Gaughan, Lecturer, and Bruce Young, Professor and department head, Department of Animal Production, University of Queensland-Gatton College (UQG), Gatton, Queensland, Australia.

Composting of Feedlot Waste—Update of Research Activities

Gary Lesoing
Terry Klopfenstein
Dan Duncan
Mark Schroeder[1,2]

Composting of feedlot manure is an alternative waste management system that is environmentally sound, provides flexibility in application as a nutrient source, and is economically feasible.

Summary

Composting of beef feedlot manure at the ARDC Integrated Farm has been a feasible waste management system from 1993 to 1996. Composting of feedlot manure provides flexibility in application, reduces the need for purchased P, reduces odor, provides a stabilized N and P source, reduces volume, and kills weed seeds and pathogens. Cost of composting and spreading ranges from $3.75 to $6.00/ton, but value of N and P in compost generally ranges from $5.00 to $8.00/ton. Spreading of compost on cropland in a uniform manner is a concern and equipment is being evaluated that will best improve this situation.

Introduction

In 1993 a composting operation was started between the Integrated Farm Project and the Agricultural Research and Development Center (ARDC) Feedlot. Progress of this project was reported in the *1996 Beef Cattle Report.* This project has continued in 1995 and 1996. Results from the first two years of this project show that composting is a feasible waste management system for beef feedlots. Many large commercial feedlots throughout the state are composting cattle waste. Composting reduces fly and odor problems associated with stockpiled and land applied manure, stabilizes nitrogen and provides flexibility for land application, and kills weed seeds and pathogens in the manure through the composting process. While composting has many advantages, it requires additional labor, time, money, land, and careful management. There is potential for greater loss

of nitrogen during the composting process compared to conventional manure handling systems and it may require the purchase of additional equipment to turn and spread the compost.

In 1995 and 1996, evaluation continued on the cost of composting, nutrient content of compost and crop response to application of compost. New projects investigated alternative methods to improve the composting process and management of the composting site.

Procedure

Economic Evaluation

Composting continued in 1995 and 1996 as the ARDC feedlot hauled manure to the compost site and put it in windrows for composting. In 1995, approximately 450 tons of feedlot manure were composted at the site. Manure hauled to the site early in the spring was wet, but later in the year as the weather became hot and dry, much of the manure hauled to the site was dry. Composted beef feedlot manure was turned an average of four times during the summer. Costs of composting and spreading compost were estimated by two methods. One method is similar to the one described in the *1996 Beef Report* for 1994. The other method involves use of custom labor and trucks to haul compost to the field and spread compost with a rented tractor. This is the procedure currently being used to spread much of the compost on the ARDC. Costs are based on $1/mile for truck usage, $30/hr for a loader and operator, $11/hr for labor, and $19.50/hr for tractor rental. We own our spreader, but estimate it costs approximately $.60/ton of compost spread. Compost was loaded twice, which added to the cost of spreading. Average distance to the field was 2.4 miles.

Crop Response

Each windrow of mature compost was sampled at several locations within the windrow, and a composite sample was analyzed for dry matter, N, and P. Compost has been applied to production fields which have tested low in soil P. Compost is applied at a rate of approximately ten tons/acre. There have been thirteen check strips established in these fields to compare crop response from compost application. Check strips run the length of the field, are 50 feet wide, receive no compost, and receive commercial N only if needed. Crop yields were monitored on these check strips in 1995.

In spring 1995, an experiment was initiated in cooperation with the Biological Systems Engineering Department (BSE). Compost was applied in alternating 20 ft.-wide strips across the length of a 36-acre center pivot at the rate of ten tons/acre in early March. One half of the pivot was planted to corn following soybeans and one half to soybeans following corn. Both crops were planted no-till. Crop yields were measured on the paired strips for both corn and soybeans in the fall of 1995. Strips were sampled to obtain baseline information on P content of soil. Observations were also made on weed pressure.

Composting Process Improvements

As previously mentioned, much of the manure hauled to the compost site was very dry. This material did not heat up or compost well. An experiment was conducted to compare manure with added water to manure which received no water. The effects of the water on compost temperature and final nutrient content were measured. Another project involved the addition of sawdust and swine lagoon water to feedlot manure compared to adding only swine lagoon water to manure for composting. Sawdust was added to give the beef feedlot manure a more favorable carbon:nitrogen ratio to help conserve more N. After composting was complete, both composts were sampled for N, P, and dry matter composition.

Environmental Concerns

The possibility of nitrates leaching below the compost site and into the groundwater is a concern of composting. To address this issue, in the summer of 1995 we collected several soil cores at our compost site as deep as 17 ft. at locations adjacent to compost windrows or where windrows were the previous year. These were compared to samples taken at the site in areas where compost had never been made or stored to see if there was any accumulation of nitrates below the site.

Results

Economic Evaluation

Costs of composting were similar to 1994, when the same method was used to estimate costs in 1995. Costs were $3.75/ton for producing beef compost, delivering it to the field, and spreading the compost. Costs of turning the compost were $1.25/ton and $2.50/ton for spreading. Cost of composting when the custom application method was used was much more expensive. Cost of spreading was approximately $4.75/ton, with turning costing $1.25/ton, for a total cost of $6.00/ton. Even though having the compost applied in this manner is expensive, the value of N and P in the compost usually equals or exceeds the cost of making and spreading the compost. Based on commercial fertilizer values ranging from $0.149 to $0.186/lb for N and $0.263 to $0.286/lb of P_2O_5, the value of compost averaged $7.44/ton in 1995. Composition of composted feedlot manure averaged 11.1 lbs N/ton and 12.3 lbs P_2O_5/ton on an "as is" basis. Dry matter of compost was 82.85 percent, very similar to 1994. N content of compost was slightly lower than in 1994, but compost was quite variable. Phosphorus content was lower in 1995, but this may be due to diets lower in P.

Crop Response

Yield response has been variable to compost additions the past three years. Corn appears to respond the most to compost the year after application. Corn yield has increased by an average of 9 percent the first year after compost additions compared to no compost additions. There was no response in corn yields the second year after compost

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application. Wheat planted shortly after compost application has shown the greatest response. Yields were increased 14 percent compared to wheat with no compost applied. Soybean yields increased an average of three percent following the first year and 13 percent following the third year of application.

In the winter of 1995, compost was applied and check strips established on an irrigated continuous corn field where ridge-till and conventional disk-plant tillage systems were practiced on different parts of the field. Yield results showed a 19 percent increase in yield (108 vs 91 bu/acre) from compost addition for the conventional tillage, with only a three percent increase on the ridge-till (93 vs 90 bu/acre). In previous years, crop yields were similar for compost applied to no-till or conventional tilled (disked) fields. This is a concern since most of the compost on our fields is surface applied under no-till conditions. We will continue to monitor crop yields and soil characteristics on compost check strips for several different crops over the long-term on production fields.

We know the application rate of compost per acre is accurate, but there is a concern about the uniformity of distribution. The variability across the width and length of the spread is great. This is the most limiting factor in getting producers to use either manure or compost as a resource rather than a waste. The machinery industry and the University are working to improve this situation.

Soil samples (0 to 6") taken from the compost study established with BSE in the spring of 1995 indicate P levels of 17 ppm with a range of 14 to 22 ppm on the soybean field and 19 ppm on the corn field ranging from 11 to 29 ppm. These average P levels fall within the medium range for P, in which additional application is not recommended for corn or soybeans. Levels below 15 ppm are considered low, and P is generally recommended for these crops. With the 10 tons/acre application of compost, approximately 200 lbs/acre equivalent of P_2O_5 were applied. These should meet P needs on this field for many years. Crop yields measured on these fields in the fall of 1995 showed a four percent increase on corn strips which received compost (159 vs 153 bu/acre). One half of the strips was cultivated to facilitate incorporation of the compost, while the other half was not. Yields were not affected by cultivation. Soybean yields were only increased one bu/acre (47 vs 46 bu/acre) with compost addition.

Weed pressure was observed on the compost and no compost strips for both soybeans and corn. Many species of weeds were present in compost and no compost strips. There was concern that compost did not heat up sufficiently to kill many of the weed seeds. It appeared shattercane, lambsquarters, and kochia weed seeds may have been in the compost. A study is currently being conducted at the compost site to determine the effectiveness of composting in killing different species of weed seeds. Yields and soil characteristics on this project will continue to be measured in future years.

Composting Process Improvements

Adding water to beef feedlot manure successfully increased the temperature of compost, which is important for stabilizing nitrogen and killing weed seeds and pathogens. Water was added during the turning process. Ideally, moisture content of manure for composting should be 40 - 60 percent, but this manure contained only 10 percent moisture, and was increased to 25 percent by adding water. Compost that received water was turned two days later, and again as temperature increased. Compost that received water was turned five times, but that without water only twice. Compost temperatures heated up to 160°F following addition of water, while compost without added water only heated up to 121°F. Nitrogen content following composting was 14.8 and 14.4 lbs/ton for compost without water and compost plus water, respectively, on an "as is" basis. This demonstrates that water additions can be made to compost to facilitate the composting process without substantial loss of N if temperatures are monitored closely.

A second project evaluating the use of sawdust as a carbon source to provide a more favorable C:N ratio did not increase N recovery. For greatest retention of N in composting, there should be at least a 20:1 C:N ratio. Unfortunately, the C:N ratio of feedlot manure usually ranges from only 10:1 to 15:1. It usually is not economical to add a carbon source or water to the manure unless the value is increased enough to make it a more marketable product. Sawdust added to manure only increased the C:N ratio to 15:1, but manure without sawdust addition had a C:N ratio of only 10:1. Swine lagoon water was pumped on the compost during turning to facilitate composting of manure that was approximately only 13 percent moisture. Adding water brought moisture levels up to over 30 percent. Swine lagoon water was very dilute, and nitrogen additions from it would be negligible. Feedlot manure was highly decomposed, and very high in ash, (approximately 80% DM). The material did not heat up very well during composting, 120°F and 140°F for manure only and manure plus sawdust, respectively. Nitrogen recovery rates were high for both treatments, approximately 90 percent due to the low temperatures generated. Nitrate levels and C:N ratios after composting were 272 and 1303 ppm and 9:1 and 8:1 for compost plus sawdust and compost without sawdust, respectively. The low nitrate levels indicate the addition of sawdust successfully composted a more stable final product.

While these practices may not be economical for producers at this time, there may be opportunities when waste carbon materials are available and the value of compost could be enhanced to make it feasible. These practices will continue to be investigated.

Environmental Concerns

Results of soil samples at the compost site indicate the concern for nitrates leaching below the site was justified. Nitrate levels averaged 16 ppm per ft. in the top 5 feet below the

surface, and 10 ppm per ft. at the 5- to 10-foot depth. This compares to 4 ppm per ft. in the 0 to 5' depth and 5 ppm per foot at the 5- to 10-foot depths for the control. Due to the higher nitrate levels below the compost site, we decided to move most of the site across the road and plant alfalfa in the spring of 1996 on the old site. Alfalfa will be used to scavenge excess nitrates out of the subsoil at lower depths before leaching into the groundwater. Part of the old site remained and composting continued in 1996, while nitrates are being monitored below the site. Alfalfa was established, but germination was poor in locations of windrows in 1995, probably due to a high salt content. Surface soil in these areas will be sampled for confirmation. The plan is to rotate between compost sites every three to four years and grow alfalfa following composting as a nitrate scavenger to prevent groundwater pollution.

Conclusions

Composting of beef feedlot manure at the ARDC Integrated Farm has been a successful method of waste management from 1993-1996. Although it requires careful management and more labor, land, and equipment, it provides flexibility in application and reduces the need for purchased P. The greatest challenge is to be able to spread compost uniformly in the field. Long-term impact of compost on crop production needs to be monitored. The addition of water and sawdust to facilitate the composting process, improve nitrogen stabilization, and increase temperatures to kill weed seeds and pathogens may have potential. Management of the compost site is important to prevent nitrates from leaching into the groundwater. Relocation of the compost site and use of alfalfa as a nitrate scavenger should solve this problem.

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[1]Gary Lesoing, Research Assistant Professor, Center for Sustainable Agricultural Systems; Terry Klopfenstein, Professor, Animal Science, Lincoln; Dan Duncan, Director ARDC, Ithaca; Mark Schroeder, Farm Manager ARDC.

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