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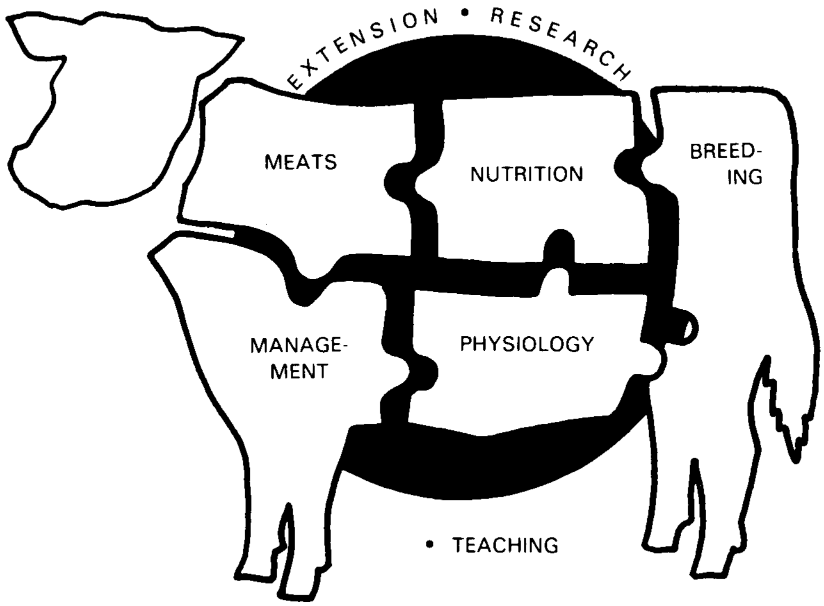
2001 Beef Cattle Report

NEBRASKA



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Beef Cattle Report

Table of Contents

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A Comparison of Beef Cattle Crossbreeding Systems Assuming Value-Based Marketing

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Optimal use of beef breeds and crossing systems depends on total-industry net returns, not just value of carcasses. Level of feed requirements, milk production and other performance characteristics are important in determining industry value.

Summary

This study simulated total life-cycle expenses and income under value-based marketing to arrive at predicted net returns for crossbreeding systems. The simulation used a deterministic model of totally contained beef breeding systems and evaluated 14 breeds and their crosses from biological data collected at the U.S. Meat Animal Research Center in Nebraska. Comparing beef cattle crossbreeding systems under value-based marketing will aid us in understanding the interactions of the total system. Besides value of carcasses, feed requirements, level of milk production and other characteristics are important in determining net returns.

Introduction

For the evaluation of breeds and crosses, the beef cattle industry should not simply base decisions on carcass value. Rather, consideration needs to be given to total life-cycle expenses and income. For example, breeds or crosses that have the highest carcass value might also have the highest production costs due to poorer reproduction and/or higher maintenance feed costs. The system also should evaluate a full, totally contained, sustainable, crossing system (i.e., one that contains all necessary purebred and crossbred groups). The purpose of this study was to simulate biological and then economic outcomes under value-based marketing for several breeding systems. All systems were simulated for two marketing scenarios for fed calves: equal age at slaughter and equal backfat at slaughter.

Procedure

Fourteen breeds and their crosses were simulated using biological performance derived from several data reports from the Germ Plasm Utilization and the Germ Plasm Evaluation projects, conducted at the U.S. Meat Animal Research Center near Clay Center, Neb. The 14 breeds were: Hereford, Angus, Simmental, Limousin, Charolais, Brahman, Red Poll, Gelbvieh, Maine Anjou, Braunvieh, Chianina, Brangus, Pinzgauer and Tarentaise. In addition, reports from other literature also were incorporated to set levels of individual and maternal heterosis for the simulation and to predict heifer performance from steers.

Simulations were done using a deterministic model (i.e., all performance was based on averages within a breed or cross with no variation between animals) encompassing conception through slaughter. All systems were simulated using an equal resource base. The standard resource base was an equal use of summer pasture. For the 14 pure breeds, the number of AUM's per 1,000-cow herd was simulated. The average of these 14 purebred systems with 1000 breeding females became the standard base of AUM usage. After establishing the standard base, the total number of cows in each total system, including all purebred systems, was varied to equalize use of the standard pasture resource.

This work simulated purebred, two-breed rotation, three-breed rotation, rota-terminal, and four-breed composite systems, using the 14 breeds. The rotational and rota-terminal systems were totally contained beef breeding systems. Separate breeding groups were part of the total rotational systems and were assumed to produce purebred breeding animals (bulls) needed for the rest of the system. The rota-terminal system assumed a two-breed rotation to generate replacement females plus terminal crossing to a third breed of sire to produce only slaughter animals. Thus for a rota-terminal system, there would be three purebred groups (two to produce bulls for the two-breed rotation plus one to produce bulls for the terminal cross) in addition to the crossbred groups that made up the total system. The four-breed composite was assumed to be already created, thus only one breeding group was simulated.

The system simulated conception through slaughter. Calving was in the spring, weaning was at 205 days, and calves immediately entered the feedlot for feeding until slaughter. The average days fed for the biological data from the U.S. Meat Animal Research Center was 235 days with slaughter at 440 days. Output was initially generated for an equal number of days fed (235) and equal age at slaughter (440 days). These outcomes are called "Equal Age." Purebred groups varied widely in backfat and yield grade when slaughtered at an equal age. Thus, another management scenario was simulated where genetic groups of animals were fed different numbers of days and then slaughtered at the same backfat. Outcomes under this management are called "Equal Fat." Because this required further extrapolation from the biological data base and minimizing

(Continued on next page)

the amount of extrapolation is desired, the average backfat of purebred groups in the "Equal Age" scenario was used as the slaughter endpoint in the "Equal Fat" scenario. For steers, this was .24 in, and for heifers, the endpoint was .28 in.

Numbers of steers and heifers fed directly for slaughter varied for each system and were a function of the total size of the system as determined by the constant pasture resource base, the reproductive rate and the number of breeding bulls (purebred and composite systems and segments of rotational systems) and replacement heifers needed (purebred and composite systems plus rotational segments of rotational and rotaterminal systems). Feedlot income, cowherd income, feedlot costs and cowherd costs were totaled and total income minus total costs yielded predicted net returns of each system. Various input costs and output values were derived from 10-year averages for Nebraska.

Fifteen traits were used in the simulations. Many of these 15 traits incorporated differences in 2-year-old, 3-year-old, and mature dams to help evaluate the cow herd. For the crossbreeding systems to be evaluated, individual and maternal heterosis estimates were determined for each of the 15 traits. An age distribution for the cow herd was simulated, based on reproductive rate and culling of all non-pregnant females at weaning time to produce income. All cows were assumed culled for salvage at 8.5 years of age. Calf losses were simulated at various times of the production year, and cows not nursing a calf were culled to generate income.

Traits simulated can be subdivided into growth and body weights, energy requirements, milk production, reproduction and carcass characteristics. Tables 1 (calf and cow weights, milk production, reproduction and calving difficulty), 2 (feed energy requirements), 3 (carcass characteristics and value under Equal Age slaughter), and 4 (carcass characteristics and value under Equal Fat slaughter) contain purebred values for samples of the traits. Value per pound of carcass for slaughter steers and heifers was based on yield grade, marbling and breed type using regression equa-

Table 1. Purebred animal weights (1b), milk production (lb/205 days), reproductive performance and calving difficulty used in simulations.

Breed	Birth weight weight mature dam[a,b]	200-day weigiht mature dam[a,b]	Breeding female mature weight[a]	Milk production mature dam[a]	% weaned of exposed mature dam[a]	% calving difficulty 2-year-old dam[c]
Hereford	83	431	1151	2156	83.3	49
Angus	78	465	1155	2846	84.7	32
Simmental	92	540	1332	4105	82.4	45
Limousin	86	474	1273	3258	85.2	34
Charolais	95	522	1416	3137	85.2	42
Brahman	75	517	1352	4262	84.0	7
Red Poll	85	484	1168	3752	84.4	58
Gelbvieh	91	543	1330	4045	85.1	53
Maine Anjou	92	505	1407	3876	85.4	48
Braunvieh	94	542	1326	4475	85.2	51
Chianina	92	509	1415	3117	86.4	37
Brangus	84	468	1302	3543	83.3	41
Pinzgauer	96	525	1278	4061	84.2	53
Tarentaise	82	506	1279	3783	83.2	36

[a]Data simulated for 2-year-old, 3-year-old, and mature dams; data from only mature dams shown here.
[b]Average for steers and heifers.
[c]Data simulated for 2-year-old, 3-year-old, and mature dams; data from only 2-year-old dams shown here.

Table 2. Purebred energy requirements and milk production used in the simulations.

Breed	Maintenance energy[a] Kcal/kg$^{.75}$/day	Preweaning gain energy Mcal/lb	Feedlot gain energy[b] Mcal/lb	Feedlot gain energy[c] Mcal/lb
Hereford	108	2.27	5.56	5.39
Angus	109	2.38	5.59	5.39
Simmental	121	2.55	5.32	5.39
Limousin	118	2.38	5.33	5.39
Charolais	116	2.50	5.31	5.39
Brahman	109	2.54	5.40	5.39
Red Poll	117	2.41	5.44	5.39
Gelbvieh	116	2.57	5.31	5.39
Maine Anjou	110	2.46	5.39	5.39
Braunvieh	117	2.56	5.34	5.39
Chianina	125	2.47	5.38	5.39
Brangus	109	2.37	5.40	5.39
Pinzgauer	114	2.50	5.33	5.39
Tarentaise	113	2.49	5.40	5.39

[a]Non-lactating, gestating cow; all other cow and calf simulated maintenance costs derived from this base value.
[b]Data simulated for steers and heifers; steer data shown here for "Equal Age" slaughter scenario.
[c]Data simulated for steers and heifers; steer data shown here for "Equal Fat" slaughter scenario.

Table 3. Purebred steer[a] carcass characteristics used in Equal Age (440 days) at slaughter simulations.

Breed	Yield grade	Marbling score	Carcass weight, lb	Value, $/lb
Hereford	3.32	421	675	1.05
Angus	3.46	441	697	1.04
Simmental	2.29	380	767	1.09
Limousin	1.89	343	728	1.10
Charolais	2.34	371	767	1.08
Brahman	2.91	351	743	1.05
Red Poll	3.11	430	694	1.06
Gelbvieh	2.09	353	750	1.09
Maine Anjou	2.49	368	747	1.08
Braunvieh	2.13	384	747	1.09
Chianina	2.24	317	732	1.09
Brangus	2.99	381	747	1.05
Pinzgauer	2.32	416	757	1.08
Tarentaise	2.91	393	728	1.07

[a]Heifer data were simulated from steer data.

Table 4. Purebred steer[a] carcass characteristics used in Equal Fat (.24 in) at slaughter simulations.

Breed	Days fed	Yield grade	Marbling score	Carcass weight,lb	Value, $/lb
Hereford	180	2.75	374	606	1.07
Angus	178	2.86	390	625	1.07
Simmental	301	2.75	431	860	1.07
Limousin	288	2.19	349	797	1.09
Charolais	314	2.91	431	877	1.06
Brahman	233	2.89	349	740	1.05
Red Poll	212	2.89	410	666	1.06
Gelbvieh	319	2.63	414	865	1.07
Maine Anjou	236	2.50	369	749	1.08
Braunvieh	274	2.38	414	800	1.08
Chianina	245	2.38	324	800	1.09
Brangus	229	2.94	376	739	1.05
Pinzgauer	286	2.68	459	797	1.07
Tarentaise	229	2.85	389	749	1.07

[a]Heifer data were simulated from steer data.

Table 5. Average net returns ($) under Equal Age at slaughter scenario for all crosses in a system and for selected crosses in each system.

System[a]	Average of all	Average of top 10[b]	Average of bottom 10[c]
Purebred	32,246	42,787	17,134
Two-breed rotation	41,450	51,175	28,975
Three-breed rotation	43,647	54,117	31,587
Rota-terminal	42,700	54,829	26,407
Composite	41,998	52,076	30,985

[a]All crossing systems are totally sustaining, thus including all necessary purebred groups. Rota-terminal has a two-breed rotation plus terminal cross. Composite has equal parts of four breeds. All systems have equal use of pasture resource derived from the average resource required for the fourteen 1000-cow purebred systems.
[b]Top 3 for purebreed.
[c]Bottom 3 for purebred.

tions developed in research work at Texas A&M (Griffin et al., 1989).

Results

Equal Age at Slaughter

Table 5 contains average net returns of the 14 purebreds, 91 possible (14!/[2! 12!]) two-breed rotations, 364 possible (14!/[3! 11!]) three-breed rotations, 1092 possible (14!/[2! 1! 11!]) rota-terminals, and 1001 possible (14!/[4! 10!]) composites under the Equal Age slaughter scenario. Because the systems were defined to have an arbitrary but equal pasture resource usage, net returns as presented are comparable on a relative basis. Overall, the three-breed rotation and rota-terminal were the most profitable systems under this scenario. These systems capitalize on appreciable amounts of heterosis. The four-breed composite also would have a high amount of heterosis, but it was constrained to have four breeds compared to the three-breed rotation and rota-terminal that contained three. Purebreeding was the least profitable system, losing out on the desirable benefits from heterosis.

Table 5 also contains averages for net returns of the top 10 and bottom 10 in each of the crossing systems plus averages for the top and bottom three purebreds for the Equal Age slaughter scenario. The average of all three-breed rotations was slightly higher than for all rota-terminals. But for the top 10 averages, the rota-terminal systems fared better than the three-breed rotations. Capitalizing on terminal crossing, especially with differential values of carcasses, was beneficial. Four-breed composite and three-breed rotation were the least risky systems because these were more profitable among the least profitable.

Table 6 contains the top 10 crosses for each crossbreeding system under the Equal Age slaughter scenario. Differences in net returns among the top 10 crosses within a system were not large, especially for those in the rota-terminal system. The top ten rota-terminals had five different breeds of terminal sire represented. Breeds that were included in many of the top crossing systems were: Charolais, Gelbvieh, Limousin,

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Table 6. Top ten crosses[a] in each system[b] on the basis of their net returns[c] ($) for Equal Age (440 days) at slaughter scenario.

Two-breed rotation		Three-breed rotation		Rota-terminal		Composite	
Cross	Net	Cross	Net	Cross[d]	Net	Cross	Net
CA*MA	52,876	LM*CA*MA	55,618	CA MA*TA	55,746	LM*CA*MA*TA	54,207
LM*MA	52,675	LM*MA*TA	55,330	LM MA*TA	55,580	LM*CA*GV*MA	52,959
MA*TA	52,406	CA*MA*TA	55,209	LM CA*MA	55,185	LM*GV*MA*TA	52,709
LM*CA	52,254	LM*CA*TA	55,087	GV MA*TA	55,107	CA*GV*MA*TA	52,637
CA*TA	52,063	LM*GV*MA	53,715	SM MA*TA	54,831	LM*CA*GV*TA	52,550
LM*TA	51,829	CA*GV*MA	53,515	GV CA*MA	54,701	SM*LM*CA*MA	51,274
GV*MA	49,821	LM*CA*GV	53,482	SM CA*MA	54,421	LM*CA*MA*PG	51,211
CA*GV	49,486	GV*MA*TA	53,141	BV MA*TA	54,315	LM*CA*MA*BV	51,206
LM*GV	49,468	LM*GV*TA	53,134	CA AN*MA	54,266	AN*LM*CA*MA	51,015
GV*TA	48,876	CA*GV*TA	52,938	CA GV*MA	54,135	SM*LM*MA*TA	50,989

[a]Breed codes: AN = Angus, BV = Braunvieh, CA = Charolais, GV = Gelbvieh, LM = Limousin, MA = Maine Anjou, PG = Pinzgauer, SM = Simmental, and TA = Tarentaise.
[b]All systems are totally sustaining, including necessary purebred groups.
[c]Net returns based on an equal use of pasture resources (average of 1000-cow purebred systems) and can be compared on a relative basis.
[d]Terminal sire breed and two-breed rotation dam breeds.

Maine Anjou and Tarentaise. On purebred carcass value, these five breeds averaged 1.6% higher value per pound than the other nine breeds.

Equal Fat at Slaughter

Table 7 contains the average net returns of the 14 purebreds, 91 two-breed rotations, 364 three-breed rotations, 1,092 rota-terminals, and 1,001 composites under the Equal Fat slaughter scenario. Overall, the three-breed rotation and composite were the most profitable systems under this scenario. These systems capitalize on appreciable amounts of heterosis, with substantial benefits coming through increased reproductive performance and increased rate of growth. Consistent with the Equal Age slaughter scenario, purebreeding was the least profitable system, losing out on the desirable benefits from heterosis.

Table 7 also contains the averages for net returns of the top 10 and bottom 10 in each of the crossing systems plus the averages for the top and bottom three purebreds for the Equal Fat slaughter scenario. The averages of all three-breed rotations and of all composites were slightly higher than for all rota-terminals. But for the top 10 averages, the rota-terminal systems fared better than the three-breed rotations and the composites. Being able to capitalize on terminal crossing, gaining the benefit of larger calf size relative to cow size in some systems, was beneficial. Four-breed composite and three-breed rotation were the least risky systems because these were more profitable among the least profitable.

Table 7. Average net returns ($) under Equal Fat at slaughter scenario for all crosses in a system and for selected crosses in each system.

System[a]	Average of all	Average of top 10[b]	Average of bottom 10[c]
Purebred	36,077	45,662	20,703
Two-breed rotation	49,121	60,459	36,411
Three-breed rotation	55,404	69,711	38,622
Rota-terminal	51,771	70,757	32,992
Composite	53,971	68,757	38,783

[a]All crossing systems are totally sustaining, thus including all necessary purebred groups. Rota-terminal has a two-breed rotation plus terminal cross. Composite has equal parts of four breeds. All systems have equal use of pasture resource derived from the average resource required for the fourteen 1000-cow purebred systems.
[b]Top 3 for purebreed.
[c]Bottom 3 for purebred.

Table 8 contains the top 10 crosses for each of the crossbreeding systems under the Equal Fat slaughter scenario. Differences in net returns among the top 10 crosses within a system were not as large in the composites as in the systems that used rotational crossing. The top 10 rota-terminals had six different breeds of terminal sire represented. Breeds that were included in many of the top crossing systems were: Angus, Charolais and Gelbvieh. On purebred carcass value, these three breeds averaged slightly less value per pound than the other 11 breeds. Thus value per pound of carcass had little or no influence on the value of breeds in crossing systems in the Equal Fat slaughter scenario.

Choices among breeds to use in crossing systems should be based on their overall contribution to total system net returns. There were 78 different combinations of crossbred dams for each terminal sire in the rota-terminal systems. Table 9 lists average net returns for the top 10 breeds when used as terminal sires in the rota-terminal systems and the top 10 two-breed rotations used for dams in the rota-terminal systems under the Equal Fat slaughter scenario. As terminal sires, Simmental, Gelbvieh and Charolais ranked as the top breeds. Angus was included as part of the dam-breed rotation in all of the top 10 rota-terminal systems.

Discussion

As with any simulation, results depend on the assumed models and data as well as the marketing system. All systems that were simulated had a constant amount of summer pasture usage for the cow-calf herd. This resulted in varying numbers of cows for the different crossbred and purebred groups. For

Table 8. Top ten crosses[a] in each system[b] on the basis of their net returns[c] ($) for Equal Fat at slaughter scenario.

Two-breed rotation		Three-breed rotation		Rota-terminal		Composite	
Cross	Net	Cross	Net	Cross[d]	Net	Cross	Net
AN*CA	64,906	AN*CA*GV	74,250	SM AN*GV	73,559	AN*LM*CA*GV	70,671
AN*GV	63,872	HE*CA*GV	72,366	GV AN*CA	73,335	AN*SM*CA*GV	69,586
HE*CA	62,598	AN*LM*CA	70,352	CA AN*GV	73,236	AN*CA*GV*MA	69,540
HE*GV	61,613	AN*LM*GV	69,961	SM AN*CA	72,577	HE*LM*CA*GV	69,194
CA*MA	60,345	AN*SM*CA	69,291	BV AN*GV	69,891	AN*CA*GV*PG	68,747
CA*TA	59,589	AN*SM*GV	68,759	LM AN*GV	69,649	HE*CA*GV*MA	68,544
GV*MA	58,784	CA*GV*MA	68,596	BV AN*CA	69,354	AN*CA*GV*TA	68,526
GV*TA	57,897	HE*LM*CA	67,956	LM AN*CA	69,129	HE*SM*CA*GV	68,479
AN*LM	57,729	CA*GV*TA	67,855	PG AN*GV	68,446	AN*CA*GV*BV	68,144
AN*SM	57,261	AN*CA*PG	67,724	GV AN*MA	68,390	HE*AN*CA*GV	67,929

[a]Breed codes: AN = Angus, BV = Braunvieh, CA = Charolais, HE=Hereford, GV=Gelbvieh, LM = Limousin, MA = Maine Anjou, PG = Pinzgauer, SM = Simmental, and TA = Tarentaise.
[b]All systems are totally sustaining, including necessary purebred groups.
[c]Net returns based on an equal use of pasture resources (average of 1000-cow purebred systems) and can be compared on a relative basis.
[d]Terminal sire breed and two-breed rotation dam breeds.

Table 9. Top ten terminal-sire breeds and top ten dam-breed rotations for net returns ($) averaged across rota-terminal systems[a] for Equal Fat at slaughter scenario.

Terminal Sire	Net Returns	Dam Rotation	Net Returns
Simmental	57,085	Angus*Gelbvieh	66,052
Gelbvieh	56,429	Angus*Charolais	66,041
Charolais	55,364	Hereford*Gelbvieh	61,917
Braunvieh	54,270	Hereford*Charolais	61,141
Limousin	53,673	Charolais*Maine Anjou	60,707
Pinzgauer	53,064	Angus*Maine Anjou	60,474
Chianina	51,613	Gelbvieh*Maine Anjou	60,353
Maine Anjou	51,362	Angus*Pinzgauer	59,664
Tarentaise	51,352	Angus*Simmental	59,587
Brangus	49,985	Angus*Limousin	59,571

[a]All systems are totally self sustaining, including necessary purebred groups.

example, the number of breeding females including replacement heifers, set to average 1,000 total breeding females, ranged in the purebreeding systems from 915 for Chianina to 1,216 for Hereford. Likewise, numbers of animals sold for income (cull females from the reproducing herd and fed steers and heifers) ranged widely too.

Several slaughter/marketing endpoints are possible. The “easiest” endpoint to simulate was the Equal Age at slaughter (440 days). Because the biological data on feedlot performance and carcass characteristics were available on a constant-time basis, simulation was relatively straightforward. The Equal Age scenario also is the easiest to follow for a producer trying to make comparisons using real, not simulated, cattle: It is very easy to designate a fixed number of days on feed and age at slaughter and then follow that. But, the range in carcass fatness at the Equal Age endpoint was large in the systems simulated under that scenario (e.g., purebred steers ranged in yield grade from 1.89 to 3.46, Table 3). Thus, the Equal Age scenario is probably not a realistic scenario for comparing possible performance of different systems.

The Equal Fat (.24 in for steers and .28 in for heifers) is more realistic and provides a much better basis for comparison. Producers can, through use of ultrasound or visual appraisal and experience, identify animals that are at the desired endpoint with reasonable accuracy. The differences between breeds and crossing systems in carcass value per pound are diminished when carcasses have the same outside fat. A possible weakness of the simulations under this Equal Fat scenario is linear adjustments, unique for each breed, were used to derive the carcass characteristics in Table 4 from those in Table 3. Because there were wide differences in backfat when slaughtered at 440 days of age, large differences then had to be simulated in days on feed to attain the target Equal Fat endpoints. Note in Table 4, that the different breeds of steers varied from 178 days on feed (slaughter at 383 days old) to 319 days of feed (slaughter at 524 days old).

Variation in value of slaughter animals from the feedlot was important in both scenarios but in different ways. The correlation between the average net returns for terminal sire breeds in rota-terminal systems and the value per steer was .94 in the Equal Age scenario and .96 in the Equal Fat scenario. But the correlation between the average net returns of terminal sire breeds in rota-terminal systems and the price per pound of carcass was .85 in the Equal Age scenario and only .31 in the Equal Fat scenario. Thus under an Equal Fat scenario, price per pound of carcass had very limited influence on net returns for the system.

Yet another marketing scenario could be examined, but it would require even further extrapolation and assumption. Assigning slaughter endpoints for breeds and crosses based on maximizing net returns would appear to be the most useful for ultimate decision-making in our industry. This would require assessing net returns for each cross in each system for variable days on feed, and then maximizing to set the endpoint. In the absence of this other scenario, net returns under the Equal Fat endpoint is our most useful scenario for making industry breeding decisions.

Breeds with high maintenance energy requirements generally did not surface as top maternal-use breeds. Cow size was not an important determiner of net returns for maternal use. Likewise, breeds with higher milk production levels did not rank well for maternal use. Breeds with the heavier slaughter weights at the target backfat ranked as the top terminal-sire breeds.

A marketing system that assigns “value” to individual carcasses and relays this information back to producers will affect choices of crossing systems plus influence selection and management decisions. By comparing beef cattle crossbreeding systems assuming value-based marketing we can better understand the interactions of the total system.

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June Versus March Calving for the Nebraska Sandhills: Production Traits

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Matching calving with growth of natural forages by moving traditional March calving to June resulted in a substantially lower amount of hay fed and less labor to produce a calf.

Summary

Our objective was to determine if labor and purchased inputs could be reduced and profitability improved by matching lactation (i.e., calving date) with nutrient content of grazed forages to extend the grazing season in beef cow/calf systems. By adjusting a traditional March calving date to a non-traditional June calving date, nearly 2 tons of harvested feed/cow was replaced by grazing. Feeding and calving labor inputs of mature cows were 61% lower for the June calving compared to the March calving system. Weaning rates were comparable between March and June calving systems. Weaning weights for June-born calves were 70 lbs lighter than March-born calves.

Introduction

The amount of harvested and purchased feeds required to sustain a cow herd is highly correlated with calving date. Calving in February and/or March in the Nebraska Sandhills results in the high nutrient requirements for lactation occurring when nutrient content of range forages are low. Thus, significant inputs of harvested and processed feeds are required to ensure that a high percentage of cows rebreed and produce a calf the following year. We hypothesized that a June calving date would match the high nutrient lactation requirements of the cow with high nutrient content of immature growing plants and extend grazing compared to a traditional March calving date. Our primary objective was to determine if harvested and/or purchased feeds and labor could be reduced and sustainability and profitability improved by matching lactation (i.e. calving date) with nutrient content of grazed forages in beef cow/calf systems.

Procedure

In 1993, cows from a March calving cow herd were bred to calve beginning either March 15 (75 cows) or June 15 (120 cows). Steer calves from March calving were finished as calf-feds. One-half of the steer calves from June calving were finished as calf-feds and one-half grazed summer Sandhills range as yearlings before being finished. Calving dates, weaning dates, and feeding periods are given in Table 1. Only mature cows were used in this study. Heifer calves are being developed for replacements and research is ongoing.

June calving cows were split into two groups for the breeding season. One group was bred on subirrigated meadow regrowth (60 cows) and the other on upland range (60 cows). Breeding season was 60 days for March calving cows and 45 days for June calving cows.

Weaning rates were calculated according to Standardized Performance Analysis (SPA) guidelines and were the same for the March and June systems. Because of potential bias from conversion of cows from March to June calving cycle, pregnancy rates during years 1993 and 1994 were not included in data analysis. Animal production and resource use (grazing, feed, and labor) records were maintained on each cow-calf herd from breeding through to slaughter through 1999 (4 production cycles). March calving cows were fed hay from subirrigated meadows about mid-January through April. June calving cows were fed meadow hay for three days after weaning and during a winter storm.

Results

Matching calving with growth of natural forages substantially reduced the amount of hay fed (Table 2). Over four years about 2 tons of hay were fed to March calving cows annually compared to about .1 ton of hay for June calving cows. However, about 60 lb/cow more protein supplement was fed to June calving cows annually than March calving cows. Labor for feeding and calving to produce a weaned calf in the June system was 61% lower than the March system (Table 2). In addition to differences in resource use shown in Table 3, a calving building commonly used in the traditional March system is not needed in the June system. Post-weaning resource requirements for calf feds (hay and supplement to prepare a weaned calf for shipment to the feedlot) were higher in

Table 1. Approximate dates for March and June calving systems.

	March	June	
Item	Calf feds	Calf feds	Yearlings
Breed cows	June-August	September-October	September-October
Calving	March-April	June-July	June-July
Wean	September 26	January 9	January 9
Steers Onto Grass	—	—	June 3
Steers Into Feedlot	November 13	February 13	September 12
Slaughter	May 22	August 19	January 23

Table 2. Average resource use per head for March and June calving systems 1995 to 1999.

	March	June			
		Calf feds		Yearlings	
Resource use	Calf feds	Range	Meadow	Range	Meadow
Cows					
Hay (tons)	1.97	0.11	0.11	0.11	0.11
Purchased feed (lb)	96	154	154	154	154
Grazing days (range)	233	207	162	207	162
Grazing days (meadow)	—	150	195	150	195
Feeding labor (hr)	0.66	0.18	0.18	0.18	0.18
Calving labor (hr)	0.57	0.30	0.30	0.30	0.30
Calves (wean to on grass/feedlot)					
Hay (tons)	—	0.22	0.22	0.79	0.79
Purchased feed (lb)	—	105	105	375	375
Grazing days (range)	49	—	—	31	31
Feeding labor (hr)	—	0.15	0.15	0.53	0.53
Yearlings (on grass to feedlot)					
Grazing days (range)	—	—	—	102	102
Calves/Yearlings (in feedlot)					
Feedlot days	191	189	189	134	134

Table 3. Pregnancy rate and weaning rate (percentage of cows exposed to the bull) of cows in March and June calving systems.

	March calving	June Calving	
Item		Range	Meadow
Pregnancy rate, %[a]	94.8	92.1	91.7
Weaning Rate, %[a]	88.8	90.2	87.7

[a]Means were similar (P>.10) for March vs. June systems and for meadow vs range during the breeding season within the June calving system.

Table 4. Average weights and ADGs for March and June calving systems 1995-1999.

	March	June			
	Calf feds	Calf feds		Yearlings	
Weights at:		Range	Meadow	Range	Meadow
Wean, lb	486	417	440	417	440
ADG wean to grass/feedlot, lb	0.55	0.22	0.17	1.01	1.11
On to Grass	—	—	574	607	
ADG on grass to feedlot, lb	—	—	—	1.61	1.32
Into Feedlot, lb	518	436	462	738	753
ADG in feedlot, lb	3.49	3.70	3.56	4.01	4.06
Slaughter (live wt.)[a], lb	1178	1124	1123	1265	1287

[a]Slaughter (live wt.) = hot carcass weight ÷ .62.

the June system. March-born calves grazed subirrigated meadow between weaning and the feedlot while June-born calves were fed hay and protein supplement. Calves grown as yearlings in the June calving system required more supplement, harvested forage, and grazing than June- or March-born calf-feds but were finished in the feedlot about eight weeks faster.

Pregnancy rate and weaning rate are reported in Table 3. Pregnancy rate and weaning rate were similar (P>.10) for March vs. June calving and for June calving cows bred on subirrigated regrowth and upland range.

Calf weaning weights and average daily gain (ADG) were different between March and June calving and between calves June calving that grazed subirrigated meadow and range during the breeding season (Table 4). June-born steer calves were about 50 to 70 lb lighter (meadow- and range-bred treatments, respectively) at weaning than March-born steer calves. The lower weaning weight of June-born calves compared to March-born calves is best explained by low calf gains produced on the low quality forages typical of Sandhills range during November through January. The ADG was greater for the March-born calves than June-born calves during backgrounding between weaning and shipment to the feedlot. However, ADG in the feedlot was higher for the June-born calf feds. Live weights at slaughter were higher for the March-born calf feds. A greater percentage of the carcasses from the March system graded Choice (53%) than the June system (33%). Sixty-six percent of the June system yearling carcasses graded Choice or upper 2/3 Choice. Carcass yield grades were 3 or less in all systems.

Matching calving date to immature, nutrient dense forages reduced the amount of hay fed and calving and feeding labor compared to March calving without reducing weaning rate. Although weaning weight was lower for June-born than March-born calves, the labor and feed savings appeared to offset the lower weaning weight.

We emphasize that the June calving date was selected as a means to match nutrient requirements of the cow with nutrients in grazed forages. Other calving dates are likely to be selected to match nutrient requirements of the cow with forage nutrients in other geographical areas. Adaption of an alternate calving season should be based on expected returns and ranch resources.

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June versus March Calving for the Nebraska Sandhills: Economic Comparisons

Gordon Carriker
Dick Clark
Don Adams
Russ Sandberg[1]

A June calving system extended grazing, reduced feed costs, reduced labor inputs and had higher net returns than a March calving system.

Summary

Costs and returns of June and March calving systems were compared at four production phases. Financial costs of the June system were lowest, due primarily to lower costs of producing a weaned calf. Post-weaning financial and economic costs at each phase were nearly identical. Selling June-born steer calves at January weaning would double net returns compared to selling March-born steer calves at October weaning due to lower costs and higher market prices. Net returns for June-born steer calves retained beyond weaning are highest if calves are retained as yearlings and finished. Calves finished as calf-feds provided the highest net returns for the March calving system.

Introduction

Input requirements for the June system are lower at some phases than those for the March system as described in the previous article, "June versus March Calving for the Nebraska Sandhills: Production Traits." The objectives of this research were to: 1) develop cost budgets for each system and compare the costs at several production phases in the two systems; and 2) develop net returns budgets for each system and compare the net returns at several production phases in the two systems. We hypothesized that the June system costs would be lower and net returns higher than those for the March system.

Procedure

Financial cost budgets were developed for each system through weaning. Economic and financial cost budgets were then developed for each production phase after weaning. Budgets were based on the 4-year (1995-1998) average resource use during each phase and 1998 input prices. All budgets include costs for harvesting hay and purchased feed, grazing (fence and water maintenance, livestock checking, etc.), labor, operating interest, management, overhead and heifer replacement. The budgets do not include charges for land, property taxes, insurance, or buildings. Ownership costs for hay harvesting and feeding equipment, but not other equipment, are included. Based on other research at GSL it was determined that the same land base (about 90% upland and 10% subirrigated meadows) could support equivalent numbers of cows year around for either system. Therefore, land charges and taxes would be the same. The March calving system would use the meadows for hay production while the June calving system would use them for summer and some spring and fall grazing . The economic costs for all phases beyond weaning reflect the opportunity costs of growing the steer calf during a production phase by also including the value of the incoming animal as if it was purchased at market. Valuing the steer calf at the beginning of each phase of production permits each phase to be evaluated independently, as if each phase was an independent enterprise. The financial costs reflect the accumulated cash costs of growing the steer calf through a particular production phase.

Annual net returns budgets were developed using the cost budgets, average annual steer weights at the end of each production phase, and 1992 through 1998 real (deflated market prices) prices received at western-Nebraska and eastern-Wyoming auctions. Potential selling strategies for the calf crops were determined based on the various production phases. The economic net returns at each production phase are calculated as the difference between gross revenue per calf and the opportunity cost of growing the calf and reflect the ability of each production phase to generate a return on investment, i.e., make profit. The financial net returns are calculated as the difference between gross revenue per calf and the accumulated costs of growing the calf and reflect the ability of each production phase to generate a cash flow.

The major costs for a weaned calf are those necessary to support the cow enterprise. As indicated, only budgets for financial costs were calculated through weaning. The hay cost, $40/t, was based on budget estimates for harvesting ($30/t) and feeding ($10/t) excluding labor. These costs included ownership costs for interest and depreciation on the equipment. Labor costs included in the budgets were based on actual labor for feeding and calving as recorded by the University staff at GSL. We charged labor at the rate of $7.50/hr except calving labor which was charged at time and a half since we believe calving to require more skilled labor and often occurs at night. No other labor was included in cow budgets since we assumed that other labor would be similar between systems. Purchased feeds such as protein supplement and salt and mineral were charged at actual costs based on 1998 prices. Interest on the value of cows and bulls was charged at 7.5%. Following Standardized Performance Analysis guidelines, replacement heifer costs were estimated from the net cost to produce a weaned calf. We used an initial selection rate of 20% of the heifer calves with 16% of these heifers ending up in the cow herd. We did not include the additional costs to take the heifer from calf to cow status. Based on preliminary research, it appears the first calf heifers can be developed for similar costs in the two systems. Costs for ensuring that the first calf heifer is bred for the second calf may be higher for the June system, but research is incomplete at this time. It is not likely that costs for the second calf will be different enough between the two systems to alter the conclusions of this paper. Each cow cost budget was credited with cull income for sale of cull cows, bulls and heifers minus death loss. We assumed the same cull weight of 1,100 pounds for both (March and June) cow herds. Cull prices varied from year to year and between systems since culls are usually available at different times of the year in the two systems. Grazing costs were estimated at $4/cow/month when grazing upland and $6/cow/month while grazing meadow. These are financial costs only and cover such items as repair and upkeep on fence and water and operating costs for checking cattle. To properly graze meadows, more fencing and water is required than with upland. The costs do not include the value of the forage. Animal health was not greatly different between the two systems; however, we did include $15/cow veterinary and medicine costs in both systems.

Costs beyond weaning were based on the actual feeds fed and feeding labor. Grass for June-born calves that were summered on grass the second summer was charged at the rate of $0.50/hd/day. This cost is intended to cover the costs of renting additional grass where the landlord checks the calves and takes care of all pasture and water management.

Feedlot costs were actual charges from the University feedlot near Mead, Neb., which included a $0.30/hd/day yardage charge. The costs were based on 1998 ration ingredient cost plus $1/cwt trucking charge to and from the feedlot.

Table 1. Average annual costs for March-born calf-fed and June-born calf-fed and yearling steers.

		June			
	March	Calf-fed		Yearling	
Production phase	Calf-fed	Range	Meadow	Range	Meadow
Economic costs/steer calf[a]					
Cow cost/calf weaned	$252	$173	$178	$173	$178
Calf costs: wean to on grass or feedlot	$404	$397	$417	$466	$487
Yearling costs: on grass to feedlot	—	—	—	$543	$559
Feedlot costs	$653	$666	$671	$751	$751
Financial costs/steer calf[a]					
Cow cost/calf weaned	$252	$173	$178	$173	$178
Calf costs: wean to on grass or feedlot	$294	$219	$225	$283	$289
Yearling steer costs: wean to feedlot	—	—	—	$382	$389
Feedlot costs: wean to slaughter	$580	$505	$511	$636	$643

[a]Economic costs include the opportunity cost of the incoming animal, i.e., the value of the animal priced at market. Financial costs include the accumulated costs of producing the animal.

Table 2. Average annual net returns for March-born calf-fed and June-born calf-fed and yearling steers.

		June			
	March	Calf-fed		Yearling	
Production phase	Calf-fed	Range	Meadow	Range	Meadow
Economic net returns/steer calf					
Calving to weaning	$86	$151	$161	$151	$161
Weaning to on grass	($36)	($20)	($34)	($28)	($32)
On grass to in feedlot	—	—	—	($45)	($62)
In feedlot to slaughter	$27	($38)	($45)	$20	$34
Financial net returns/steer calf					
Calving to weaning	$86	$151	$161	$151	$161
Weaning to on grass	$74	$158	$158	$156	$165
On grass to in feedlot	—	—	—	$115	$108
In feedlot to slaughter	$100	$124	$117	$135	$141

Results

The economic and financial cost budgets are summarized in Table 1. Through weaning the costs for both the economic and financial budgets were treated the same since there is no opportunity cost of an incoming animal at weaning. The cost of producing a June-born weaned calf was $74 to $79 lower per calf than the cost of producing a March-born weaned calf due to reduced harvested forage and feeding and calving labor expenses. The additional financial costs to grow a steer calf past weaning were nearly the same for both the June- and March-born calf fed systems; therefore, the financial cost advantage remained with the June system through the feedlot. However, the post-wean economic costs for the March born, calf-feds were slightly lower into the feedlot compared to June born calves bred on meadow ($404/hd versus $417/hd) and slightly higher than June born calves bred on range (Table 2). The economic and financial costs for June-born yearlings reflect the higher incoming animal values as well as the higher costs of finishing the calves as yearlings.

The economic and financial net returns to the March- and June-born systems are summarized in Table 2. When evaluating the economic net

(Continued on next page)

returns, a negative value for a phase of production indicates that phase would not stand alone as an enterprise without being subsidized by earlier or later phases. The phase does not generate a profit. Similarly, a negative financial net return, though not experienced, would indicate that growing a steer calf to a production phase would not generate a positive cash flow. Selling a June-born weaned calf in January from either the range- or meadow-bred treatments provided $65 to $75 more net returns, on average, than a March-born weaned calf sold in September/October. This difference is due to two effects. First, it cost less to produce a June-born calf. Second, the price received for June born calves sold in January averaged nearly $10/cwt higher (real prices) compared to the price received for the March-born calf sold in September/October. The price differential is a real effect of changing systems and must be considered if changes such as this are contemplated by any producer. It comes from a typically higher seasonal price in January compared to September/October and the fact that the June-born calves are lighter so the price slide also gives these calves a price advantage. The net effect is that the gross sale value received for a June-born calf sold in January is about the same as a March-born calf sold in the September/October time frame. The post-wean economic net returns indicate the June system is only profitable if the weaned calf is finished as a yearling and the March system is profitable if the weaned calf is finished in the feedlot. From the financial (cash flow) standpoint, the June system always generated higher net returns than the March system. The greatest financial net returns were for the June-born yearling prior to being put on grass.

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June Versus March Calving for the Nebraska Sandhills: Economic Risk Analysis

Gordon Carriker
Dick Clark
Don Adams
Russ Sandberg[1]

A June calving system can be more profitable than a March calving system without increasing economic risk.

Summary

Price risk analysis of economic and financial net returns from June and March calving systems was used to rank and identify preferred production/sale strategies according to risk preferences of producers. Analysis of economic net returns identified selling a June-born steer at weaning from the breeding on meadow (meadow-bred) treatment as preferred strategy regardless of risk preferences. Post-weaning, selling a June-born finished yearling steer from the meadow-bred treatment was ranked highest. Analysis of financial net returns identified selling a June-born yearling steer from the meadow-bred treatment prior to summer grazing as preferred for all but those strongly risk averse; selling a June-born steer from the meadow-bred treatment at weaning ranked second.

Introduction

Production agriculture is subject to several sources of economic risk: output price, yield, and input and cost. A simple comparison of average net returns from alternative production strategies overlooks risk. Comparison of the June-born calving system to the traditional March-born calving system also should include an evaluation of the economic risks involved. The objectives of this research were to: 1) identify the risk efficient (preferred) set of production strategies in the two calving systems based on the economic and financial net returns; and 2) rank the production stages in order of risk preference based on the economic and financial net returns distributions. We hypothesized that the production stages in the June system would be preferred over the same stages in the March system.

Procedure

Economic and financial net returns distributions were generated for each production stage for both the March and June calving systems using average input levels and animal weights, 1998 input costs and real (inflation adjusted) prices received from 1992 through 1998. Thus, the variation in net returns reported here is due strictly to variation in cattle prices. Economic net returns indicate the ability of an individual stage of production to generate an economic profit, i.e., the ability to stand alone as a separate enterprise without being subsidized by an earlier or later production stage. Financial net returns indicate whether producing to a stage of production will generate a positive cash flow. The 15 numbered sales strategies (Table 1) correspond with the stages of production and the alternative systems. For example, number 7 refers to selling a

Table 1. Number identifiers for production/sell strategies for March and June calving systems.

Production stage/	March	June			
		Calf feds		Yearlings	
Sell at:	Calf feds	Range	Meadow	Range	Meadow
Weaning	1	4	7	—	—
Yearling calf onto grass	—	—	—	10	13
Into feedlot	2	5	8	11	14
Slaughter	3	6	9	12	15

weanling calf born in June and bred on the meadow. Risk analysis considers not only the level of net returns from all strategies, but also the variation in those returns. Ranking strategies according to risk is not an easy task unless some strategies totally dominate all others. A dominating strategy would have higher net returns under all price situations. Generalized stochastic dominance (GSD) analysis of the economic and financial net returns distributions is a tool that can identify the preferred sales strategies and can rank all strategies according to the risk characteristics of the producers. GSD is the tool we chose to rank the financial and economic net returns.

GSD analysis does not make *a priori* assumptions regarding the net returns distributions or the risk attitude of decision makers.. The analysis allows for the ranking of alternative strategies over selected risk attitudes of the decision maker. GSD has been frequently used to rank crop rotations, crop varieties, pest and fertilizer management alternatives and other agricultural risk management strategies.

First- and second-degree stochastic dominance are special cases of GSD. First-degree stochastic dominance (FSD) assumes only that the decision maker prefers more to less, with no assumption about the decision maker's risk attitude. Second-degree stochastic dominance (SSD) assumes the decision maker prefers more to less and is risk averse. FSD and SSD are limited in their ability to discriminate between risky alternatives due to the nature of the underlying distributions being compared. FSD can only choose between two alternatives when the net returns for all situations for one alternative either are equal to or greater than net returns for the other alternative. SSD can rank two alternatives when the net returns over all situations exceed those of the other at all points in the cumulative probability distribution. This criterion cannot rank two alternatives where cumulative probability of alternative b's net returns exceed alternative a's at low levels of probability and then the cumulative probability of alternative a's net returns exceed b's at higher levels of probability. The cumulative probability of a level of net returns is the probability that net returns are equal to or less than a certain level. Since FSD and SSD alone are limited, we have used stochastic dominance with respect to a function (SDRF), which gives more power for ranking alternatives, with the rankings depending on the risk attitude of the decision maker. SDRF is the most generalized decision criterion associated with GSD analysis.

Table 2. Stochastic dominance analysis rankings of *economic* net returns from March and June calving systems.

Criteria	Preference Rankings[a] More preferred → Less preferred
FSD	***7***,4,1,15,12,3,5,10,13,6,9,2,8,11,14
SSD	***7***,4,1,15,3,12,5,10,2,8,13,11,6,9,14
SDRF	
Approximate Risk Attitude	
Strongly Risk Preferring	***7***,4,1,15,6,12,3,9,13,10,5,11,8,14,2
Moderately Risk Preferring	***7***,4,1,15,3,12,6,5,10,9,13,8,11,2,14
Slightly Risk Preferring	***7***,4,1,15,3,12,5,10,13,6,8,2,9,11,14
Risk Neutral	***7***,4,1,15,3,12,5,10,8,13,6,2,9,11,14
Slightly Risk Averse	***7***,4,1,15,3,12,5,10,8,13,2,6,11,9,14
Moderately Risk Averse	***7***,4,1,15,3,12,5,2,8,10,11,13,6,14,9
Strongly Risk Averse	***7***,4,1,15,3,12,5,2,8,10,11,13,14,6,9

[a]Refer to Table 1 for strategy codes. Bolded, italicized strategies are in the most preferred set.

Table 3.Stochastic dominance analysis rankings of *financial* net returns from March and June calving systems.

Criteria	Preference Rankings[a] More preferred → Less preferred
FSD	***15,6,7,8,13,5***,10,4,9,12,14,11,3,1,2
SSD	***6,8,15,7,13,5***,12,9,4,14,11,10,3,1,2
SDRF	
Approximate Risk Attitude	
Strongly Risk Preferring	***13***,5,7,8,10,4,15,12,6,9,11,3,14,1,2
Moderately Risk Preferring	***13***,7,5,8,10,4,15,12,6,9,11,3,14,1,2
Slightly Risk Preferring	***13***,7,5,8,10,4,15,12,6,9,11,14,3,1,2
Risk Neutral	***13***,7,10,5,8,4,15,12,6,9,11,14,3,1,2
Slightly Risk Averse	***13***,7,8,5,10,4,15,12,6,9,11,14,3,1,2
Moderately Risk Averse	***13,7,8,15,6***,5,12,9,4,10,11,14,3,1,2
Strongly Risk Averse	***6***,9,15,12,7,8,4,5,13,14,11,3,10,1,2

[a]Refer to Table 1 for strategy codes. Bolded, italicized strategies are in the most preferred set.

Results

The results of the GSD analysis of economic and financial net returns are presented in Tables 2 and 3, respectively. FSD, SSD, and SDRF analyses of the economic net returns (Table 2) identify sale at weaning of June-born calf feds from the meadow breeding treatment (strategy 7) as economically preferred. All that is necessary to assume about the decision maker is that he/she prefers more to less since strategy 7 was the dominant strategy with FSD. If our goal is to only find the dominant strategy for economic returns, then FSD was adequate. Notice

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that specifying the risk attitude made no difference in the preferred set. Sale at weaning of a June-born calf fed from the range breeding treatment (strategy 4) was ranked second followed by sale at weaning of a March-born calf fed (strategy 1). However, if we are interested in the ranking of all alternatives, then the risk preference of the decision maker becomes important which can be seen by comparing the rankings after the top four strategies as the risk attitude changes.

When the analysis turns to the financial net returns, FSD and SSD cannot rank single alternatives. FSD and SSD analysis of the financial net returns identified six strategies as all in the risk efficient set (equally preferred; Table 3). The numbers in bold italics note the six equally preferred strategies. However, the more discriminating SDRF analysis identifies sale of a yearling calf from the meadow breeding treatment prior to summer grazing (strategy 13) as the risk efficient (preferred) strategy for strongly risk preferring to slightly risk averse producers. Moderately risk averse producers would be indifferent between five alternatives, all in the June calving system. The preferred strategy for strongly risk averse producers is the sale at slaughter of a June-born calf fed from the range breeding treatment (strategy 6). With some knowledge of a decision maker's risk attitudes, SDRF was able to rank the 15 strategies in most cases. Regardless of the risk attitude, SDRF analysis of the financial net returns ranks the March calving system strategies low and often least preferred. Recall that this analysis considered only risk due to cattle prices. There may be other risks that have not occurred with our research that should be considered. If future research delineates possible other risks, they will be incorporated into the analysis.

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Protein Supplements and Performance of Cows and Calves in June-Calving Production Systems

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June-born calves grazed through the winter on cows fed protein supplement. Winter gain and summer protein supplement affected gain of yearling steers on summer grass and in the feedlot.

Summary

Lactating, June-calving cows that received protein supplement January through March maintained a lower body condition than dry June cows. Dry, non-supplemented cows lost more body condition compared to dry, supplemented cows over that same time period. June-born steers wintered at a low rate of gain (.4 lb/day) had higher daily gains on sub-irrigated meadow during May than June born steers wintered at a higher rate of gain (1.6 lb/day). Supplemental protein fed during summer grazing on range increased daily gains for steers wintered at both high and low gains compared to non-supplemented steers.

Introduction

A primary factor in determining economic efficiency in the beef cattle industry is feed cost. A June calving system was developed at the University of Nebraska Gudmundsen Sandhills Laboratory (GSL) to match the nutrient requirements of the cow to the nutrients available in the forage and to reduce the amount of harvested or purchased feeds that are typically fed in February-March calving systems. The need for protein supplement for grazing winter range after weaning in January has not been determined in the June calving system. Although nutrient content of the forage is low, nutrient requirements of a dry cow in the middle third of pregnancy also are low; therefore, supplemental protein may not be needed. When yearlings are integrated into the June-calving system, harvested and/or purchased feed and labor associated with feeding the calf after weaning from January to grass in May might be decreased by extending the grazing season of the calf through the winter. Grazing by the calf through the winter may be possible by leaving the calf with the cow from January to April, provided the cow is fed supplemental protein. The effect of rate of winter gain on summer gains of yearlings from June-calving systems and the effect of supplemental protein on summer daily gain of yearling steers from a June-calving system have not been determined. Our objectives were to evaluate: 1) the efficacy of extending grazing of June-calving cows and calves through winter, 2) effects of supplemental protein on dry June-calving cows grazing winter range, and 3) response of June-born yearling steers grazing summer range to supplemental protein.

Procedure

Winter grazing for dry and lactating June calving cows

Year 1. June-calving cows (95 head) were allotted equally to three winter grazing treatments: 1) Lactating cows with protein supplement (Lact-S), 2) Dry cows with protein supplement (Dry-S), and 3) Dry cows without protein supplement (Dry-NS). The winter grazing study began Jan. 6, 1999 and ended March 30, 1999. On Jan. 6, 1999, calves from cows in treatments 2 and 3 were weaned. All heifer calves and one-half of all steer calves were weaned on Jan. 6. Steer calves not weaned on Jan. 6 and their dams were assigned to treatment 1. Supplements were individually fed three times weekly to cows in treatments 1 and 2. Supplements were formulated to meet degradable intake protein (DIP) and undegradable intake protein (UIP) requirements of dry and lactating cows. Calves in treatment 1 were weaned on March 31. Body weight, body condition score (BCS), and pregnancy were recorded on all cows. (Table 2).

Year 2. The winter grazing study was conducted from Jan. 6, 2000 through March 29, 2000 during the second year. June calving cows (n=118) were split among the three treatments and all procedures were the same as in year 1.

June-born yearling steers

Year 1. June-born steers (n=62) were allotted to two rates of gain during winter and two protein treatments during summer grazing in a 2 x 2 factorial arrangement on Jan. 6, 1999. Rates of gain during winter were: 1) high gain and 2) low gain. Protein treatments during summer grazing on range were: 1) supplemental protein and 2) no supplemental protein. June born steers on high gain were weaned Jan. 6, 1999 and were fed wheat middlings at 2.8 lb/head/day and grass hay at 11.2 lb/head/day to gain 1.6 lb/day during winter. Low gain steers nursed the cows on range Jan. 6 to March 30, 1999 (treatment 1 of the cow study) and gained .4 lb/day. Steers wintered at high and low gain grazed subirrigated meadow from April 30 to May 31 and upland Sandhills range from June 1 to Sept. 9. One-half of the steers on both low and high winter gain treatments were fed protein supplement on range from June 7 to Sept. 8, 1999.

Table 1. Composition of protein supplement fed to June-born steers grazing upland Sandhills range.

Ingredient	% of supplement
Treated Soybean Meal	76.5
Feather Meal	18.8
Molasses	3.7
Pellet Binder	1.0

Steers on the supplement treatment were individually fed 2.9 lb of supplemental protein (Table 1) three times weekly. Body weight was recorded at the beginning and/or end of each grazing period through the winter and summer and average daily gain was calculated. Steers were finished at the University of Nebraska feedlot at Mead, Neb. Feedlot and carcass data are not presented in this paper.

Results

Winter grazing of dry and lactating June calving cows

Because there were no treatment by year interactions (P > .10), year effects were pooled across treatments. Cow body weight did not differ between the Lact-S and Dry-S cows nor the Dry-S and Dry-NS cows. Protein supplement appears to be important for dry cows to maintain condition while grazing dormant winter range, as shown by the lower (P < .01) BCS of Dry-NS cows (4.4) compared to Dry-S cows (4.7) on March 30. Lactating cows receiving protein supplement had lower BCS at the end of winter grazing on March 30 than dry cows receiving protein supplement (Table 2; P < .01). Body weight (1226 lb) and BCS (5.4) were similar (P > .10) across all treatments at precalving in June and prebreeding in September for year 1. It is interesting to note that although

(Continued on next page)

Table 2. Least squares means for cow body weight and body condition score for lactating cows receiving protein supplement (Lact-S), dry, supplemented cows (Dry-S), and dry, non-supplemented cows (Dry-NS) grazing winter range in 1999 and 2000.[a]

Item	Lact-S	Dry-S	Dry-NS	Contrast
Body Weight, lb				
Jan. 6, On Trial	1118	1101	1127	ns[b]
Mar. 30, Off Trial	1074	1073	1047	ns
Body Condition Score				
Jan. 6, On Trial	5.0	4.9	5.0	ns
Mar. 30, Off Trial	4.2	4.7	4.4	Lact-S vs. Dry-S** Dry-S vs. Dry-NS**

[a]All treatment x year interactions were non-significant (P>.10).
[b]ns = Non-significant P > .10.
** Significant P < .01

variation in BCS occurred between the three treatments on March 30, BCS for all treatments was similar at precalving and prebreeding. Percentages of cows pregnant for year 1 on January 6, 2000 were 96.2% for Lact-S cows; 89.7% for Dry-S cows; and 88.0% for Dry-NS cows. Pregnancy data are considered insufficient to draw conclusions until pregnancy data are available for year 2.

Yearling steers

No rate of winter gain by protein supplement interactions occurred (P >.10). Steers wintered at high gain were 57 lb heavier (P < .01) and 24 lb heavier (P < .10) than steers wintered at low gain on March 30 and on September 14, respectively. June-born steers wintered at a low rate of gain had daily gains .7 lb greater (P < .01) than steers wintered at high gain while grazing sub-irrigated meadow in May (Table 3). Protein supplement increased daily gain of steers by .4 lb/day compared to non-supplemented steers while grazing summer range.

Table 3. Body weight and average daily gain (ADG) of June-born steers wintered at low (.4 lb/day) and high (1.6 lb/day) rates of winter gain, grazing sub-irrigated meadow without protein supplement (supp.) or range with or without protein supplement during 1999.[a]

	Winter gain			Protein supplement		
Item	Low[b]	High	P[c]	No supp.	Supp.	P[d]
Body weight, lb						
Apr. 30, On meadow	479	536	**	498	517	ns
May 28, On range	544	580	**	552	572	ns
Sep.14, Off grass	705	729	+	686	748	**
ADG, lb						
Apr. 30 - May 28, Meadow	2.3	1.6	**	1.9	2.0	ns
May 29 - Sep. 14, Range	1.5	1.4	**	1.2	1.6	**
Apr. 30 - Sep. 14, Combined	1.7	1.4	**	1.4	1.7	**

[a]Interactions between rate of winter gain and supplement were non-significant (P>.05).
[b]Calves in this treatment were nursing cows in treatment 1 of cow study.
[c]Low vs. high, ** = P < .01, + = P < .10.
[d]No supp. vs. Supp., ns = non-significant, ** = P < .01.

Wintering June-calving cows with their calves on range January through March may be a practical method to overwinter calves in yearling systems if cows are fed protein supplement. Daily gain during winter and protein supplement during summer grazing affect daily gains and body weights at the end of summer grazing.

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Performance and Economics of Winter Supplementing Pregnant Heifers Based on the Metabolizable Protein System

Trey Patterson
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Supplementing pregnant heifers grazing winter range to meet metabolizable protein versus crude protein requirements may improve two-year-old pregnancy and profitability.

Summary

In 1997-98 and in 1998-99, pregnant, March-calving heifers (2,375 head) at two locations of a ranch in Nebraska were used to evaluate the production and economic responses of winter supplementation (September to February) to meet metabolizable protein or CP requirements. Net present value was used to determine the economic benefits of supplement treatments. In 1997-98, metabolizable protein heifers had higher pregnancy rates and expected profitability than CP heifers at one of two locations. In 1998-99, metabolizable protein heifers had higher pregnancy rates and expected profitability at both locations.

Introduction

For young cows to recover development costs, they must stay in production for multiple years. Economical nutrition programs that facilitate improved 2-year-old pregnancy rate have the potential to improve expected lifetime profitability.

The undegradable intake protein (UIP) content of grazed winter forage in the Sandhills of Nebraska is low (1997 Nebraska Beef Report, pp. 3-5). Microbial crude protein (MCP) production often is inadequate to meet the metabolizable protein (MP) requirement of growing heifers, resulting in a need for supplemental UIP. Providing additional MP to pregnant heifers decreased winter body weight (BW) loss in some situations (2000 Nebraska Beef Report, pp. 7-10).

The objective of the study was to document differences in reproductive performance when heifers are supplemented to meet MP rather than CP requirements. We hypothesized supplementing to meet MP requirements would improve 2-year-old pregnancy and lifetime value of the bred heifer.

Procedure

In 1997-98 (1156 head; 772 lb) and 1998-99 (1219 head; 813 lb), pregnant heifers at two locations of a commercial ranch in the Nebraska Sandhills were used following breeding as yearlings through pregnancy testing as 2-year-olds. The average calving date was March 25 of each year. Heifers were allotted randomly to one of two treatments (approximately 300 head/treatment) each year at each location (locations near Ashby and Whitman). Heifers received supplements while grazing fall-winter upland range and meadow from mid-September to mid-February of each year. Treatments were: 1) supplementation to meet MP requirements (MPR) or 2) supplementation to meet CP requirements (CPR). Feather meal was used for the UIP source in the MPR supplement (Table 1), with the supplement composed of 53% CP and 27% UIP (DM basis). The CPR supplement was composed of 51% CP and 13% UIP. The CPR supplement was fed at the rate of .89 lb/day (DM) throughout the trial, supplying 53 grams of UIP/day. The MPR supplement feeding rate increased gradually from .70 lb/day in October to 1.6 lb/day in February, supplying 86 grams UIP/day in October, 120 grams UIP/day in November, December, and January, 135 grams UIP/day in early February, and 203 g UIP/day after Febr. 15. Supplements were fed to treatment groups three times weekly as range cubes.

Meadow hay (7-9% CP) was fed at the discretion of the manager at each location in each year. Hay was typically fed at a rate of 4.5 lb/day (DM basis) starting in mid- to late December and increased to about 18 lb/day in February as heifers approached parturition. Heifers from each treatment at each location were managed in one group from mid-February to October of each year. Approximately 18 lb/day meadow hay (DM basis) and range were available mid-February (no supplement) until calving. After calving, approximately 24 lb of meadow hay and 4 lb of alfalfa hay (DM basis) were fed daily until available grazing. Heifers were exposed to a mix of mature and yearling bulls for 90 days beginning June 10 of each year.

In 1997-98, heifers were individually weighed and assigned a body condition score (BCS) on Sept. 15 and 16, Febr. 27 and 28, and on Oct. 21 and 22 (one day for each location). Weaning weights were taken on calves on Aug. 14 at Whitman and Sept. 3 at Ashby. Pregnancy was determined by palpation on Oct. 21 and 22. In 1998-99, heifers were weighed and BCS on Sept. 16 and 17, Febr. 16 and 18, and Oct. 25 and 27. Weaning weights were taken on calves on Aug. 19 at Whitman and Sept. 2 at Ashby. Pregnancy was determined by palpation on Oct. 25 and 27.

Budgets were set up starting with an arbitrary 100 bred heifers both in 1998 and 1999, corresponding to the years that supplement treatments were applied. Budgets were consistent with management where the experiment was conducted, and actual data from the operation were used to determine pregnancy, weaning, cull, and death rates, annual cow costs, and the weight of cattle marketed (either calves or cull females). All costs were inflated by 2.0% per year. Since costs and performance were similar across locations, one set of costs and performance data were used for both locations within each year. Revenue was calculated using market data for 1998 and 1999 (Crop and Livestock Prices for Nebraska, 1998), and projected prices for year 2000. Market prices for years 2001 through age 15 of the cows were estimated by historical data reported from 1985 to 1996. Annual net cash flow was determined for the original set of 100 females for each year up to when the cattle turned 15 years old. The inventory of heifers changed each year within each budget, as it was reduced by the number of cows sold or dead. All cows remaining at age 15 were considered to be sold.

Since the CPR treatment was the conventional supplementation protocol for this operation, the 2-year-old pregnancy rate for the CPR treatment was used as the "base" for each location within each year. Pregnancy rate of 2-year-old cows from the MPR treatment then was used in the budget to determine change in lifetime cash flow. Effects of treatments on 2-year-old pregnancy were assumed to not affect future production parameters.

Net present value (NPV) of the bred heifers (2-year-old production year) was determined from the budgets using the formula: $NPV = E1/(1+i)^1 + E2/(1 + i)^2 + ... + En /(1 + i)^n$, where E is net cash flow in each year 1 through n (n = 15 in this case), and i is the discount rate. A discount rate of 7.0% was used for all calculations, and this was assumed to be a real rate of discount. The NPV of bred heifers was calculated for both treatments at each location within each year. The NPV for the group was divided by the original 100 head to obtain NPV on a per head basis.

The MPR treatment cost more than CPR in 1997-98 ($2.71 and $3.33 difference in total supplement costs per head at Ashby and Whitman, respectively), and in 1998-99 ($0.58 and $0.59 at Ashby and Whitman, respectively). The different treatment costs were associated with costs of ingredients (Table 1)

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Table 1. Composition of supplements fed to heifers grazing winter sandhills range (% of DM).[a]

Ingredient	MPR	CPR
Cottonseed Meal	—	58.8
Feather Meal	40.2	—
Soybean Meal	—	17.8
Sunflower Meal	30.2	13.7
Wheat Middlings	26.2	—
Distillers Grains	—	3.4
Molasses (Cane)	2.1	2.1
Urea	—	2.8
Minerals/Vitamins	1.3	1.4

[a]Supplements were provided as range cubes fed 3 times weekly. MPR: designed to meet the metabolizable protein requirement; CPR: designed as conventional protein supplement.

and the amount of supplement fed. The difference between MPR and CPR supplement costs was lower in 1998-99, because the trial ended earlier in February before the scheduled increase in the amount of MPR to be fed.

Results

No treatment interactions or treatment effects on cow BW or BCS change between September and February, February and October, or September and October were observed (Table 2; P > .15). Calf weaning weights were similar between treatments. A treatment × year × location interaction for pregnancy rate (P = .07) was present. Therefore, pregnancy rate was analyzed within location of each year (Table 3).

In 1997-98, both MPR and CPR heifers at Ashby had a pregnancy rate of 95%. At Whitman in 1997-98, however, MPR heifers had a higher pregnancy rate (P = .01; 84%) than CPR heifers (75%). In 1998-99, the MPR heifers had a higher pregnancy rate (P = .01; 95%) than CPR heifers (88%) at Ashby, and MPR heifers tended to have a higher pregnancy rate (P = .15; 89%) than CPR heifers (85%) at Whitman.

The 95% pregnancy rate of both treatments at Ashby in 1997-98 indicate supplemental UIP above the amount in the CP balanced supplement was not necessary. Based on BW change, BCS change, and pregnancy rate at Ashby in 1997-98, it appears energy intake was not markedly restricted to the heifers. Since MCP production is a function of energy intake, higher energy intakes allow more MCP production and less need for supplemental UIP. The effects of year on fall-winter diet quality in the Nebraska Sandhills have been documented (1998 Nebraska Beef Report, pp. 20-21). An increased diet quality and/or forage intake at Ashby in 1997-98 potentially could explain the lack of response to supplemental UIP.

In the situations in this study where pregnancy rate was improved by supplementing to meet MP requirements, BCS loss over the winter was greater than .5 units. Patterson et al. (2000 Nebraska Beef Report, pp. 7-10) reported supplementing to meet MP versus CP requirements improved heifer BW gain over the winter in one of two experiments. The authors reported substantial BCS losses (-1.5 BCS from October to February) in the study where response to supplementing to meet MP requirements occurred. Energy intake can become low in some situations (2000 Nebraska Beef Report, pp. 7-10), and energy limits heifer performance during the winter instead of MP.

The increase in pregnancy rate in MPR compared to CPR heifers without improved BW or BCS change overwinter was not expected. However, similar responses have been reported with fat supplementation during gestation. The response to fat supplementation has been associated with altered hormone profiles. Supplemental UIP post-partum alters endocrine profiles in 2-year-old heifers. Supplementing UIP

Table 2. Body weight (BW), body condition score (BCS), and calf weaning weight of heifers supplemented to meet metabolizable protein requirements (MPR) or CP requirements (CPR) across two locations and two years (1997-98 and 1998-99) in the Nebraska Sandhills.[a]

Item	MPR	CPR	SEM[b]
Sept. BW, lb	792	787	2
Feb., BW, lb	913	904	7
Oct. BW, lb	937	928	9
BW Change, Sept.-Feb., lb	121	117	4
BW Change, Feb.-Oct., lb	24	26	7
BW Change, Sept.-Oct., lb	146	141	7
BCS, Sept.	5.8	5.8	<0.1
BCS, Feb.	5.2	5.2	0.1
BCS, Oct.	5.3	5.3	0.1
BCS Change, Sept.-Feb.	-0.6	-0.6	0.1
BCS Change, Feb.-Oct.	0.1	0.1	0.1
BCS Change, Sept.-Oct.	-0.4	-0.5	0.1
Calf Weaning Weight, lb	344	342	7

[a]2375 heifers were group fed supplement in treatment groups (approximately 300 heifers per treatment at each location during each year).
[b]Standard error of the mean; n = 8.

Table 3. Pregnancy rate of heifers supplemented to meet metabolizable protein requirements (MPR) or CP requirements (CPR) at two locations in the Nebraska Sandhills in 1997-98 and 1998-99.

	Ashby[a]		Whitman[b]	
Item	MPR	CPR	MPR	CPR
1997-1998, %[c]	95	95	84	75
1998-1999, %[d]	95	88	89	85

[a]n = 531 in 1997-98; n = 527 in 1998-99.
[b]n = 501 in 1997-98; n = 560 in 1998-99.
[c]Treatments different at Whitman (P = .01).
[d]Treatments different at Ashby (P = .01) and Whitman (P = .15).

Table 4. Net present value (NPV) of bred heifers when two-year-old pregnancy rate was affected by supplementing the heifers during the winter prior to calving to meet metabolizable protein requirements (MPR) or crude protein requirements (CPR).[a]

	1997-1998		1998-1999	
Item	Ashby	Whitman	Ashby	Whitman
MPR NPV, $/hd	882.22	830.86	886.10	860.03
CPR NPV, $/hd	882.22	788.84	855.68	842.65
Difference, $/hd[b]	0.00	42.02	30.43	17.38
Return, $/hd[c]	-2.71	38.69	29.84	16.79

[a]Supplements fed from September to February each year.
[b]Difference in NPV between MPR and CPR within location and year.
[c]Advantage of MPR treatment in NPV after additional supplement cost of that treatment was subtracted.

to heifers during gestation may cause post-partum physiological changes in the heifer that positively influence re-breeding performance.

It is important to note effects of gestational UIP supplementation occurred even though supplements were not fed immediately before or after calving. Although heifers started calving in early March, the last day to feed the treatment supplements was 25 and 35 days before the average calving date in 1997-98 and 1998-99, respectively. The 1996 NRC equations predicted the meadow hay and range diet offered during this time was deficient in MP (60 to 100 grams per day). Metabolizable protein requirements increase exponentially in the three weeks before calving. Although it is surprising that reproduction was positively affected without supplementation 25-35 days before calving, it is possible that greater improvements in 2-year-old pregnancy would have been noticed had UIP been supplemented through the calving season. The NRC predicted that cattle were adequate in MP after calving.

The NPV of heifers in each treatment group at each location during each year are shown in Table 4. As expected, in all cases where pregnancy was improved by the MPR treatment (Table 3), NPV was higher for heifers in the MPR treatment. Since the MPR treatment was more expensive, the added costs associated with this supplement strategy were subtracted from the difference in NPV to determine the expected return on the treatment.

Based on NPV figures for the 1997-98 data, the MPR treatment cost the females at Ashby $2.71 over their lifetime compared to the CPR group, but gained those at Whitman $38.69. In 1998-99, the MPR treatment returned $29.84 and $16.79 over CPR females at Ashby and Whitman, respectively. The average difference between treatments in NPV, $20.00 per head, would bring substantial revenue to an operation. The importance of reproduction in young breeding females to profitability has been demonstrated in previous studies.

The heifers in question were only at approximately 67% of their mature BW at yearling pregnancy check time in the fall. The literature would indicate that 65% of mature weight should be obtained before breeding the replacement heifer. Rather modest nutritional inputs into these heifers prior to calving, despite their low BW, showed substantial improvements in profitability in three out of four situations.

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Forage Intake and Nutrient Balance of Heifers Grazing Sandhills Winter Range

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Metabolizable protein is deficient in pregnant heifers grazing winter range. Energy may be first limiting if grazed forage intake is less than 2.0% of body weight.

Summary

Two experiments with pregnant heifers grazing winter range investigated effects of supplementation to meet metabolizable protein versus CP requirements. Supplements were fed from October to February, and hay was fed in January and February of the second experiment. Supplementation to meet metabolizable protein requirements decreased weight loss in one experiment. Winter hay feeding reduced weight loss and body condition loss compared to no hay feeding. Forage intake declined from 2.1% of body weight in November to 1.3% in February. Metabolizable protein was deficient when animals were supplemented to meet CP requirements. Supplementation to meet metabolizable protein requirements may improve performance when energy intake is not deficient.

Introduction

Pregnant, spring-calving heifers have an elevated requirement for metabolizable protein (MP) during the winter, and this requirement increases exponentially as heifers approach calving. Due to low energy and undegradable intake protein (UIP) content, the MP value of winter sandhills range is low. The result is an MP deficiency in the heifer. Supplementation with protein sources high in UIP may alleviate this deficiency.

A study was conducted at a commercial operation to determine effects of supplements fed over the winter to meet MP or CP requirements of pregnant heifers. Metabolizable protein was balanced with a feather meal-based supplement. Supplementation to meet MP requirements improved subsequent 2-year-old pregnancy (2001 Nebraska Beef Report). However, it could not be determined from the experiment if MP requirements were met by the supplement strategy. In addition, a prediction of forage intake over the winter was difficult due to little published data on heifers grazing Nebraska Sandhills winter range. Therefore, two experiments were conducted to evaluate the effect of supplementing heifers to meet MP

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requirements versus CP requirements on weight and body condition score change, forage intake, and nutrient balance.

The performance results were published in the 2000 Nebraska Report pp. 7-10. Complete intake and nutrient analyses have now been conducted. These nutrient balance data, combined with the performance data, can be used to help define the supplemental requirements of the grazing heifer.

Procedure

Specific procedures are as described in the 2000 Nebraska Beef Report pp 7-10. Twelve pregnant heifers in 1997-98 (Exp. 1) and 18 heifers in 1998-99 (Exp. 2) were individually fed one of two protein supplements from mid-October to mid-February while grazing sandhills range. In Exp. 1, two treatments were: 1) a supplement designed to meet MP requirements (MPR) and 2) a conventional protein supplement fed to meet CP requirements (CPR). No hay was fed during the experiment. In Exp. 2, treatments were : 1) heifers supplemented to meet MP requirement and fed hay (approximately 5 lb/day) beginning in January (MPR/Hay) 2) heifers supplemented with conventional supplement and fed hay beginning in January (CPR/Hay), and 3) heifers supplemented to meet MP requirement and offered no hay during the experiment (MPR/No Hay). Hay was 8.4% CP and was determined to be 65% digestible in a 5-day in vivo trial with five steers.

The MPR supplement (Table 1) was composed of 53% CP and 28% UIP (DM basis). The CP supplement contained 51% CP and 14% UIP. The CPR supplement was fed at the rate of .89 lb/day (DM) throughout the trial, supplying 53 grams of UIP/day. The MPR supplement feeding rate increased gradually from .70 lb/day in October to 1.6 lb/day in February, supplying 86 grams UIP/day in October, 120 grams UIP/day in November, December, and January, 135 grams UIP/day in early February, and 203 g UIP/day after February 15.

Intake measurements were taken in six-day periods beginning Nov. 10, Jan. 5, and Febr. 9 in 1997-98 (Exp. 1). Intake measurements were taken beginning Dec. 15 and Febr. 18 in 1998-99 (Exp. 2). Time release chromium boluses were used for determination of fecal output in each animal, and predictions were validated with four steers using total fecal collection. Diets were collected with esophageally fistulated cows during each intake period and frozen for subsequent analyses. Diet samples were freeze dried and analyzed for DM, OM, CP, UIP, IVDMD, and in vitro organic matter digestibility (IVOMD). Forage UIP was determined by the amount of neutral detergent insoluble protein remaining after a 48-hour in situ incubation. Forage organic matter intake was calculated by dividing fecal output from forage by forage indigestibility (1-IVOMD).

Intake and nutrient data were used in the 1996 NRC model to determine nutrient balances at the time intakes were conducted during each experiment. Data were modeled assuming no effects of environmental conditions on nutrient requirements. Microbial crude protein production was assumed to be 9.5% of TDN intake. Forage intake, CP, and UIP were calculated on an OM basis and adjusted to a DM basis assuming 10% ash. In vitro dry matter digestibility was used for the forage TDN value.

Results

In Exp. 1, heifers supplemented to meet MP requirements lost less weight over the winter than those supplemented to meet CP requirements (Table 2; P = .04). All cattle lost substantial body condition over the course of the experiment (-1.5 BCS). As previously reported, cattle on the MPR treatment gained the weight advantage early in the fall, but both groups lost weight in January and February (2000 Nebraska Beef Report, pp. 7-10). Grazed forage intake declined linearly (P < .01) from an average of 21 lb (2.1% of body weight) in November

Table 1. Composition of supplements fed to heifers in Experiments 1 and 2 (% of DM).[a]

Ingredient	MPR	CPR
Cottonseed Meal	—	58.8
Feather Meal	40.2	—
Soybean Meal	—	17.8
Sunflower Meal	30.2	13.7
Wheat Middlings	26.2	—
Distillers Grains	—	3.4
Molasses (Cane)	2.1	2.1
Urea	—	2.8
Minerals/Vitamins	1.3	1.4

[a]Supplements were provided as range cubes fed 3 times weekly. MPR: designed to meet the metabolizable protein requirement; CPR: designed as conventional protein supplement.

Table 2. Weight, BCS, and forage intake (FI) of heifers grazing winter Sandhills range from October 1997 to February 1998 (Experiment 1).[a]

Item	MPR	CPR	SD[b]
Beginning wt, lb	955	948	54
Final wt, lb[c]	965	921	49
Wt change, lb[d]	10	-26	27
Beginning BCS	6.4	6.3	.5
Final BCS	4.9	4.8	.3
BCS change	-1.6	-1.7	.7
November FI,[e,f]			
lb	22.2	19.1	3.7
% BW	2.2	2.0	.3
January FI,[e,f]			
lb	15.5	14.8	4.1
% BW	1.6	1.5	.4
February FI,[e,f]			
lb	13.1	12.6	2.0
% BW	1.4	1.4	.2

[a]MPR: heifers supplemented to meet metabolizable protein requirement; CPR: heifers supplemented with conventional protein supplement. No hay fed during the experiment.
[b]Standard deviation, n = 12.
[c]Treatments differ, P = .16.
[d]Treatments differ, P = .04.
[e]Dry matter basis.
[f]Forage intake declined linearly over time (P = .0001).

Table 3. Weight and BCS of heifers grazing winter Sandhills range from October 1998 to February 1999 (Experiment 2).[a]

Item	MPR/Hay	CPR/Hay	MPR/No Hay	Stdev[b]
Beginning wt, lb	940	945	923	41
Final wt, lb[c]	914	921	808	69
Wt change, lb[d]	-26	-23	-114	48
Beginning BCS	6.1	6.0	6.1	.4
Final BCS[e]	5.7	5.4	5.0	.5
BCS change[f]	-.4	-.6	-1.0	.6
December FI,[g,h]				
lb	14.7	16.0	17.7	2.7
% BW	1.7	1.8	2.1	.3
February FI,[g,h]				
lb	11.3	12.4	11.6	1.8
% BW	1.3	1.4	1.4	.2
February FI + HI[g,i]				
lb	17.3	18.4	11.6	3.5
% BW	1.9	2.0	1.4	.3

[a]MPR/Hay: heifers supplemented to meet metabolizable protein requirements and fed hay (average 5 lb/day) in January and February; CPR/Hay: heifers supplemented with conventional protein supplement and fed hay in January and February; MPR/No Hay: heifers supplemented to meet metabolizable protein requirements and fed no hay.
[b]Standard deviation, n = 18.
[c]MPR/Hay and CPR/Hay versus MPR/No Hay, P = .001.
[d]MPR/Hay and CPR/Hay versus MPS/No Hay, P = .0001.
[e]MPR/Hay versus MPR/No Hay, P = .01; CPR/Hay versus MPR/No Hay, P = .10.
[f]MPR/Hay versus MPR/No Hay, P = .10.
[g]Dry matter basis..
[h]Forage intake declined linearly over time (P = .0001).
[i]Forage intake + hay intake.

Table 4. Nutrient composition of diets collected in the Nebraska Sandhills[a].

	1997-1998			1998-1999	
Nutrient	November	January	February	December	February
CP, % DM	5.25	5.19	5.13	6.13	5.60
UIP, % DM[b]	1.13	1.10	1.35	1.45	1.63
DIP, % CP[c]	78.48	78.81	73.68	76.35	70.89
IVDMD, %	51.99	48.91	49.43	51.20	47.39

[a]Diets collected from esophageally fistulated cows.
[b]Undegradable intake protein; calculated from neutral detergent insoluble CP remaining after 48 hour in situ incubation.
[c] Degradable intake protein.

to 13 lb (1.4% of body weight) in February. There were no differences between treatments in forage intake.

In Exp. 2, heifers on the MPR/No hay treatment lost significantly more weight than hay fed heifers (Table 3; P < .01) and more body condition than MPR/Hay heifers (P = .10). Body weight loss was greater than reported in Experiment 1, but body condition loss was not as severe. Grazed forage intake declined (P < .01) from 16 lb (1.8% of body weight) in December to 12 lb (1.3 % of body weight) in February. There were no differences in forage intake between treatments. Total intake (forage + hay) was greater for heifers fed hay than those not fed hay (P < .01).

The decline in intake over the winter was more severe than expected. Reduced digestibility, cold stress and reduced forage availability can cause a depression in forage intake over the winter. In Exp 1., IVDMD (Table 4) decreased from 52.0% in November to 48.9% in January, but then increased to 49.4% in February. Reduced forage digestibility does not explain the drop in intake from January to February. In Exp. 2, IVDMD dropped from 51.2% in December to 47.4% in February. The stocking rate in the pasture where heifers grazed was .70 AUM/acre during Exp. 1., with a cumulative grazing pressure (total AUM per ton of DM forage initially available) of .59 AUM/ton. This would be considered a moderate level of grazing for Nebraska Sandhills winter range. It is unlikely that forage was limiting to the heifers during Exp. 1, especially in January. In Exp. 2, the pasture was stocked at 1.06 AUM/acre (.83 AUM/ton cumulative grazing pressure). Forage potentially became limiting to the heifers in Exp. 2. However, the decline in grazed forage intake was consistent across years.

We hypothesize that advancing growth of the fetus and fluids reduces rumen volume before calving. Heifers are typically at 85% of their mature weight at calving, but the space acquired by the fetus and fluids is similar to a mature cow. Rumen fill limits intake of low quality diets, and reduced rumen volume reduces intake. This would be expected to have the greatest effect during the last month of gestation, when the size of the fetus increases markedly. A reduction in grazed intake occurs at a nutritionally stressful time for the heifer, as protein and energy requirements increase substantially in the last six weeks of gestation. Feeding hay that is more digestible and can exit the rumen faster will allow for a higher total intake.

The nutrient composition of diets collected by esophageally fistulated cows during both experiments is shown in Table 4. Protein did not change markedly across sampling time and year, but appeared to be higher in December of 1998 (6.1%) than November of 1997 (5.3%). The undegradable intake protein content of diets was lower in 1997-98 (1.2% of DM) than in 1998-99 (1.5% of DM). Less UIP in the forage can contribute to MP deficiencies. However, the biological implications of 0.3% UIP are small.

Due to both low UIP and digestibility, winter Sandhills range has a low MP value. Metabolizable protein comes from two sources: 1) microbes leaving the rumen (MCP), and 2) intake protein that escapes rumen degradation (UIP). Microbial crude protein is a function of TDN intake, and can range from 8.0% to 13.0% of TDN. When rate of passage is slow, MCP production is reduced, and may be around 9.5%. The reduced MCP

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efficiency, along with the lower TDN intake, creates a reduction in MP coming from microbes. This is why cattle with high protein requirements, such as the heifer, can experience an MP deficiency when grazing winter range.

The nutrient balances of the cattle during Experiments 1 and 2 are shown in Tables 5 and 6, respectively. Degradable intake protein was adequate in all diets during both experiments. However, energy (NEm) and MP were not adequate in all situations. Heifers receiving the MPR supplement had a more positive NEm balance than CPR heifers in November of Exp. 1. This was due to a numerical increase in intake associated with that treatment. MP was deficient (-19 grams) to the CPR heifers in November, but was 46 grams positive for MPR heifers. The energy and protein balance of the MPR heifers during November explains the increased body weight gain observed for that treatment during the fall. It appears that the MPR supplement was formulated correctly to meet the MP requirements of the heifers in the fall. Energy and MP were deficient in both groups of heifers in January and February of Exp. 1, explaining the decline in gain and body condition. Low energy intakes, combined with increasing animal requirements, caused an NEm deficiency reaching -5.5 Mcal per day in February. The low energy intakes reduced MP balance in January and February as well, and the MPR supplement did not supply enough UIP to meet the MP requirement. The MPR heifers were less deficient in MP than CPR heifers.

The MPR heifers were adequate in MP in December of Exp. 2 (Table 6), while CPR heifers were 26 grams deficient. Energy intake was slightly deficient in December for all heifers. Unlike Exp 1, where NEm balance was 1.0 to 2.0 Mcal positive in the fall, energy appeared to be limiting body weight gain. Dry matter intakes (forage + supplement) in December of Exp 2 were low compared to November intakes in Exp 1.

Table 5. Nutrient balance of heifers supplemented to meet metabolizable protein requirements (MPR) or crude protein requirements (CPR) in 1997-1998 (Experiment 1)[a].

	November		January		February	
Item	MPR	CPR	MPR	CPR	MPR	CPR
DM Intake[b]	23.2	20.0	16.5	15.7	14.2	13.5
NEm balance, Mcal	2.3	0.9	-2.9	-3.2	-5.4	-5.5
MP supplied, g	531	417	394	323	376	298
MP required, g	484	436	461	456	540	527
MP balance, g	46	-19	-67	-133	-163	-229
DIP supplied, g	527	508	401	425	348	367
DIP required, g	529	457	360	341	314	298
DIP balance, g	-2	50	41	84	34	69

[a]Calculated using 1996 NRC Model.
[b]Total intake.

Table 6. Nutrient balance of heifers supplemented to meet metabolizable protein or crude protein requirements with hay feeding in January and February (MPR/Hay and CPR/Hay, respectively) or supplemented to metabolizable protein requirements and not fed hay (MPR/No Hay) in 1998-99 (Experiment 2)[a].

	December			February		
Item	MPR Hay	CPR Hay	MPR No Hay	MPR Hay	CPR Hay	MPR No Hay
DM Intake[b]	15.7	16.9	18.7	18.9	19.3	13.2
NEm balance, Mcal	-1.2	-0.9	0.3	-1.7	-1.9	-5.1
MP supplied, g	408	374	465	552	441	415
MP required, g	395	400	404	523	525	497
MP balance, g	13	-26	61	29	-84	-82
DIP supplied, g	426	489	488	572	562	389
DIP required, g	358	381	423	453	452	288
DIP balance, g	68	108	66	120	110	101

[a]Calculated using 1996 NRC Model.
[b]Total intake.

The MPR/Hay heifers were adequate in MP in February, while the other treatment groups were negative. However, energy was deficient in all treatments. Feeding hay helped reduce the energy deficiency in February noted in heifers not fed hay.

When energy intake is adequate to meet the NEm requirement of pregnant heifers, the heifers appear to respond to UIP supplementation. Conventional supplements, such as the CPR supplement, do not supply adequate UIP to the pregnant heifer. This is true even when 5 lb of high quality hay are fed. However, the energy requirements of the spring calving heifer are high over the winter. Grazed forage intake needs to be over 2.0% of body weight for energy requirements to be met. In the Nebraska Sandhills, grazed forage intake will not supply adequate energy for March calving heifers in January and February. Balancing supplements to meet MP requirements can be an effective management strategy if energy requirements are met.

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Summer Grazing and Fall Grazing Pressure Effects on Protein Content and Digestibility of Fall Range Diets

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Protein content and digestibility of fall cow diets may decline with increasing levels of fall grazing pressure. Summer grazing has variable effects on fall diet protein.

Summary

In 1997 and in 1998, four blocks of Sandhills range were used to examine summer grazing time and fall grazing pressure effects on fall diet quality. Three pastures within each block were grazed in June, July, or deferred from summer grazing each year. Multiple grazing pressures were created by grazing cows at various stocking rates in the fall. Diets were collected by esophageally fistulated cows. In 1997, diet protein and digestibility declined with increasing grazing pressure. In 1998, there were no effects of grazing pressure on fall diet protein or digestibility. July grazing reduced fall diet protein compared to June grazing in 1997, and summer grazing reduced fall diet protein compared to no summer grazing in 1998.

Introduction

The effects of summer grazing date and fall-winter stocking rate in the Nebraska Sandhills have been evaluated separately (1998 Nebraska Beef Report, pp. 20-21). However, no data have been generated in the Nebraska Sandhills to determine if the effects of fall-winter stocking rate on fall-winter diet quality differ in pastures grazed at different times the previous summer (stocking rate by summer grazing date interaction).

The amount of forage available for grazing per unit of land area varies across years, range sites and management systems. Therefore, it often is more useful to measure the amount of animal demand for forage applied per unit of forage available. Cumulative grazing pressure (CGP), measured in animal unit days (AUD) per metric ton of initial standing forage (t), is a way to express animal demand per unit of available forage. The effects of fall CGP on fall diet quality have not been evaluated in the Nebraska Sandhills.

Defining the protein content and digestibility of fall-winter diets across various grazing systems will allow for the development of accurate supplementation protocols, alleviating inefficiencies associated with over-feeding or under-feeding supplements.

The objective of this study was to examine summer grazing time and fall (October-December) grazing pressure effects on Fall diet CP and in vitro organic matter digestibility (IVOMD).

Procedure

Experiment 1.

Four blocks of rangeland at the University of Nebraska's Gudmundsen Sandhills Laboratory, Whitman, Nebr., each were separated into three .74 acre pastures. The blocks were located on a sands range site in good to excellent condition and dominated by little bluestem, prairie sandreed, sand bluestem and switchgrass. Each of the three pastures in each block were randomly assigned to receive one of three summer grazing treatments in 1997: 1) no summer grazing, 2) grazing in late-June by yearling cattle at .2 AUM/acre, and 3) grazing in late-July by yearling cattle at .2 AUM/acre. Beginning Oct. 9, 1997, six esophageally fistulated cows (two cows/pasture) were stratified by age and weight and randomly assigned to pastures in the first block. Blocks were grazed sequentially throughout the fall for seven days each, with the fourth period ending Nov. 22, 1997.

Cows grazed each .74 acre pasture for the first four days of each 7-day grazing period to create a cumulative stocking rate (SR) of .4 AUM/acre. On day 5, the pastures were split in half by electric fence and .37 acres of each pasture were grazed for two days to create a cumulative SR of .8 AUM/acre. On day 7, each .37 acre paddock was split in half and cows grazed the remaining .19 acres for one day, for a final cumulative SR of 1.2 AUM/acre. Diets were collected by the two fistulated cows grazing each pasture when the cumulative Fall SR was 0, .2, .4, .6, .8, and 1.2 AUM/acre.

Diets were immediately frozen following collection. They were subsequently freeze dried, ground, and analyzed for DM, OM, CP, IVOMD and undegradable intake protein (UIP; 1998 Nebraska Beef Report, pp. 90-92). Forge UIP was calculated using the rate (Kd) of neutral detergent insoluble CP (NDICP) between 2 and 12 hours and a passage rate (Kp) of 2.0% ((Kp/(Kd +Kp)) + undegradable NDICP).

To determine the amount of standing forage per unit area, clipped samples were taken at a rate of 10 per .19 acres with .25 meter squared rectangular frames prior to application of fall grazing treatments. Samples were dried at 140° Fahrenheit for 48 hours prior to weighing. Cumulative grazing pressure was calculated as the cumulative AUD applied to a given paddock (or sub-paddock) at the time of diet collection

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divided by the metric tons of forage initially available (0 AUM/acre) in that paddock.

The effects of summer treatment, SR and summer treatment × SR were analyzed in a split-plot design. Whole plot error was calculated as block × summer treatment with SR as the sub-plot. Summer treatment effects were detected with contrasts (grazed versus deferred; June grazed versus July grazed). Simple regressions across CGP were calculated for CP, IVOMD, and UIP.

Experiment 2.

In 1998, summer grazing treatments were randomly applied to three .74 acre pastures in four blocks of upland range as described for Exp. 1. The blocks were located on a different site with less little bluestem than the site used in the first experiment. Diets were collected by two esophageally fistulated cows per pasture on Oct. 17. Each pasture was then split into one .37 acre and two .19 acre paddocks. The three paddocks in each pasture were grazed simultaneously by intact cows at either .4, .8, or 1.2 AUM/acre for three consecutive days (two blocks at a time) between Oct. 19 and 24. Due to animal and labor constraints, diets were collected with esophageally fistulated cows (two cows/paddock) seven weeks following the application of fall grazing treatments. When post-graze diets were being collected, diets were taken in an adjacent ungrazed pasture to adjust for any effect of advancing season on diet quality. Undegradable intake protein was not measured in this experiment. Clipped samples were taken immediately before application of Fall grazing treatments. Other procedures and analyses were as described for Exp. 1.

Table 1. Crude protein, undegradable intake protein (UIP), and in vitro organic matter digestibility (IVOMD) of fall diets following various summer grazing dates in the Nebraska Sandhills (Exp. 1).

	Summer Treatment			
Item	Deferred	June	July	SEM[a]
CP, % OM[b]	7.2	7.5	7.1	0.1
UIP, % DM[c]	1.41	1.62	1.49	0.08
IVOMD, %	51.5	50.6	51.9	0.7

[a]Standard error of the mean; n = 72.
[b]Significant contrast: June versus July (P = .11).
[c]Significant contrasts: Grazed versus Deferred (P = .10); June versus July (P = .14); calculated using rate of NDIN digestion (2 and 12 hours) and a 2.0% rate of passage.

Table 2. Crude protein and in vitro organic matter digestibility (IVOMD) of fall diets following various summer grazing dates in the Nebraska Sandhills (Exp. 2).

	Summer Treatment			
Item	Deferred	June	July	SEM[a]
CP, % OM[b]	9.0	8.5	7.9	0.3
IVOMD, %	54.0	54.5	52.9	0.6

[a]Standard error of the mean; n = 45.
[b]Significant contrast: Grazed versus Deferred (P = .09).

Results

In Exp. 1, there were no SR× summer treatment interactions for fall diet CP, IVOMD, or UIP (P > .50). The main effect of SR was significant for all variables (P < .01). Fall diet CP was higher (P = .11) in pastures grazed in June (Table 1) than those grazed in July. Undegradable intake protein (DM basis) in the fall was higher (P = .10) in summer grazed pastures than deferred pastures, and UIP tended to be higher (P = .14) in June versus July grazed pastures. Summer treatment had no effect on IVOMD.

Also in Exp 1., CP responded cubically (P < .01) to increasing CGP (Figure 1), declining from 8.6% pre-grazing (0 AUD/t) to 6.5% at 50 AUD/t. There were no effects of CGP on diet UIP content. Diet IVOMD also responded cubically (P = .05) to increasing CGP (Figure 2), declining from 54% at 0 AUD/t to 50% at 50 AUD/t.

In Exp. 2, no SR× summer treatment interactions existed for CP or IVOMD (P > .15), and SR was not significant for either variable (P > .20). However, CP in fall diets from pastures deferred from summer grazing was greater (P = .09) than in diets grazed in the summer (Table 2). There were no effects of CGP on CP or IVOMD.

Downs (1998 Nebraska Beef Report, pp. 20-21) found no response of summer grazing date (deferred, June, or July) on the CP content of fall-winter diets in the Nebraska Sandhills. In these two experiments, however, summer grazing date did affect CP in fall diets. Conditions such as precipitation, temperature, and date of first freeze may affect how plants respond to late season herbivory, thus affecting diet protein content in the fall. The response of increased UIP in June grazed pastures is similar to that measured by Downs (1997 Nebraska M.S. Thesis). However, with values at 1.5% of DM, biological implications to foraging cattle do not likely exist. Indeed, degradable intake protein (DIP), not UIP, has been shown to be first limiting to cows grazing winter Nebraska Sandhills range (1996 Nebraska Beef Report, pp. 14-16).

Crude protein (7.3 and 8.5%) and digestibility (52 and 54%) values were lower in Exp. 1 than in Exp. 2, respectively. Other data have indicated year to year variation in fall-winter diet CP values. Data from Gudmundsen Sandhills Laboratory showed not only different diet CP values collected in two consecutive years, but CP content of diets changed from December to February in the opposite direction each year (1993 Nebraska Beef Report, pp. 8-10). The fall conditions during Exp. 2 (1998) included warmer than normal temperatures and above average precipitation. Data are not available as to the effects of environment on the response of diet quality to increasing fall grazing pressure. Nevertheless, the CP and IVOMD response was different in Experiments 1 and 2.

Another explanation for the lack of response of CP and IVOMD to fall CGP

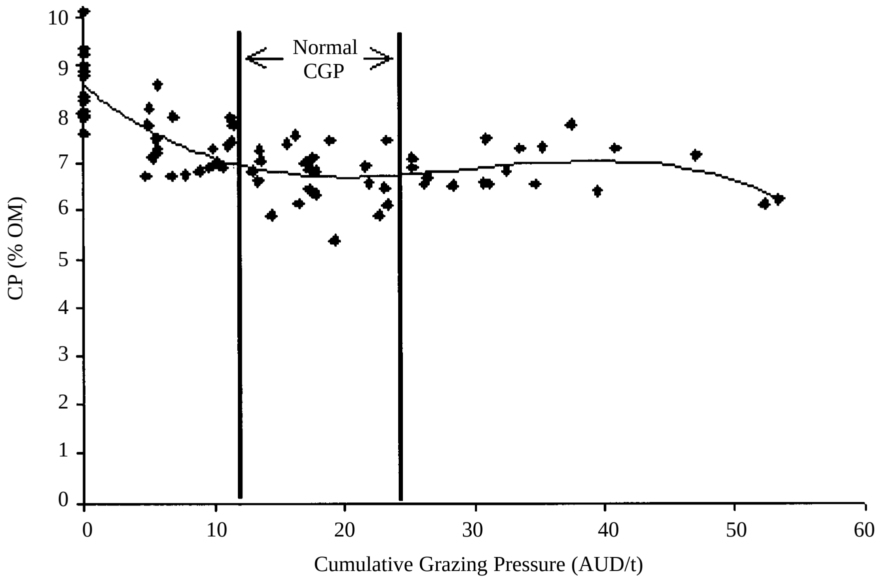

Figure 1. Change in CP of cow diets from upland Sandhills range collected across multiple cumulative fall grazing pressures. Cubic response, P < .01.

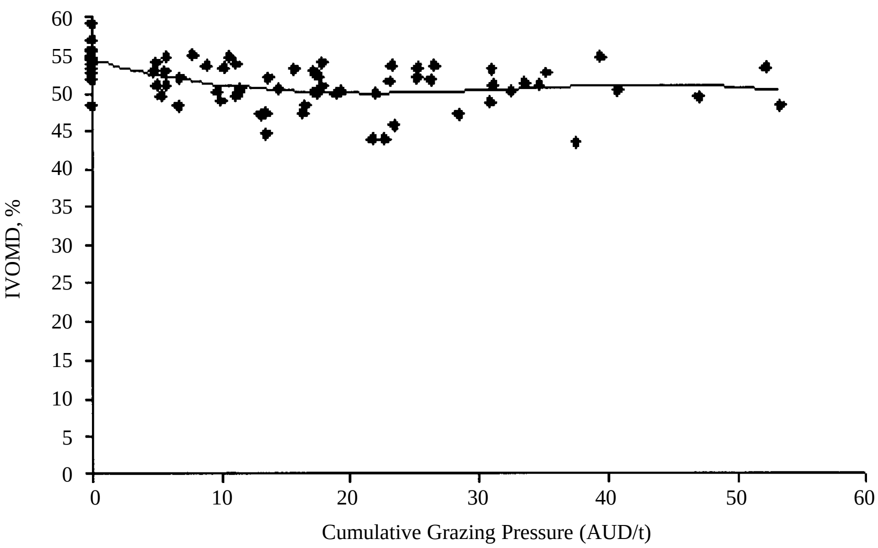

Figure 2. Change in in vitro organic matter digestibility (IVOMD) of cow diets from upland Sandhills range collected across multiple cumulative fall grazing pressures. Cubic response, P < .05.

in Exp. 2 could lie in the fact that post-graze diets were collected seven weeks after application of fall treatments. Observations indicated that sedges regrew following the October grazing period; therefore the cows could have collected some regrowth in December in addition to residue remaining after the October grazing.

As shown in Figures 1 and 2, the decline in CP and IVOMD across CGP in Exp. 1 occurred with the first imposed grazing pressures. This is consistent with that reported by Downs (1997 Nebraska M.S. Thesis). It appeared that when low stocking rates (.2 AUM/acre), or imposed grazing pressures (5-10 AUD/t) were reached, diet protein and digestibility were relatively consistent irrespective of further increases in grazing pressure. After this initial decline, supplemental requirements of grazing cattle may remain constant with increasing grazing pressures until the point when grazed forage intake is reduced by the amount of available forage.

The range of normal grazing pressures in the Nebraska Sandhills also is shown in Figure 1. In a 90-day continuous grazing program with similar initial standing forage as reported here, it would take between 45 and 90 days of grazing before a CP deficiency occurred in a mature beef cow (180 days pregnant). Therefore, defining the decline in cow diet CP is important in determining both the timing and amount of supplementation required. The effect of year on diet quality may be larger than the effect of grazing pressure. Combining the two years of diet quality data collected by Downs (1997 Nebraska M. S. Thesis) and the data from the two experiments reported here, generalizations on winter supplement requirements to spring calving cows can be made. Across the four years of data, fall/winter diet CP ranged from 5% to 8.5% of OM (4.5 to 7.7% of DM). Likewise, fall/winter diet digestibility (TDN) ranged from 51% to 55%. With this range of diet CP, cow requirements for supplemental DIP are between 0 and 230 grams/day. If DIP requirements are met, supplemental UIP is not necessary until just prior to calving. Between 50 and 120 grams/day of supplemental UIP may be required in last month of gestation. With adequate forage availability, energy is not deficient to the mature cow until the last six weeks before calving. If winter diets are 51% TDN, cows grazing range will be 1.6 Mcal/day deficient in NEm at 45 days pre-calving.

The lack of an interaction between fall stocking rate and summer grazing date was consistent between experiments. Increased fall grazing pressure caused a reduction in CP and IVOMD in one of two experiments. The decline in quality occurred with the first levels of imposed grazing pressure. July grazed pastures had lower CP values than June pastures in Exp. 1, and summer grazed pastures were lower in CP than deferred pastures in Exp.2.

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Annual Forage Production and Quality Trials

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Forage crude protein, digestibility and available energy in small grain and sorghum forages will vary with variety and maturity at harvest. Sorghum hybrids containing the brown midrib trait have higher digestibility.

Summary

Two-year forage trials showed higher dry matter yields for winter triticale than for winter wheat while forage qualities were similar. Likewise, a spring triticale cultivar had higher dry matter yields than spring barley or oat cultivars when harvested for forage after heading, and forage qualities were similar. In summer trials, dryland forage sorghum and sorghum x sudangrass hybrids had higher crude protein, digestibility and energy values than irrigated forages because they were not as mature. Lower lignin content and higher digestibility resulted when the brown midrib trait was present in forage sorghum or sorghum x sudangrass hybrids.

Introduction

Data are limited on the forage production and quality potential for currently available annual forages. Changes in production potential and feed quality have occurred, such as lower lignin content and higher digestibility associated with the brown midrib (BMR) trait that has been crossed into some forage sorghum, sudangrass, sorghum x sudangrass and corn hybrids. Forage trials were conducted over two years to compare some of the newer forage cultivars with some that have been around long enough to be considered standards. Forage production and quality were evaluated for cereal forages grown under dryland management and for sorghum, sorghum x sudangrass, and pearl millet forages grown under dryland or irrigated management systems.

Procedure

Dryland winter wheat and triticale cultivars were harvested for forage at Mead, McCook, and Sidney in 1997 and 1998 after producing a seed head. Ten wheat cultivars were planted, including Arapahoe, Lamar, Longhorn, Pronghorn and six experimental cultivars. Five triticale cultivars were planted, including Trical, Newcale, and three experimental cultivars. There were four replications of each cultivar at each location.

Dryland spring seeded cereal crops were harvested as forage at Sidney in 1998 and 1999 after most of the cultivars had produced a seed head. There were two triticale, two barley, and three oat cultivars with four replications of each cultivar. All annual forages were planted in six row plots with a double disc grain drill with 12 in between rows. All forage plots were harvested with a plot swather that cut the center four rows. Mechanical chopping of the forages allowed subsampling for dry matter and forage quality analyses. Quality results were available from 1998 trials only at the time this paper was prepared.

Summer dryland forages were planted at Sidney and included one sudangrass, six sorghum x sudangrass, and eight forage sorghum cultivars. Forages were harvested after the majority of cultivars had headed in growing seasons of 78 and 75 days in 1998 and 1999, respectively. The plots were fertilized with 60 lb of N and 40 lb of P_2O_5 in 1998 and 45 lb of N in 1999.

Summer irrigated forages planted at Scottsbluff included one sudangrass, five sorghum x sudangrass, nine forage sorghum, and three pearl millet cultivars. The plots were harvested after the majority of cultivars had produced a seed head in growing seasons of 82 and 88 days in 1998 and 1999, respectively. They were fertilized with 120 of N and 80 lb of P_2O_5 as a side dress in both years.

Forage quality tests included percentages of dry matter for total and nitrate nitrogen, neutral detergent fiber, acid detergent fiber, acid detergent lignin and in vitro dry matter digestibility (IVDMD). The acid detergent fiber (ADF) values were used to calculate energy values as TDN, net energy and metabolizable energy by using equations listed by the National Forage Testing Association. Least significant differences at the 5% probability level of incorrectly stating a difference were determined for each trait by using the general linear model in the Statistical Analysis Services computer program.

Results

Fall and spring seeded cereal forage results are shown in Table 1. Averages are shown for the 10 winter wheat and 5 triticale cultivars harvested at each location in 1997 and 1998. Although differences in dry matter forage yields were not large, the top yielding winter wheat cultivar at all three locations was Pronghorn, and the top yielding winter triticale cultivar at McCook and Sidney was Newcale. Both of these cultivars were developed by plant breeders in the University of Nebraska system. Forage crude protein (CP) and ADF levels were similar among the wheat and triticale culti-

Table 1. Production and quality of dryland small grain forages in University of Nebraska trials in 1997, 1998, 1999[a].

Winter Forages, 1997-98[b]		DMYLD	CP	NDF	ADF	IVDMD	TDN	NE_m	NE_g	ME
Crop	Location	lb/acre	%	%	%	%	%	Mcal/lb	Mcal/lb	Mcal/lb
Wheat	Mead	6000	8.5	61	29	68	67	.70	.43	1.10
Wheat	McCook	8000	8.8	63	32	70	66	.69	.42	1.09
Wheat	Sidney	5200	9.7	64	35	67	66	.68	.41	1.07
Wheat	Mean	6400	9.0	63	32	68	66	.69	.42	1.09
Triticale	Mead	6800	7.6	65	33	65	66	.68	.41	1.08
Triticale	McCook	9400	8.6	67	36	66	65	.67	.40	1.07
Triticale	Sidney	6400	10.1	68	37	64	65	.67	.40	1.06
	Mean	7500	8.8	67	35	65	65	.67	.40	1.07
Spring Forages, 1998-99[c]										
Crop	Cultivar									
Triticale	2700	4900	8.2	67	37	66	65	.67	.40	1.06
Barley	Horsford	4310	8.8	66	33	70	66	.68	.42	1.09
Barley	Westford	4090	7.9	63	32	66	66	.69	.42	1.09
Oat	Monida	3760	8.9	68	35	70	65	.67	.41	1.07
Oat	Russell	3580	8.4	68	36	66	65	.67	.40	1.07
Oat/Pea	Russell/Pea	3320	9.6	67	36	69	65	.67	.40	1.07
Triticale	Grace	3310	9.2	66	36	68	65	.67	.40	1.07
Oat	Magnum	3120	8.7	67	35	73	65	.68	.41	1.07
	Mean	3800	8.7	67	35	69	65	.68	.41	1.07
	LSD .05	350	1.0	1.3	.9	3.0	.3	.01	.01	.01

[a]Abbreviations are: DMYLD = dry matter yield, CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, IVDMD = in vitro dry matter digestibility, TDN = total digestible nutrients, NE_m = net energy for maintenance, NE_g = net energy for gain, ME = metabolizable energy, LSD = least significant difference.
[b]There were 10 wheat and 5 triticale cultivars grown at each location each year in the winter forages.
[c]Dry matter yields are averages for two years, but quality is from 1998 only in the spring forages.

Table 2. Production and quality of dryland summer forages at the University of Nebraska High Plains Ag Lab, Sidney, NE, 1998-99[a].

Crop[b]	Cultivar	DMYLD[c] lb/acre	CP %	NO_3N ppm	NDF %	ADF %	ADL %	IVDMD %	TDN %	NE_m Mcal/lb	NE_g Mcal/lb	ME Mcal/lb
SXS	SX8	6780	11.8	1450	58	30	2.8	76	67	.70	.43	1.10
FS	X24442	6210	11.2	1300	56	28	2.5	79	68	.71	.44	1.11
FS	Sweet N Red	6120	11.3	1450	55	27	2.2	81	68	.71	.44	1.11
SXS	Att-A-Graze	5890	10.6	1100	58	30	3.4	71	67	.70	.43	1.10
FS	XBMR	5700	11.9	1400	54	26	2.2	82	68	.71	.44	1.12
SXS	Sooner Sweet	5680	11.7	1300	58	29	3.3	74	67	.70	.43	1.10
SXS	SXS 94X63	5660	10.4	1100	58	30	3.5	73	67	.70	.43	1.10
SXS	Nutri + BMR	5640	11.9	1500	54	26	2.6	77	68	.71	.44	1.12
FS	BMRX1	5550	12.7	1700	53	25	2.0	82	68	.72	.45	1.12
FS	Canex BMR208	5330	12.2	1450	55	26	2.0	82	68	.71	.44	1.12
FS	X43024	5210	13.0	1750	57	28	2.9	80	68	.71	.44	1.11
SXS	Super Sweet ST	5050	12.0	1200	58	29	3.4	73	67	.70	.43	1.10
FS	Rox Orange	4770	11.5	1550	54	26	2.2	82	68	.72	.44	1.12
S	Piper	4530	9.4	900	62	33	4.1	67	66	.68	.42	1.08
FS	Early Sumac	4300	11.3	1350	55	27	2.2	81	68	.71	.44	1.11
	Mean	5490	11.5	1650	56	28	2.8	77	68	.71	.44	1.11
	LSD .05	790	1.0	200	1.9	1.3	.4	2.3	.4	.01	.01	.01

[a]Abbreviations are: CP = crude protein, NO_3N = nitrate nitrogen, NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin, IVDMD = in vitro dry matter digestibility, TDN = total digestible nutrients, NE_m = net energy for maintenance, NE_g = net energy for gain, ME = metabolizable energy, LSD = least significant difference.
[b]Crop abbreviations are as follows: SXS = sorghum x sudangrass, FS = forage sorghum, S = sudangrass.
[c]Dry matter yields are averages for two years, but quality is from 1998 only.

vars at each location, making energy levels calculated from ADF similar also.

The top yielding spring cereal forage was triticale cultivar 2700. The barley cultivars ranked second and third in dry matter yields. Forage CP levels were similar with an average of 8.7% of dry matter. Energy levels were also similar with an average of 65% TDN, which was the same as in the winter forages.

Dry matter yields for dryland summer forages in Table 2 are an average of trials in 1998 and 1999. Dry matter percentages, plant heights and maturity scores are not shown, but were similar between years. Crude protein levels for 1998 ranged from 13 to 9.4% of dry matter, which was consistent with the maturity stages that ranged from boot to headed. Producers who want summer forage high in crude protein and digestibility should harvest crops more than once a season when the crops have regrowth capability. Other producers may want more dry matter yield with a single cut system when the crude protein

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Table 3. Production and quality of irrigated summer annual forages at the UNL Panhandle Res. & Ext. Center, Scottsbluff, NE, 1998[a].

Crop[b]	Cultivar	DMYLD[c] lb/acre	CP %	NO_3N ppm	NDF %	ADF %	ADL %	IVDMD %	TDN %	NE_m Mcal/lb	NE_g Mcal/lb	ME Mcal/lb
SXS	Super Sweet ST	13600	8.5	500	61	35	5.7	65	65	.67	.41	1.07
FS	XBMR	13520	8.7	800	58	32	2.5	77	66	.69	.42	1.09
FS	Sweet N Red	13230	9.7	1000	61	34	4.2	69	66	.68	.41	1.08
SXS	Att-A-Graze	13120	8.9	650	61	36	6.5	62	65	.67	.40	1.07
FS	X24442	13040	9.8	800	62	36	4.6	67	65	.67	.40	1.07
SXS	Sooner Sweet	12980	9.0	700	62	36	5.7	65	65	.67	.40	1.07
FS	Canex BM208	12900	8.7	800	53	29	3.7	77	67	.70	.43	1.10
FS	X43024	12760	10.8	1050	63	36	4.0	70	65	.67	.40	1.07
SXS	Nutri + BMR	12100	7.9	700	61	35	5.3	64	65	.67	.41	1.07
SXS	SXS 94X63	12010	8.0	500	61	36	5.6	64	65	.67	.40	1.07
FS	Early Sumac	11930	9.5	750	61	35	4.4	68	65	.67	.41	1.07
FS	FS22	11920	11.1	1100	64	36	4.2	67	65	.67	.40	1.07
PM	Mega Mil	11300	11.8	2000	66	39	4.7	68	64	.66	.39	1.06
FS	Rox Orange	11220	9.2	900	61	35	4.1	70	65	.67	.41	1.07
S	Piper	10910	8.2	500	66	39	5.9	60	64	.66	.39	1.05
PM	P10XIM	10800	10.5	1250	66	38	5.7	61	64	.66	.39	1.06
FS	BMRX1	10780	9.9	1000	60	34	4.0	68	66	.68	.41	1.08
PM	HPM	9990	12.0	2100	65	37	5.3	63	65	.66	.40	1.06
	Mean	12120	9.6	950	62	35	4.8	67	65	.67	.41	1.07
	LSD .05	1240	1.6	650	3.6	2.8	1.0	4.2	2.9	.01	.01	.02

[a]Abbreviations are: DMYLD = dry matter yield, CP = crude protein, NO_3N = nitrate nitrogen, NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin, IVDMD = in vitro dry matter digestibility, TDN = total digestible nutrients, NE_m = net energy for maintenance, NE_g = net energy for gain, ME = metabolizable energy, LSD = least significant difference.
[b]Crop abbreviations are as follows: SXS = sorghum x sudangrass, FS = forage sorghum, S = sudangrass, PM = pearl millet.
[c]Dry matter yields are averages for two years, but quality is from 1998 only.

and TDN contents are adequate for the animals that will consume the forage.

Dry matter yields for irrigated summer forages are shown in Table 3 as an average of 1998 and 1999 trials. In Tables 2 and 3, cultivars with an X before or after numbers or a name were experimental cultivars in the years of these trials. High yielding cultivars included both forage sorghum and sorghum x sudangrass hybrids. Some brown midrib hybrids had good yields but showed some lodging in the single harvest system that allowed them to grow 6 to 7 ft tall, but this was also true for some non-BMR hybrids.

Forage quality results shown for 1998 indicate variation in CP and IVDMD, which often is due to maturity differences when harvested. However, the emergence of summer forages with increased digestibility, such as the brown midrib cultivars in forage sorghum, sorghum x sudangrass, pearl millet and corn hybrids, brings new opportunities for improved animal performance through grazing or feeding of these forages. Reduced lignin fiber content of these forages allows for greater digestibility, but multiple harvest or grazing systems may be needed to minimize lodging problems that can occur if they get too tall. In both the irrigated and dryland trials in 1998, the highest IVDMD values were associated with the lowest acid detergent lignin percentages which are typical for many BMR hybrids.

Nitrate nitrogen levels in Tables 2 and 3 were generally below the 2000 ppm level often listed for initial toxicity concern for ruminants. However, previous research with similar forages in western Nebraska showed some potentially toxic nitrate levels in irrigated forage in the first of two harvests during the summer, especially with high nitrogen fertility in the soil. Thus, nitrogen application rates will need to be managed carefully along with maturity stage at harvest to achieve satisfactory levels of CP without increasing nitrates to toxic levels.

The choice of an annual forage crop and cultivar may depend more on the time forage is needed in the grazing or harvested forage system rather than on differences in yield potential. Fitting a forage crop into a cropping system would be an important consideration. Also, equipment requirements for the shorter annuals, like small grain or foxtail millet forages, may already be in an operation for other hay crops, whereas equipment needed to easily harvest and feed the taller forages may be unique. Getting the thicker stemmed forages to dry down in a reasonable time period for making hay will usually require a crimping action of the forage during cutting. The emergence of hybrids with higher digestibility may enhance grazing of standing or windrowed summer annual forages during the winter.

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Compensatory Growth and Slaughter Breakevens of Yearling Cattle

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Increased winter gains resulted in heavier final weights and increased profits ($/head) when compared to animals wintered on a minimal input system or calf finishing.

Summary

A two-year summary of growing/finishing systems indicates that steer calves wintered at 1.5 lb/day had lower slaughter breakeven (P < .05) costs compared to animals wintered at 0.5 lb/day. Additionally, feeding wet corn gluten feed as an energy source to increase winter gains tended (P < .15) to produce slaughter breakevens which were lower than the same winter gains produced by feeding corn. Restricting animal gain over the winter (0.5-1.0 lb/day) resulted in 25-32% compensation on grass compared to controls (1.5 lb/day). Comparison of calf finishing vs. yearling growing/finishing systems showed that steers wintered with a "fast" rate of gain (1.5 lb/day) profited $28.85/head compared to losses by steers wintered with a "slow" rate of gain (0.5 lb/day; $-30.24/head) or calf finishing ($-20.87/head).

Introduction

Many backgrounding systems vary in length, grow cattle at various rates of gain, and are designed around available resources. Because producers and resources vary widely, different degrees of compensatory growth are experienced based on wintering conditions. Predicting the amount of compensatory growth based on gain during the winter and/or feed resources used will allow producers to make informed and economically sound decisions when evaluating a growing/finishing program. If a large and reliable compensation response can be achieved, backgrounding animals with minimal inputs should result in increased profitability. However, research conducted at the University of Nebraska indicates that compensation of animals backgrounded at 0.5 lb/day is consistently around 30% compared to animals wintered at 1.5 lb/day (2000 Nebraska Beef Cattle Report, pp. 23-26; 1999 Nebraska Beef Cattle Report, pp. 26-28). Therefore, in the absence of greater compensation, animals must be backgrounded at increased rates of winter gain for maximum profits.

The objectives of this report were 1) to examine the compensatory growth response of yearling steers on grass following backgrounding and evaluate subsequent slaughter breakevens, and 2) to compare profitability of calf finishing and growing/finishing systems.

Procedure

Yearling Trials

Wintering Period. One hundred eighty medium-framed english cross steers (519 lb) were used in each of two years. Steers were purchased in the fall and allowed a 28-day acclimation period. Steers were wintered on cornstalks from about Dec. 1 through Febr. 15 (phase I), and placed in drylots from Febr. 16 through May 1 (phase II). Cattle were assigned randomly to one of five treatments used to establish winter gains for subsequent evaluation of compensatory growth on grass. Treatments were: 1) "Fast"-gaining steers supplemented with wet corn gluten feed (WCGF) for the entire winter, 2) "Fast"-gaining steers supplemented with corn (CORN) for the entire winter, 3) "Intermediate"-gaining steers fed to gain "fast" (using wet corn gluten feed) during phase I followed by a "slow" rate of gain in phase II (FAST/SLOW), 4) "Intermediate"-gaining steers fed to gain "slow" during phase I followed by a "fast" rate of gain (using wet corn gluten feed) in phase II (SLOW/FAST), and 5) Steers fed to gain "slow" for the entire wintering period (SLOW; Figure 1). Cattle were managed in three groups during the winter. In phase I, WCGF steers (group 1) were supplemented with 5 lb/head/day (DM basis) of wet corn gluten feed and 0.18 lb/head/day (DM basis) of a mineral supplement, group 2 (CORN) consisted of steers which received 4 lb/head/day (DM basis) of corn and 1.8 lb/head/day (DM basis) of a sunflower meal-based supplement, and group 3 (SLOW) consisted of steers which grazed cornstalks and received 1.8 lb/head/day (DM basis) of the same sunflower meal based supplement. In phase II, half of the WCGF steers were switched to the SLOW treatment and half of the SLOW steers were switched to the WCGF treatment, resulting in FAST/SLOW and SLOW/FAST treatments (Figure 1). During phase II, WCGF steers received ammoniated wheat straw ad-libitum, 5 lb/head/day (DM basis) wet corn gluten feed, and 0.14 lb/head/day (DM basis) of a mineral supplement. Steers on the CORN treatment received ammoniated wheat straw ad-libitum, 4 lb/head/day (DM basis) rolled corn, 0.6 lb/head/day (DM basis) of the sunflower meal-based protein supplement, and 0.2 lb/head/day (DM basis) of a mineral supplement. The SLOW steers received ad-libitum ammoniated wheat straw and 0.2 lb/head/day (DM basis) of a mineral supplement.

Summer Period. On about May 1, steers were weighed, fly tagged, and implanted with Synovex S. In year 1, steers were placed on bromegrass near Mead, NE for 45 days (April 29, 1998 through June 12, 1998). On June 13, 1998, steers were weighed and shipped to native warm-season pastures near Rose, NE where they remained until

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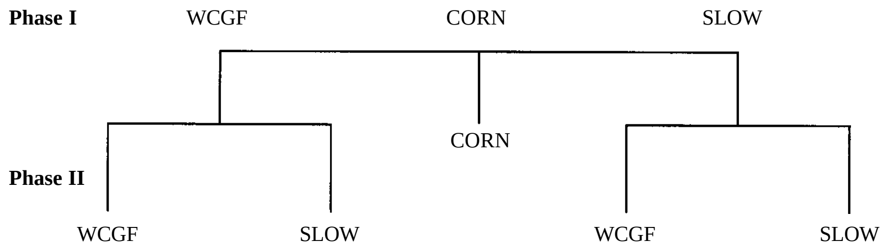

Figure 1. Treatment structure.

Sept. 2, 1998 (82 days). On Sept. 3, 1998, steers were returned to Mead, and grazed bromegrass re-growth until Sept. 28, 1998 (26 days). Steers were managed in one group throughout the summer. Steers were rotated on bromegrass pastures in late spring and early fall so that forage never became limiting to steer performance. On warm-season pastures, steers were rotated between two 320 acre pastures (total = 640 acres) in the same manner. In year 2, it was necessary to change the pasture management strategy following poor grass gains in year 1. Because the Rose, NE location contains significant low-land areas, poor gains were likely due to significant cool-season grasses. Steers were sent to that location in mid-June, and cool-season grasses had likely matured, contributing to decreased steer performance. Therefore, in year 2, cattle were managed in two groups. One group was sent to Rose, NE while the other group remained on cool-season grass at Mead, from May 4, 1999 through October 5, 1999. Again, an effort was made to manage both groups so that forage quality and quantity never became limiting to steer performance.

Finishing Period. In both years, upon removal from grass, all steers were implanted with Revalor-S and placed into the feedlot for finishing (18 head/pen). Steers were adapted to the finishing diet in 21 days using four step-up diets containing 45, 35, 25, and 15% roughage fed for 3, 4, 7, and 7 days, respectively. The final diet (7.0% roughage) was formulated to contain a minimum of 12% CP, .7% Ca, .35% P, .6% K, 30 g/ton monensin, and 10 mg/kg tylosin (DM basis). The finishing diet contained 40% wet corn gluten feed, 48% high-moisture corn, 7.0% alfalfa, and 5% supplement (DM basis). Final weights were calculated using hot carcass weight and a common dressing percentage (63). Hot carcass weights were obtained at slaughter, and fat thickness over the 12th rib, quality grades, and yield grades were gathered following a 24-hr chill.

Initial and final weights in the winter, summer, and finishing periods were the average of two consecutive day weights following three days of limit feeding a common diet containing 50% wet corn gluten feed and 50% alfalfa hay fed at 2% of body weight (DM basis).

Economic Analysis. Portions of the costs associated with each treatment were different through the growing phases. Differences between systems in input costs will be noted, otherwise it should be assumed that inputs were similar.

For initial steer cost, average weight of a pen was multiplied by the 7-year average October calf price ($82.57/cwt.) for 500-550 lb feeders (USDA Agricultural Marketing Service). Simple interest was charged on the total sum of initial animal cost for the entire ownership period. All interest charges discussed herein were based on a simple 9.8% rate. Twenty-five dollars/head was charged for health, processing, and implanting. Interest was charged against health cost over the entire ownership period.

All three winter groups were charged a stalk charge of $0.12/head/day during phase I. Interest was charged for half of the stalk grazing period plus the remainder of ownership. Also, during phase I, animals in the WCGF group were supplemented with wet corn gluten feed (5lb/head/day; DM basis) at a cost of $102.99/ton (DM basis), which is equal to a corn price of $2.48/bu (as-is), and a mineral supplement ($36.40/ton; DM basis) at the rate of 0.18 lb/head/day (DM basis). Interest was charged on wet corn gluten feed and mineral supplement for half of the stalk period and for the remainder of ownership. Steers in the CORN group received 4 lb/head/day (DM basis) of dry-rolled corn ($2.48/bu; as-is) in phase I and 1.8 lb/head/day (DM basis) of protein supplement ($216.60/ton; DM basis). Interest was charged on the cost of both corn and protein supplement for half of the stalk grazing period plus the remainder of ownership. Steers in the SLOW group received the same protein supplement in phase I as the CORN group at the same feeding rate and cost. Interest was handled in a similar way as described above.

During phase II, all three groups were fed ammoniated wheat straw ad-libitum. Intake of the groups was monitored for cost calculations (12.3, 15.1, and 15.3 lb/head/day [as-is] for WCGF, CORN and SLOW, respectively). Ammoniated wheat straw was priced at $40/ton (as-is) and interest was charged on straw for half of phase II plus the remainder of ownership. In phase II, steers in the WCGF group were supplemented with a mineral supplement ($40.40/ton; DM basis) at the rate of 0.158 lb/head/day (DM basis) and wet corn gluten feed in the same manner as in phase I. Therefore, costs and feeding rate for wet corn gluten feed were the same in phase II as in phase I. Steers in the CORN group received corn in the same way as in phase I (feeding rate and cost were similar), the same protein supplement as in phase I at the rate of 0.6 lb/head/day (DM basis), and a mineral supplement at the rate of 0.185 lb/head/day ($86.00/ton; DM basis). Steers in the SLOW group were fed the same mineral supplement as the CORN group at the rate of 0.278 lb/head/day (DM basis). Interest was charged on all feed ingredients for all groups for half of phase II plus the remainder of ownership. Stalk and drylot yardage was charged at the same rate ($0.12, 0.11, and 0.10/head/day for WCGF, CORN and SLOW, respectively). Yardage charge differences were the result of increased feeding costs associated with wet corn gluten feed and corn compared to the SLOW group. The WCGF group was charged slightly more than the CORN group because a feed truck was required for wet corn gluten feed delivery as opposed to corn feeding which was fed using a pick-up truck. In addition to the drylot yardage charge, a day charge of $0.12/head was applied to animals in all groups. Interest was charged on yardage and drylot costs for half of the respective period plus the remainder of ownership.

For summer costs, grazing was charged at the rate of $0.50/head/day, and interest was charged for half of the grazing period plus the remainder of ownership.

Finishing costs include both feed and yardage. For feed, DM intakes for a pen were determined and a diet cost of $114.20/ton (DM basis) was applied. Feedlot yardage was applied at $0.30/head/day. Interest was charged on feed and yardage costs for half of the feeding period. Total steer cost was the sum of steer, winter, summer, and finishing costs plus 2% death loss. To calculate slaughter breakeven, total cost was divided by final weight.

For all supplemental ingredients, prices were determined based on actual prices paid for those ingredients by the University of Nebraska Feed Mill with a 5% handling fee. Supplemental ingredients include all ingredients used in the winter protein and mineral supplements, and the supplemental ingredients used in the finishing diet. Wet corn gluten feed, whole corn, dry-rolled corn and high-moisture corn were charged on an equal dry basis, and price was determined using 10-year average corn price for Nebraska ($2.48/bu; as-is). A 10% shrink, processing, and handling fee was applied to corn and wet corn gluten feed. Alfalfa in the finishing diet was priced based on 10-year average price in Nebraska ($60.72/ton; as-is) along with a 10% markup.

Calf vs. Yearling Comparison

Experiments. The calf vs. yearling comparison used data from four years of calf finishing and yearling growing/finishing systems compiled at the University of Nebraska from 1995-1998. Calf finishing trials were chosen which had begun in the fall of the year, meaning that calves would have been sorted from a pool of animals from which calves placed into the yearling systems originated. Yearling systems were handled in the same way as described previously in the yearling trials; however, two additional years of data were used which were not reported previously. In addition, only SLOW and WCGF treatments were used in the comparison.

Economic Analysis. Economics for yearling systems were handled in the same manner as described previously in the yearling trials. Calf finishing (CALF) slaughter breakevens were calculated on pens of animals from each of the respective trials. Initial animal cost was based on the USDA 7-year average October feeder cattle price discussed previously for the yearling trials ($82.57), indicating $78.44/cwt. for 600-650 lb steer calves. However, data from Oklahoma suggests about $2.66/cwt. (total = $81.10/cwt.). should be added back to the purchase price for black exotic cross steers (May 15, 2000 Feedstuffs, pp. 9). In our calf finishing trials, black exotic cross steers were purchased. Additionally, calf purchase data compiled at Nebraska over the past seven years shows that $81.65/cwt. was paid for animals weighing 600-650 lb. Therefore, an average between Oklahoma and Nebraska data was used to arrive at a purchase price of $81.38/cwt. for 600-650 lb steers used for calf finishing. Interest was applied to initial cost of the animal over ownership. Health, processing, and implanting were assessed a flat rate of $25.00/head. Feed charges for the CALF treatment were based on the same finishing diet cost charged to the yearlings ($114.20/ton; DM basis). Average DM intake for each pen was used to determine feed consumption. Yardage was charged at $0.30/head/day. Interest was charged on the finishing diet and yardage for half of the feeding period. A 2% death loss was applied to all of the calves. To calculate slaughter breakeven, total cost was divided by final weight. Profitability was determined for both CALF and yearling (WCGF and SLOW) treatments. Profitability was calculated using the seven-year average May-June USDA Choice slaughter steer price ($66.21/cwt.; USDA Agricultural Marketing Service) for the CALF data. Likewise, the seven-year average December-January USDA Choice slaughter steer price ($67.48/cwt.; USDA Agricultural Marketing Service) was used for yearling data.

Results

Yearling Trials

Winter Period. Significant ADG differences were established between faster gaining treatments (WCGF and CORN), intermediate treatments (FAST/SLOW and SLOW/FAST), and the SLOW treatment ($P < .05$; Table 1). More importantly, differences in final winter weight ($P < .05$) were established for subsequent evaluation of compensatory growth on grass (Table 1).

Summer Period. Animals on FAST/SLOW, SLOW/FAST, and SLOW treatments gained faster ($P < .10$) compared to animals on fast gaining treatments (WCGF and CORN). No differences were noted in gains of steers on the two "faster" gaining winter treatments (Table 1). Gains of steers on the SLOW treatment and "intermediate" treatments were similar ($P > .10$). Prior research conducted at the University of Nebraska has shown that animals restricted to be 50 lb lighter compared to a "fast" gaining group at the end of a winter period (106 days) fully compensated at the end of summer grazing (1989 Nebraska Beef Cattle Report, pp. 34-35). In contrast, another study demonstrated that animals more severely restricted (150 lb weight difference; 160 days) only compensated 20% at the end of summer grazing (1998 Nebraska Beef Cattle Report, pp. 63-65). In the present study, "intermediate" gaining treatments began the summer period approximately 80-90 lb lighter than animals on WCGF and CORN treatments. Following summer grazing, a 50-60 lb weight difference remained, resulting in compensation of 33%. At the onset of summer grazing, steers on the SLOW treatment were approximately 145 lb lighter than steers on "faster" gaining treatments. By the end of the summer, the weight difference was 108 lb, resulting in compensation of 26%. Clearly, degree of restriction had little

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effect on compensation. In addition, winter energy source (WCGF vs. CORN), length of restriction (intermediate treatments vs. SLOW), and pattern of restriction (FAST/SLOW vs. SLOW/FAST) had little or no effect on compensation. Previous work which found that full compensation could be expected following summer grazing has not been supported in four consecutive years of compensatory gain work (two years not reported here). Therefore, it appears that steers fed at "faster" rates of winter gain can be expected to maintain 70-80% of their weight advantage following summer grazing. While summer gains reported here are below those typically seen in Nebraska, other studies in which steers have gained 2 lb/day have shown similar compensation, indicating that level of summer gain may not be a key factor (2001 Nebraska Beef Cattle Report, pp. 34-36; 2000 Nebraska Beef Cattle Report, pp. 30-32).

Finishing Period. No differences among winter treatments were noted in ADG, DM intake, or feed conversion ($P > .10$; Table 1). Only differences in final weight were apparent which are a carryover from differences imposed in the winter.

Economic Analysis. Steers on the WCGF treatment tended ($P < .15$) to have a lower breakeven compared to steers on the CORN, FAST/SLOW, and SLOW/FAST treatments (Table 2). Animals on the SLOW treatment had the highest breakeven ($P < .05$). Final weight appears to be the largest single factor which accounts for a reduced slaughter breakeven ($P < .0001$; as final weight increases, slaughter breakeven decreases), accounting for 78% of the variation. Because of increased winter weight gain and little summer compensation by steers in the "intermediate" and SLOW treatments, steers on the WCGF treatment had a lower slaughter breakeven. Breakeven differences between WCGF and CORN treatments are due to increased winter inputs (protein supplement) for the CORN treatment, whereas wet corn gluten feed supplied energy, protein, and minerals in one package.

Table 1. Steer performance and carcass data.

Item[a]	WCGF	CORN	FAST/SLOW	SLOW/FAST	SLOW
Winter					
Days	154	154	154	154	154
Initial weight, lb	520	518	521	513	523
ADG, lb	1.48[b]	1.43[b]	0.89[c]	0.96[c]	0.49[d]
Final weight, lb	747[b]	739[b]	658[c]	661[c]	598[d]
Summer					
Days	154	154	154	154	154
ADG, lb	1.29[e]	1.26[e]	1.46[f]	1.45[f]	1.52[f]
Final weight, lb	944[b]	932[b]	881[c]	883[c]	830[d]
Finishing					
Days	94	94	94	94	94
ADG, lb	4.77	4.83	4.81	4.78	4.69
DMI, lb/day	31.4	31.6	31.5	31.0	30.7
Feed/gain[g]	6.56	6.54	6.55	6.48	6.55
Final weight, lb[h]	1396[b]	1389[b]	1337[c]	1338[c]	1276[c]
Carcass Data					
Carcass weight, lb	879[b]	875[b]	842[c]	843[c]	804[d]
Yield grade	2.6	2.6	2.6	2.4	2.5
Fat thickness, in	.48[b]	.46[bc]	.46[bc]	.43[d]	.44[cd]
Quality grade[i]	522[bc]	527[c]	513[bcd]	502[cd]	500[d]

[a]WCGF = wet corn gluten feed; CORN = corn; FAST/SLOW = fast gain then slow winter gain; SLOW/FAST = slow gain then fast winter gain; SLOW = slow winter gain.
[bcd]Means within row with unlike superscripts differ ($P < .05$).
[ef]Means within a row with unlike superscripts differ ($P < .10$).
[g]Feed/gain was analyzed as gain/feed. Gain/feed is the reciprocal of feed/gain.
[h]Calculated from hot carcass weight adjusted to a common dressing percentage (63).
[i]Quality grade: 400-499 = Select, 500-599 = Choice.

Table 2. Economics and slaughter breakevens.

Item[a]	WCGF	CORN	FAST/SLOW	SLOW/FAST	SLOW
Steer cost, $	475.20	474.14	476.52	469.11	477.80
Health	27.69	27.69	27.69	27.69	27.69
Winter costs, $					
Feed	74.23	93.69	58.34	70.45	54.97
Yardage	29.45	27.79	27.88	27.69	26.12
Summer costs, $					
Grazing	80.27	80.27	80.27	80.27	80.27
Finishing costs, $					
Yardage	28.63	28.63	28.63	28.63	28.63
Feed	170.83	172.30	171.48	168.68	166.99
Total costs, $	899.46	917.84	883.83	885.49	875.41
Final weight, lb	1396[b]	1389[b]	1337[c]	1338[c]	1276[d]
Breakeven, $/100 lb[e]	64.56[b]	66.22[b]	66.23[b]	66.25[b]	68.68[c]

[a]WCGF = wet corn gluten feed; CORN = corn; FAST/SLOW = fast gain then slow winter gain; SLOW/FAST = slow gain then fast winter gain; SLOW = slow winter gain.
[bcd]Means within row with unlike superscripts differ ($P < .05$).
[e]Slaughter breakeven price.

Table 3. CALF vs. yearling steer performance.

Item	CALF	FAST	SLOW
Winter initial wt., lb	—	522	524
Winter ADG, lb	—	1.53	0.42
Grass initial wt., lb	—	764	592
Grass ADG, lb	—	1.21	1.64
Days on feed	182	91	105
Feedlot initial wt., lb	611	931	814
Feedlot ADG, lb	3.47[a]	4.55[b]	4.26[c]
DM intake, lb/day	21.1[a]	30.8[b]	28.9[c]
Final wt., lb[d]	1238[a]	1359[b]	1242[c]
Carcass wt., lb	780[a]	856[b]	783[c]
Fat, in.	0.47	0.49	0.47
Yield grade	2.40	2.65	2.61

[abc]Means within a row with unlike superscripts differ ($P < .05$).
[d]Calculated from hot carcass weight adjusted to a common dressing percentage (63).

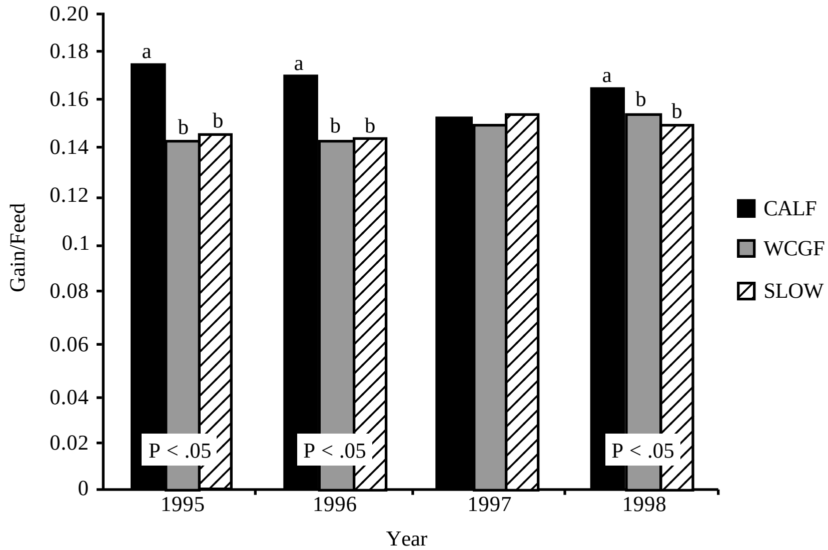

Figure 2. Feed efficiency year × treatment interaction.

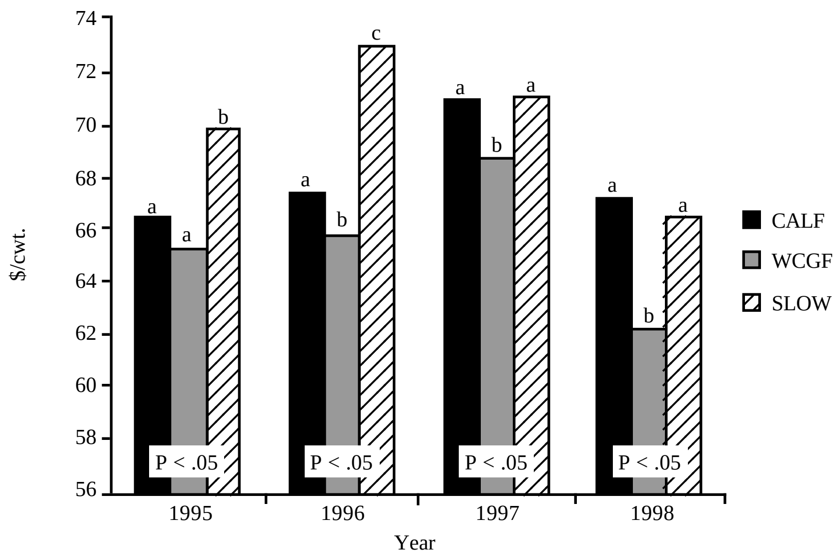

Figure 3. Slaughter breakeven year × treatment interaction.

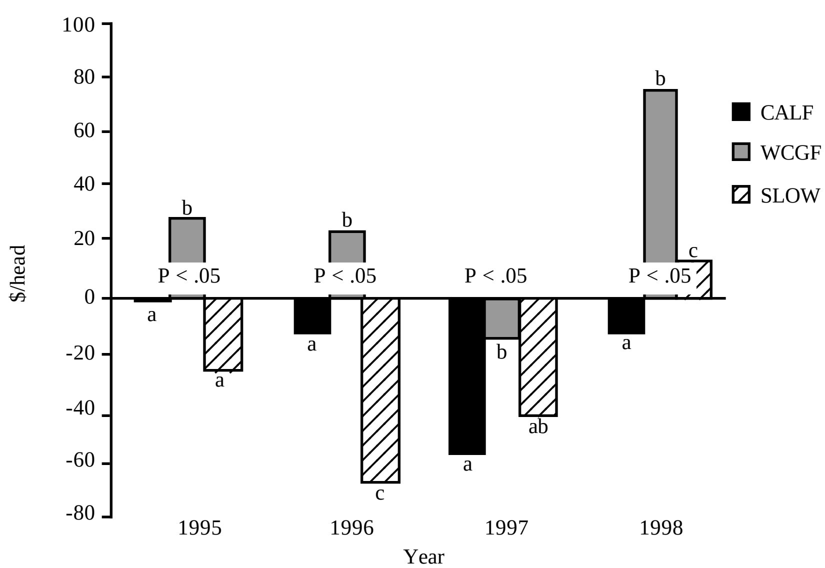

Figure 4. Profit/loss year × treatment interaction.

Calf vs. Yearling Comparison

Animals on the CALF treatment gained slower and consumed less feed compared to yearling systems ($P < .05$; Table 3). For feed efficiency, a year × treatment interaction was evident ($P < .05$; Figure 2). In 1995 and 1996, calves were more efficient compared to the yearling systems ($P < .05$); however, in 1997 no differences in efficiency were noted ($P > .05$). Likely, the reason for the discrepancy in 1997 is that calves on feed in the spring of 1998 encountered significant mud which reduced performance (ADG and feed efficiency). In 1998, calves were more efficient ($P < .05$) than both yearling treatments, and the WCGF treatment was more efficient ($P < .05$) compared to SLOW. The WCGF treatment produced carcasses which were heavier (~75 lb; $P < .05$) compared to SLOW and CALF treatments. In terms of slaughter breakeven, a year × treatment interaction ($P < .05$; Figure 3) was evident. In 1995, WCGF and CALF treatments resulted in similar breakevens, while SLOW treatment breakevens were higher ($P < .05$). In 1996, the WCGF treatment had the lowest ($P < .05$) breakeven compared to CALF which was lower ($P < .05$) compared to SLOW. In 1997 and 1998, the WCGF treatment had a lower breakeven ($P < .05$) compared to both CALF and SLOW.

When comparing groups which were fed (and therefore sold and slaughtered) at different times, slaughter breakeven may not be appropriate. Profitability is a better measure because it accounts for different marketing times. Figure 4 shows the profitability of each of the treatments within each year. Calf finishing failed to show a profit in all four years, whereas the WCGF yearling system was profitable in three years. The SLOW yearling system was profitable in 1998; however, it also produced the largest losses in two of the years examined with the most substantial losses occurring in 1996. While not statistically appropriate based on the year× treatment interaction, averaging profit/loss numbers across years is realistic in terms of producer profitability. The WCGF yearling system was

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advantageous compared to CALF or SLOW, showing an average profit of $28.85/head over the four-year period. Losses incurred by CALF and SLOW were $-20.87 and -30.24/head, respectively. Final weight was the largest determining factor in terms of both slaughter breakeven and profit/loss, explaining 47 and 49% of the variation, respectively.

Steer purchase price can have a relatively large impact on profitability. Data from Kansas indicates that large deviations in the price spread can occur with changes in the price of corn (2000 Kansas State Cattleman"s Day Report, pp. 88-91). For example, the price differential between 500 and 800 lb steers with below average corn price ($1.68/bu) is approximately $20.00/cwt.; however, when corn price rises to $3.52/bu, the price differential can diminish to $7.00/cwt. for the same steers. Producers should be aware of the price differential paid for calves for calf finishing compared to calves which will be grown in a yearling program, as well as marketing times and expected prices received before making decisions to background or place calves on feed.

In the present analysis, the WCGF wintering system was superior to either calf finishing or a growing/finishing system utilizing a "slow" rate of winter gain; however, several factors can interact with slaughter breakevens and profitability such as corn price, purchase price and slaughter cattle price.

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Undegradable Intake Protein Supplementation of Compensating, Grazing Steers

Kelly Creighton
Mark Ullerich
Terry Klopfenstein[1]

Yearlings wintered at a faster rate of winter gain responded better to undegradable intake protein supplementation during the summer, however increased gains were not maintained during the finishing phase.

Summary

A trial was conducted to evaluate the effect of previous winter gain on response to undegradable intake protein (UIP) supplementation during the summer grazing period. Steers wintered at the FAST rate of gain had a greater response to UIP supplementation than steers with SLOW rate of gain. Maximum response for FAST cattle occurred at 150 g/d of supplemental UIP, while SLOW cattle showed no response through 150 g/d. Forage DM intake was similar for FAST and SLOW cattle, therefore SLOW cattle consumed more as a percentage of body weight. Increased gains from UIP supplementation were not maintained during the finishing phase.

Introduction

Because of the high degradability of protein in actively growing forages, undegradable intake protein (UIP) may be first limiting before energy (1991 Nebraska Beef Report, pp. 27-28). Therefore, supplementation of UIP should increase gains during the summer grazing phase.

Compensatory gain typically occurs in animals that have been previously restricted or maintained on a low plane of nutrition, and enhanced intake is often cited as a mechanism for which compensatory gain occurs. Previous research at the University of Nebraska has shown that the rate of winter gain and subsequent compensatory gain affects the response of grazing steers to UIP supplementation but not dry matter intake (DMI) during the summer phase (2000 Nebraska Beef Report, pp. 30-32). Steers with higher daily gains during the winter phase respond more to UIP supplementation, even though cattle with slower rates of winter gain experience compensatory growth during the summer. Therefore, it appears that cattle with different degrees of compensatory gain have different requirements for UIP. Additionally, cattle wintered at different rates of daily gain still consume the same amount of DM. Therefore, the objectives of our study were to evaluate the effects of previous winter gain on response to UIP supplementation and forage DMI during the summer grazing period.

Procedure

Forty-nine steers (503 lb; 11/24/98) were used in a 2x7 factorial treatment design. Steers were allotted randomly to one of two rates of winter gain, 1.5 (FAST, n=25) and .5 lb/day (SLOW, n=24). Steers then were randomly assigned to one of six UIP supplements (n=3) or an energy control (n=7). Protein supplements were formulated to deliver 75, 112.5, 150, 187.5, 225, or 262.2 g/day of supplemental UIP. The

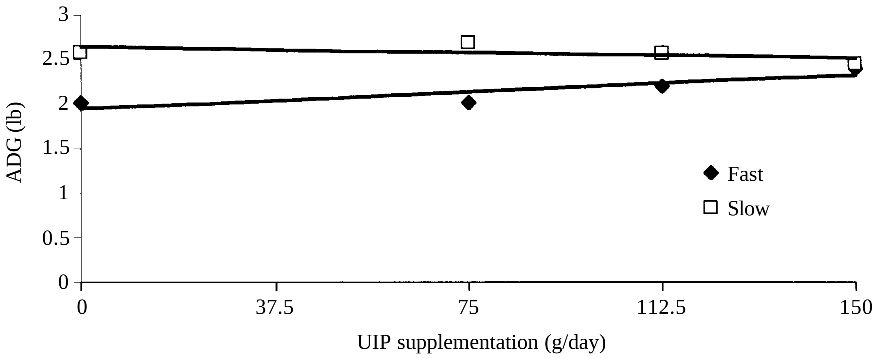

Figure 1. Average daily gain (lb) of steers during the summer grazing period excluding UIP supp. levels >150 g/day. Summer x winter interaction (P<.10).

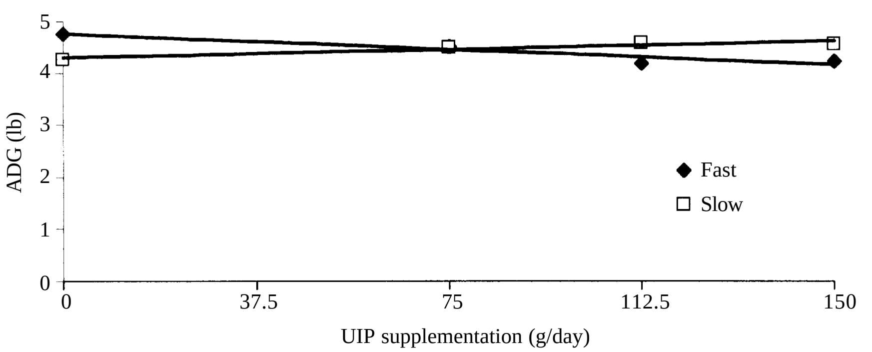

Figure 2. Average daily gain (lb) of steers during the finishing phase excluding UIP supp. levels >150 g/day. Summer x winter interaction (P<.10).

protein supplement was composed of 74% Soypass (treated soybean meal), 19% feather meal, 3% molasses, and 4% salt. The energy supplement consisted of 56% soyhulls, 9% tallow, 6% Carolac (a rumen protected fat), 24% molasses, and 5% salt. Combinations of the protein and energy supplements provided the graded levels of UIP and all supplements were formulated to be isocaloric. Steers were individually fed supplements four days per week.

Steers grazed four 8-acre fertilized brome pastures in a rotational grazing system from May 5 to June 11. Steers were then moved to pastures containing a mixture of warm season grasses and were maintained there in a four-pasture rotational system until the end of the trial Aug. 19. A fifth pasture was used in late July because of slow regrowth of the warm season grasses due to drier than normal conditions. Biweekly diet samples were collected via ruminally fistulated animals and samples were analyzed for CP, UIP, and IVDMD. An intake determination period, consisting of two one-week periods, was conducted while cattle grazed brome (early June) and warm season (mid-July) pastures. All steers receiving the energy control supplement (n=7) and the highest levels of UIP (n=7) within each winter treatment received a Captec continuous release chromium bolus to estimate fecal output. Fecal grab samples were taken for five consecutive days during each week of each intake period. Samples were composited within week for analysis and determination of fecal output. Total chromium payout from the bolus was verified using total fecal collection with six bag steers. Forage intake was calculated by dividing fecal output by forage indigestibility.

At the end of the summer grazing phase, steers were assigned within winter treatment to feedlot pens for finishing. Steers were stepped-up to the finishing ration which consisted of 47% high moisture corn, 44% wet corn gluten feed, 5% alfalfa and 4% supplement. All steers were fed for 106 days, at which point animals were slaughtered and carcass characteristics were recorded.

Results

A significant winter gain by UIP supplementation interaction (P=.09) was observed for summer grazing ADG; therefore, effects within winter treatment are reported (Figures 1 and 2). A significant quadratic effect (P=.09) on ADG across all UIP levels was detected for FAST cattle, with the maximum response occurring at the 150 g/day level. SLOW cattle responded linearly (P=.02) to increasing UIP levels; however, the response was negative. Supplemental levels above 150 g/day caused a reduction in gains of FAST cattle. Therefore, in order to determine a response to UIP supplementation within the range of positive effects, the data were reanalyzed excluding UIP levels greater than 150 g/day. These new analyses showed FAST cattle responded linearly (P=.08; .44 lb/day) to increasing UIP, while the SLOW cattle had no response to UIP. Additionally, SLOW cattle experienced compensatory growth and had higher gains overall (2.0 v. 2.7 lb/day for FAST vs. SLOW cattle receiving the energy control, respectively). Therefore, cattle with slower ADG during the winter phase were able to partially compensate for weight differences that were created by the winter treatment. Because of the length and severity of restriction in the SLOW cattle during the winter, they were only able to compensate 25% of the difference created by the winter treatments (177 v. 143 lb for initial and final grazing weight differences, respectively).

Crude protein, UIP (%DM), and IVDMD averaged 16.8%, 1.09%, and 70.3%, respectively, for the brome pastures and 15.5%, 1.40%, and 60.6%, respectively, for the warm season pastures. Dietary UIP content was measured using an in situ neutral detergent insoluble nitrogen (NDIN) technique, and calculated using rate of passage and rate of digestion.

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Results from intake determination are summarized in Table 1. There was a significant effect (P<.005) of forage type on forage intake. Therefore, means within forage type are reported. Winter treatments did not affect pounds of DMI during the brome or warm season grazing period. However, there was a winter treatment effect (P<.0001) when DMI was expressed as a percentage of body weight. For both forage types, FAST and SLOW cattle consumed similar amounts of DM; however, due to weight differences created by the winter treatments, the SLOW cattle consumed more DM as a percentage of BW. The increase in consumption, when expressed as a percentage of BW, has been previously reported and may partially explain the compensatory gain that occurred with the SLOW cattle.

A summer by winter treatment interaction (P=.09) occurred for feedlot performance. Therefore, data were analyzed within winter treatment. Additionally, performance data were analyzed excluding the same treatment groups as described for ADG in the grazing phase (UIP levels >150 g/day). Analysis with these levels showed that there was no effect of summer supplementation level on feedlot performance in the SLOW cattle. A negative linear effect (P=.09) of UIP supplementation during summer grazing occurred on feedlot ADG in FAST cattle. Cattle that responded to UIP supplementation during the summer had significantly lower ADG than those cattle that received the energy control and lower levels of UIP during the grazing period. This decrease in gains allowed for cattle to compensate for weight differences created by summer treatments. There were no differences (P>.3) in carcass characteristics due to summer treatments in either FAST or SLOW cattle. There was an effect (P=.0002) of winter treatment on hot carcass weight since SLOW cattle were able to only compensate 25% of the weight difference created by winter treatments during the grazing phase. There were no other effects of winter treatment on carcass characteristics.

Table 1. Forage intake of steers within forage type.

	Winter treatment			
	FAST	SLOW	SEM	P-value
Brome				
DMI, lb/day	15.4	15.7	.67	.76
DMI, % BW	1.92	2.52	.09	.0001
Warm Season				
DMI, lb/day	20.9	21.2	.71	.81
DMI, % BW	2.29	2.80	.09	.0006

Table 2. Metabolizable protein balances for steers during the summer grazing period.

	FAST		SLOW	
	Energy	Protein	Energy	Protein
Brome				
Actual gain, lb/day	1.94	2.36	2.54	2.56
ME allowable gain	2.33	2.33	2.54	2.54
MP balance, g/day	-93	+122	-65	+150
Warm season				
Actual gain, lb/day	2.05	2.31	2.69	2.78
ME allowable gain	2.31	2.31	2.76	2.76
MP balance, g/day	+22	+237	+18	+234

Performance, intake and diet composition data were used to evaluate the 1996 NRC computer model at the end of the trial. Actual DMI and forage digestibilities were used for each forage type, as well as ADG during each grazing phase. Adjustments for NEm and NEg were calculated using metabolizable energy intake (NE adjuster = (-.0360 $\pm$ 0.0047) x MEI + (1.6869 $\pm$ 0.0785)). Using the NE adjusters, the metabolizable energy allowable ADG for the highest responding protein level was calculated using the model. The metabolizable protein (MP) balance was then determined for the energy control and highest responding protein level treatments. The model predicted that the SLOW gaining cattle were deficient in MP during the brome grazing period; therefore, the SLOW cattle should have responded to UIP supplementation (Table 2). Additionally, the model predicted the FAST cattle were deficient in MP while grazing brome, but that this deficiency was overly compensated for with UIP supplementation. The model also predicted neither group to be deficient during the warm season period. The NRC model inaccurately estimated MP balance for cattle at different physiological states and adjustments need to be made to the model to account for differences in efficiency created by compensatory gain.

Previous winter treatment and subsequent compensatory gain do affect the response to UIP during the summer grazing period. Cattle maintained at a slower rate of gain during the winter and experience a greater degree of compensatory gain during the summer respond less to UIP than those yearlings that were wintered at a FAST rate of gain. Additionally, forage intake (in pounds) was not affected by winter treatment, however, slower cattle eat more as a percentage of body weight due to weight differences created by the winter treatment. Body weight advantages gained by supplementation during the summer are completely compensated for during the finishing phase. We concluded that supplementation during the summer grazing period was not economical.

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Undegradable Intake Protein Content of Corn Steep Compared to Soybean Meal

Trey Patterson
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Casey Wilson
Ryan Mass
Rick Stock[1]

Undegradable intake protein content of corn steep is approximately 30% of crude protein.

Summary

Thirty calves were used in an 84-day growth trial to evaluate protein efficiency of corn steep compared to soybean meal. Calves were individually fed a base diet supplemented with either 1) urea, 2) soybean meal, or 3) corn steep. Soybean meal and corn steep were fed at graded levels replacing urea. In vitro ammonia release analyses showed the protein in both corn steep and soybean meal to be approximately 30% undegradable in the rumen. Calves fed corn steep had similar protein efficiency to calves fed soybean meal, supporting the in vitro data.

Introduction

Corn steep, a byproduct of wet corn milling, is a combination of corn steep liquor and distillers solubles. Corn steep liquor is concentrated solubles from the steeping process, containing soluble protein, vitamins, minerals, and lactic acid. Distillers solubles contain sugar and yeast cells remaining after the distilling process.

Corn steep is added to beef cattle diets to supply both protein and energy. Corn steep is also added to corn bran to form wet corn gluten feed. Corn steep and wet corn gluten feed have been shown to improve performance in dry-rolled corn finishing diets (1997 Nebraska Beef Report, pp. 70-74). Degradable intake protein (DIP), or natural protein degraded in the rumen, has been implicated in the improved performance.

Corn steep has not been associated with having significant undegradable intake protein (UIP), due to the solubility of protein in steep liquor. However, the distillers solubles contain heated yeast cells. Heat processing has been demonstrated to reduce the solubility of protein. Feeding heated brewer's yeast to calves has produced lower rumen ammonia concentrations than feeding live brewer's yeast, indicating protein in the heated yeast was degraded to a lesser extent in the rumen. In vitro ammonia release data indicated protein in distillers solubles was 80.6% undegradable and protein in steep liquor protein was 13.2 % undegradable. This would make a typical corn steep product (36% CP, DM basis) have a UIP value of 33% of CP.

The UIP content of corn steep, as measured in the laboratory, has not been validated in a cattle feeding experiment. The hypothesis is that corn steep protein is degraded to a similar extent as soybean meal protein (30% UIP). The objective of this experiment was to compare the UIP value of corn steep to soybean meal in growing calf diets.

Table 1. Composition of supplements fed to growing calves (percentage of DM)[a].

Ingredient	Urea Control	SBM[b]	Steep[c]
Bran	82.8	35.8	—
Soybean meal	—	55.7	—
Corn Steep	—	—	88.9
Urea	7.6	—	1.6
Dicalcium Phosphate	4.0	2.2	—
Limestone	3.2	4.3	7.6
Salt	1.5	1.5	1.5
Ammonium sulfate	0.4	—	—
Trace Mineral Premix	0.3	0.3	0.3
Vitamin Premix	0.2	0.2	0.2
Selenium Premix	0.1	0.1	0.1

[a]Supplement included in diet at 20% of DM.
[b]Soybean meal supplement replacing urea control at 25, 50, 75 and 100% of supplement DM.
[c]Corn steep supplement replacing urea control at 25, 50, 75 and 100% of supplement DM.

Procedure

Thirty calves (476 $\pm$ 57 lb) were stratified by sex and randomly allotted to treatment and level within treatment. Three treatments were: 1) supplement to supply the degradable intake protein requirement with urea and corn bran (n = 6, urea control); 2) soybean meal replacing urea and bran in the supplement at 25, 50, 75, or 100% of the supplemental CP (n = 3 per level, SBM); and 3) corn steep replacing urea and bran in the supplement at 25, 50, 75, or 100% of the supplemental CP (n = 3 per level, Steep). Diets were 40% sorghum silage, 20% corncobs, 20% dry corn bran, and 20% supplement (DM basis; Table 1). Diets were formulated to contain a minimum of 11.5% CP. All calves were fed to the same percentage of body weight, with the feeding level starting at

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2.0% of body weight and increasing to 2.6% over the course of the experiment. Diets were individually fed with a Calan Gate system for 84 days. Three day weights were taken at the initiation and completion of the trial. Calves were implanted with Ralgro at the beginning of the experiment.

Protein efficiency, calculated as gain above the urea control over natural protein intake above the urea control, was calculated for SBM and Steep using the slope ratio technique. Non-linear regression was used to determine the slope (protein efficiency) of the response lines before maximum gains were achieved. Slopes were compared with a Modified T-Test for unequal variances.

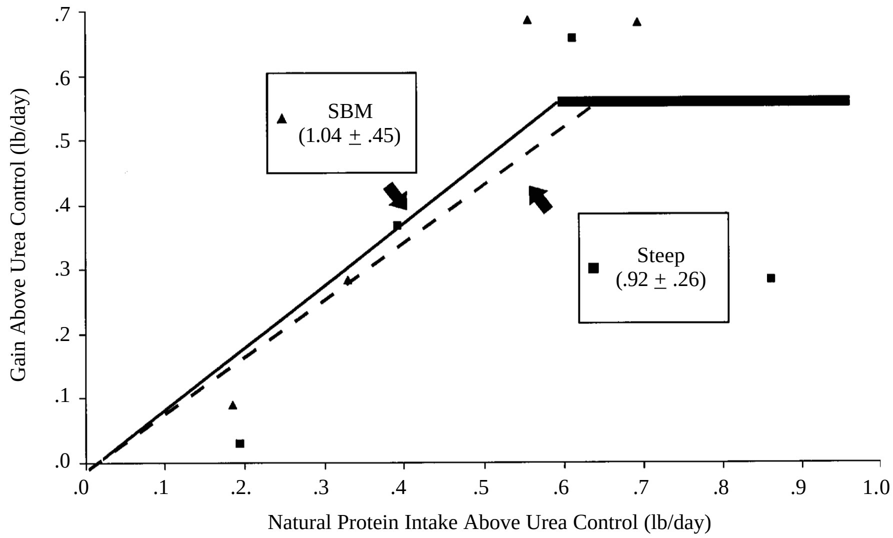

Figure 1. Protein efficiency of growing calves fed graded levels of soybean meal or corn steep (protein efficiency values in parentheses).

Table 2. Nutrient composition of diets fed to growing calves.

Nutrient	Urea Control	100% SBM[a]	100 % Steep[b]
DM, %	49.9	49.9	45.5
CP, % of DM	12.0	13.0	14.4
Calcium, % of DM	0.60	0.64	0.76
Phosphorus, % of DM	0.28	0.28	0.52
Sulfur, % of DM	0.15	0.16	0.25

[a]Soybean meal supplement replacing urea control at 25, 50, 75 and 100% of supplement DM.
[b]Corn steep supplement replacing urea control at 25, 50, 75 and 100% of supplement DM.

Results

Calves on the urea control gained 1.6 lb/day, and the maximum gain realized by calves supplemented with either SBM or Steep was 2.25 lb/day. The regression of gain above the urea control on natural protein intake above the urea control is shown in Figure 1. The maximum gain above urea control, .57 lb, was reached at .55 and .62 lb of natural protein intake above the urea control for SBM and Steep, respectively. The protein efficiency of Steep (.92 ± .26) was not different (P > .10) from SBM (1.04 ± .45). The base diet supplied 5.6% natural protein. Assuming the natural degradable protein requirement of rumen microbes was met by the base diet, any response above the urea control was due to UIP supplied by the Steep and SBM. Similar protein efficiency between Steep and SBM indicate similar UIP contents.

Nutrient concentrations in the urea control diet and the 100% SBM and 100% Steep diets are shown in Table 2. Both corn bran and steep were higher in protein than anticipated, so diets exceeded 11.5% CP. This does not change interpretation of results since 1) all diets supplied adequate DIP, 2) protein efficiency calculations take into account both protein intake and gain above the control, and 3) protein efficiency was calculated prior to maximum gain. In vitro ammonia release analyses on steep samples from this trial showed that corn steep protein was 32.8% undegradable, compared to 29.6% for soybean meal. These data are consistent with previous measurements in the laboratory.

While the standard errors are high for the protein efficiency values, the means are quite similar. The conclusion of equal UIP values for Steep and SBM is consistent with the in vitro ammonia release data. We conclude the UIP value of corn steep is approximately 30% of crude protein.

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[1]Trey Patterson, research technician; Terry Klopfenstein, professor, Animal Science, D. J. Jordon, Ryan Mass, and Casey Wilson, research technicians, Lincoln; Rick Stock, Cargill Corn Milling, Blair, NE.

Utilization of Bt Corn Hybrids in Growing Beef Steers

Jeffrey Folmer
Galen Erickson
D.J. Jordon
Todd Milton
Terry Klopfenstein[1]

The feeding value of corn residue or silage is similar between Bt and nonBt corn hybrids.

Summary

Two trials were completed to evaluate the efficacy of Bt corn hybrids for growing steers. After grain harvest, trial 1 used two fields of N7333 Bt and nonBt corn to evaluate grazing performance and preference of growing steers. Trial 2 compared early and late maturing varieties (N4242 and N7333, respectively) of Bt and nonBt corn hybrids in corn silage-based growing diets. No differences in performance or grazing preference were observed between N7333 Bt or nonBt residue. Steers fed corn silage from hybrids N4242 gained 11% faster (P>.01) and were 7% more efficient (P>.01) than those fed N7333 hybrids. Effects of the Bt trait in the corn silage growing study were inconsistent between hybrids.

Introduction

Bt corn hybrids have been genetically engineered to control European corn borer without pesticide use. Corn residue and corn silage are commonly used as feedstuffs for growing cattle. The objectives of this research were to 1) compare corn residue from a Bt and near-isogenic nonBt corn hybrid on performance and grazing preference, and 2) compare corn silage from two Bt corn hybrids and their near-isogenic counterparts on performance of growing beef steers.

Materials and Methods

Experiment 1

Sixty-seven large framed steer calves (625 lb) were used in a two-part 70-day grazing trial. Thirty acres of later maturing Novartis N7333 Bt and 28 acres of nonBt corn residue were divided into six pastures (3 Bt and 3 nonBt) and then stocked with 51 steers. To achieve equal stocking rates (.69 AUM/acre), the three nonBt pastures were each assigned eight steers and the three Bt pastures were each assigned nine steers. Prior to grazing, residual corn (bushels/acre) was estimated by counting full and partial ears in each of the six pastures. Steer weights were taken for two consecutive days at the start and finish of the trial after a three-day period of limit-feeding to equalize gut fill. The second component of experiment one evaluated grazing preference for Bt and nonBt corn residue. Sixteen steers grazed one pasture containing equal acres of Bt and nonBt corn residue for 70 days. Animals were observed once daily between 6 and 9 a.m., and numbers of animals grazing Bt and nonBt residue were recorded. All steers (performance and preference experiments) received an equal amount of protein supplement (1 lb as fed/hd/d) to ensure protein did not limit performance.

Experiment 2

One hundred twenty-eight medium-framed steer calves (620 lb) were used in a completely randomized design with a 2x2 factorial arrangement of treatments. Early vs late maturing varieties of Bt and non-Bt corn hybrids (N4242 and N7333, respectively) were grown under similar agronomic conditions. Silages were harvested at 3/4 milk line in the grain, and stored separately in large plastic Agbags®. Silages were ensiled approximately 100 days prior to initiation of the experiment.

Sixteen pens were used with eight steers per pen and four replications per treatment. Corn silage growing diets contained 90% corn silage and 10% supplement (DM basis, Table 2). The supplements were formulated for adequate degradable intake protein (DIP), undegradable intake protein (UIP), vitamins, and minerals based on the 1996 NRC Nutrient Requirements of Beef Cattle. All diets contained 20 g/t Rumensin®. Steers were implanted with Ralgo Magnum®, and fed for 101 days. Weights were taken on two consecutive days at the initiation and end of the experiment with interim weights taken approximately every 35 days. Initial and final weights were obtained following a three-day period of equalized intake (2% of BW; DM basis) to minimize differences in gut fill.

Results and Discussion

Experiment 1

Grain yield for N7333 Bt was 184 bu/acre and was 182 bu/ac for the N7333 nonBt. These two corn fields were approximately 75% pivot irrigated and 25% dryland. Results of the grazing trial indicated no difference in steer performance due to incorporation of the Bt trait (Table 1). Previous Nebraska research has demonstrated a high correlation (r=.79)between residual corn and daily gain of steers grazing corn residue (Jordan et al., 1997). Low European corn borer pressure and

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good harvesting conditions contributed to the low amount of residual corn (1.0 and 1.5 bu/acre, Bt and nonBt respectively), which is typically 2-4% of the corn yield . These conditions also contributed to lower than expected daily gains. Previous research and experience at the University of Nebraska would predict the average daily gain to be .9 to 1.2 lbs/day.

There was no preference (F-test; P=.51) in grazing distribution between Bt and nonBt varieties. During the grazing period, 47.5% of the steers were observed grazing Bt residue, and 52.5% of the steers were observed grazing nonBt residue (Table 1).

Experiment 2

Corn grain and silage yield data are summarized in Table 3. These dryland fields showed a greater difference in grain yield between the Bt and nonBt varieties. Corn borer infestation data are also summarized in Table 3. These measurements were taken from Aug. 28 through Sept. 1, 1998. The nonBt corn fields did incur some degree of European corn borer infestation. Results from six strip trials in various locations across the state showed an average of an 11% infestation rate (B. Siegfried, University of Nebraska Entomology Department, personal communication).

Results for the silage growing study are summarized in Table 4. Dry matter intake was higher (P=.02) for steers fed the Bt hybrids compared with nonBt hybrids. Additionally, N4242 tended (P=.09) to have a higher dry matter intake compared to N7333. An interaction (P< .05) was observed for daily gain and feed efficiency between corn hybrid and incorporation of the Bt trait. Daily gain was increased 7% (P <.05) when N4242 Bt was fed compared to its near-isogenic nonBt counterpart. In contrast, incorporation of the Bt trait into N7333 depressed daily gain by 4% (P =.09) when compared with its near-isogenic nonBt counterpart. Feed efficiency was improved 4% (P =.11) in steers fed N4242 Bt, compared with N4242 nonBt. Steers fed N7333 nonBt were 8% (P <.05) more efficient than those fed the N7333 Bt. Although the

Table 1. Performance and grazing preference of growing steers grazing Bt and nonBt corn residue in Experiment 1.

Item	Bt	nonBt	SEM	P-Value
Performance				
Initial wt, lb	626	626	.77	.89
End wt, lb	664	675	4.5	.15
ADG lb/day	.54	.70	.06	.12
IVDMD[a], %	33	36	.7	.04
Residual corn bu/acre	1.0	1.5	—	—
Grazing Preference				
Distribution[b], %	47.5	52.5	5.2	.51

[a]*In vitro* dry matter digestibility measured using modified procedures of Tilley and Terry (1963).
[b]Percentage of steers observed grazing Bt or non Bt corn residue.

Table 2. Composition of corn silage diets fed to growing steers in Experiment 2.

Ingredients (DM%)	N4242 Bt and nonBt		N7333 Bt and nonBt	
Corn Silage	90.0		90.0	
Supplement	10.0		10.0	
Supplement Composition (%)				
Soybean Meal	65.00		75.00	
Sorghum Dry Roll	11.58		0.00	
Urea	8.50		10.00	
Limestone	8.23		8.47	
Salt	3.00		3.00	
Tallow	2.20		2.20	
Dicalcium Phosphate	1.02		0.86	
Vit. Min. Premix	0.47		0.47	
Nutrient Composition (DM%)	**N4242Bt**	**N4242 nonBt**	**N7333 Bt**	**N7333nonBt**
DM	37.30	37.30	37.30	37.30
CP	12.37	12.37	12.37	12.37
NDF	34.99	33.05	36.99	38.19
ADF	22.21	19.93	23.74	21.44
Ca	0.600	0.600	0.609	0.609
P	0.250	0.250	0.250	0.250

Table 3. Yield of corn grain and silage used in Experiment 2.

Item	N4242 Bt	N4242 nonBt	N7333 Bt	N7333 nonBt
% Infested[a]	33	0	56	0
Grain Yield bu/acre	132.6	122.0	151.5	142.7
Silage Yield t/acre	14.1	12.1	16.2	17.6
DM t/acre[b]	5.7	4.7	6.1	6.7

[a]Indicates percentage of plants infested with live larvae.
[b]Silage yield multiplied by actual silage dry matter content.

Table 4. Performance (101 days) of growing steers in experiment 2 fed Bt and nonBt silage.

Item	N4242 Bt	N4242	N7333 Bt	N7333	SEM	Gene[a]	Hybrid[a]	Gne* Hyb.[a]
Initial wt, lb	619	621	619	621	1.0	0.08	0.88	0.93
End wt, lb	944[b]	923[bc]	898[d]	910[cd]	7.3	0.56	0.002	0.04
DMI lb/d	19.2	18.6	18.8	18.1	0.24	0.02	0.09	0.96
ADG, lb	3.22[b]	2.99[c]	2.76[d]	2.86[cd]	0.07	0.39	<0.01	0.03
Feed / Gain	5.98[b]	6.22[bc]	6.81[d]	6.33[c]	0.11	0.32	<0.01	<0.01

[a]Gene = main effect of Bt genetics; Hyb = main effect of hybrid ; Gne*Hyb = interaction of Bt gene and hybrid.
[bcd]Means in the same row not bearing a common superscript differ (P< .05).

Table 5. Chemical analysis of silages used in Experiment 2.

Item (% of DM)	N4242 Bt	N4242 nonBt	N7333 Bt	N7333 nonBt	SEM
DM %	40.2	39.0	37.6	37.8	—
Ash	4.1	4.5	6.1	4.7	.07
CP	7.0	7.2	6.1	6.3	.11
NDF	38.9	36.7	41.1	42.4	.60
ADF	24.7	22.1	26.4	23.8	.20
PL[a]	5.2	4.4	5.6	5.1	.15
ADL[b]	3.3	2.7	3.6	3.4	.04
Starch	37.6	38.6	37.3	37.1	.21
30-h NDF Dig.[c]	32.4	30.8	34.4	31.6	.07
IVDMD[d]	74.3	65.6	69.1	65.6	1.41

[a]Permanganate lignin measured according to Goering and Van Soest (1971).
[b]Acid detergent lignin measured according to Goering and Van Soest (1971).
[c]30-hour neutral detergent digestibility measured in vitro.
[d]In vitro dry matter digestibility measured using modified procedures of Tilley and Terry (1963).

interaction was observed for daily gain and efficiency, steers fed the N4242 gained 11% faster (P<.01) and were 7% more efficient (P<.01) than those fed corn silage produced from N7333.

The data from these experiments suggest incorporation of the Bt trait has no effect on corn residue value or preference in grazing beef steers. Producers can take advantage of increased yields and reduced pesticide use with Bt corn hybrids without adverse effects on corn residue grazing performance. Stocking rates may need to be adjusted for Bt hybrids because of the potential reduction in residual corn, or more supplemental feed may be needed to maintain daily gain compared with nonBt hybrids. The interaction of hybrid genetics and incorporation of the Bt trait observed with corn silage growing diets is difficult to explain, and may be related to slight changes in the chemical composition of the silages (Table 5). Most importantly, hybrid genetics have a larger influence on daily gain and feed efficiency of growing steers fed corn silage-based diets compared with changes associated with incorporation the Bt trait in these hybrids.

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Wet Corn Gluten Feed Supplementation of Calves Grazing Corn Residue

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Terry Klopfenstein
Todd Milton[1]

Feeding wet corn gluten feed to calves grazing cornstalks increases weight gain above non-fed controls. The optimum feeding level is 6.0 lb DM/head/day which can result in 1.8-1.9 lb/day gain.

Summary

Incremental levels of wet corn gluten feed were fed to calves grazing corn residues. Based on statistical and economical analysis of the data collected, feeding wet corn gluten feed (5.0-6.5 lb/head/day; DM basis) will increase stocking rate on corn residue and reduce winter costs by 11%. Given that 3.5 lb DM/day wet corn gluten feed will meet the protein and phosphorus needs of calves, and feeding above 6.0 lb/d will not increase gains, wet corn gluten feed should be fed at 3.5-6.0 lb DM/day, producing gains from 1.28-1.88 lb/day.

Introduction

Wet corn gluten feed has roughly the same energy value as corn (NEg = 0.64-0.68 Mcal/lb), is moderate in protein (23% CP) and phosphorus (0.95%), is palatable, and is safe to feed in terms of little or no risk of acidosis or founder. With the high concentration of nutrients discussed, WCGF supplies several expensive nutrients in one package. Feeding five lb of WCGF (DM/head/day) is sufficient to meet the metabolizable protein requirement of calves grazing corn residues. However, no animal performance trials have been conducted to specifically determine the optimum feeding level of WCGF to calves grazing corn residues.

The objective of our study was to evaluate calf growth response to incremental levels of wet corn gluten feed supplemented on corn residues in the late fall and early winter.

Procedure

A steer growth trial was conducted from Oct. 27, 1999 through Jan. 13, 2000 using thirty-seven crossbred steer calves (552 lb) which were individually fed a supplement while grazing corn residues. Steers were assigned randomly to one of seven levels of supplement (2.0, 2.75, 3.5, 4.25, 5.0, 5.75, and 6.5 lb of DM/head/day). The control treatment (7 head) consisted of a sunflower meal-

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based supplement fed at 2 lb/head/day (DM basis) that was formulated to meet the degradable intake protein (DIP) requirement of the steers. The second treatment (5 head) was a combination of WCGF (68%) and sunflower meal (32%) fed at 2.75 lb DM/head/day. Sunflower meal was required in the second treatment to meet DIP requirement of the steers. The remaining 5 treatments (5 head/treatment) consisted entirely of WCGF (3.5, 4.25, 5.0, 5.75, and 6.5 lb/head/day; DM basis). All steers were individually fed the appropriate amount of supplement once daily using Calan electronic gates. Each morning at approximately 6:30, steers were gathered for feeding. Steers were allowed a maximum of one hour to consume the respective supplement offered. Following feeding, steers were returned to the cornstalk field. Four 7.4 acre fields were allocated for grazing. Steers were allowed access to a new paddock when visual appraisal indicated that leaf and husk material was limiting.

Initial and final weights were the average of three consecutive-day weights following three days of limit feeding a common diet containing 50% wet corn gluten feed and 50% alfalfa hay fed at 2% of body weight (DM basis).

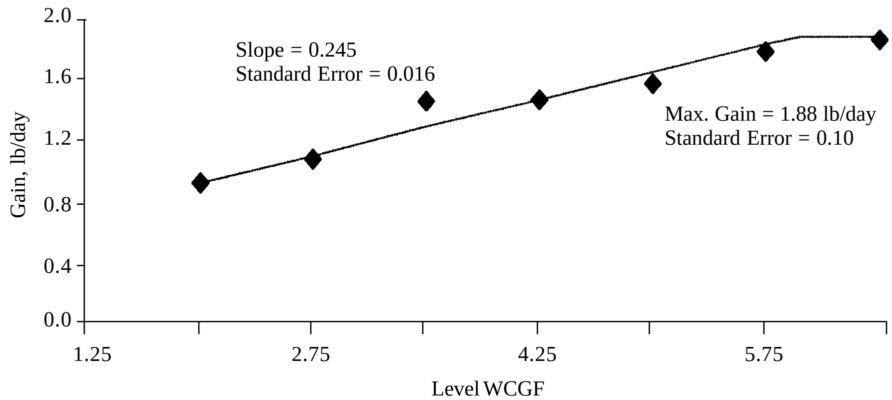

Figure 1. Daily gain of steers supplemented with wet corn gluten feed on cornstalks.

Table 1. Supplement effects on cornstalk intake predicted by two methods.

Supplement Intake[a]	NRC Computer Model[a]	Stalk Intake Equation[ab]
2.00	10.4	9.8
2.75	10.2	10.2
3.50	10.1	10.2
4.25	9.3	10.1
5.00	8.5	9.7
5.75	8.6	9.8
6.50	8.6	9.7

[a]Values expressed as DM lb/head/day.
[b]Equation: $RI = (0.0365W^{0.75} - SD(SI))/1-RD$, where RI = Residue Intake, SD = Supplement Digestibility, SI = Supplement Intake, and RD = Residue Digestibility.

Results

Steers on the control treatment gained 0.91 lb/day. Average daily gain increased up to 1.86 lb/day as WCGF was included at the 6.5 lb DM/head/day level. When a non-linear statistical analysis was applied to the data, it predicted that gains leveled off at 6.0 lb DM (Figure 1). The analysis suggests feeding WCGF above 6.0 lb DM/day would not increase gains and presumably, the cattle would begin to replace stalk intake with WCGF. Over the past four years, research conducted at the University of Nebraska has used 5.0 lb/head/day (DM basis) of WCGF to increase winter gains (2001 Nebraska Beef Cattle Report, pp. 29-34). Based on the previous research, feeding WCGF in the winter will reduce slaughter breakeven compared to feeding a protein supplement similar to the control treatment in the present study. The reduction in slaughter breakeven has been attributed to increased winter weight gain which is maintained throughout summer grazing and finishing, resulting in more sale weight. Therefore, feeding 6.0 lb DM/head/day of WCGF might increase winter weight gain and should further reduce slaughter breakevens compared to feeding 5.0 lb DM/head/day.

Feeding WCGF to calves grazing corn residues should increase the carrying capacity of the cornstalks. Estimates of cornstalk intake were determined from two sources: the 1996 Nutrient Requirements of Beef Cattle computer model and an equation developed specifically to predict corn residue intake from residue digestibility and fecal output (1989 Journal of Animal Science, pp. 581-589). Table 1 shows the intake predictions based on each model. In order to predict stalk intake from the 1996 NRC computer model, net energy adjustments were made based on another article contained within this report (2001 Nebraska Beef Cattle Report, pp. 116-119). Cornstalk intake was first predicted based on the stalk prediction equation for each level of supplementation. Once a stalk intake was established, it was used to determine the TDN concentration of the total diet and a net energy adjustment was calculated and applied to the 1996 NRC computer model. The 1996 NRC computer model then was used to predict stalk intake to determine how comparable the values were between the two sources. Table 1 shows the stalk intake predicted by the 1996 NRC computer model. While the predicted intakes do not always agree, especially at higher supplement intakes, true values should fall within the range of the two intake predictions at a given level of supplementation. Therefore, higher levels of WCGF (5.0-6.5 lb/head/day DM) reduced cornstalk intake by 10%, from about 10.1 lb/head/day (DM basis) with low level supplementation to 9.1 lb/head/day (DM basis). Economic analysis of winter supplementation of WCGF (2001

Nebraska Beef Cattle Report, pp. 29-34) indicates that extending stalk grazing by 10% would reduce wintering costs and increase profit/head by $1.00. Without taking the calves completely through a growing/finishing system, it is not possible to determine the optimum level of WCGF supplementation on corn residue. However, these data indicate what gains might be expected with different levels of WCGF supplementation. About 3.5 lb DM/day is needed to meet the protein and phosphorus requirements of the calves. Therefore, it is logical to feed at least that amount. Based on the nonlinear analysis, it seems that 6.0 lb DM/day is a logical upper limit. This range of feeding should result in gains ranging from 1.28-1.88 lb/day. Producers may then select a level of WCGF based on desired daily gain, stalk availability, cattle frame and weight (as it affects market weight), and length of summer grazing season.

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Impact of Grazing Corn Stalks in the Spring on Crop Yields

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Walker Luedtke
Gary Lesoing[1,2]

Grazing corn residue in the spring had no detrimental effect on subsequent soybean yields and may slightly increase yields.

Summary

A two-year experiment was designed to determine the impact of grazing corn residue during the spring on subsequent soybean yields in a corn-soybean rotation. Tillage treatments consisting of ridge-till, fall-till, spring-till, and no-till were also evaluated to determine if yields could be maintained by alleviating compaction from grazing in the spring. Grazing treatments overall, and specifically in the ridge-till and no-till systems, resulted in increased yields. Residue cover was also more sensitive to changes in tillage rather than grazing; however, both treatments decreased residue cover.

Introduction

Traditional corn residue grazing occurs from November to February. Based on numerous research trials at the University of Nebraska Agricultural Research and Development Center, grazing corn residue during this period does not impact subsequent crop yields, whether corn or soybeans (1997 Nebraska Beef Report, pp. 34-37). While grazing corn residues decreases residue and increases bulk density of soil, presumably no impact is observed, because cattle were only maintained in crop fields while the ground was frozen (1997 Nebraska Beef Report, pp. 34-37).

However, producers require both holding areas and feed sources for cattle from February until pastures are available in late April. Fields generally are very wet and not frozen from February to April. Therefore, compaction from cattle may cause detrimental yield losses in subsequent crops. The objective of this study was to determine the impact from grazing corn residue from late February until late April on subsequent soybean yields.

Procedure

In 1997, a 90-acre field was identified. The field was split into quarters with ungrazed check strips replicated across each quarter. Crop production was based on an annual corn-soybean rotation with one-half of the field grown to each crop. The field was irrigated by a linear-move (2425 feet width) irrigation system (Valmont, Valley, Neb.) and the grazing areas replicated within each half grown to corn for grazing experiments. The grazing trials were conducted from Febr. 25 until April 14 in 1998 (48 days) and from March 1 until April 26 in 1999 (56 days). Animals were fed supplement daily at 1.5 lb per head per day. Calf stocking rate was approximately .8 acres per calf for 60 days. The stocking rate was based on average stocking rates to optimize animal performance. Some producers may use spring grazing areas as holding or calving pens where stocking rates are greater than .8 acres per calf.

Tillage treatments included ridge-tilling during the summer, no-tillage, fall tillage with a chisel followed by conventional tillage (disk) in the spring, or spring conventional tillage alone. All tillage treatments were conducted during the corn rotation with no tillage following the soybean crop. Grazed and ungrazed treatments were superimposed on tillage treatments. The no-till, ridge-till, and spring-till treatments each contained a grazed and ungrazed section. Treatments were applied to an eight-row strip and grazing treatments managed with electric wires. Residue cover was measured by determining residue at points in a transect across the eight-row treatment strip.

At harvest, the middle six rows were harvested out of the 8-row strip to maintain one border row on each side and eliminate effects from grazing pressure and fences. Soybean harvest was conducted with a 3300 John Deere combine with a 10-foot head. Each six-row strip

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was harvested in two passes, taking four rows first followed by two rows. After each individual replication (eight replications per treatment; seven treatments) was harvested, total weight was recorded using an experimental weigh wagon. Samples were collected at this time to determine DM and DM yield. Corn harvest (in 1999) was conducted with normal production equipment and all eight rows included in the replication. Weighing and sampling were performed similar to soybeans except a Brent 550 bu grain cart with J-star load cells was used for weighing.

Results

Animal performance

Calf performance was variable across years (Table 1). In 1998, calves gained 2.12 lb per day. In 1999, ADG was significantly less and calves just maintained weight during the 56 days (ADG = -.1lb per day). In 1998, calves were lighter, with initial weights of 612 lb as compared to 688 lb in 1999. However, final weights were not significantly different between years. When comparing performance based on field management, whether no-till or ridge-till, performance was not influenced (P > .70) and initial and final weights were similar. Gains were different across years based on residual corn grain in fields. In 1998, residual grain estimation from surrounding fields suggested that an average of 15 bu of corn grain per acre was available to calves. In 1999, no corn grain was available based on residual grain measurements.

Table 1. Animal performance of calves grazing corn residue in the spring.[a]

	Tillage treatment[b]		Year[c]		
Item	Ridge-till	No-till	98	99	SE
Initial weight, lb	645	655	612	688	17
Final weight, lb	693	703	714	683	18
ADG, lb	1.0	1.0	2.1	-.1	.13

[a]Stocking rates were approximately 1 calf per acre across tillage treatments and years.
[b]No effect of tillage treatment was observed (P > .70).
[c]Significant year effect was observed for IW and ADG (P < .05).

Crop production

Soybean yields the following fall after spring grazing were influenced by treatments (P < .01). Soybean yields on the grazed no-till areas tended to be greater than the ungrazed no-till and ungrazed ridge-till treatments (P < .20). Yield on the ridge-till grazed area was greater (P < .05) than all other treatments except the no-till grazed treatment (P > .40). Grazing from approximately Febr. 20 until April 20 did not depress soybean yields as was our original hypothesis. Based on these results, grazing improved subsequent soybean yields in the ridge-till and no-till management systems. Our hypothesis was that yields would potentially be depressed, but tillage treatments might help alleviate yield depressions due to soil compaction from spring grazing. Based on these results, spring and fall tillage caused a depression in yields relative to ridge-till and no-till grazed treatments.

Corn residue was influenced by both grazing and tillage treatments (Table 2). Based on measurements before grazing and after grazing, corn residue decreased in all treatments including ungrazed areas. In ungrazed areas, residue cover decreased by 13 to 18%. Fall tillage and spring tillage decreased residue as was expected. Fall tillage resulted in much lower initial cover (38%) and was lowest the following spring with only 23% cover. The no-till grazed treatment resulted in a 27% decrease and ridge-till grazing led to a 37% reduction in cover. Spring tillage (following grazing) decreased cover by approximately 55% for both grazed and ungrazed treatments. The tillage treatments appear to have much larger impacts on residue cover than grazing; however, both management factors decrease cover.

Due to the unstructured treatment design, contrasts were used to distinguish differences between treatment groups. Table 3 illustrates contrasts used and statistics for soybean yield and

Table 2. Effect of spring grazing and tillage treatments on residue cover before and after grazing and soybean yields the following fall.[a]

Tillage:[b]	Ridge	Ridge	None	Fall/Spring	Spring	Spring	None		
Grazing:	GR	UG	UG	UG	UG	GR	GR		
Treatment:	1	2	3	4	5	6	7		
Item[c]								SE	F-test
Yield (lb)	329[d]	319[e,f]	318[e,f]	314[f]	316[f]	319[e,f]	326[d,e]	3.8	.01
Yield (bu/acre)	59.3[d]	57.3[e,f]	57.2[e,f]	56.5[f]	56.9[f]	57.2[e,f]	58.5[d,e]	.67	.04
Residue-B, %	82.5[d]	83.7[d,e]	90.2[e]	37.8[f]	89.4[e]	86.9[e]	89.5[e]	1.5	.01
Residue-A, %	50.0[d]	72.6[e]	81.6[f]	22.6[g]	36.9[h]	36.9[h]	65.5[e]	3.5	.01
Change, %	37.0[d]	16.9[e]	13.2[e]	18.4[e,f]	56.1[g]	53.6[g]	26.5[f]	3.6	.01

[a]No significant year by treatment interaction was observed (P > .90). Yields were determined from 16 plots per treatment (8 plots per year) that ranged from .07 to .12 acres.
[b]Tillage treatments included ridge-till, no-till, fall tillage, and spring tillage. Superimposed on those were grazing (GR) and ungrazed (UG) treatments.
[c]Soybean yield measured in lb of DM and bushels per acre on a 90% air-dry basis, percent residue cover before (B) grazing and after fall tillage, percent residue cover after (A) grazing and spring tillage, and the change from before grazing to after in % cover by subtraction. Residue measurements after grazing and the subsequent change in residue are based on 1998 only.
[d,e,f,g,h]Means within a row with unlike superscripts differ (P < .10).

Table 3. Grazing and tillage impacts on soybean yields and residue cover.

Contrast	Treatments[a]	Yield (bu/acre) P=	Yield (bu/acre) means	Residue change (%) P=	Residue change (%) means
Grazed vs Ungrazed	1,6,7 vs 2,3,4,5	.01	58.4 vs 56.9	.01	38.3 vs 26.1
Ridge vs No-till	1,2 vs 3,7	.43	58.4 vs 57.9	.05	26.9 vs 18.3
Spring-till vs No-till	5,6 vs 3,7	.23	57.1 vs 57.9	.01	55.1 vs 18.3
No-till UG vs Tillage UG	3 vs 4,5	.60	57.2 vs 56.7	.01	13.2 vs 37.2
Ridge GR vs Ridge UG	1 vs 2	.04	59.3 vs 57.3	.01	37.0 vs 16.9
No-till GR vs No-till UG	7 vs 3	.14	58.5 vs 57.2	.01	26.5 vs 13.2

[a]Treatment numbers are: 1=Ridge-till grazed, 2=Ridge-till ungrazed, 3=No till ungrazed, 4=Fall/Spring till ungrazed, 5=Spring till ungrazed, 6=Spring till grazed, and 7=No till grazed.

change in residue cover. Comparing grazed to ungrazed treatments averaged across tillage treatments suggests grazing increases (P < .01) soybean yields by 1.5 bu per acre. Grazing corn residue in the spring also increased the amount of residue loss from 26 to 38%. Separating effect of grazing within ridge-till suggests grazing increased (P < .04) yields by 2.0 bu per acre. Grazing corn residue in the spring with no-till management tended (P < .14) to increase soybean yields as well. Based on the comparisons of ridge-till and fall/spring tillage with no-tillage, tillage did not influence soybean yields. Tillage and grazing both increased losses of residue cover over no-tillage and ungrazed treatments.

Corn yields two years after grazing in February of 1998, and harvesting beans in the fall of 1998 were recorded in 1999. No significant yield differences were observed.

In summary, spring corn residue grazing appears to have no detrimental impacts on subsequent soybean yields. Yields were statistically higher in grazed no-till and ridge-till treatments than the other treatments. Fall and spring tillage treatments had little impact on yields. Residue cover appears to be effected more by tillage treatments than grazing. Tillage also appears to "mask" any grazing effects on corn residue cover.

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Economic Returns of Wet Byproducts as Cattle Feed

Richard Perrin
Terry Klopfenstein[1]

Feeding wet byproducts from grain processors to cattle has grown in Nebraska until over a million tons are now being fed, with net benefits of over $42 million per year.

Summary

Research at the University of Nebraska and other institutions has demonstrated the feasibility of feeding corn sweetener/ethanol industry byproducts directly to cattle in wet form, rather than marketing them as dried feeds. Using a combination of experimental results, survey data and market prices, the average value of these wet feed products was about $130 per ton of dry matter during the 1990s, compared to their alternative value as dried feed of $93 per ton. Given the amounts fed, the annual net benefits of this innovation in Nebraska grew from about $1 million in 1992 to an annual average of about $42 million during 1997-99.

Introduction

Due to new technologies and ample irrigation resources, Nebraska's grain production grew faster than any other major producing state during the 1970s and 1980s. The relatively cheap grain that resulted was a factor that both encouraged cattle feeding (to the extent that during the same period Nebraska went from fifth to second largest cattle feeding state) and attracted grain processing plants (Nebraska capacity for producing corn sweeteners and ethanol grew faster than any other state in the past decade). A second factor important in attracting corn processing plants was the research demonstrating that processing byproducts can be fed directly to the expanding numbers of finishing cattle, rather than being dried and shipped to distant markets. The study reported here is an evaluation of the direct economic benefit of the innovation of feeding wet byproducts directly to finishing cattle, rather than further processing them for the dried feed market.

The experimental work at the University of Nebraska and elsewhere has established the possibilities for substituting wet corn gluten feed, wet distillers grains and steep liquor for other feeds in beef cattle feedlots. The approach of this study is to estimate the feed value of these byproducts (the value of the feeds for which they substitute) and to subtract from that, the value of the byproducts in their next best use, which is their value as dried feeds

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adjusted for drying costs. This is a measure of the net benefit of the innovation of feeding a unit of the material in wet form rather than dry. We use survey data and plant production estimates to estimate the total amount of such feeds fed. We also examine the distribution of benefits between the processor and the cattle feeder, which depends upon the price charged for the byproducts.

Procedure

The imputed value of byproduct feed (the "shadow price" of the feed) was determined from the results of 18 different experiments (or sets of experiments) as the change in the cost of other feed inputs per pound of beef produced, divided by the number of pounds of byproduct fed per pound of beef. This in turn depends upon the prices of alternative feeds and can be represented as:

V_j = *imputed value per pound of the j-th byproduct fed*

$$= \frac{1}{x_j}\frac{\partial c}{\partial \tau} = \sum_{i \neq j} p_i \frac{1}{x_j}\frac{\partial x_i}{\partial \tau}$$

$$= \sum_{i \neq j} \beta_{ij} p_i, \text{ where } \beta_{ij} = \frac{1}{x_j}\frac{\partial \tau_i}{\partial \tau}$$

Here x_i represents pounds of feed i (dry matter basis) fed per pound of gain, c is feed cost per pound of gain, $\partial x_i/\partial \tau$ the amount in a standard ration minus that in a wet byproducts ration, p_i the price of feed i (dry matter basis here), and β_{ij} is the pounds of dry matter of feed i for which a pound of byproduct j substitutes. For those experiments which included multiple wet byproduct rations, we considered only that byproduct ration that provided the lowest cost per pound of gain.

Table 1. Wet byproduct feed value coefficients, per ton of byproduct dry matter.

		Feed value coefficient (β_{ij})[b]		
Feed ingredient and units	Avg price per unit[a]	Wet distillers grains	Wet gluten feed	Steep liquor
Alfalfa hay, per ton	$57.88	0.0301	0.0094	0.2082
Alfalfa silage, per ton	$22.36	0	0	0
Corn cobs, per ton	$20.00	0	0.0015	0
Corn silage, per ton	$22.64	0.0279	0.0741	0
Dry rolled corn, per bushel	$2.43	49.8432	38.0045	64.2591
Liquid 32, per cwt	$7.00	0	0.0305	0
Molasses, per cwt	$9.71	1.1248	2.0104	0
Soybean meal, per ton	$192.68	0	0.0108	0
Suppl, per ton	$100.00	0.0100	0.0172	0.0405
Urea, per ton	$210.00	0.0211	0.0155	0
Other, per ton	$200.00	0	0.0064	0
Average imputed value		$140.03	$122.81	$165.07

[a]1992 to 99.
[b]Per unit of ingredient, rather than per pound of dry matter.

The imputed value of wet byproduct feeds as determined by the above procedure will vary from year to year as the value of substituted feeds change. To determine the net benefit of feeding the byproduct in wet form, the estimated opportunity cost of selling the feed as a dried byproduct subtracted from the imputed value was estimated. This opportunity cost for a given year was the market price of the dried feed less an estimated $20 per ton of dry matter for drying cost. Finally, to calculate the distribution of this net benefit between cattle feeder and processor, we used the average delivered price of wet byproducts, as determined from survey responses from 183 feedlot operators in Nebraska.

Finally, to estimate the total benefits of the wet feeding innovation in Nebraska, we obtained estimates from the Nebraska Ethanol Board of the amount of grain processed by Nebraska plants, and from this we estimated the total amount of byproducts fed in wet form by Nebraska cattle feeders, from 1992 through 1999.

Results

Table 1 summarizes the value coefficients for the three wet byproducts, expressed in terms of units of traditional ingredients (units as specified in the table) for which one ton of wet byproduct substituted in the experiments. One ton of dry matter in wet distillers grains, for example, substituted for .03 tons of alfalfa hay, 49.8 bushels of dry rolled corn, etc, which had a total value of $140.03 per ton, when these traditional ingredients were valued at average 1992-99 prices. The imputed value of wet gluten feed was somewhat lower at $122.81, while that for steep liquor was somewhat higher at $165.07.

Table 2 summarizes our estimates of

Table 2. Summary of value and benefits per ton DM of wet byproduct fed from 1992-1999.

	Wet distillers grain				Wet gluten feed				Steep liquor			
	Feed value	Deliv. price	Opp. cost	Total benefit	Feed value	Deliv. price	Opp. cost	Total benefit	Feed value	Deliv. price	Opp. cost	Total benefit
1992	114.33	82.28	95.78	18.55	154.18	100.00	95.78	58.39				
1993	111.31	86.76	80.92	30.39	149.44	95.85	80.92	68.52				
1994	141.35	67.48	121.82	19.53	122.83	98.99	84.23	38.59	167.43	83.91	84.23	83.20
1995	146.08	123.96	107.02	39.06	127.67	90.26	81.98	45.69	173.02	102.13	81.98	91.04
1996	173.24	123.12	160.71	12.53	149.75	121.63	114.69	35.05	207.19	107.20	114.69	92.50
1997	150.66	113.78	135.33	15.33	131.43	102.66	80.67	50.76	178.64	113.60	80.67	97.97
1998	138.98	98.67	97.78	41.20	122.78	93.32	95.56	27.22	162.53	92.12	95.56	66.98
1999	112.47	93.97	83.33	29.13	102.37	88.87	77.78	24.60	128.15	87.73	77.78	50.37
Avg	140.03	107.08	117.24	22.79	122.81	97.09	88.95	33.86	165.07	100.45	88.95	76.12

Table 3. Quantity fed and economic benefits of wet byproduct feeds in Nebraska from 1992-1999.

	1992	1993	1994	1995	1996	1997	1998	1999
Wet distillers grains								
Quantity (1,000 tons DM)	0	0	70.0	145.8	173.3	311.0	345.1	352.4
Benefit ($1,000,000)	$0.00	$0.00	$1.37	$5.69	$2.17	$4.77	$14.22	10.27
Wet corn gluten feed								
Quantity (1,000 tons DM)	30.2	233.3	233.3	581.2	446.9	752.7	825.1	825.1
Benefit ($1,000,000)	$0.56	$7.09	$9.00	$26.55	$15.66	$38.21	$22.46	$20.30
Steep liquor								
Quantity (1,000 tons DM)	6.8	52.5	52.5	57.8	44.0	69.5	78.5	78.5
Benefit ($1,000,000)	$0.40	$3.60	$4.37	$5.27	$4.07	$6.81	$5.26	$3.95
All byproduct feeds								
Quantity (1,000 tons DM)	37.0	285.8	355.8	784.8	664.2	1133.3	1248.7	1256.0
Benefit ($1,000,000)	$0.96	$10.69	$14.74	$37.51	$21.90	$49.78	$41.94	$34.51

the net economic benefit of the wet byproduct feeding innovation. The bottom line indicates the average feed value of wet distillers grain was $140 per ton, while the opportunity cost as dried feed was $118 per ton, for an average net benefit of $22 per ton. Delivered price averaged $107, indicating an average gain of $32 per ton to feeders, and a $10 per ton loss to processors. Over the past two years processors have obtained a positive $5.77/ton benefit. It appears processors sold wet grains lower than the opportunity cost in order to establish the market during the first few years.

Conversely, corn gluten feed was marketed above the opportunity cost beginning in 1992. The benefit to the processors has been $8.14 per ton and the benefit to producers has been $25.72.

In Table 3 we summarize our estimates of the quantities of byproduct feeds fed in Nebraska, and the total net benefits generated according to the estimated values per ton as reported in Table 2. As of 1992, the amount of byproducts fed was negligible, but by 1997 the amount fed had grown to over a million tons, with an estimated net benefit of nearly $50 million. Currently, 30% of the benefits are from distillers grains from the dry milling industry and 70% from the wet milling industry which produces corn gluten feed and steep liquor.

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[1]Richard Perrin, professor, Agricultural Economics; Terry Klopfenstein, professor, Animal Science.

Urinary Allantoin Excretion of Finishing Steers: Effects of Grain Adaptation and Wet Milling Byproduct Feeding

Ryan Mass
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Todd Milton
Terry Klopfenstein
Rick Stock[1]

Steep liquor and distillers solubles do not stimulate microbial crude protein supply, as measured by allantoin excretion. Rumen pH correlated with microbial crude protein supply.

Summary

A metabolism trial investigated microbial protein supply for finishing cattle. In Phase I, cattle were adapted to a dry-rolled corn diet. Urinary allantoin excretion was positively correlated with TDN supply. In Phase II, cattle were fed that diet or diets with a portion of the corn replaced by one of two levels of the corn wet milling byproducts steep liquor or distillers' solubles. Byproducts inclusion did not increase microbial crude protein supply, as measured by urinary allantoin excretion. Rumen pH also correlated with microbial crude protein supply.

Introduction

Corn wet milling plants often blend corn steep liquor (STEEP) and distillers' solubles (DS) together, making it impossible to differentiate if one or both ingredients cause a performance response. A possible explanation for a response may be stimulation of microbial crude protein supply (MCP) due to amino acids and peptides present in STEEP and/or DS. Urinary allantoin excretion is a non-invasive marker of MCP supply (see related beef report article). The objectives of our research were to: 1) make estimates of urinary allantoin excretion as a marker of MCP supply for beef cattle fed dry-rolled corn based finishing diets; and 2) test the hypothesis STEEP and/or DS stimulate MCP synthesis when they replace dry-rolled corn in finishing diets.

(Continued on next page)

Procedure

Five crossbred yearling steers (mean wt = 775 lbs.) were fitted with rumen cannulas according to the guidelines of the UNL Institutional Animal Care and Use Committee. Cattle were housed in 10' x 10' box stalls, fed every two hours via automatic feeders, and allowed ad libitum access to feed. The trial was conducted in two phases: a common grain adaptation phase (Phase I) and a 5 x 5 Latin square (Phase II). In Phase I, cattle were adapted to a dry-rolled corn based finishing diet by feeding diets consisting of 45, 35, 25, 15, and 7.5% alfalfa for 4, 4, 7, 7, and 7 days, respectively. Dry-rolled corn replaced alfalfa in those adaptation steps. In Phase II, each period of the 5 x 5 Latin square was 21 days. All diets contained 7.5% cobs as the roughage source and were balanced to 15.3% CP using urea (this is the CP concentration of the 15% STEEP treatment). Treatments were: 1) CONT = 92.5% dry-rolled corn plus dry supplement; 2) 7.5% STEEP; 3) 15.0% STEEP; 4) 7.5% DS; and 5) 15.0% DS. In treatments two through five, the byproducts replaced dry-rolled corn in the ration.

In Phase I, cattle were tethered continuously to facilitate urine collection by abdominal funnels attached to a vacuum pump. Although urine was collected continuously in Phase I, urine volume was measured and aliquots were saved for analysis on the last four days of each adaptation step only. In Phase II, cattle were allowed to move freely in their stalls on days 1 through 17 and were tethered for urine collection on days 18 through 21. Aliquots of urine were analyzed for allantoin. Daily dry matter intake was measured in both phases and rumen pH was measured every three hours during days 18-21 of each period of Phase II.

The following were estimated for each steer and grain adaptation step combination in Phase I: average daily dry matter intake and average daily allantoin excretion in the urine. The following estimates were made for each steer and period combination in Phase II: average daily dry matter intake, average daily rumen pH and average daily allantoin excretion in the urine.

Table 1. Dry matter intakes and urinary allantoin excretion of cattle during Phase I, the grain adaptation phase.

	Steps[a]					
Item[b]	1	2	3	4	5	SEM
DMI, lb/day	17.4	18.0	19.1	16.7	17.8	1.6
Allantoin, mmol/day	55.7	51.6	58.6	62.0	89.6	7.5

[a]Cattle were adapted to a dry-rolled corn based finishing diet in five steps: 45, 35, 25, 15, and 7.5% alfalfa for 4, 7, 7, 7, and 7 days, respectively.
[b]Each number is the mean of all five animals, except for Step 5 (one animal went off feed because of a blown rumen cannula).

Table 2. Dry matter intakes, daily rumen pH, and urinary allantoin excretion of cattle during Phase II.

	Diets[a]					
Item	CONT	7.5STEEP	15STEEP	7.5DS	15DS	SEM
DMI, lb/day	17.6	18.7	16.7	18.7	19.1	1.8
Rumen pH[b]	5.75	5.65	5.58	5.68	5.60	.10
Allantoin, mmol/day[c]	105.5	94.5	93.1	87.6	82.7	6.6

[a]Dry-rolled corn finishing diet (CONT) balanced to 15.3% CP with urea (if needed). In all other treatments, by-product (STEEP = steep liquor; DS = distillers' solubles) replaced dry-rolled corn at the percentage of DM indicated.
[b]Orthogonal contrast for CONT vs. average of other four treatments (*P* = .32).
[c]Orthogonal contrast for CONT vs. average of other four treatments (*P* = .05).

Results

Dry matter intake and urinary allantoin excretion data for Phase I are shown in Table 1. Because grain adaptation step is confounded with time, no test of statistical difference can be made. However, the data serve as a useful observation of the trend allantoin excretion follows as cattle are adapted to a dry-rolled corn finishing diet. As alfalfa hay is replaced in the diet by dry-rolled corn, the total amount of allantoin excretion increases. This is intuitively correct because the total DMI remained relatively constant while the amount of dry-rolled corn increased. Therefore, the amount of TDN available for rumen fermentation increased, resulting in a greater amount of MCP supply. These data are the only known estimates of urinary allantoin excretion by cattle during a grain adaptation period.

Data for Phase II are shown in Table 2. There were no differences in DMI. Average daily rumen pH was numerically lower for the average of the wet milling byproducts versus the control (*P* = .30). The power of the test of rumen pH was compromised because there was a failure to obtain rumen pH data on two of the five periods in the Latin square. From these data, one could only speculate as to the possible cause of reduced rumen pH by wet milling byproducts; however, the pH of those feed ingredients may provide an explanation of the trend. The pH of the steep liquor and distillers' solubles fed in this trial were 4.22 and 4.96, respectively. Previous research with the byproducts shows they contain lactic acid and a significant amount of acetate, propionate and butyrate. These acids would certainly lower the pH of the feedstuffs.

Allantoin excretion was lower (*P* = .05) for the average of the wet milling byproducts versus the control. These data refute our hypothesis that one or both of these byproducts may stimulate MCP supply. Rumen pH was correlated (r^2 = .61) with allantoin excretion (Figure 1). This is in agreement with the 1996 NRC Model of Nutrient Requirements for Beef Cattle. In the research cited in the NRC, bacterial cultures were grown in vitro and pH was manipulated, resulting in lower MCP as pH declined. The data provide support for the concept

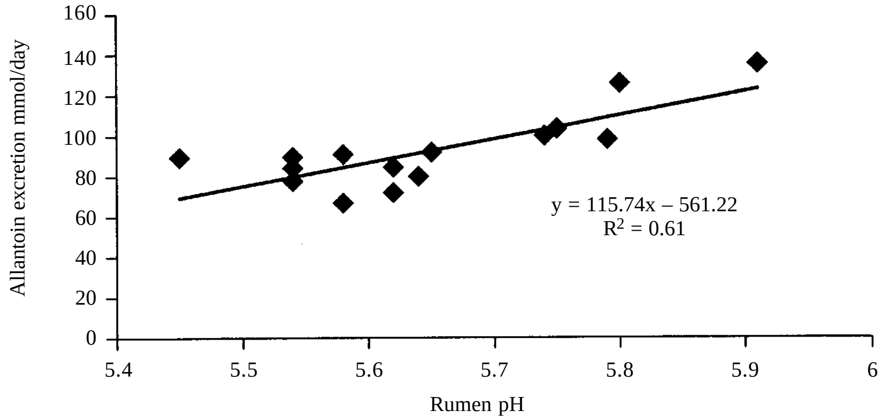

Figure 1. Urine allantoin excretion versus rumen pH of cattle fed various dry-rolled corn finishing diets (inclusion of wet-milling byproducts varies).

of pH sensitivity of rumen microbes in practical feeding conditions.

We conclude that steep liquor and distillers' solubles do not stimulate MCP supply. When averaged together, these byproducts reduced MCP supply, probably because of a trend toward lower rumen pH. The performance response of finishing cattle fed the wet milling byproducts steep liquor and distillers' solubles cannot be explained by increased MCP supply.

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Programmed Gain Finishing Systems In Yearling Steers Fed Dry-rolled Corn Or Wet Corn Gluten Feed Finishing Diets

Tony Scott
Todd Milton
Terry Klopfenstein[1]

Programming gain during the first 100 days of a 161-day finishing period resulted in reduced cumulative performance compared to ad libitum feeding.

Summary

One hundred sixty crossbred yearling steers were used in a completely randomized design to determine the response to a programmed gain finishing system in diets with and without wet corn gluten feed. Including a programmed gain phase in the finishing period reduced daily gain, hot carcass weight, fat thickness and marbling score in diets with and without wet corn gluten feed. Diets containing wet corn gluten feed increased daily gain, hot carcass weight and fat thickness compared with diets containing only dry-rolled corn. Programming gain improved efficiency but reduced net return per animal and increased cost of gain versus ad libitum feeding.

Introduction

Improvements in feed efficiency have been demonstrated with feeding systems designed to control feed intake in feedlot cattle; however, daily gain may decrease, resulting in increased days on feed. There are many methods that can be used to control feed intake, one of which is an approach referred to as programmed gain. Programmed feeding techniques are systems in which the net energy equations are used to calculate the amount of feed required to achieve a predetermined rate of gain. Based on the diet being fed, a programmed rate of gain is selected and the amount of feed required to achieve the programmed rate of gain can be calculated. The interest in programmed gain feeding systems has been increased by reports that similar daily gains, hot carcass weights and days on feed can be achieved with programmed gain feeding systems when compared to ad libitum feeding. At the same time, reductions in the amount of feed consumed result in improvements in efficiency. However, two previous studies (1999 Nebraska Beef Report, pp 46-48; 2000 Nebraska Beef Report, pp 41-43) conducted at the University of Nebraska to determine the effects of programmed gain feeding strategies failed to observe a significant improvement in feed efficiency while both daily gains and hot carcass weights were lower as a result of using a programmed gain feeding system.

Both of the previously conducted studies included wet corn gluten feed in the finishing diet. The objective of this study was to determine if the response to a programmed gain feeding system differed in finishing diets with and without wet corn gluten feed.

Procedure

One hundred sixty crossbred yearling steers (643 lb) were stratified by weight

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and randomly assigned to one of 16 pens (10 head/pen). Each pen was randomly assigned to one of four treatments with a 2x2 factorial treatment structure. Treatment factors were: ad libitum feeding system (AL) or programmed gain feeding system (PG); and dry-rolled corn finishing diet (DRC) or wet corn gluten feed finishing diet (WCGF). Pens assigned to PG were targeted to gain 3.0 lb/d for d 1-50 and 3.4 lb/d for d 51-100. On day 101, pens assigned to PG were allowed to consume feed AL for the remainder of the trial. Feed intakes required to achieve the programmed rates of gain were calculated using the net energy equations contained in the NRC (1996) computer model and were adjusted every seven days.

The final diets (Table 1) were formulated to contain a minimum of 13.5% CP, .70% Ca, .35% P, and .65% K, and contained 27g/ton Rumensin and 10 g/ton Tylan (DM basis). Steers were implanted with Synovex®-C on d 1 and reimplanted with Synovex®-Plus on d 50. Steers were slaughtered at a commercial packing plant when the AL control groups were visually estimated to have reached .45 in of fat over the 12th rib. Following a 24-h chill, USDA yield grade, marbling score and 12th rib fat thickness were recorded. Final weights were calculated by adjusting hot carcass weights to a common dressing percentage (63%). Net return and cost of gain for each pen were calculated using Nebraska 10-year average prices for feedstuffs, feeder cattle and slaughter cattle. Wet corn gluten feed was priced at 93% the price of corn.

Results

Performance during the PG period (d 1-100) is presented in Table 2. There was a significant (P<.05) feeding system x finishing diet interaction for DMI during d 1-100. By design, DMI of both PG treatments were similar and significantly less than either AL treatment. However, in steers offered feed AL, feeding WCGF increased DMI significantly versus feeding DRC. Daily gain was not affected by PG; however, feeding WCGF increased (P<.10) daily gain when compared to feeding DRC. A significant

Table 1. Composition of finishing diets (100% DM basis).

Ingredient	DRC[a]	WCGF[a]
Dry-rolled corn	82.4	52.0
Wet corn gluten feed		35.0
Alfalfa hay	4.0	4.0
Sorghum silage	4.0	4.0
Soybean meal	4.0	
Molasses	3.0	
Supplement	2.6	5.0
Finely ground grain sorghum		3.043
Limestone	1.448	1.542
Urea	.685	
Salt	.300	.300
Dicalcium phosphate	.100	
Potassium chloride	.050	.050
Trace mineral	.020	.020
Rumensin	.017	.017
Vitamin premix	.015	.015
Tylan	.013	.013

[a]DRC = dry-rolled corn; WCGF = wet corn gluten feed.

Table 2. Effect of programmed gain (PG) and finishing diet (DRC or WCGF) on programmed gain period performance (d 1-100).

	Treatment[a]				
	DRC		WCGF		
	AL	PG	AL	PG	SEM
DMI, lb/day[b]	21.60[f]	15.61[e]	23.91[g]	15.43[e]	.32
ADG, lb[c]	3.65	3.45	3.72	3.82	.15
Feed:gain[bd]	5.9[e]	4.5[f]	6.4[e]	4.0[g]	

[a]DRC = dry-rolled corn; WCGF = wet corn gluten feed; AL = ad libitum; PG = programmed gain.
[b]Feeding system x finishing diet interaction (P<.05).
[c]Finishing diet effect (P<.10).
[d]Analyzed as gain:feed.
[efg]Means within a row with unlike superscripts differ (P<.10).

Table 3. Effect of programmed gain (PG) and finishing diet (DRC or WCGF) on cumulative performance and carcass characteristics.

	Treatment[a]				
	DRC		WCGF		
	Ad Lib	PG	Ad Lib	PG	SEM
Days on feed	161	161	161	161	
Initial wt., lb	644	643	643	643	1
DMI, lb/day[b]	23.03[i]	19.60[k]	25.62[h]	20.33[j]	.31
Total feed, lb/hd[b]	3708[i]	3155[j]	4124[h]	3273[j]	49
ADG, lb[cd]	3.83	3.35	4.07	3.62	.10
Feed:gain[be]	6.0[i]	5.8[i]	6.3[h]	5.6[j]	
Hot carcass wt, lb[cd]	794	745	808	772	11
Marbling score[ce]	492	444	501	448	14
Fat thickness, in.[cd]	.43	.36	.48	.39	.02
Net return, $/head[cdf]	79.15	29.12	119.89	83.69	8.34
Cost of gain, $/cwt[cdf]	41.70	47.32	36.48	39.41	1.19

[a]DRC = dry-rolled corn; WCGF = wet corn gluten feed; AL = ad libitum; PG = programmed gain.
[b]Feeding system x finishing diet interaction (P<.05).
[c]Feeding system effect (P<.05).
[d]Finishing diet effect (P<.10).
[e]Analyzed as gain:feed.
[f]Marbling score: 400 = Slight 0; 450 = Slight 50; 500 = Small 0.
[g]Values used in calculations: cattle purchase price = $81.00/cwt; cattle sales price = $108.00/cwt hot carcass; yardage = $0.30/d; feed cost = $108.58/ton (DRC) and $97.02/ton (WCGF); interest on cattle and 1/2 feed = 10%.
[hijk]Means within a row with unlike superscripts differ (P<.10).

(P<.05) feeding system x finishing diet interaction was observed for feed conversion. Feed conversion was improved in both PG treatment groups irrespective of diet when compared with AL. Additionally, feed efficiency of the PG/WCGF treatment group was improved versus all other treatments.

Cumulative performance and carcass data are presented in Table 3. All steers were fed for 161 days. There was a significant (P<.05) feeding system x finishing diet interaction for DMI related to the magnitude of the difference between each AL control group and its PG counterpart. When feeding DRC, PG reduced intake by 3.43 lb/d. However, the difference when feeding WCGF was 5.29 lb/d. The relationship for the total amount of feed consumed throughout the trial responded similarly. There were significant main effects of both feeding system (P<.05) and finishing diet (P<.10) for daily gain. Feeding WCGF increased daily gain while the PG feeding system reduced daily gain.

There was a significant (P<.05) feeding system x finishing diet interaction for feed conversion similar to that observed for both dry matter intake and total feed consumed. When feeding DRC, PG improved feed conversion 2.4% and the two feeding systems were not statistically different. However, when feeding WCGF, efficiency was improved 11.9% in the PG feeding system.

There were main effects of both feeding system (P<.05) and finishing diet (P<.10) for hot carcass weight. Feeding WCGF increased hot carcass weight while the PG feeding system decreased hot carcass weight. The PG feeding system significantly reduced (P<.05) marbling score. There were significant main effects for both feeding system (P<.05) and finishing diet (P<.10) for 12th rib fat thickness. Feeding WCGF increased fat thickness while the PG feeding system reduced fat thickness. Net return was increased (P<.10) by feeding WCGF and was reduced (P<.05) by the PG feeding system. Similarly, cost of gain was reduced (P<.10) when feeding WCGF and increased (P<.05) by the PG feeding system.

These data indicate that including a programmed gain phase in the finishing system reduced both daily gain and profitability. Regardless of diet, feeding cattle ad libitum was strongly favored in this trial when compared to the programmed gain finishing system. However, there may be differences in the observed efficiency response to programmed gain finishing systems among finishing diets that differ in composition.

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Economic Evaluation of Corn Processing for Finishing Cattle

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Terry Klopfenstein
Dick Clark[1]

Economics of high-moisture corn are highly dependent on the discount at which it is purchased to dry corn. Economics of steam-flaked corn are attractive at corn prices common in Nebraska.

Summary

A finishing trial was conducted to determine performance of steers fed dry-rolled, high-moisture and steam-flaked corn-based diets. High-moisture corn and steam-flaked corn were determined to have 100% and 108% the value of dry-rolled corn, respectively. Estimated costs of corn processing ($/ton) ranged from $1.44 to $1.60 for dry-rolled corn, $1.98 to $2.34 for high-moisture corn, and $6.79 to $7.16 for steam-flaked corn. Economics of high-moisture corn are dependent on the discount at which it is purchased to dry corn. Economics of steam-flaked corn are dependent on corn price, but appear attractive at prices common in Nebraska.

Introduction

The cattle feeding industry in the United States commonly processes corn to some degree before it is incorporated into a ration and delivered to the animal. The goal of most processing methods is to increase starch availability of corn, thereby increasing its value to the animal. Corn processing can vary in methodology, cost and effectiveness in increasing value. Dry rolling, high moisture and steam flaking are the most common forms of corn processing in feedyards today. High moisture and steam flaking are more costly than dry rolling, but an increase in cattle performance may offset these costs. Objectives of this evaluation were to determine economic return of high-moisture and steam-flaked corn relative to dry-rolled corn in diets for finishing cattle.

Procedure

Performance

Ninety crossbred yearling steers (612 lb) were used in a completely randomized design with a 3 x 5 factorial treatment structure to evaluate effect of corn processing on performance of

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finishing cattle. Steers were randomly assigned to one of three finishing diets (Table 1) which were based on dry-rolled (DRC), high-moisture (HMC), or steam-flaked corn (SFC). Within each diet, steers were randomly assigned to one of five levels of urea (0, .5, 1.0, 1.5, or 2.0% of dietary DM).

Steers were individually fed using Calan electronic gates. Steers were offered their respective finishing diet on day 1 at 1.8% of body weight (DM basis). Feed offered then was increased .5 lb per day (DM basis) until steers were ad libitum (approximately 21 days).

Steers were weighed initially on three consecutive days after being limit-fed at 2.0% of body weight for five days in order to minimize differences in gut fill. Steers were implanted with Synovex C on day 1, reimplanted with Synovex Plus on day 67, and fed for a total of 167 days. Final weights were calculated using hot carcass weights adjusted to a common dress (63%). Data were analyzed using Mixed procedure of SAS. Least square means were separated using the Least Significance Difference method.

Table 1. Composition of finishing diets (% of DM).

	Diet[a]		
Ingredient	DRC	HMC	SFC
Dry rolled corn	82.0	—	—
High moisture corn[b]	—	82.0	—
Steam flaked corn[c]	—	—	82.0
Alfalfa hay	5.0	5.0	5.0
Cottonseed hulls	5.0	5.0	5.0
Molasses	3.0	3.0	3.0
Dry supplement[d]	5.0	5.0	5.0

[a]DRC = dry-rolled corn, HMC = high-moisture corn, SFC = steam-flaked corn.
[b]High-moisture was rolled at harvest and stored in covered concrete bunker and was 29% moisture and 46% soluble protein at time of trial.
[c]Steam-flaked corn was processed to 29 lb/bushel flake weight at a commercial feedyard facility and hauled to research feedlot on weekly basis.
[d]All diets supplemented to contain a minimum of .7% Ca, .28% P, .6% K, and .15% S (DM basis). All diets contained 27 g/ton Rumensin and 10 g/ton Tylan (DM basis).

Economics

Economics of corn processing are dependent on both value change in corn as well as cost of processing. Information regarding both of these factors is discussed below. It is important to note that many assumptions are made in this economic evaluation. Although assumptions are believed accurate given available information, readers are encouraged to substitute values that more accurately reflect their own situation.

Value of processing. The best indicator of value change due to corn processing is cattle performance. For this discussion, it will be assumed that a change in feed conversion is directly related to a change in value of corn. Therefore, if feed/gain is improved by 10% by a processing method, the corn has 10% more value. This approach has limitations, but seems conservative and straightforward. This approach is conservative because corn does not comprise 100% of the diet. All changes in value in this discussion are relative to DRC because it is the simplest form of processing in the performance data.

Costs of processing. There are four primary costs associated with corn processing: initial costs of equipment, electricity, natural gas and diesel fuel. Available literature was reviewed to estimate these costs.

Initial costs of equipment are difficult to estimate because they can be extremely variable depending on the type of system and available resources. Costs reported in literature (Schake et al. 1981. Energy and economic evaluation of corn and sorghum processing. Texas Agricultural Experiment Station, pp. 1-12) were used for this evaluation; however, readers should substitute costs which more accurately reflect their own situation. In the report mentioned above, initial equipment costs ($/head feedyard capacity) associated with DRC, HMC, and SFC for 5,000 and 20,000 head feedyards were estimated (Table 2). No attempt was made to update these costs for inflation because we were unsure how much costs on a $/head basis have changed. For this discussion, equipment was depreciated over a 10-year period, assuming no salvage value, and interest (10%) was charged on the average value of the investment.

Energy costs of corn processing are primarily composed of electricity, natural gas and diesel fuel usage (Table 2). Electrical usage was assumed to be

Table 2. Costs of corn processing for 5,000 and 20,000 head feedyards.

	Processing Method[a]					
	DRC		HMC		SFC	
Item	5,000	20,000	5,000	20,000	5,000	20,000
Equipment costs						
Initial investment, $/hd[b]	17.07	13.15	33.39	24.68	31.92	22.74
Initial investment, $	85,350	263,000	166,950	493,600	159,600	454,800
Annual depreciation, $[c]	8,535	26,300	16,695	49,360	15,960	45,480
Annual interest, $[d]	4,268	13,150	8,348	24,680	7,980	22,740
Annual costs, $[e]	12,803	39,450	25,043	74,040	23,940	68,220
Annual corn usage, ton[f]	18,250	73,000	18,250	73,000	18,250	73,000
Equipment costs, $/ton[g]	.70	.54	1.37	1.01	1.31	.94
Energy costs						
Electricity, kwh/ton	17.9	17.9	17.9	17.9	17.9	17.9
Natural gas, mcf/ton	—	—	—	—	1.1	1.1
Diesel, gal/ton	—	—	.05	.05	—	—
Electricity, $/ton[h]	.90	.90	.90	.90	.90	.90
Natural gas, $/ton[h]	—	—	—	—	4.95	4.95
Diesel, $/ton[h]	—	—	.07	.07	—	—
Energy costs, $/ton	.90	.90	.97	.97	5.85	5.85
Total processing costs, $/ton[i]	1.60	1.44	2.34	1.98	7.16	6.79

[a]DRC = dry-rolled corn, HMC = high-moisture corn, SFC = steam-flaked corn.
[b]Source: 1981 Texas Agricultural Experiment Station, pp. 1-12.
[c]Assumes 10-year depreciation period and no salvage value.
[d]Assumes 10% interest rate on average investment.
[e]Annual costs = annual depreciation + annual interest.
[f]Assumes 100% capacity and 20 lb/day corn intake (15% moisture basis).
[g]Equipment costs = annual equipment costs divided by annual corn usage.
[h]Electricity = $.05/kwh, natural gas = $4.50/mcf, diesel = $1.31/gal.
[i]Total processing costs = equipment costs + energy costs.

Table 3. Performance of finishing cattle fed dry-rolled, high-moisture, or steam-flaked corn.

	Processing Method[a]		
	DRC	HMC	SFC
Dry matter intake, lb/day	22.2[b]	21.6[b]	20.3[c]
Average daily gain, lb	3.61	3.55	3.60
Feed/gain	6.13[b]	6.10[b]	5.62[c]
Feed/gain, % of DRC	—	100	108

[a]DRC = dry-rolled corn diet, HMC = high-moisture corn diet, SFC = steam-flaked corn diet.
[bc]Means in same row with unlike superscripts differ (P < .001).

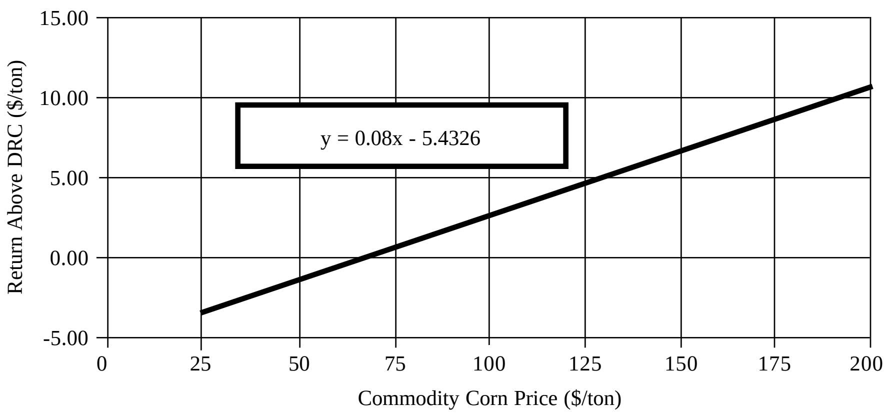

Figure 1. Economic return of steam-flaked corn above dry-rolled corn (DRC) for a 5,000 head feedyard.

similar among processing methods (17.9 kwh/ton) and priced at $.05/kwh. Natural gas usage for steam flaking was assumed to be 1.1 mcf/ton of corn processed and priced at $4.50/mcf which reflects current costs in Nebraska. Diesel fuel usage of .05 gal/ton of corn processed was assumed for high-moisture corn for packing in a bunker silo and use of a front-end loader while feeding. Diesel fuel was priced at $1.31/gal, which was the 12-month average price in Nebraska for 1999. Total estimated processing costs for DRC, HMC, and SFC in 5,000 and 20,000 head feedyards are shown in Table 2.

High-moisture corn and SFC were analyzed by their return above DRC, because DRC was the simplest form of processing in performance data. Return of either HMC or SFC above DRC was calculated by the equation: Return of processing above DRC ($/ton) = [((corn price, $/ton) + (cost of dry rolling, $/ton)) x (% improvement in feed/gain)] - [(corn price, $/ton) + (cost of respective processing, $/ton)].

Results

Results from the finishing trial are shown in Table 3. Corn processing method x urea level interactions were detected for DM intake ($P < .05$) and ADG ($P < .05$), but not for feed/gain ($P > .10$). Because feed/gain is the measurement of interest for this evaluation, only main effects of corn processing are shown in Table 4. Steers fed SFC consumed approximately 7.3% less DM ($P < .01$) than steers fed DRC and HMC diets. Daily gains were similar ($P > .50$) for all diets. As a result, steers consuming the SFC diet were 8% more efficient ($P < .001$) than steers consuming DRC or HMC diets.

Results from the performance trial are in close agreement with those reported in literature. A recent review of grain processing summarized performance from 353 research trials in which DRC, HMC, and/or SFC were fed. In this report, feed/gain was similar for steers consuming DRC and HMC, whereas steers consuming SFC were about 11% more efficient (1997 Journal of Animal Science, 55:868-879).

Based on results from the finishing trial and calculations described above, HMC has 100% the value of DRC, whereas SFC has 108% the value of DRC. Therefore, if DRC costs $2.00/bu, then HMC also is worth $2.00/bu, whereas SFC is worth $2.16/bu. It is important to note that these values are all on an equal DM basis. In addition, these values do not account for factors such as: buying high-moisture corn at a discount compared to dry corn, differences in shrink among the processing types and differences in interest on purchased corn.

High-moisture corn has 100% the value of DRC (equal DM basis). Given cost assumptions described above, HMC would result in a $.74/ton loss in a 5,000 hd feedyard compared to DRC. Whereas in a 20,000 hd feedyard, HMC would result in $.54/ton loss compared to DRC. These values are all on an equal DM basis and assume the same commodity corn price. Therefore, purchase of HMC would need to be discounted by these amounts, plus costs of any additional shrink and interest which may occur, in order to break even with DRC. There are several ways in which feedyards discount purchase price of HMC. One way might be a $.02/bu discount per point of moisture above 15%. Therefore, if a feedyard purchases corn at 28% moisture, commodity price would be discounted by $.26/bu. At the 10-year average Nebraska commodity corn price ($2.48/bu), HMC would be purchased at $2.22/bu (15% moisture basis). This would result in $8.55/ton return for HMC above DRC in a 5,000-head feedyard. Again, this value does not account for any additional shrink or interest which may occur with HMC.

Steam-flaked corn has 108% the value of DRC (equal DM basis). Figure 1 shows economic return above dry rolling for SFC in a 5,000-head feedyard at various price levels for commodity corn. Regression equation ($y = mx - b$) is given so that actual return above dry rolling can be calculated at any corn price, where: y = return above dry rolling ($/ton), m = slope of line, x = commodity corn price ($/ton), b = intercept). The regression line for a 20,000-head feedyard (y = .08x

(Continued on next page)

- 5.2293) was not displayed because it was not visually distinguishable from the 5,000-head feedyard line. Corn price at which SFC breaks even with DRC can be determined by setting y equal to zero and solving for x. For a 5,000-head feedyard, corn price would need to be at least $67.91/ton ($1.90/bu) in order for SFC to break even with DRC. For a 20,000-head feedyard, corn price would need to be at least $65.37/ton ($1.83/bu) for SFC to break even with DRC. At 10-year average commodity corn price for Nebraska ($2.48/bu; $88.57/ton), SFC would return $30,167 per year above DRC ($1.65/ton on 18,250 ton/year) in a 5,000-head feedyard. In a 20,000-head feedyard, SFC would return $135,510 per year above DRC ($1.86/ton on 73,000 ton/year). These calculations assume 100% capacity, 20 lb/day corn intake (15% moisture basis) and do not account for differences in shrink, moisture appreciation, or labor between DRC and SFC.

Economics of HMC are greatly dependent on the magnitude of discount at which it is purchased compared to dry corn. Clearly, the largest cost associated with HMC is the initial investment in a concrete bunker. High-moisture corn can be economically attractive to a feedyard if the discount at which it is purchased is greater than additional processing costs, shrink and interest above DRC. This probably varies somewhat from feedyard to feedyard. Economics of SFC appear to be more clearly defined given assumptions made in this report. Economics of SFC are highly dependent on commodity corn price, but appear to breakeven at a corn price well below the 10-year average, even in a relatively small 5,000-head feedyard.

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Effect of Corn Processing on Degradable Intake Protein Requirement of Finishing Cattle

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Degradable intake protein requirement of finishing cattle is affected by method of corn processing and presumably rate and extent of ruminal starch fermentation.

Summary

Three finishing trials were conducted to determine effect of corn processing on degradable intake protein requirement of feedlot cattle. Finishing diets consisted of 82% processed corn which was either dry rolled, high moisture, or steam flaked. Degradable intake protein levels were achieved by adding 0 to 2.0% urea (DM basis) to the control diets. Estimates of degradable intake protein requirement for a dry-rolled corn-based diet were approximately 6.3% of dietary DM. Degradable intake protein requirement for high-moisture corn-based diets was approximately 10% of dietary DM. Degradable intake protein requirement for steam-flaked corn-based diet was between 7 and 9.5% of dietary DM.

Introduction

Degradable intake protein (DIP) is the fraction of feed crude protein which is available to the microbial population. In typical diets for finishing cattle, DIP is composed of both degradable true protein and non-protein nitrogen. A deficiency in DIP would have two effects. First, DIP deficiency would lower microbial crude protein production, possibly resulting in metabolizable protein (MP) deficiency if sufficient UIP was not supplemented. Second, DIP deficiency would reduce energy yield from carbohydrate fermentation, thereby lowering volatile fatty acid production and energetic efficiency of the diet. Therefore, a deficiency in DIP may lead to reduced finishing performance even when the animal's metabolizable protein requirement has been met.

Level 1 of the 1996 NRC model predicts that DIP requirement for a typical dry-rolled corn-based finishing diet is approximately 6.8% of dietary DM. Few data exist that directly evaluate the effect of corn processing on DIP requirement. Average ruminal starch digestibilities of 78, 89 and 83% for dry-rolled, high-moisture and steam-flaked corn have been reported. It is our hypothesis that grain processing methods which increase rate and extent of starch fermentation may increase the dietary DIP requirement relative to dry-rolled corn. Objectives of these experiments were to determine DIP requirements of finishing cattle fed dry-rolled, high-moisture and steam-flaked corn-based finishing diets.

Procedure

Trial 1

Two hundred and fifty-two crossbred yearling steers (834 lb) were used in a randomized complete block design to determine DIP requirement of finishing steers fed a high-moisture corn-based diet. Steers were split into three initial weight blocks and randomly assigned to one of 12 pens and to one of four dietary treatments (21 steers per pen, 3 pens per treatment). Dietary treatments consisted of four levels of dietary DIP that were accomplished by adding 0, .4, .8, or 1.2% urea to the base diet (DM basis).

High-moisture corn-based finishing diet (HMC) is shown in Table 1, while dietary crude protein and DIP values are shown in Table 2. High-moisture corn was harvested at approximately 29% moisture, processed through a rollermill, and stored in a covered concrete bunker. Steers were adapted to finishing diet in 21 days using alfalfa hay to replace high-moisture corn (50% alfalfa for 3 days, 40% of 4 days, 30% for 7 days, and 20% for 7 days, DM basis). Cottonseed hulls were only included in the finishing diet.

Steers were weighed initially on two consecutive days after being limit-fed at 2% of body weight for 5 days in order to minimize differences in gut fill. Steers were implanted with Synovex Plus on day 1 and fed for 108 days. Final weights were calculated using hot carcass weights adjusted to a common dress (63%). Data were analyzed using linear, quadratic and cubic contrasts. Nonlinear analysis of feed/gain was used to predict the DIP requirement.

Table 1. Composition of finishing diets (% of DM).

	Diet[a]		
Ingredient	DRC	HMC	SFC
Dry-rolled corn	82.0	—	—
High-moisture corn	—	82.0	—
Steam-flaked corn	—	—	82.0
Alfalfa hay	5.0	5.0	5.0
Cottonseed hulls	5.0	5.0	5.0
Molasses	3.0	3.0	3.0
Dry supplement[b]	5.0	5.0	5.0

[a]DRC = dry-rolled corn, HMC = high-moisture corn, SFC = steam-flaked corn.
[b]All diets supplemented to contain a minimum of .7% Ca, .28% P, .6% K, and .15% S (DM basis). All diets contained 27 g/ton Rumensin and 10 g/ton Tylan (DM basis).

Trial 2

Two hundred and sixty-four crossbred yearling steers (781 lb) were used in a completely randomized design to determine DIP requirement of finishing steers fed a steam-flaked corn-based diet. Steers were stratified by initial weight to one of 24 pens (11 steers per pen). Pens were randomly assigned to one of six dietary treatments (4 pens per treatment). Treatments consisted of six levels of dietary DIP which were accomplished by adding 0, .4, .8, 1.2, 1.6, or 2.0% urea to the base diet (DM basis). Steam-flaked corn-based finishing diet (SFC) is shown in Table 1, while dietary crude protein and DIP values are shown in Table 3. Steam-flaked corn was processed to a flake density of 29 lb/bushel at a commercial feedlot facility and hauled to the research feedlot on a weekly basis. Steers were adapted to finishing diet in 21 days using alfalfa hay to replace steam-flaked corn (40% alfalfa for three days, 30% of four days, 20% for seven days and 10% for seven days, DM basis). Cottonseed hulls were included at 5% of DM in all diets.

Steers were weighed initially on two consecutive days after being limit-fed at 2% of body weight for five days to minimize differences in gut fill. Steers were implanted with Synovex C on day 1, reimplanted with Revalor S on day 47 and fed for a total of 129 days. Final weights were calculated using hot carcass weights adjusted to a common dress (63%). Data were analyzed using linear, quadratic and cubic contrasts. Nonlinear analysis of feed/gain was used to predict the DIP requirement.

Table 2. Dietary protein composition and finishing performance for high moisture corn-based diet (Trial 1).

	Treatment				
Urea, % of DM	0	.4	.8	1.2	SEM
Crude protein, % of DM[a]	10.7	11.9	13.0	14.2	—
DIP, % of DM[a]	7.1	8.2	9.4	10.6	—
DIP balance, g/day	-19	122	262	403	—
MP balance, g/day	78	90	90	90	—
DM intake, lb	27.0	26.7	26.6	26.7	.2
Daily gain, lb[b]	3.75	3.77	4.01	4.08	.07
Feed/gain[b]	7.19	7.09	6.62	6.54	.19
Fat depth, in[c]	.35	.39	.39	.42	.02
Marbling score[bd]	523	507	502	493	8

[a]Based on NRC tabular values.
[b]Linear ($P < .03$).
[c]Linear ($P = .06$).
[d]400 = Traces 0, 500 = Small 0, 600 = Modest 0.

Trial 3

Ninety crossbred yearling steers (612 lb) were used in a completely randomized design with a 3 x 5 factorial treatment structure to evaluate effect of corn processing on DIP requirement of finishing cattle. Steers were randomly assigned to one of three finishing diets which were based on DRC, HMC, or SFC (Table 1). Within each diet, steers were randomly assigned to five levels of dietary DIP which were accomplished by adding 0, .5, 1.0, 1.5, or 2.0% urea to the base diet (DM basis). Dietary CP and DIP values are shown in Table 4. High-moisture corn and steam-flaked corn were similar to Trials 1 and 2, respectively, while dry-rolled corn was processed so that particle size was as coarse as possible with relatively few whole kernels passing through the rolls. Ideally, kernels were broken into approximately four pieces.

Steers were individually fed using Calan electronic gates. Steers were adapted to their respective finishing diet over an approximately 21-day period. Steers were offered their respective finishing diet on day 1 at 1.8% of body weight (DM basis). Feed offered then was increased .5 lb per day (DM basis) until steers were ad libitum. Steers were weighed initially on three consecutive days after being limit-fed at 2.0% of body weight for five days in order to minimize differences in gut fill. Steers were implanted with Synovex C on day 1, reimplanted with Synovex Plus on day 67, and fed for a total of 167 days. Final weights were calculated using hot carcass weights adjusted to a common dress (63%). Data were analyzed using Least Significance Difference method and linear, quadratic and cubic contrasts. Nonlinear analyses of feed/gain were used to predict DIP requirements.

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Results

Trial 1

Effects of DIP level on performance of finishing steers fed a high-moisture corn-based diet are shown in Table 2. Dry matter intake was not affected (P = .75) by dietary DIP and averaged 26.8 lb/day. However, both average daily gain and feed/gain improved linearly (P < .03) as dietary DIP increased. Nonlinear analysis of feed/gain predicted that the DIP requirement would be met by 1.1% urea (95% confidence interval was from 1.0 to 2.2%), which would provide a dietary DIP level of 10.2%. We hypothesized that DIP requirement for a high-moisture corn-based diet would be greater than 7.1% of dietary DM as predicted by 1996 NRC. However, we did not expect the requirement to be as high as 10.2% of dietary DM. This level of DIP is greater than is commonly fed in high moisture corn-based diets.

Trial 2

Effect of DIP level on performance of finishing steers fed a steam-flaked corn-based diet are shown in Table 3. Dry matter intake responded quadratically (P = .01) as dietary DIP increased. In addition, average daily gain and feed/gain also responded quadratically (P < .0001) as dietary DIP increased. Nonlinear analysis of feed/gain predicted a breakpoint at .8% urea (95% confidence interval was .79 to .88%). This dietary urea concentration would provide a dietary DIP value of approximately 7.1%. Level 1 of 1996 NRC model predicted that the DIP requirement would be met at 7.1% of DM.

Trial 3

Effects of DIP level on performance of finishing steers fed dry-rolled, high-moisture, and steam-flaked corn-based diets are shown in Table 4. Processing method x urea level interactions were found (P < .01) for DM intake and daily gain. Simple effects for feed/gain are also shown in Table 4, although no interaction was noted (P = .34). For DRC, dry matter intake (P = .08) and average daily gain (P = .03) responded linearly with DIP level. However, feed/gain was not affected (P > .50) by DIP level. Nonlinear analysis of feed/gain did not predict a breakpoint suggesting that the DIP requirement was met by the first increment of urea.

In the HMC diet, dry matter intake was not affected (P > .10), while average daily gain responded cubically (P = .03) with DIP level. Feed/gain was not affected (P > .10). Nonlinear analysis of feed/gain predicted a breakpoint at 1.1% urea. This level of urea suggests that dietary DIP requirement for HMC is approximately 10% of dietary DM, which agrees well with results from Trial 1.

In the SFC diet, dry matter intake and average daily gain responded quadratically (P < .001) with DIP level. Feed/gain responded linearly (P = .007) with DIP level. Nonlinear analysis of feed/

Table 3. Dietary protein composition and finishing performance for steam flaked corn-based diet (Trial 2).

	Treatment						
Urea, % of DM	0	.4	.8	1.2	1.6	2.0	SEM
Crude protein, % of DM[a]	9.5	10.6	11.8	13.0	14.1	15.3	—
DIP, % of DM[a]	4.7	5.8	7.0	8.2	9.3	10.5	—
DIP balance, g/day	-264	-135	-6	123	251	380	—
MP balance, g/day	-107	-24	58	62	62	62	—
DM intake, lb[b]	22.6	23.8	24.3	24.3	24.8	24.1	.4
Daily gain, lb[c]	3.17	3.82	4.40	4.40	4.44	4.48	.10
Feed/gain[c]	7.11	6.22	5.53	5.53	5.57	5.37	.19
Fat depth, in[d]	.37	.47	.51	.49	.51	.50	.02
Marbling score[de]	479	520	532	504	519	511	13

[a]Based on NRC tabular values.
[b]Quadratic (P = .01).
[c]Quadratic (P < .001).
[d]Quadratic (P < .10).
[e]400 = Traces 0, 500 = Small 0, 600 = Modest 0.

Table 4. Dietary protein composition and finishing performance for Trial 3[a].

	Treatment					
Urea, % of DM	0	.5	1.0	1.5	2.0	SEM
Crude protein, % of DM[b]	9.5	10.9	12.4	13.8	15.3	—
DIP, % of DM[b]						
DRC	4.8	6.3	7.7	9.2	10.6	—
HMC	6.7	8.1	9.6	11.0	12.5	—
SFC	4.7	6.1	7.6	9.0	10.5	—
DM intake, lb/day						
DRC	21.8[c]	21.1	21.9	23.4	22.8[c]	.8
HMC	23.0[c]	21.1	21.4	21.8	20.8[d]	.8
SFC[f]	17.8[d]	22.3	20.8	21.9	18.7[e]	.8
Daily gain, lb/day						
DRC[g]	3.39[c]	3.61[cd]	3.38[c]	3.96	3.70[c]	.14
HMC[h]	3.70[c]	3.45[c]	3.51[cd]	3.75	3.32[d]	.14
SFC[f]	2.99[d]	3.79[d]	3.72[d]	4.07	3.45[cd]	.14
Feed/gain						
DRC	6.41	5.81	6.49[c]	5.88[c]	6.17[c]	.22
HMC	6.21	6.13	6.06[cd]	5.81[cd]	6.25[c]	.22
SFC[g]	5.95	5.85	5.59[d]	5.38[d]	5.38[d]	.22
Fat depth, in	.42	.45	.45	.53	.43	.03
Marbling score[i]	511	530	519	535	501	13

[a]DRC = dry-rolled corn, HMC = high-moisture corn, SFC = steam-flaked corn.
[b]Based on NRC tabular values.
[cde]Means with unlike superscript within column differ (P < .10).
[f]Quadratic effect of urea level (P < .05).
[g]Linear effect of urea level (P < .05).
[h]Cubic effect of urea level (P < .05).
[i]500 = Small 0, 600 = Modest 0.

gain predicted a breakpoint at 1.6% urea (95% confidence interval was 1.55 to 1.66%). This level of urea suggests that dietary DIP requirement for SFC-based diet is approximately 9.5% of dietary DM.

Degradable intake protein requirement for DRC-based diets could not be determined by nonlinear analysis because the first increment of urea provided the best feed/gain. This suggests that the DIP requirement for the DRC-based diet was met at 6.3% of dietary DM. Degradable intake protein requirement for HMC was consistent between Trials 1 and 3 (approximately 10% of dietary DM) and considerably higher than predicted level (7.1% of DM). The greater DIP requirement for HMC is most likely due to greater rate and extent of starch fermentation with HMC compared to DRC. Degradable intake protein requirement for SFC was the same as predicted in Trial 2 (7.1% of DM), but higher in Trial 3 (9.5% of DM). Reasons for differences in estimated DIP requirement for a SFC-based diet are not clear, but may be due to differences in initial weight, intake, and/or method of grain adaptation.

Our results suggest that the average dietary DIP requirements for DRC, HMC, and SFC-based diets are 6.3, 10.0, and 8.3% of DM, respectively. These dietary DIP requirements are highly related to ruminal starch digestibilities reported in literature (78, 89, and 83% for DRC, HMC, and SFC, respectively). Level 1 of the NRC (1996) accurately predicts the DIP requirement for a DRC-based diet. However, DIP requirements for HMC and SFC-based diets are underestimated because Level 1 of the NRC does not account for differences in ruminal starch digestion. Level 2 of the NRC (1996) accounts for differences in ruminal starch digestion, and therefore, may more accurately predict DIP requirements for HMC and SFC-based diets.

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High Moisture and Dry-Rolled High-Oil Corn for Finishing Feedlot Steers

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When fed in the dry rolled form, high-oil corn improved feed efficiency over normal corn. However, high-oil corn did not improve efficiency over normal corn when fed in the high moisture form.

Summary

Finishing steers fed diets containing dry-rolled high-oil corn had a 2.5% reduction in dry matter intake and 4.2% better feed efficiency than steers fed diets containing dry-rolled normal corn. Hot carcass weight, dressing percent, liver abscess score, rib fat thickness, marbling score and yield grade did not differ among treatments. Steers fed high-moisture high-oil corn had larger ribeye area and greater percent kidney, pelvic and heart fat than steers fed high moisture normal corn. No differences in performance or efficiency were detected from substituting high-oil high moisture corn for normal high moisture corn.

Introduction

Nutritionally modified grain varieties, such as “high-oil” (HO) corn, have been developed that may improve efficiency of livestock production. Higher oil content of grain increases energy density of the diet and aids in dust control. However, the ideal management systems (processing method; fat, ionophore, mineral supplementation) for nutritionally modified grains may differ from those ideal for normal grain. For example, South Dakota State University researchers detected a processing by corn type interaction between normal and high-oil corn. Dry matter intakes and gains were 5 to 10% greater for steers fed rolled HO corn than steers fed whole HO corn. These results indicate that HO corn may need to be processed prior to feeding to finishing beef cattle. To date, no information has been published on HO corn harvested, stored and fed as high moisture grain to feedlot cattle. The objective of this study was to evaluate high-oil corn versus normal corn when fed as dry-rolled or high moisture grain to finishing feedlot steers.

Procedure

In separate locations, normal (N) and high-oil (HO) corn varieties were planted at the University of Nebraska, Northeast Research and Extension Center in Concord, Neb. Varieties were harvested as both high-moisture (HM) and as dry corn. At harvest each load of corn was sampled and analyzed for DM content. High-oil and normal high moisture corn were harvested at 28 % DM. Corn harvested as HM grain was rolled and stored in two separate bunker silos. Dry corn (D) was coarsely rolled prior to feeding.

Three hundred eighty British x continental crossbred steers were purchased in early November 1998 and were processed in mid- to late November. Processing included: weighing, implanting, tagging, vaccinating, and deworming. Weights at processing were used to divide the steers into light (LWG) and heavy (HWG) weight groups. On Dec. 7, the LWG again was weighed and sorted by weight into additional groups and placed into their respective trial pens on Dec. 8. Initial weight for the LWG was an average of full live weights taken on Dec. 7 and Dec. 8. The HWG was treated the same as the LWG, with full live weights taken

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Table 1. Percentage of grain from each grain type and form in each diet.

Grain type	Treatment 1	2	3	4
Normal				
Dry-rolled	50	0	0	50
High moisture	50	0	50	0
High-oil				
Dry-rolled	0	50	50	0
High moisture	0	50	0	50

on Dec. 9 and Dec. 10. Fifteen steers were excluded from the research pool for the following reasons: too heavy, too light, or lame.

The LWG included 200 steers with 10 steers/pen in 20 pens (five weight groups with four treatments in each weight group). The HWG included 160 steers with 10 steers/pen (four weight groups with four treatments in each weight group). Pens were assigned randomly within each weight group to one of four treatments. Each diet contained equal amounts of DM corn from D and HM. This made the four different combinations of N and HO corn in the D and HM form: (1) ND plus NHM, (2) HOD plus HOHM, (3) HOD plus NHM, and (4) ND plus HOHM as shown in Table 1.

On a DM basis, the finishing diets contained 84% corn, 7.5% alfalfa hay, 4.5% liquid supplement, 2.0% soybean meal, and 2.0% Rumensin®, Tylan®, thiamine supplement. Diet ingredients and feedbunk samples were obtained every second week and analyzed for DM content. Corn samples were also analyzed for CP, pepsin insoluble nitrogen and crude fat. High-moisture corn was also analyzed for pH, ethanol and selected volatile fatty acids. Feedbunk samples were analyzed for nitrogen, calcium and phosphorus. Fecal samples were collected from two steers/pen and four pens/treatment and analyzed for pH, crude fat, and starch content.

The LWG and HWG were harvested after 92 and 81 days on feed, respectively. On day of harvest, liver abscess scores and hot carcass weights were recorded. After a 24-hour chill, rib eye area (REA), rib fat thickness (RF), USDA quality grade, USDA yield grade and percent kidney, pelvic and heart fat (% KPH) were recorded. Tissue samples were removed from the neck region of a sub-sample of carcasses (mean of 20 carcasses/treatment) of the HWG on the day carcass data was collected. Lipid extracted from both the lean and fat tissue were analyzed for following fatty acids: myristic, myristoleic, palmitic, palmitoleic, stearic, oleic, linoleic, linolenic, arachidic, ecosenoic, and summed to calculate total saturated, and mono-, di-, and tri-unsaturated.

Table 2. Corn analysis, Dry Matter Basis.

	Normal	High-oil	P < .10
High Moisture Corn			
Dry matter at harvest, %	71.6	71.8	
Dry matter at feeding, %	66.8	68.8	.028
Crude fat, %	5.00	8.12	.0001
pH	4.04	4.14	
Crude protein, %	8.45	8.87	.045
Pepsin insoluble nitrogen, %	10.43	10.72	NS
Ethanol, %	1.97	1.88	NS
Lactate, %	3.97	4.18	.063
Acetate, %	1.40	1.25	NS
Propionate, %	.20	.17	NS
Dry-Rolled Corn			
Dry matter, %	86.4	86.4	NS
Crude fat, %	4.48	6.98	.0001
Pepsin insoluble nitrogen, %	26.77	26.30	NS

Table 3. Summary of steer performance, intake and efficiency comparing high moisture and dry-rolled high-oil corn over approximately 90 day feeding period.

Item	Treatment 1	2	3	4
No. head	90	90	90	90
No. pens	9	9	9	9
Initial weight, lb	900	898	900	900
Average daily gain, lb/day[a]	4.16	4.18	4.18	4.07
DM intake (DMI), lb/day[b]	26.07	25.50	25.28	25.98
Feed efficiency, DMI/gain[c]	6.28	6.09	6.07	6.38
Final weight, lb	1261	1263	1261	1254

[a]Adjusted to a common dress of 63%.
[b]Treatments 1 plus 4 vs 2 plus 3 differ ($P < .10$).
[c]Treatments 1 plus 4 vs 2 plus 3 differ ($P < .05$).

Table 4. Summary of steer carcass data comparing high moisture and dry-rolled high-oil corn in feedlot diets.

Item	Treatment 1	2	3	4
Hot carcass weight, lb	794	795	794	790
Actual dress, %	62.6	62.5	63.1	62.7
KPH fat, % of carcass[a]	2.29	2.36	2.30	2.34
Ribeye area, sq in	13.73	13.91	13.65	13.94
Estimated fat, in	.42	.43	.42	.43
Marbling score[b]	537	531	504	530
USDA yield grade	2.51	2.43	2.48	2.39
Final yield grade[c]	2.64	2.62	2.66	2.58
Liver abscesses, %	3.33	5.56	7.78	10.00

[a]Treatments 1 plus 3 vs 2 plus 4 differ ($P < .05$).
[b]Marbling score of 400 = Traces, 500 = Small, 600 = Modest, 700 = Moderate.
[c]Final yield grade = 2.50 + (2.50 x estimated fat thickness) + (.20 x percent KPH) + (.0038 x hot carcass weight) – (.32 x ribeye area).

Results

Even though HOHM corn and NHM corn were harvested at the same moisture content, HOHM corn had a higher ($P < .05$) DM content (based on oven

DM determinations) than NHM corn after fermentation (Table 2). The CP content was greater (*P* < .10) for HO corn than N corn as is typical for high-oil corn (Table 2).

Based on analysis of feces from these steers, no differences (P > .05) in fecal starch content were detected among treatments. However, crude fat content of feces was 5.04%, 7.96%, 6.85%, and 6.31% for treatments 1, 2, 3 and 4 respectively. Thus steers fed HODR corn (treatments 2 and 3) had more (*P* < .05) of their fecal DM as crude fat than steers fed NDR corn (treatments 1 and 4).

When compared with steers fed diets containing dry-rolled normal corn, (mean of treatments 1 and 4) steers fed diets containing HODR corn (mean of treatments 2 and 3) tended to have lower (*P* < .10) dry matter intakes but had improved (*P* < .05) feed conversions. No differences (*P* > .10) were detected in feed intake, gain and efficiency between steer groups fed high-moisture normal corn (mean of treatments 1 and 3) vs high-moisture high-oil corn (mean of treatments 2 and 4; Table 3).

No differences (*P* > .05) in saturation of fatty acid from lean or fat tissue among treatments were detected. However, steers fed high-oil corn tended to have greater (*P* < .10) percentages of arachidic acid (C20:0) in both meat (.66 vs .59) and fat (.92 vs .86) samples. Steers fed high-oil high-moisture grain had greater (*P* < .05) internal (KPH) fat than steers fed normal high moisture grain (2.35 vs 2.30). Feeding a mixture of high-oil grain with normal corn grain (mean of treatments 3 and 4) tended to slightly increase (*P* < .10) the incidence of liver abscesses when compared to steers fed either grain form alone (average of treatments 1 and 2; Table 4).

Results from this study indicate that substituting dry high-oil corn for a portion of the dry corn with normal oil content in diets for feedlot steers can decrease dry matter intake and improve feed conversion. Although no problems with fermentation of high-moisture high-oil corn were encountered, no performance advantage from substituting high-moisture high-oil corn for high-moisture corn with normal oil content was detected.

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Corn Processing Method in Finishing Diets Containing Wet Corn Gluten Feed

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Feed efficiency and dietary net energy available for gain tended to be improved by more intensively processing corn in finishing diets containing wet corn gluten feed.

Summary

Two trials were conducted to determine the effects on performance and carcass characteristics of corn grain diets differing in degree of processing and containing wet corn gluten feed. Generally, more intensive processing methods such as fine-grinding, high moisture ensiling, and steam-flaking resulted in lower daily feed consumption compared to feeding rolled or whole corn. Feed efficiency and dietary net energy concentration tended to be improved by more intensive processing methods in finishing diets containing wet corn gluten feed.

Introduction

Inclusion of wet corn gluten feed in place of corn grain replaces dietary starch with highly digestible fiber. The resultant effect can be increased feed intake and daily gain as well as decreased incidence and severity of acidosis in finishing cattle. While feeding wet corn gluten feed is a widely accepted practice, limited information is available about the effects different grain processing methods may have in diets containing wet corn gluten feed.

The objectives of this research were to evaluate the effects of corn processing method in finishing diets containing wet corn gluten feed and to evaluate the value of feeding wet corn gluten feed in minimal (dry-rolled) and intensive (steam-flaked) processed corn-based finishing diets on performance and carcass characteristics of finishing calves.

Procedure

Trial 1

Four hundred eighty crossbred steer calves (667 lb) were stratified by weight and randomly assigned to one of 32 pens (15 head/pen). Each pen was randomly assigned to one of eight treatments. Four treatments were designed based on dry-rolled corn

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(DRC) or steam-flaked corn (SFC; 29 lb/bu) with or without replacement of corn with 32% Sweet Bran 60® wet corn gluten feed (WCGF). Also, a finishing diet in which DRC replaced SFC in an equal proportion to the replacement of SFC with WCGF was fed.

The three other treatments were finishing diets containing 32% WCGF (DM basis) and either finely ground corn (FGC), early harvested (30% moisture) and rolled high-moisture corn (HMC), or whole corn (WC). Data from all of the treatments containing 32% WCGF were analyzed to determine the performance and carcass responses to grain processing method in finishing diets containing WCGF. The cost of gain for each treatment was calculated with ration cost adjustments for each grain processing method. The adjustments were based upon the average of the values reported by Cooper et al. elsewhere in this report (Economic Evaluation Of Corn Processing For Finishing Cattle) with the exception of finely ground corn for which an additional 3% was added to the cost of dry-rolling and whole corn which was assessed no processing charge. The ingredient costs (as-is basis) for corn grain ($2.49/bu), alfalfa hay ($60.72/ton), and soybean meal ($209.20/ton) were based on 10-year average prices (1988-1997) paid/received by Nebraska producers. Other ingredient costs were based on the previous year's average paid by the University of Nebraska feedmill.

Adaptation diets contained 45, 35, 25, and 15% alfalfa hay (DM basis). The final diets (Table 1) were formulated to contain a minimum of 13.4% CP, .70% Ca, .35% P, and .65% K, and contained 27 g/ton Rumensin® and 10 g/ton Tylan® (DM basis). The supplement in diets not containing WCGF included 5% soybean meal (DM basis) as a source of naturally degradable protein to ensure sufficient metabolizable protein. Due to bunk management problems related to the accumulation of fines, the molasses level in the FGC diet was increased to 6% (DM basis) on day 87. Steers were implanted with Synovex®-S on day 1 and reimplanted with Synovex®-Plus on day 87.

Table 1. Composition of Trial 1 finishing diets (100% DM basis).

	Treatment[a]							
Ingredient	DRC	DRC WCGF	SFC WCGF	SFC	DRC SFC	FGC WGCF	HMC WCGF	WC WCGF
DRC	81.55	52.50			30.99			
FGC						52.50		
HMC							52.50	
SFC			81.55	52.50	50.56			
WC								52.50
WCGF		32.00		32.00		32.00	32.00	32.00
Alfalfa hay	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
Molasses	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Supplement	7.95	5.00	7.95	5.00	7.95	5.00	5.00	5.00

[a]DRC = dry-rolled corn; FGC = finely-ground corn; HMC = high-moisture corn; SFC = steam-flaked corn; WC = whole corn; WCGF = wet corn gluten feed.

Table 2. Composition of Trial 2 finishing diets (100% DM basis).

	Treatment[a]					
Ingredient	DRC	DRC WCGF	SFC	SFC WCGF	FRC WGCF	HMC WCGF
DRC	82.50	62.50				
FRC					62.50	
HMC						62.50
SFC			84.50	62.50		
WC						
WCGF		22.00		22.00	22.00	22.00
Alfalfa hay	7.50	7.50	7.50	7.50	7.50	7.50
Molasses	3.00	3.00	3.00	3.00	3.00	3.00
Supplement	7.00	5.00	5.00	5.00	5.00	5.00

[a]DRC = dry-rolled corn; FGC = finely-rolled corn; HMC = high-moisture corn; SFC = steam-flaked corn; WC = whole corn; WCGF = wet corn gluten feed.

Trial 2

Two hundred eighty-eight crossbred yearling steers (888 lb) were stratified by weight and randomly assigned to one of 24 pens (12 head/pen). Each pen was randomly assigned to one of six treatments. Four treatments were designed based on dry-rolled corn (DRC) or steam-flaked corn (SFC; 29 lb/bu) with or without replacement of corn with 22% Sweet Bran 60® wet corn gluten feed (WCGF).

The two other treatments were finishing diets containing 22% WCGF (DM basis) and either finely rolled corn (FRC) or early harvested (30% moisture) and rolled high-moisture corn (HMC). Data from all of the treatments containing 22% WCGF were analyzed to determine the performance and carcass responses to grain processing method in finishing diets containing WCGF. The cost of gain for each treatment was calculated with ration cost adjustments for each grain processing method. The adjustments were the same as in Trial 1 with the exception of finely rolling corn for which an additional 3% was added to the cost of dry-rolling.

Adaptation diets contained 45, 35, 25, and 15% alfalfa hay (DM basis). The final diets (Table 2) were formulated to contain a minimum of 13.5% CP, .70% Ca, .35% P, and .65% K, and contained 27 g/ton Rumensin® and 10 g/ton Tylan® (DM basis). Supplemental protein in all finishing diets was supplied with urea and soybean meal in a 60:40 ratio (CP basis). Steers were implanted with Synovex-®-Plus on day 28.

In both Trials 1 and 2, steers were fed once daily and allowed ad libitum access to feed and water. Final weights were calculated by adjusting hot carcass weights to a common dressing percentage (63%). Steers were slaughtered at a commercial packing plant where car-

Table 3. Effects of grain processing method and wet corn gluten feed inclusion in finishing diets on performance and carcass characteristics (Trial 1).

	Treatment[a]					
	DRC	DRC WCGF	SFC	SFC WCGF	SFC DRC	SEM
Days on feed, days	169	169	169	169	169	
Initial wt., lb	666	665	666	670	668	1
Final wt., lb[bcd]	1319	1381	1338	1387	1342	9
DMI, lb/day[de]	20.61[k]	23.42[i]	20.41[k]	22.03[j]	20.83[k]	.22
ADG, lb[cd]	3.86	4.24	3.98	4.25	3.99	.04
Feed:gain[f]	5.35	5.52	5.13	5.18	5.24	
Diet NEg, Mcal/cwt[cf]	68.9	66.0	71.8	70.9	70.5	.9
Cost of gain, $/cwt[cdfg]	39.31	36.91	38.80	35.68	39.05	.46
Hot carcass wt, lb[cd]	831	870	843	874	846	6
Marbling score[ch]	525	559	528	552	519	13
Percent Choice, %	74.7	70.0	67.5	80.0	61.7	10.0
Yield grade	2.7	2.9	2.9	2.9	2.8	.1
Fat thickness, in	.58	.59	.58	.60	.57	.01

[a]DRC = dry-rolled corn; SFC = steam-flaked corn; WCGF = wet corn gluten feed.
[b]Final wt. = Hot carcass wt. / .63 (common dressing percentage).
[c]Effect of WCGF (P<.10).
[d]Effect of replacing SFC with WCGF versus DRC (P<.01).
[e]Processing method x WCGF interaction (P<.05).
[f]Effect of grain processing method (P<.10).
[g]Values used in calculations: Ration prices: DRC = $115.55/ton; DRC+WCGF = 105.56/ton; SFC = $119.10/ton; SFC+WCGF = $107.84/ton; SFC+DRC = 117.75; Yardage = $0.30/d; interest on 1/2 feed = 10%. Cattle interest not included.
[h]Marbling score: 500 = Small 0 (low Choice).
[ijk]Means within a row with unlike superscripts differ (P<.01).

Table 4. Effect of grain processing method on performance and carcass characteristics of calves fed finishing diets containing wet corn gluten feed (Trial 1).

	Treatment[a]					
	SFC WCGF	HMC WCGF	FGC WCGF	DRC WCGF	WC WCGF	SEM
Days on feed, days	169	169	169	169	169	
Initial wt., lb	670	667	667	665	668	2
Final wt., lb[b]	1387	1368	1371	1381	1375	8
DMI, lb/day	22.03[g]	21.82[g]	22.19[g]	23.42[f]	24.79[e]	.25
ADG, lb	4.25	4.15	4.17	4.24	4.18	.04
Feed:gain	5.18[e]	5.26[ef]	5.32[f]	5.52[g]	5.92[h]	
Diet NEg, Mcal/cwt	70.9[h]	69.8[gh]	68.8[g]	66.0[f]	61.2[e]	.5
Cost of gain, $/cwt[c]	35.68[e]	35.66[e]	35.97[e]	36.91[f]	39.05[g]	.23
Hot carcass wt, lb	874	862	864	870	866	5
Marbling score[d]	552	537	532	559	549	12
Percent Choice, %	80.0	68.1	71.7	70.0	68.3	7.3
Yield grade	2.9	3.0	2.8	2.9	2.8	.1
Fat thickness, in	.60	.63	.59	.59	.61	.02

[a]DRC = dry-rolled corn; FGC = finely-ground corn; HMC = high-moisture corn; SFC = steam-flaked corn; WC = whole corn; WCGF = wet corn gluten feed.
[b]Final wt. = Hot carcass wt. / .63 (common dressing percentage).
[c]Values used in calculations: Ration prices: DRC = $105.56/ton; FGC = 105.58/ton; HMC = $105.56/ton; SFC = $107.84/ton; WC = $104.76/ton; Yardage = $0.30/d; interest on 1/2 feed = 10%. Cattle interest not included.
[d]Marbling score: 500 = Small 0 (low Choice).
[efgh]Means within a row with unlike superscripts differ (P<.10).

cass data were collected following a 24-hour chill. The NEg of each diet was calculated using initial weight, carcass adjusted final weight, DMI and ADG for each pen.

Results

Trial 1

The performance and carcass data from the DRC and SFC treatments are presented in Table 3. A significant (P<.05) grain processing method x WCGF interaction existed for DMI. When DRC was fed, DMI was increased by 2.81 lb/day when WCGF was fed, whereas, when SFC was fed, DMI was increased by 1.62 lb/day when WCGF was fed. Additionally, the replacement of SFC with DRC resulted in a significantly (P<.01) lower DMI than replacing SFC with WCGF.

Grain processing method did not affect daily gain. However, daily gain was increased (P<.10) 7.7% by replacing corn grain with WCGF. Likewise, replacement of SFC with WCGF resulted in a 6.5% improvement (P<.01) in daily gain compared to replacing SFC with DRC.

Feed efficiency was improved (P<.10) 5.4% when steers were fed SFC compared to DRC. Feed efficiency tended (P=.10) to be improved by feeding corn grain alone (5.24 and 5.35 for corn grain and WCGF, respectively). Feed efficiency was similar when DRC or WCGF replaced SFC. Dietary NEg was 5.3% higher (P<.10) in SFC diets than in DRC diets, while the addition of WCGF reduced (P<.10) dietary NEg by 3.9%. There was no difference in the dietary NEg when DRC or WCGF replaced SFC. Cost of gain was decreased (P<.10) both by feeding SFC and by feeding WCGF. Replacement of SFC with WCGF decreased (P<.01) cost of gain compared to replacing SFC with DRC.

Inclusion of WCGF in the diet increased (P<.10) hot carcass weights. Likewise, replacement of SFC with WCGF increased (P<.01) hot carcass weights compared to replacement of SFC with DRC. Marbling score was increased (P<.10) by inclusion of WCGF compared to feeding corn grain alone. The percentage of animals grading Choice or greater was 75% in diets containing WCGF and 71% in diets containing corn grain alone. Neither processing method nor replacement of SFC with DRC influenced marbling score. Yield grade and fat thickness were not affected by treatment.

The performance and carcass data from all diets containing 32% WGCF are presented in Table 4. Feed

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consumption was higher (P<.10) when feeding WC with DRC being intermediate and FGC, HMC and SFC being similar. Feeding WC increased DMI by 10.8% when compared to the average of the other four treatments. Daily gain was similar among the treatments. On average, feeding SFC improved (P<.10) efficiency 7.1% compared with feeding DRC, FGC, or WC. Efficiency was similar between calves fed SFC or HMC. Finely grinding corn improved (P<.10) efficiency compared to feeding DRC or WC. Feeding unprocessed corn (WC) in the finishing diet reduced (P<.10) feed efficiency compared with all other treatments. Dietary NEg was higher (P<.10) when feeding SFC compared to feeding DRC, FGC, or WC. Net energy available for gain was similar when feeding SFC or HMC. Finely grinding corn improved (P<.10) dietary NEg compared to feeding DRC or WC. Cost of gain was decreased (P<.10) by feeding FGC, HMC and SFC compared to feeding DRC or WC. Cattle fed WC had a higher (P<.10) cost of gain than all other treatments. Hot carcass weight, marbling score, yield grade and fat thickness were not affected by treatment.

Trial 2

The performance data from the SFC and DRC treatments are shown in Table 5. A grain processing x WCGF interaction (P<.10) similar to that observed in Trial 1 was detected for DMI. The increase in DMI observed with the addition of WCGF to the diet was greater when feeding DRC than when feeding SFC (2.28 lb/day versus 1.00 lb/day, respectively). In addition, cattle fed SFC alone consumed slightly more feed than cattle fed DRC alone which contrasts with previous research results.

Grain processing had a significant effect (P<.10) on daily gain. Feeding SFC improved daily gain 8.1% compared to DRC. Inclusion of WCGF improved (P<.10) daily gain 7.0% compared to feeding corn grain alone.

Grain processing significantly affected (P<.10) efficiency with SFC improving efficiency 8.3% compared to DRC. Inclusion of WCGF had no effect on efficiency or dietary NEg. Feeding SFC increased (P<.10) NEg compared to feeding DRC. Cost of gain was decreased (P<.10) by feeding SFC and by feeding WCGF.

Feeding SFC increased (P<.10) hot carcass weights compared to feeding DRC. Inclusion of WCGF also increased (P<.10) hot carcass weights compared to feeding corn grain alone. Marbling scores were unaffected by grain processing method; however, similar to Trial 1,

Table 5. Effects of grain processing method and wet corn gluten feed inclusion in finishing diets on performance and carcass characteristics (Trial 2).

	Treatment[a]				
	DRC	DRC WCGF	SFC	SFC WCGF	SEM
Days on feed, days	117	117	117	117	
Initial wt., lb	836	845	844	847	4
Final wt., lb[bcd]	1263	1310	1315	1341	9
DMI, lb/day[e]	21.93[h]	24.21[i]	22.35[h]	23.35[i]	.35
ADG, lb[cd]	3.64	3.98	4.02	4.22	.08
Feed:gain[c]	6.02	6.08	5.56	5.54	
Diet NEg, Mcal/cwt[c]	64.6	63.3	69.3	69.5	1.0
Cost of gain, $/cwt[cdf]	43.25	40.91	39.03	38.31	.62
Hot carcass wt, lb[cd]	796	826	828	845	6
Marbling score[dg]	488	513	496	516	10
Percent Choice, %	47.5	55.8	54.9	60.4	7.1
Yield grade[cd]	2.0	2.5	2.3	2.6	.1
Fat thickness, in[cd]	.44	.48	.51	.55	.02

[a]DRC = dry-rolled corn; SFC = steam-flaked corn; WCGF = wet corn gluten feed.
[b]Final wt. = Hot carcass wt. / .63 (common dressing percentage).
[c]Effect of grain processing method (P<.10).
[d]Effect of WCGF (P<.10)
[e]Processing method x WCGF interaction (P<.10).
[f]Values used in calculations: Ration prices (DM basis): DRC = $114.38/ton; DRC+WCGF = 108.00/ton; SFC = $111.65/ton; SFC+WCGF = $110.72/ton; Yardage = $0.30/d; interest on 1/2 feed = 10%. Cattle interest not included.
[g]Marbling score: 500 = Small 0 (low Choice).
[hi]Means within a row with unlike superscripts differ (P<.10).

Table 6. Effect of grain processing method on performance and carcass characteristics of calves fed finishing diets containing wet corn gluten feed (Trial 2).

	Treatment[a]				
	SFC WCGF	HMC WCGF	FRC WCGF	DRC WCGF	SEM
Days on feed, days	117	117	117	117	
Initial wt., lb	847	848	841	845	4
Final wt., lb[b]	1341[f]	1318[ef]	1303[e]	1310[e]	9
DMI, lb/day	23.35	24.01	24.30	24.21	.32
ADG, lb	4.22[e]	4.02[f]	3.95[f]	3.98[f]	.07
Feed:gain	5.54[e]	5.97[f]	6.15[g]	6.09[fg]	
Diet NEg, Mcal/cwt	69.5[g]	64.6[f]	62.4[e]	63.3[ef]	.8
Cost of gain, $/cwt[e]	38.31[e]	40.21[f]	41.39[fg]	40.92[g]	.45
Hot carcass wt, lb	845[f]	831[ef]	821[e]	826[e]	6
Marbling score[d]	516	516	503	513	12
Percent Choice, %	60.4	63.2	61.4	55.8	7.6
Yield grade	2.6	2.4	2.4	2.5	.1
Fat thickness, in	.55	.53	.50	.48	.02

[a]DRC = dry-rolled corn; FRC = finely-rolled corn; HMC = high-moisture corn; SFC = steam-flaked corn; WCGF = wet corn gluten feed.
[b]Final wt. = Hot carcass wt. / .63 (common dressing percentage).
[c]Values used in calculations: Ration prices (DM basis): DRC = $108.00/ton; FRC = 108.02/ton; HMC = $108.00/ton; SFC = $110.72/ton; Yardage = $0.30/d; interest on 1/2 feed = 10%. Cattle interest not included.
[d]Marbling score: 500 = Small 0 (low Choice).
[efg]Means within a row with unlike superscripts differ (P<.10).

inclusion of WCGF increased (P<.10) marbling scores. The percentage of animals grading Choice or greater was 58% in diets containing WCGF and 51% in diets containing corn grain alone. Both grain processing and inclusion of WCGF affected yield grade and fat thickness. Steers fed SFC had higher yield grades (P<.10) and were fatter (P<.10) than steers fed DRC. Similarly, inclusion of WCGF increased (P<.10) both yield grade and fat thickness (P<.10) when compared to feeding corn grain.

The performance data from all diets containing 22% WCGF are presented in Table 6. Grain treatment had no effect on DMI. Daily gain was improved (P<.10) 6.0% by feeding SFC compared with all other treatments. Feeding DRC, FRC or HMC resulted in similar daily gains. Feeding SFC resulted in an 8.7% improvement (P<.10) in efficiency compared to the average of the other treatments. Efficiency was similar when feeding HMC or DRC; however, feeding HMC improved (P<.10) efficiency when compared to feeding FRC. Dietary NEg was higher (P<.10) when feeding SFC compared with the other treatments. Dietary NEg was similar when feeding DRC or HMC. Feeding HMC improved NEg compared to feeding FRC. Cost of gain was reduced (P<.10) by feeding SFC with all other treatments being similar. Feeding SFC increased (P<.10) hot carcass weights compared with feeding DRC or FRC with HMC being intermediate. Other carcass characteristics were not affected by treatment.

The slight numerical reductions in efficiency observed in both Trials 1 and 2 with the addition of WCGF to a DRC-based finishing diet are in contrast to previous research conducted at the University of Nebraska. In Trial 1, efficiency was reduced 3.2% when comparing DRC and DRC with WCGF. In Trial 2, a smaller numerical reduction (1.2%) in efficiency was observed. In a summary of five finishing trials conducted at the University of Nebraska from 1996-1998 (Stock, et al., Journal of Animal Science, 2000), feeding finishing diets containing an average of 34.8% WCGF (DM basis; Cargill Corn Milling, Blair, NE) resulted in a 5.1% improvement in efficiency. However, the data of Scott et al. published elsewhere in this report (Programmed Gain Finishing Systems In Yearling Steers Fed Dry-rolled Corn Or Wet Corn Gluten Feed Finishing Diets) support the reduced efficiency response observed in this study. A 4.8% improvement in efficiency was observed when comparing a DRC control diet to a DRC diet containing 35% WCGF in steers offered ad libitum access to feed. A portion of the improvement in efficiency when feeding WCGF in DRC finishing diets has been attributed to a reduction in subacute acidosis. Therefore, a possible explanation for the differing efficiency responses may be due to a difference in the degree to which acidosis occurred in the respective control (DRC) groups in these studies and that of Scott et al. compared with those of the summary. Changes in milling procedures may have resulted in differences in the extent to which acidosis was occurring. In the summary data, a double-roller mill was used.

If subacute acidosis is controlled, increased processing of corn grain increases starch availability and feed efficiency. If acidosis occurs, improved feed efficiency will not be observed in response to increased processing of corn grain. Wet corn gluten feed has been shown to reduce acidosis; therefore, corn-based finishing diets that contain WCGF may allow corn grain to be more extensively processed without increasing the risk of acidosis. Generally, the data from these trials indicate that feed conversion was improved as the degree of processing was increased in diets containing WCGF. Processing methods such as steam-flaking, high moisture ensiling, and fine-grinding tended to improve efficiency when compared to either minimal processing methods (i.e., rolling) or no processing. Also, on the pen surface, there was a significant amount of whole corn kernels in the feces of steers fed WC and a significant amount of whole and large broken kernels in the feces of steers fed DRC. The amount of whole and broken kernels observed on the pen surface in the other treatments was limited. The increased intake observed when feeding WCGF may increase rate of passage which would likely reduce the starch digestion of the large grain particles, the consequence of which is reduced efficiency despite similar or greater daily gain. Therefore, increasing the extent to which grain is processed may improve efficiency in diets containing WCGF.

These results indicate that feeding SFC results in improved feed efficiency with or without inclusion of WCGF compared to DRC. These data also indicate that grain processing methods more intensive than dry-rolling (i.e., fine-grinding, high moisture ensiling, steam-flaking) can be used to improve feed efficiency and dietary net energy available for gain in finishing diets containing WCGF.

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Implant Programs for Feedlot Heifers Using Synovex® Plus™

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Implanting feedlot heifers with Synovex Plus improves ADG and cost of gain compared to heifers implanted with Finaplix-H and fed MGA. MGA maintains carcass quality.

Summary

Two commercial feedyard experiments evaluated implant strategies for feedlot heifers. In both experiments, implanting heifers with Synovex Plus increased ADG compared to heifers implanted with Finaplix-H and fed MGA. In Experiment 1, implanting heifers with Synovex Plus improved feed conversion and increased live basis net returns, and the use of MGA with Synovex Plus increased carcass merit basis net returns and had similar marbling scores compared with Finaplix-H and MGA.

Introduction

Growth-promoting implants are widely used by the cattle feeding industry. Implants can vary in composition, dosage and carrier. Implants can have different effects on animal performance and carcass characteristics, changing economic returns. Implants can have a single active compound as well as combination of active compounds. An implant that is commonly used in finishing heifers is Finaplix-H. Finaplix-H contains 200 mg of trenbolone acetate (TBA). Melengestrol acetate (MGA) is routinely supplemented in feedlot heifers implanted with Finaplix-H to enhance TBA activity. Synovex Plus has been recently approved for use in finishing heifers. Synovex Plus is a combination implant, containing 28 mg estradiol benzonate (20 mg E_2) and 200 mg TBA. Objectives of these trials were to: 1) compare performance, carcass characteristics, and feeding economics in heifers implanted with Synovex Plus or Finaplix-H and 2) determine if MGA supplementation is beneficial in finishing heifers implanted with Synovex Plus.

Procedure

Experiment 1.

Eight hundred seventy-nine heifers (726 lb) were randomly allotted to one of three implant programs and assigned to one of 15 pens (5 replications/treatment) on arrival to the feedyard. Heifers were kept separate by truck load-lot and randomly assigned to the three implant treatments in groups of two head by a gate sort. Within a replication, all heifers arrived at the feedyard at the same time. After sorting, pens were reweighed, processed and moved to their home pen. During processing, heifers were vaccinated, treated for internal and external parasites, implanted with Ralgro®, and given a lot-tag for identification.

Initial weights were calculated by prorating pen weights, obtained between sorting and processing, back to the group's original pay weight. Hot carcass weight was adjusted to a common dressing percentage of 63% to determine final weight.

Reps of heifers were reimplanted with either Synovex Plus or Finaplix-H, on average, 90 days (range 84 to 101) prior to harvest. Heifers assigned to Finaplix-H were fed MGA once they were stepped up to the final diet (20 days on feed). Additionally, one Synovex Plus treatment was fed MGA once they were stepped up to the final diet (20 days on feed). The final diet contained 57.0% steam-flaked corn, 16.9% dry-rolled corn, 9.1% supplement, 7.5% alfalfa hay, 6.5% corn steep liquor and 3.0% fat, and was formulated to contain 13.6% CP, 7.0% crude fat, 0.77% Ca, 0.40% P and 0.77% K. Heifers were fed an average of 149 days (range 128 to 172). All pens within a replication were harvested under identical conditions. Hot carcass weights were recorded on the day of harvest. Carcass fat thickness, marbling score, KPH fat, longissimus muscle area and U.S.D.A quality grade were recorded following a 24 to 36 hour chill.

Performance, carcass and economic data were analyzed using the General Linear Model of SAS. LS Means were used to separate treatment differences. Additionally, independent contrasts were used to compare: 1) the average of Synovex Plus, with and without MGA supplementation, versus Finaplix-H with MGA supplementation and 2) Synovex Plus without MGA supplementation versus the average of Synovex Plus and Finaplix-H when MGA was fed. Quality and yield grade distributions and the percentage of dark cutting carcasses were analyzed using the frequency procedure (Proc Freq) of SAS. Variables were considered significant when probability values less than .10 were obtained.

Experiment 2.

Eight hundred seventy heifers (828 lb) were used in a randomized complete block design. The pen of heifers was the experimental unit. Six pens were used, resulting in three experimental observations for each implant treatment. Heifers were blocked by arrival date into the feedyard. Heifers were processed on arrival and maintained in three large pens until reimplanting. At reimplanting, heifers were randomly allotted to treatments by sorting individual heifers at chute-side. Thus, if the first heifer received Synovex Plus, the second heifer through the chute would have been implanted with Finaplix-H, and so on. All heifers were fed a finishing diet containing 78.0% dry-rolled corn, 11.0% corn steep liquor, 6.8% alfalfa hay and 4.2% supplement, and was formulated to contain 13.3% CP, 4.5% crude fat, 0.75% Ca, 0.40% P and 0.77% K. The finishing diet contained MGA for both treatments.

Initial weights were determined on individual heifers at the time of reprocessing. Final weights were determined by adjusting hot carcass weight to a common 63% dressing percentage. Heifers were slaughtered at a commercial packing facility and carcass characteristics were determined following a 36 to 48-hour chill. Carcass measurements included: hot carcass weight, marbling score, KPH fat, 12th rib fat thickness, longissimus muscle area and U.S.D.A. quality grade.

Data were analyzed as a randomized complete block design using the General Linear Model of SAS. Treatment means were separated using a t-test protected by a significant overall F-test. Distribution of U.S.D.A. quality and calculated yield grades were analyzed using the frequency procedure (Proc Freq) of SAS. Differences between implant treatments were considered significant when probability values were less than .10.

Table 1. Effect of implant strategy on performance and carcass characteristics in finishing heifers (Experiment 1).

Item	Implant Strategy[a]			SEM[b]
	SynPlus No MGA	SynPlus MGA	FinH MGA	
Number of pens	5	5	5	
Number of heifers	294	292	293	
Days on feed	149	149	149	
Initial weight, lb	725	722	732	3.0
Final weight, lb[c]	1211	1221	1209	7.8
Dry matter intake, lb	19.0	19.2	19.1	.15
Daily gain, lb[d]	3.27[e]	3.35[f]	3.19[g]	.04
Feed/gain[d]	5.81[h]	5.74[h]	6.00[i]	.05
Carcass weight, lb	765	771	762	3.9
12th rib fat, in.[k]	.48[h]	.55[i]	.51[j]	.01
Longissimus muscle area, sq. in.[l]	14.3[h]	14.0[hg]	13.6[g]	.22
Calculated yield grade[kl]	2.44[h]	2.72[i]	2.80[i]	.08
Marbling score[klm]	5.19[h]	5.46[i]	5.42[i]	.04
Quality grade distribution[n], %				
Prime	1.0	3.8	1.0	
Upper 2/3 Choice	17.0	20.9	19.6	
Low Choice	38.8	43.8	53.2	
Select	41.8	29.8	25.9	
Standard	1.4	1.7	.3	
Dark cutters[o], %	1.3	0	0	

[a]SynPlus No MGA = Synovex Plus fed no MGA; SynPlus MGA = Synovex Plus fed MGA; FinH MGA = Finaplix-H fed MGA.
[b]SEM = Standard error of the mean.
[c]Final weight calculated as hot carcass weight divided by .63 (common dressing percentage).
[d]Contrasts of Synovex Plus treatments versus Finaplix-H differ (P < .05).
[e,f,g]Means within a row with different superscripts differ (P < .10).
[h,i,j]Means within a row with different superscripts differ (P < .05).
[k]Contrasts of MGA treatments versus no MGA differ (P < .05).
[l]Contrasts of Synovex Plus treatments versus Finaplix-H differ (P < .10).
[m]Marbling score: 4.0 = Slight; 4.5 = Slight 50; 5.0 = Small; 5.5 Small 50; etc.
[n]Chi square statistics: Prime (P < .02); upper 2/3 Choice (P = .49); low Choice (P < .01); Select (P < .01); Standard (P = .27).
[o]Chi square statistic (P = .13)

Economic Analysis for Experiment 1 and 2.

The economic influence of the implant treatments was determined using the ration cost at the feedyard during the period the experiment was conducted. The ration cost used in the analysis includes markup in Experiment 1. Non-feed costs (medicine, processing, etc.) were calculated for each pen of heifers in the experiment and averaged. This average non-feed cost was applied to each pen of heifers for calculation of cost of gain and net profit(loss). Final heifer value was calculated by using a live price or a carcass price based on individual heifer carcass value. Carcass value was calculated based on U.S.D.A. quality grade, calculated yield grade, carcass weight and nonconformance (i.e. dark cutters). A carcass base price of $105/cwt was used for low Choice, yield grade 3 carcasses weighing 550 to 950 lb. Discounts were calculated as: $10, Select; $20, Standard; $30, dark cutters; $25, light (<550 lb) and heavy (>950 lb) carcasses; and $15, yield grades 4 and 5. Premiums were calculated as: $8, Prime; $3, upper 2/3 Choice; and $3, yield grades 1 and 2.

Results

In both experiments, data are presented with deads and railers removed from the analysis. Feed intake and head days were adjusted one day prior to the removal of the animal from the pen as either a dead or railer.

Experiment 1.

Dry matter intake was similar among treatments. Heifers implanted with Synovex Plus gained 3.8% faster (P = .01) and were 3.9% more efficient (P = .01) than those implanted with Finaplix-H (Table 1). Heifers implanted with Synovex Plus and fed MGA had higher (P < .05) daily gains compared both to heifers implanted with Synovex Plus fed no MGA and heifers implanted with Finaplix-H fed MGA.

Carcass characteristics are presented in Table 1. Heifers implanted with Synovex Plus as the terminal implant had lower (P = .07) calculated yield grades and increased longissimus muscle area (P = .06) compared with those implanted with Finaplix-H. Marbling scores (P < .01) and the percentage of carcasses grading U.S.D.A. low Choice (P < .01) were reduced and the percentage of carcasses grading Select was increased (P < .01) when heifers not being fed MGA were implanted with Synovex Plus compared with the Finaplix-H/MGA program. Feeding MGA with the use of Synovex Plus as the terminal implant eliminated any deleterious effects on

(Continued on next page)

carcass quality as indicated by a higher (P < .01) percentage of U.S.D.A. Prime carcasses, little change in the percentage of U.S.D.A. Choice carcasses, and similar (P = .47) marbling scores compared with the Finaplix-H/MGA program. There was no effect of treatment on the percentage of upper 2/3 Choice or Standard grading carcasses. There was no influence of treatment on the incidence of dark cutting carcasses.

Feeding MGA, either when heifers were implanted with Synovex Plus or Finaplix-H, increased 12th rib fat thickness (P < .01), calculated yield grade (P = .01), and marbling score (P < .01). The percentages of carcasses grading U.S.D.A. Prime (P = .02) and low Choice (P < .01) increased with feeding MGA. This experiment demonstrates that Synovex Plus can be used effectively with MGA to increase performance without compromising carcass quality relative to a program using Finaplix-H and MGA.

Experiment 2.

Dry matter intake was similar between the implant strategies (Table 2). Heifers implanted with Synovex Plus gained 4.1% (P = .02) faster compared with those implanted with Finaplix-H. Feed conversion was similar between implant strategies.

Carcass characteristics are presented in Table 2. Carcass weight of heifers implanted with Synovex Plus was 10 lb heavier (P = .10) compared with those implanted with Finaplix-H. Longissimus muscle area, 12th rib fat thickness, yield grade and marbling score were similar between heifers implanted with Synovex Plus or Finaplix-H. Additionally, the distribution of U.S.D.A. quality grade was similar between implant treatments.

Economic Analysis for Experiment 1 and 2.

A summary of the economic analysis is provided in Table 3. In experiment 1, cost of gain was improved (P = .01) with Synovex Plus compared with Finaplix-H. On a live basis, net profit(loss) was increased (P = .03) $14.00 or $9.01

Table 2. Effect of implant strategy on performance and carcass characteristics in finishing heifers (Experiment 2).

Item	Implant Strategy[a] SynPlus MGA	FinH MGA	SEM[b]	P-value[c]
Number of pens	3	3		
Number of heifers	432	438		
Days on feed	107	107		
Initial weight, lb	829	826	5.5	.77
Final weight, lb[d]	1183	1166	4.2	.11
Dry matter intake, lb	21.7	21.0	.37	.32
Daily gain, lb	3.31	3.18	.01	.02
Feed/gain	6.55	6.62	.13	.75
Carcass weight, lb	745	735	2.6	.10
12th rib fat, in.	.54	.55	.02	.91
Longissimus muscle area, sq. in.	13.5	13.3	.04	.10
Calculated yield grade	2.92	2.96	.05	.71
Marbling score[e]	5.65	5.69	.11	.83
Quality grade distribution[f], %				
Prime	3.7	4.0		
Upper 2/3 Choice	32.9	32.4		
Low Choice	38.4	39.9		
Select	23.1	23.1		
Standard	1.7	.7		

[a]SynPlus MGA = Synovex Plus fed MGA; FinH MGA = Finaplix-H fed MGA.
[b]SEM = Standard error of the mean.
[c]T-test of significance between implant treatments.
[d]Final weight calculated as hot carcass weight divided by .63 (common dressing percentage).
[e]Marbling score: 4.0 = Slight; 4.5 = Slight 50; 5.0 = Small; 5.5 Small 50; etc.
[f]Chi square statistics: Prime (P = .80); upper 2/3 Choice (P = .88); low Choice (P = .88); Select (P = .94); Standard (P = .19).

Table 3. Feeding economics of heifers implanted with Synovex Plus, with or without MGA supplementation, or Finaplix-H and MGA.

Item	Implant Strategy[a] SynPlus No MGA	SynPlus MGA	FinH MGA	SEM[b]	P-value[c]
Experiment 1					
Ration cost[d], $/ton	131.00	132.50	132.50		
Cost of feed, $/head	185.78	190.05	189.58	1.4	
Non-feed cost[e], $/head	9.91	9.91	9.32		
Total feeding cost, $/head	195.69	199.96	198.90	1.4	
Cost of gain[f], $/cwt	40.11[g]	40.03[g]	41.72[h]	.35	
Carcass value[fij], $/cwt	102.43[k]	103.27[l]	103.99[m]	.28	
Profit(loss)[n], $/head					
Live basis[f]	83.96[gh]	88.95[g]	74.95[h]	3.7	
Carcass merit basis	81.20[k]	91.63[l]	80.68[k]	3.8	
Experiment 2					
Ration cost, $/ton	—	85.00	85.00		
Cost of feed, $/head	—	98.26	95.11	1.7	.32
Non-feed cost[e], $/head	—	51.00	51.00		
Total feeding cost, $/head	—	149.26	146.11	1.7	.32
Cost of gain, $/cwt	—	42.25	43.11	.60	.42
Carcass value[j], $/cwt	—	103.84	103.90	.35	.91
Profit(loss)[n], $/head					
Live basis	—	39.62	33.81	2.4	.23
Carcass merit basis	—	44.41	38.68	2.1	.19

[a]SynPlus No MGA = Synovex Plus fed no MGA; SynPlus MGA = Synovex Plus fed MGA; FinH MGA = Finaplix-H fed MGA.
[b]SEM = Standard error of the mean.
[c]T-test of significance between implant treatments.
[d]Includes feed mark-up.
[e]Average of all medicine, processing, and other costs for all replications in experiment and appropriate implant costs per treatment.
[f]Contrasts of Synovex Plus treatments versus Finaplix-H differ (P < .05).
[g,h]Means within a row with different superscripts differ (P < .05).
[i]Contrasts of MGA treatments versus no MGA differ (P < .05).
[j]Calculated using a $105/cwt carcass base price: discounts = $10, Select; $20, Standard; $15, yield grade 4 and 5; $30, dark cutter; premiums = $8, Prime; $3, upper 2/3 Choice; $3, yield grades 1 and 2.
[k,l,m]Means within a row with different superscripts differ (P < .10).
[n]Initial animal cost = $70/cwt; animal returns based on $65/cwt live cash price or calculated carcass value, respectively, interest not included.

when heifers were implanted with Synovex Plus with or without MGA supplementation, respectively, compared to Finaplix-H with MGA supplementation. When carcass discounts and premiums were applied to calculate profit(loss), heifers implanted with Synovex Plus without MGA supplementation were similar to those implanted with Finaplix-H and fed MGA. The reductions in percentage of cattle grading low Choice in this experiment were large enough, using a $10 Choice/Select spread, to offset the advantage in cost of gain. Although not statistically different, the incidence of dark cutting carcasses was included in this calculation at a discount of $30/cwt. The additive effect of implanting heifers with Synovex Plus and feeding MGA increased carcass merit returns (P < .09) by $10.95 per head compared to the Finaplix-H, MGA fed heifers.

In experiment 2, cost of gain was not significantly influenced by implant treatment. Overall profit(loss) tended (live basis, P = .23; carcass basis, P = .19) to be greater for heifers implanted with Synovex Plus.

These data suggest that Synovex Plus can be used in feedlot heifers to enhance daily gain and improve net live basis profit(loss) compared with a implant program using Finaplix-H. Carcass quality is similar between heifers implanted with Synovex Plus or Finaplix-H when MGA is included in the diet, increasing overall net carcass merit profit(loss) in Synovex Plus heifers.

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The Effect of Feeding Pressed Sugar Beet Pulp in Beef Cattle Feedlot Finishing Diets

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Feeding pressed beet pulp in place of corn silage in a finishing diet resulted in equal feed efficiencies though dry matter intake was slightly affected.

Summary

Two trials were conducted to evaluate feeding pressed beet pulp as the roughage source in finishing diets. British crossbred steers were fed 8.5% corn silage, 8.5% beet pulp, or 12.5% beet pulp with the remainder of the diet consisting of dry rolled corn and supplement. When the two trials were analyzed together, average daily gain was higher in the corn silage treatment compared to the two levels of beet pulp. However, feed to gain conversions between the treatments were not different. Beet pulp can serve as a substitute for corn silage and even though dry matter intake may be slightly affected, feed efficiency will be equal.

Introduction

Sugar beet pulp is a byproduct of the sugar beet industry. After the sugar is extracted from the beet, the remaining fraction is mechanically pressed to around 24% dry matter. The pulp can be fed fresh or ensiled, allowing it to be accessible year round. Previous studies have shown that replacing corn silage dry matter with increasing levels of beet pulp have improved average daily gain and feed efficiency in growing beef cattle diets (1992 Nebraska Beef Report, pp. 24-25, 1993 Nebraska Beef Report, pp. 48-49, 2000 Nebraska Beef Report, pp. 36-37). Replacing all of the corn silage in the diet (10 % diet dry matter) with beet pulp resulted in similar daily gains and a trend toward improved feed efficiency in a feedlot finishing diet (1993 Nebraska Beef Report, pp. 48-49). The NDF and ADF of beet pulp (54% and 33%, respectively) are similar to those of corn silage (51% and 28%, respectively). Beet pulp has a highly digestible fiber fraction, and is therefore considered to be both an energy and roughage source in beef cattle diets. Because of similar energy values, the costs are usually comparable on a dry matter basis. However, little is known how or if beet pulp functions as a roughage source in the diet. Therefore, the objective of this experiment was to determine if beet pulp could replace corn silage (DM basis) as a fiber source in a feedlot finishing diet.

Procedure

Two groups of British crossbred yearling steers were used in separate trials in a complete randomized design. In Trial 1, 118 steers (initial BW 1030 lb) were assigned randomly to one of 12 pens with nine or 10 steers per pen. Pens then were assigned randomly to one of three dietary treatments, with four replicates per treatment. All steers were fed for 77 days. In Trial 2, 90 steers (initial BW 859 lb) were assigned randomly to one of nine pens with 10 steers per pen. Pens were then randomly assigned to dietary treatment as in Trial 1. There were 3 replicates per treatment and steers were fed for 133 days.

In both trials, steers were individually weighed for two consecutive days at the initiation of the trial and every 28 days throughout the feeding period. The three diet treatments (Table 1) on a DM basis were: 8.5% corn silage (CON), 8.5% beet pulp (8.5BP), and 12.5% beet

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pulp (12.5BP). The 8.5% beet pulp treatment replaced the 8.5% corn silage on a one to one basis. The 12.5% beet pulp treatment had the same level of NDF as that supplied by the 8.5% corn silage treatment. The remainder of the diets consisted of dry rolled corn and protein supplement. The diets were formulated to be isonitrogenous at 13% CP. In Trial 1, the beet pulp was stored on a concrete pad for several months prior to the trial, while it was fed fresh in Trial 2. Steers were implanted with Revalor S at the beginning of the finishing period. Carcass characteristics were taken at the time of slaughter. Final weights, used to calculate ADG and feed to gain, were calculated from hot carcass weight (HCW) adjusted to a common dressing percentage (62%). Performance data were analyzed using the GLM procedures of SAS with feedlot pen as the experimental unit. Quality grades were analyzed using the chi-square procedure of SAS. Significance was determined at P = .10 unless otherwise specified.

Results

Steer performance is shown in Table 2. Data were tested for treatment by trial interactions. There was no treatment by trial interaction for ADG (P = .18). Gains were higher in the CON treatment compared to the 8.5BP and 12.5BP treatments (P = .05). A significant trial by treatment interaction (P = .08) occurred for DMI, therefore dry matter intakes are reported within trial. In Trial 1, cattle consuming CON had a higher DMI (26.2 vs. 23.5 and 23.6, for CON, 8.5BP,and 12.5BP, respectively; P < .001) than steers fed the pulp rations, but no differences in DMI between the 8.5BP and the 12.5BP treatments occurred. In Trial 2, no differences in DMI across the treatments were indicated. The different responses observed for DMI as beet pulp replaced corn silage in the diet may have been due to the storage of the beet pulp. In Trial 1, the beet pulp was ensiled for several months prior to feeding and in Trial 2 the pulp was fed fresh. There was not a significant treatment by trial interaction (P = .96) in feed conversion. Therefore, data were pooled and no differences in feed conversion between the three treatments were detected. Beet pulp can effectively replace corn silage in a finishing diet and it appears that the feeding value is similar (DM basis).

Carcass data are shown in Table 3. There were no treatment by trial interactions (P > .10) for carcass characteristics, therefore data were pooled. Hot carcass weights were higher for the CON treatment (P < .10). The CON treatment had higher marbling scores compared to 8.5BP (P < .05), but it was not different from 12.5BP. Backfat was higher in the

Table 1. Diet dry matter composition and calculated nutrient analysis.

	Treatment[a]		
	CON	8.5BP	12.5BP
Diet composition, dry matter basis, %			
Corn silage	8.5	0	0
Beet pulp	0	8.5	12.5
Dry rolled corn	82.7	83.3	79.5
Protein supplement 58[b]	6.4	6.4	6.4
Protein supplement 40[c]	2.5	1.8	1.7
Calculated nutrient composition, dry matter basis			
Dry matter, %	76.3	70.7	65.4
Crude protein, %	13.0	13.0	13.0
NEm, Mcal/cwt	92.7	93.6	93.2
NEg, Mcal/cwt	63.6	63.6	63.2
Rumensin, g/ton	29.0	29.0	29.0

[a]CON = Dry-rolled corn control with 8.5% corn silage; 8.5BP = 8.5% bet pulp replacing corn silage; 12.5BP = 12.5% beet pulp replacing corn silage and dry rolled corn.
[b]Supplement contains 58 percent crude protein, with Rumensin at 420g/ton, air dry basis.
[c]Supplement contains 40 percent crude protein, air dry basis.

Table 2. Performance of steers in trial 1 and trial 2 fed dry-rolled corn based finishing diets with corn silage or wet beet pulp as the roughage source.

	Treatment[a]		
	CON	8.5BP	12.5BP
DMI, lb/day[b]			
Trial 1	26.2[c]	23.4[d]	23.6[d]
Trial 2	22.9	23.3	22.4
ADG, lb/day	3.44[c]	3.18[d]	3.19[d]
Feed/gain	7.17	7.41	7.26

[a]CON = dry-rolled corn control with 8.5% corn silage; 8.5BP = 8.5% beet pulp replacing corn silage; 12.5BP = 12.5% beet pulp replacing corn silage and dry-rolled corn.
[b]Significant treatment x trial interaction (P = .08).
[c,d]Means within the same row bearing different superscripts differ (P < .05).

Table 3. Carcass characteristics of steers fed dry-rolled corn based finishing diets with corn silage or wet beet pulp as the roughage source.

	Treatment[a]		
	CON	8.5BP	12.5BP
Trial 1 and Trial 2			
Hot carcass weight, lb	812[b]	796[c]	799[c]
Backfat, in	.39[d]	.38[e]	.38[e]
Ribeye area, in^2	13.2	13.1	13.1
Marbling score[f]	5.27[d]	4.84[e]	5.11[de]
Yield grade[g]	2.74	2.68	2.68
U.S.D.A. Choice or above, %[h]	59	43	59

[a]CON = dry-rolled corn control with 8.5% corn silage; 8.5BP = 8.5% beet pulp replacing corn silage; 12.5BP = 12.5% beet pulp replacing corn silage and dry-rolled corn.
[b,c]Means on same row with different superscripts are different (P < .10).
[d,e]Means on same row with different superscripts are different (P < .05).
[f]Slight 0 = 4.0, Slight 50 = 4.5, Small 0 = 5.0, Small 50 = 5.5, etc.
[g]Yield grade = 2.5 + (2.5 * backfat) + (.0038 * hot carcass weight) + (.2 * kidney-pelvic-heart fat) - (.32 * ribeye area).
[h]Chi-square statistic (P = .09).

CON treatment compared to the two levels of beet pulp (P < .05). No differences between treatments for ribeye area or yield grade were found. Quality grades were analyzed by chi-square distribution. The percent grading Choice or above varied by treatment (P = .09).

Feed conversions between the corn silage and beet pulp diets were similar. There was a difference in DMI between the CON and beet pulp treatments, although when the two levels of beet pulp were compared, they were not different. Beet pulp can serve as a replacement for corn silage in finishing diets and it has a similar feeding value. In this experiment, dry matter intake was slightly affected, however feed efficiency was not different when beet pulp was fed. These results agree with those reported in the 1993 Nebraska Beef Report (pp. 48-49) where daily gains and feed conversions were not different when 10% corn silage was replaced with 10% beet pulp on a DM basis in a finishing diet.

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Effects of Feeding Regimen on Performance, Behavior and Body Temperature of Feedlot Steers

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Wanda Cerkoney[1]

Changing feeding regimen of feedlot animals during potential heat stress periods can effectively lower body temperature, thus decreasing the risk of possible heat related production losses.

Summary

One hundred forty-four predominantly Angus x Charolais steers were used to determine effects of different feeding regimens on performance, behavior and tympanic temperatures of steers under environmental heat stress. Steers were assigned to one of three treatments: 1) ad libitum fed at 0800 hr (ADLIB); 2) fed at 1600 hr with bunks slick by 0800 hr (BKMGT); and 3) fed 85% of predicted DMI at 1600 hr (LIMFD). Treatments were imposed for 23 days after which all steers were allowed ad libitum access to feed at 0800 hr. Overall performance was not affected by treatment. Altering feed time and amount reduced tympanic temperature and altered eating pattern.

Introduction

Daily feed intake contributes to the metabolic heat load of animals. When animals are presented with adverse climatic conditions consisting of elevated ambient temperature, relative humidity, and solar radiation, they may be unable to effectively dissipate metabolic heat load. Altering feeding regimen during times of potential heat stress may be beneficial in maintaining overall performance.

Possible strategies for altering the timing or reducing the peak metabolic heat load include adjusting the time of feed consumption and limit-feeding, respectively. Research has shown limit-feeding may reduce metabolic rate and improve overall efficiency when cattle are subsequently provided ad libitum access to feed. The objectives of our study were to determine effects of altered feeding regimen on performance and changes in eating behavior of feedlot steers during potential heat stress periods. Additionally, tympanic temperatures of the steers were monitored under both thermoneutral and hot environmental conditions to determine alterations in body temperature in response to altered feeding regimen.

Procedure

One-hundred forty-four Angus x Charolais steers were used. Upon initiation of the trial steers were implanted with Synovex-Plus® with average body weight on two consecutive days serving as initial weight. Steers were blocked by color (black or white) and randomly assigned to one of 24 pens. All steers were fed a 65 Mcal/cwt NEg ration consisting of (DM basis): 84% dry rolled corn, 7.5% alfalfa hay, 4.5% liquid supplement, 2% soybean meal and 2% dry supplement. Treatments were assigned to pens and consisted of: 1) ad libitum feeding at 0800 hr (ADLIB); 2) bunk management, feed delivered at 1600 h and managed to be empty by 0800 hr (BKMGT); and 3) limit-fed, delivered 85% of predicted DMI at 1600 hr (LIMFD). Treatments were initiated on day 0 (June 23, 1999) and imposed for 23 days (managed feeding phase), then all animals were allowed *ad libitum* access to feed delivered at 0800 hr.

Daily feed and water intakes were recorded. Body weights were obtained on days 23 and at the termination of the trial (day 82; Sept. 13, 1999). On day 83 steers were transported to a commercial slaughter facility. Hot carcass weight, fat thickness, marbling score, and yield

(Continued on next page)

Table 1. Effect of feeding regimen on feedlot performance of yearling steers.

Item	Treatments[a]			
	ADLIB	BKMGT	LIMFD	SEM[b]
Body weight, lb				
Day 0	951.5	955.0	951.3	2.0
Day 23	1055.6[d]	1061.1[d]	1032.9[e]	5.7
Day 82[d]	1229.8	1231.6	1236.0	7.5
Daily gain, lb/day				
Days 0-23	4.51[d]	4.60[d]	3.54[e]	.22
Days 23-82	2.95[d]	2.88[d]	3.63[e]	.11
Days 0-82	3.39	3.37	3.45	.09
Dry matter intake, lb/day				
Days 0-23	21.12[d]	21.10[d]	18.57[e]	.29
Days 23-82	23.34[d]	24.16[ed]	25.10[e]	.48
Days 0-82	21.52	21.93	22.00	.35
Feed:gain				
Days 0-23	4.76	4.72	5.33	.25
Days 24-82	8.02[ed]	8.43[d]	7.35[e]	.26
Days 0-82	6.38	6.50	6.41	.13
Water intake, gal/day				
Days 0-23	8.77	8.85	7.28	.45
Days 23-82	10.87	11.51	9.28	.18
Days 0-82	10.41	10.89	8.61	.23

[a]ADLIB = cattle were allowed access to feed at all times; BKMGT = cattle were fed at 1600 hr with bunks slick at 0800 hr the following day; LIMFD = cattle were fed 85% of their predicted dry matter intake at 1600 hr
[b]Standard error of mean
[c]Day 82 body weight x .96
[de]Values within a row with different superscripts differ (P < .05)

grade were obtained.

An automated weather station, located in the center of the facility, compiled minute by minute monitoring of temperature (Ta), relative humidity (RH), black globe temperature (BGT), wind speed and wind direction into hourly observations. Temperature humidity and black globe-humidity indices (THI and BGTHI, respectively) were calculated hourly using the weather station data to characterize the climatic heat load experienced by the animals. The THI equation is defined as:

$$THI = Ta - (.55 - (.55 * (RH/100))) * (Ta - 58)$$

The BGTHI is determined by substituting BGT for Ta in the equation. Black globe is more comprehensive in its evaluation of weather conditions because it incorporates the effects of wind speed and solar radiation along with temperature.

Behavioral observations were made at 0900, 1300, 1700 and 2100 hr on various days throughout the trial and included assessments of panting and feed available in the bunk. Panting scores were assigned to each animal and consisted of the following: 0 = normal breathing; 1 = slightly elevated respiration rate; and 2 = excessive panting accompanied by salivation. Bunk scores were assigned on a pen basis and consisted of the following: 0 ≤ 10% of the days feed amount left in bunk; 1 = 10 – 50% of the days feed remaining; and 2 ≥ 50% of the days feed remaining in the bunk. Upon termination of the trial, data were grouped according to climatic conditions (thermoneutral vs. hot) and feeding phase (managed vs. *ad libitum*). This resulted in five distinct periods consisting of: 1) MTNL 1; thermoneutral conditions (THI < 74) during the managed feeding period, days 9 and 13; 2) MHOT 1; hot environmental conditions (THI > 75) during the managed feeding period, days 11 and 12; 3) MTNL 2; thermoneutral conditions (THI < 74) during the managed feeding period, days 14 and 15; 4) MHOT 2; a second episode of hot environmental conditions (THI > 75) during the managed feeding period, days 21 and 22; and 5) AHOT; hot environmental conditions (THI > 75) during the *ad libitum* period (days 35 and 36)

Tympanic temperature (TT), an indicator of body temperature, was determined using 24 animals on days 9 - 22 (managed feeding) and 35 – 41 (*ad libitum*). The same animals were used during each period. Within each pen, loggers were placed in one white and one black animal in order to determine if coat color contributes to heat stress. Temperatures were collected hourly via thermistor leads placed in the ear canal at an approximate depth of 6". At this depth the lead was very near the tympanic membrane of the steers. Thermistor leads were attached to Stowaway® XTI data loggers which were secured in the ear using padded gauze. Data were grouped into three-day periods, which overlapped the two-day MHOT 1, MTNL 2, MHOT 2 and AHOT behavioral periods.

Performance and carcass data were analyzed using GLM procedures of SAS with treatment (TRT) and replication included in the model while behavioral assessments were analyzed by Chi-square analysis. Tympanic temperatures were analyzed using repeated measures ANOVA within TRT, animal, coat color and animal(TRT) in the model.

Results

Performance of the steers during the trial is presented in Table 1. Limit-fed steers had lower (P < .05) BW, DMI, and ADG than BKMGT and ADLIB steers during the managed feeding period (days 0-23). Following *ad libitum* feeding of all cattle, LIMFD steers compensated for their reduced growth during the managed feeding period with 26.0 and 23.1% higher (P < .05) ADG than both ADLIB and BKMGT steers, respectively, and 7.5% higher (P < .05) DMI than ADLIB steers. Limit-fed cattle were 14.7% more efficient following ad libitum feeding than BKMGT steers and tended (P < .10) to be more efficient than ADLIB. Results such as these are common in programmed gain and limit-feeding studies. When overall performance is compared, TRT differences were not significant, suggesting altering feeding regimen for 23 days early in the finishing phase does not impact performance. It is noteworthy that LIMFD cattle tended (P < .10) to consume less water following the managed feeding period than ADLIB and BKMGT steers. The reduction also tended (P < .10) to influence overall water intake in the same

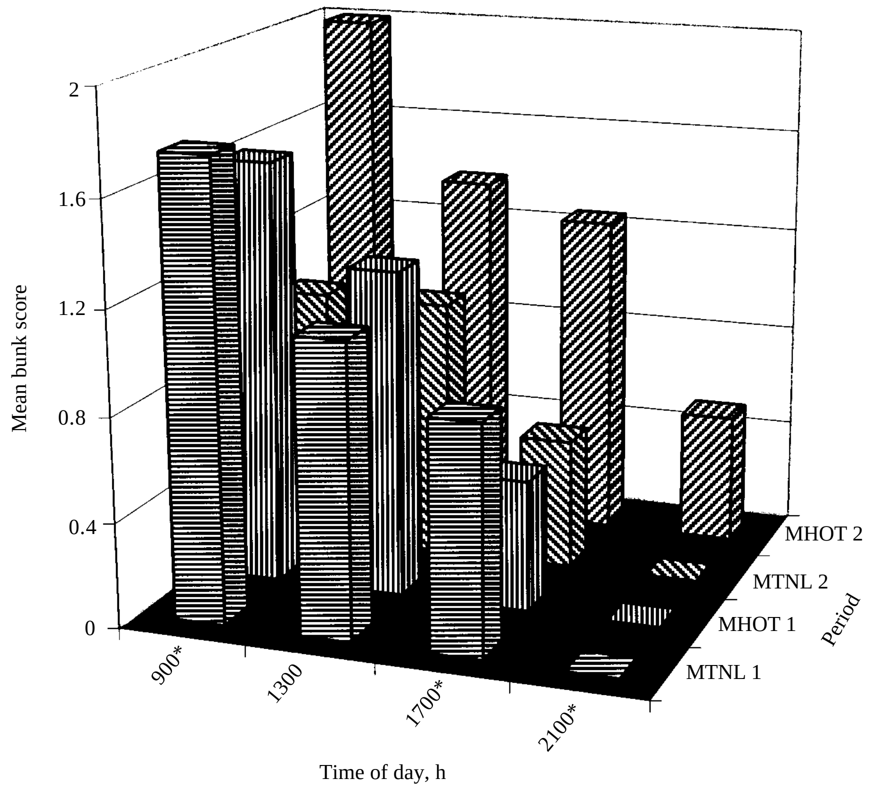

Figure 1. Effect of ad libitum on bunkscores during varying environmental conditions. MTNL 1 = Thermoneutral conditions (days 9 and 13); MHOT 1 = Hot environmental conditions (days 11 - 12); MTNL = Thermoneutral conditions (days 14 - 15); and MHOT 2 = Hot environmental conditions (days 21 - 22). *Bunk scores differ (Chi-square P-value < .05).

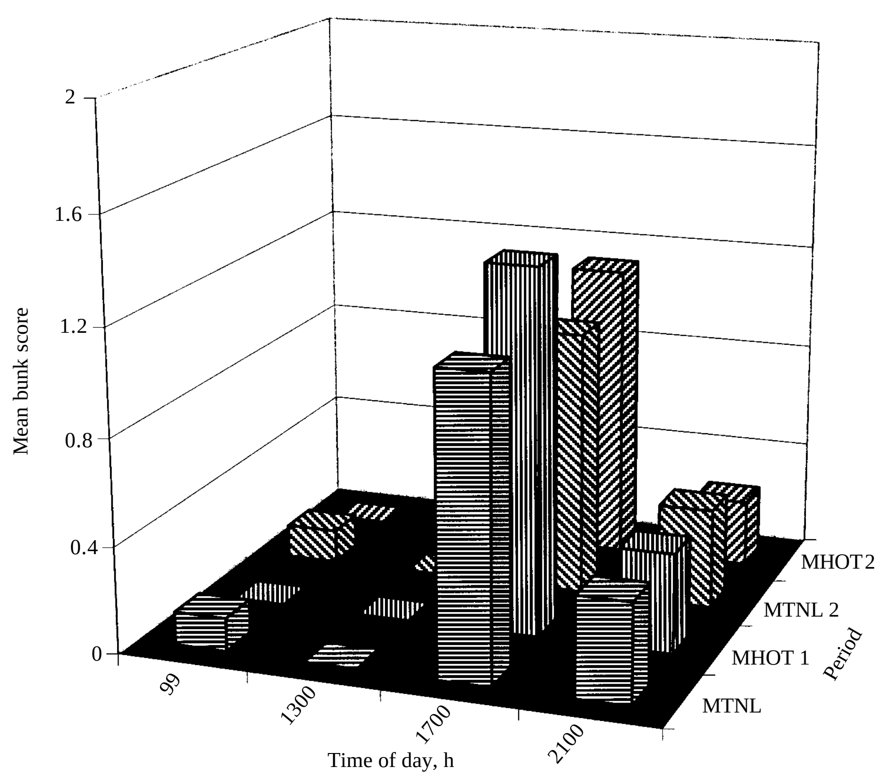

Figure 2. Effect of bunk management feeding on bunkscores during varying environmental conditions. MTNL 1 = Thermoneutral conditions (days 9 and 13); MHOT 1 = Hot environmental conditions (days 11 - 12); MTNL 2 = Thermoneutral conditions (days 14 - 15); and MHOT 2 = Hot environmental conditions (days 21 - 22).

manner. Carcass characteristics did not differ among TRT (data not shown).

Panting scores during TNL periods (MTNL 1 and 2) were not affected by TRT (data not shown). Panting scores were affected by TRT (P < .10) in MHOT 1 (data not shown). At 0900 hr, BKMGT steers had the highest (P < .10) panting score with LIMFD steers being intermediate (.10, .29, and .21 for ADLIB, BKMGT, and LIMFD, respectively). By 1300 hr no differences in panting scores among TRT were observed. However, by 1700 hr BKMGT and ADLIB steers had higher (P < .10) panting scores than LIMFD (.85, .88, and .71 for ADLIB, BKMGT, and LIMFD, respectively). The lower panting scores of LIMFD steers likely are a result of reduced metabolic heat production due to their reduced intake. During the MHOT 2 period, a similar trend in panting scores to MHOT 1 was observed.

Eating behavior of steers on different feeding regimens was characterized with bunk scores being grouped by treatment and analyzed across environmental period. It is generally assumed that cattle will eat a large meal after being fed and then continue to periodically consume smaller meals for the remainder of the day. Environmental conditions alter the feeding patterns of steers such that on hot days, steers will tend to not consume as much feed. At 0900 hr, ADLIB steers had similar bunk scores during the MTNL 1 and MHOT 1 periods (Figure 1). These cattle became more aggressive eaters during MTNL 2 as exemplified by their considerably lower bunk scores at 0900 hr. However, when ambient temperature was elevated a second time (MHOT 2), the steers altered their eating pattern such that they consumed little or no feed at 0900 hr. This shift in intake pattern of these steers during this period resulted in higher bunk scores at 1700 and 2100 hr.

Scores for BKMGT steers are presented in Figure 2. By design, BKMGT steers had no feed in their bunks at the time of the 0900 and 1300 hr observations. Unlike ADLIB steers, steers in this TRT showed no alteration in feed intake pattern associated with environ-

(Continued on next page)

mental period. Although bunk scores during MHOT 1 and 2 were numerically higher than the TNL periods, differences were not significant (P > .05). This consistent eating pattern suggests that feeding at 1600 hr allowed cattle to maintain a uniform eating pattern under varying environmental conditions. A consistent eating pattern is very important in preventing metabolic disorders sometimes associated with heat stress.

Similar to BKMGT steers, LIMFD steers had no feed at the 0900 and 1300 hr observations (Figure 3). At 1700 hr there was a significant (P < .05) change in bunk scores across environmental period. During MTNL 1, steers consumed a good proportion of their feed within the first hour (1600 – 1700 hr). However, their intake was slowed somewhat during this same time period of MHOT 1. This is likely due to the fact that these animals had already experienced the hottest part of the day and were reluctant to eat a large meal. This, however, was not the case in the MHOT 2 period. In this period, LIMFD steers ate all of their feed within a one-hour period. This aggressive eating behavior occurred despite elevated Ta associated with this period, possibly due to a reduction in the metabolic rate and heat load. Decreases in metabolic rate have routinely been shown in animals experiencing nutritional restriction.

Mean tympanic temperatures of the steers during managed and ad libitum feeding periods are presented in Table 2. There were no TRT effects during MHOT 1. Coat color was significant during this time with black-haired steers having higher (P < .05) TT. By the MTNL 2 period, differences among TRT were significant (P < .05). During this period, BKMGT cattle had lower (P < .05) TT than both ADLIB and LIMFD steers. The lack of a TRT by hour interaction (P > .10) suggests that time of peak heat load was not altered by varying feeding time. However, the magnitude of the peak was lower in BKMGT cattle possibly due to the fact that peak metabolic heat load did not coincide with peak environmental temperature. During MTNL 2 a coat color by time interaction (P < .05) was observed with white-haired steers

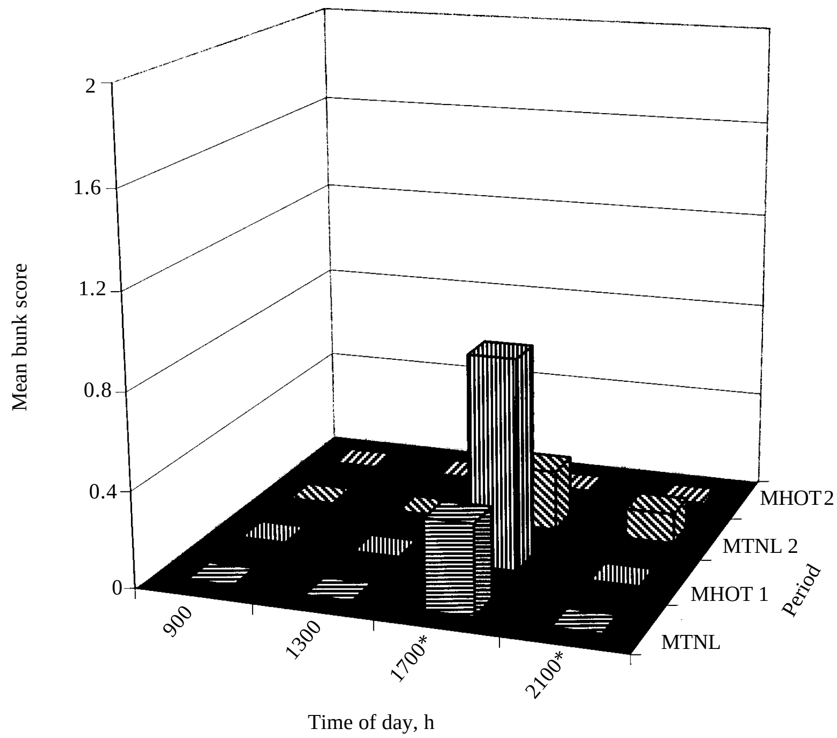

Figure 3. Effect of limit feeding on bunkscores during varying environmental conditions. MTNL 1 = Thermoneutral conditions (days 9 and 13); MHOT 1 = Hot environmental conditions (days 11 - 12); MTNL 2 = Thermoneutral conditions (days 14 - 15); and MHOT 2 = Hot environmental conditions (days 21 - 22). *Bunk scores differ (Chi-square P-value < .05).

Table 2. Main effect means of tympanic temperature for feeding regime (top table) and coat color (bottom table) of yearling feedlot steers under varying environmental conditions.

	Treatments[a]			
Period	ADLIB	BKMGT	LIMFD	SEMc
MHOT 1	101.8	101.9	101.8	< .1
MTNL 2	102.1[d]	101.7[e]	102.0[d]	< .1
MHOT 2	102.6[d]	102.2[e]	101.7[f]	.1
AHOT[g]	103.6[d]	102.8[e]	102.0[f]	.1

	Coat color		
Period	Black	White	SEM[c]
MHOT 1	102.0[d]	101.7[e]	< .1
MTNL 2[g]	101.9	101.9	< .1
MHOT 2	102.4[d]	102.0[e]	< .1
AHOT	103.0[d]	102.6[e]	.1

[a]MHOT 1 = Hot environmental conditions (temperature-humidity index; THI > 74) during managed feeding (days 0 – 23), MTNL 2 = thermoneutral conditions (THI < 74) during managed feeding, MHOT 2 = a second episode of hot environmental conditions during managed feeding, AHOT = hot environmental conditions during *ad libitum* feeding (days 23 – 82).
[b]ADLIB = ad libitum feeding at 0800 h, BKMGT = fed at 1600 h with bunks slick by 0800 the following day, LIMFD = fed 85% of predicted dry matter intake at 1600 h.
[c]Standard error of the mean
[def]Means within a row differ (P < .05)
[g]Main effect interaction with time (P < .05)

having lower TT at 1800 (104.4 vs. 103.8,°F) and 1900 (104.5 vs. 103.7,°F) hr. The timing of these differences corresponds to the two to three hour lag typically associated with body temperature in relation to Ta. The higher TT for black-haired steers than for white-haired steers is an indication of the effects solar radiation has on TT. Under peak climatic heat load, maximum TT differences between white and black coat colored steers ranged from .2 to .8°F. Differences in TT due to hair color may be confounded with breed of the

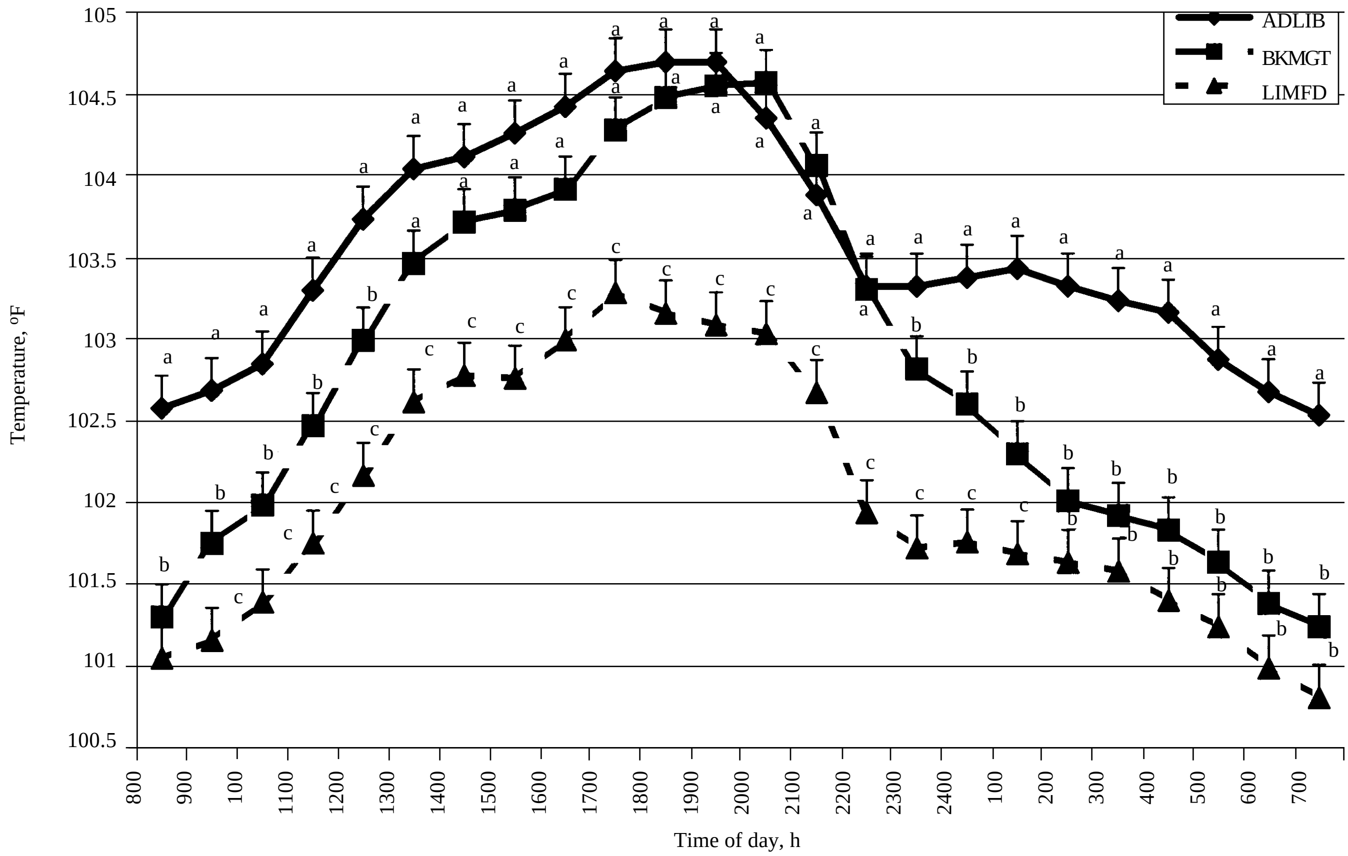

Figure 4. Effect of feeding regimen on tympanic temperature of yearling feedlot cattle during hot (temperature-humidity index > 74) environmental conditions during ad libitum feeding (days 36 - 38). [abc]Values within a time differ (P < .05).

animals. However, there is no evidence to suggest that TT of *Bos taurus* steers is affected solely by breed. Furthermore, the group was of similar genetic composition.

The lowered TT of LIMFD steers during the MHOT 2 period was likely due to decreased metabolic rate that often accompanies prolonged feed restriction. The lack of TRT differences in these animals earlier in the feeding period (MHOT 1; days 10 – 12 and MTNL 2; days 13 - 15) suggests decreased TT in response to limit-feeding is not instantaneous. Although, coat color affected TT during the MHOT 2 period with black-haired steers having higher (P < .05) TT than white-haired steers.

When all steers were placed on ad libitum feeding at 0800 hr, carryover effects of TRT were evident. A TRT by time interaction was noted for TT during the AHOT period (days 34 - 36; Figure 4). Limit-fed steers had lower (P < .05) TT than ADLIB steers at all times measured with BKMGT cattle being intermediate. Bunk management steers were lower than ADLIB steers from 2300 – 1200 hr. The reduced TT of LIMFD steers following ad libitum feeding is an important finding and suggest benefits of limit-feeding cattle during period of potential heat stress are not restricted to only the time in which the cattle are limit-fed. Reductions in the TT of BKMGT relative to ADLIB steers may partially be attributed to lower DMI during the days which TT were recorded (18.14, 17.45, 18.72 lb/day for ADLIB, BKMGT, and LIMFD, respectively).

Altering the feeding regimen of feedlot steers during the summer is a management strategy available to producers to mitigate adverse effects high summer temperatures have on performance. These changes may alter tympanic temperature and eating pattern without compromising overall performance. If limit-feeding is chosen as a means to reduce overall heat load of feedlot steers, it should be initiated for at least two weeks before potentially hot weather and, based on these results, may by stopped approximately two weeks prior to the last threat of heat stress. Bunk management strategies, such as the one employed in this study, appear to have more immediate effects on reducing body temperature.

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Restricted Feeding Strategies for Reducing Heat Load of Yearling Steers

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Tony Scott
Shane Davis[1]

Restricting intake in feedlot cattle lowered body temperature during the summer.

Summary

Eighty-four ***Bos taurus*** *crossbred steers were used to investigate effects of level and duration of limit feeding feedlot cattle in a hot environment. Restricting feed intake to 70 to 80% of ad libitum for 21 days duration (RES21) or for 42 days duration (RES42) reduced tympanic temperature in both RES21 and RES42 when compared with ad libitum treatment groups under both thermoneutral and hot conditions. Temperature reduction approached 1.5 F⁰ depending on time of day. Limit feeding feedlot cattle during early summer is a successful tool for enhancing animal comfort by alleviating the combined effects of high temperatures and relative humidities.*

Introduction

Estimated economic losses to heat stress in Nebraska alone exceeded $20 million in 1999 due to reduced performance and cattle death. A major source of economic loss to heat stress is the reduction in feed intake, though the response is variable and dependent on the animal's thermal susceptibility, acclimation and diet. However, a managed or controlled reduction in feed intake to lessen heat stress may not cause an economic loss. In some situations feed restriction increases feed efficiency in ruminants, possibly by lowering maintenance energy expenditure and increasing diet digestibility. A further effect of feed restriction is a possible change in diurnal range of internal body temperature. Our study was undertaken to investigate effects of level and duration of restricted feeding of feedlot cattle in a hot environment on growth, feed efficiency and metabolic response. In addition, ad libitum feeding of a high-energy, high fiber diet, containing corn gluten feed (CGF), was compared to ad libitum feeding of a traditional dry rolled corn (DRC) based diet during the summer.

Procedure

As a part of a previously reported study (2000 Nebraska Beef Report, pp 41-43), 84 *Bos taurus* crossbred steers were used in a 63-day study, beginning June 24, 1998, to assess body temperature and behavior pattern of feedlot cattle. Steers were blocked by weight. Within a block, steers of similar color were randomly assigned to each pen to ensure a similar number of red, white and black coated cattle were equally distributed within each pen. Pens of steers were then randomly assigned to treatments. Treatments were: 1) CGF-based ration restricted to 70 to 80% of ad libitum for 21 days duration (RES21), 2) CGF-based ration restricted to 70 to 80% of ad libitum for 42 days duration (RES42), 3) CGF-based ration fed ad libitum (CGFAD), and 4) DRC-based ration fed ad libitum (DRCAD). Cattle on RES21 and RES42 treatment groups were stepped up over four to six days to ad libitum following the 21- and 42-day restriction. Daily dry matter intake of steers on CGFAD and DRCAD was projected using computer software (NRC, 1996), based upon breed type, age, body

Table 1. Composition (DM basis) of corn gluten feed (CGF) and dry rolled corn (DRC) based diets.

Item	CGF	DRC
Ingredient, %		
Corn silage	8	10
CGF	40	0
DRC	49	79
Soybean meal	0	4.5
Liquid supplement	0	4.5
Dry supplement	3	2
Chemical		
Crude protein, %	13.5	13.5
NDF, %	22.2	11.8
Dry matter, %	65.7	72.3
NEm Mcal/cwt	97.6	96.3
NEg, Mcal/cwt	67.0	66.0

Table 2. Dry matter intake, lb/day for each period and over the entire study.

	Treatment[a]			
	RES21	RES42	CGFAD	DRCAD
Period 1 (day 1-21)	18.6[b]	18.5[b]	24.5[d]	20.6[c]
Period 2 (day 22-42)	23.8[c]	18.7[b]	24.9[d]	26.1[e]
Period 3 (day 43-63)	26.0[c]	24.7[b]	26.7[c,d]	27.2[d]
Overall (day 1-63)	22.8[c]	20.7[b]	25.4[d]	24.7[d]

[a]RES21 & RES42 = restricted fed corn gluten feed based diet (CGF) for 21 and 42 days, respectively. CGFAD & DRCAD = ad libitum fed CGF and dry rolled corn based diet (DRC), respectively.
[b,c,d,e]Means within a row with different superscripts are different ($P < .05$).

Table 3. Mean tympanic temperature (TT) of feedlot cattle fed under hot climatic conditions[a]

	Treatment[a]			
	RES21	RES42	CGFAD	DRCAD
Day 1-21	102.7[c]	102.6[c]	103.2[d]	103.3[d]
Day 22-42	102.8[d]	102.2[c]	102.8[d]	103.0[e]
Day 43-63	102.0[d]	102.5[e]	102.1[d]	101.7[c]
Overall (day 1-63)	102.5[c]	102.5[c]	102.8[d]	102.9[d]

[a]Climatic conditions where mean daily THI was equal to or greater than 74.
[b]RES21 and RES42 = restricted fed corn gluten feed based diet (CGF) for 21 and 42 days, respectively. CGFAD and DRCAD = ad libitum fed CGF and dry rolled corn based diet (DRC), respectively.
[c,d,e]Means within a row with different superscripts are different ($P < .05$).

condition and frame size. The DMI of RES21 and RES42 were adjusted accordingly from the projected amount. Diets (Table 1) were formulated to contain a minimum of 13.5% CP, .63% Ca, .35% P, and .65% K, and contained 25g/ton Rumensin and 10 g/ton Tylan (DM basis). Steers were implanted with Revalor-S® at the beginning of the trial. All steers were fed in the morning at approximately 0800.

Steers were weighed at approximately 0800 on two consecutive days (d -1 and 0), prior to the start of the trial, to obtain an average starting weight. Steers were then weighed on days 21, 42, and 63.

Temperature (T_a °F), relative humidity (RH, %), and other climatic data were collected hourly throughout the study via a weather station located at the feedlot facilities. The primary indicator of heat load was temperature-humidity index (THI); $THI=T_a - (.55-.55(RH/100)) \times (T_a - 58)$.

During each of the three 21-day periods, thermistors were inserted into an ear canal of a total of 12 steers (two/ad libitum groups and four/limit-fed groups) within each treatment for approximately a seven-day period to obtain tympanic temperature (TT) on an hourly basis. Steers were selected based on coat color and weight in an attempt to compare similar steers among treatments. Thermistor leads were placed into the ear canal, close to the tympanic membrane, to an approximate depth of five inches. Data loggers (Onset Data Loggers, Pocassatt, MA.) were then connected to the thermistor, wrapped with padded gauze, placed on the inside of the ear and secured to the ear.

Within each period, behavior data (panting and bunching) were obtained during thermoneutral (TNL) days (THI less than 74) and hot (HOT) days (THI equal to or greater than 74) at 1600. Panting score was obtained by visual assessment of flank movements and overall breathing in individual steers. A score of 1 indicated little or no panting and 2 indicated moderate to excessive panting with mouth opened and/or salivation occurring. At the same time, a bunching score was assigned. This measure indicates the proximity of each animal to its nearest neighbor (within a pen), where 1 indicates animals are bunched (any part of one animal within 3 feet of the midline of any other animal, with midline determined from shoulders to tailhead) and 2 indicates animals are separated from others.

Results

For the study's duration, THI averaged 71.5 and ranged from a daily average of 64.2 to 79.4. Mean daily ambient temperature for the entire study was 73.4 °F with an average daily low and high of 65.0 and 83.4 °F, respectively, while relative humidity ranged from 60% to 98% with a mean of 83.6%.

By design, differences in DMI were found among treatments ($P < .05$) during restricted feeding periods (Table 2). These differences tended to be carried over into subsequent periods, in which cattle previously restricted in DMI also had significantly lower DMI during the period following restriction.

Differences in tympanic temperature (TT) were found among treatments within periods ($P < .05$; Table 3). Restricting DMI reduced TT .6 to .8 °F when compared to ad libitum fed cattle. On the average, cattle fed ad libitum diets (CGFAD vs DRCAD) had equal TT, even though the CGFAD treatment group consumed a slightly greater quantity of feed. The greatest environmental challenge was experienced in period 2 (day 22 to 42), in which both maximum ambient temperature and maximum THI were obtained. During this period the cattle remaining on the restricted DMI diet (RES42) had the lowest overall TT. The greatest differences in TT, between this group and the other treatment groups, began to occur between 1600 and 1700 hr. The TT in the RES42 group remained 1.0 to 2.0°F below the TT of cattle in the other groups, throughout the nighttime hours (Figure 1). On the average, TT of the other groups began to decline approximately four hours later than TT of the RES42 cattle group.

Within respective periods, no differences ($P > .05$) were found among treatments for panting or bunching score in either thermoneutral (TNL) or hot (HOT) climatic conditions. However, within treatments, different proportions of cattle were bunched and panting (Table 4). This is particularly evident in periods 2 and 3, in which cattle assigned to the CGFAD treatment had the greatest percentage of cattle bunched and a greater percentage of cattle panting. In general,

(Continued on next page)

Figure 1. Hourly tympanic temperature (TT) of cattle fed various diets from day 21 to day 42.

Table 4. Chi square analysis of percentage of cattle panting and bunching by treatment and period.

	Panting score[a] (period 1)			Panting score[a] (period 2)			Panting score[a] (period 3)		
Item	1	2	P value	1	2	P value	1	2	P value
RES21									
Bunching score[b]									
1	84	79.17		74.45	85.27		80.95	92.38	
2	16	20.83	.38	25.55	14.73	.028	19.05	7.62	.03
RES42									
Bunching score[b]									
1	79.05	85.71		77.93	90.08		80.88	90	
2	20.95	14.29	.22	22.07	9.92	.008	19.12	10	.092
CGFAD									
Bunching score[b]									
1	83.33	73.21		84.72	94.12		86.84	98.28	
2	16.67	26.79	.24	15.28	5.88	.07	13.16	1.72	.024
DRCAD									
Bunching score[b]									
1	83.33	86.84		85.51	89.47		83.87	95.12	
2	16.67	13.16	.7	14.49	10.53	.5	16.13	4.88	.11

[a]Panting score 1 = % of cattle showing little or no panting, 2 = % of cattle showing moderate to excessive panting.
[b]Bunching score 1 = % of cattle bunched together, 2 = % of cattle not bunched.

cattle that are panting tend to display a greater level of bunching. Bunching is often observed with cattle under heat stress and possibly contributes to added heat load by diminishing air flow.

Coat color (black or white) was found to have significant ($P < .01$; Table 5) effect on panting score. When averaged across diet treatments, black cattle had the greatest percentage of cattle showing moderate to excessive panting, while white cattle displayed the least panting under TNL climatic conditions. A similar pattern was seen under HOT climatic conditions. The percentage of cattle showing moderate to excessive panting increases approximately 30% from TNL to HOT conditions. Only when cattle were exposed to HOT climatic conditions did trends in bunching become apparent. Under HOT conditions, dark

Table 5. Chi square analysis of percentage of cattle panting and bunching by climatic conditions and coat color.

	Hide color		
Item	Black	White	*P* value
Thermoneutral conditions (THI < 74)			
Panting score[a]			
1	54.39	77.19	
2	45.61	22.81	< .01
Bunching score[b]			
1	78.72	78.36	
2	21.28	21.64	.95
Hot conditions (THI 74)			
Panting score			
1	27.64	48.29	
2	72.36	51.71	< .01
Bunching score			
1	90.7	85.04	
2	9.3	14.96	.073

[a]Panting score 1 = % of cattle showing little or no panting, 2 = % of cattle showing moderate to excessive panting.
[b]Bunching score 1 = % of cattle bunched together, 2 = % of cattle not bunched.

cattle bunched more (*P* < .08) than white cattle. Since cattle of different coat colors were in the same pens, it would appear that the white cattle tend to stay away from the dark cattle. Whether they are not bunching because they are cooler, having fewer problem with flies than black cattle, or sense heat coming from the black animals, is not known. Although not shown, observed effects of coat color on bunching tended to diminish over time, particularly from period 2 (*P* < .03) to period 3 (*P* < .14). Thus, the percentage of white animals bunching appears to increase over time, as body condition and days of feed increase. These data suggest that as white cattle get fatter, they tend to behave more like the black cattle under hot conditions.

Under hot environmental conditions, heat loads can be reduced by restricted feeding which is beneficial in protecting cattle from the effects of hot, humid conditions. However, the preferred length of time to limit-feed, prior to a heat episode, is still in question. Immediate benefits to restricting DMI occur by reducing metabolic heat load, however, additional benefits likely occur, longer term, in which metabolic rate and associated heat production are reduced.

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Managing Heat Stress in Feedlot Cattle Using Sprinklers

Shane Davis
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Wanda Cerkoney[1]

Water application to feedlot mounds lowers body temperature of steers without adversely affecting mound microclimate.

Summary

Ninety-six Bos taurus steers were used to determine the effect of water application to feedlot mounds on performance, behavior and tympanic temperature of steers and microclimatic conditions of the mounds. Steers were assigned to 12 pens subjected to no water application (CON), water applied between 1000 and 1200 (AM), or 1400 and 1600 hr (PM). Water application lowered soil temperatures of the mounds with little effect on temperature-humidity index. Tympanic temperatures were lowered by treatment. Performance variables were not affected; however, AM steers were more efficient than PM steers.

Introduction

Reductions in performance of feedlot cattle during summer months can be in large part due to elevated ambient air temperature. These detrimental effects may be further compounded when elevated ambient temperature is coupled with high humidity, low wind speed and/or solar radiation. When these adverse weather parameters exist, the gradient by which heat is transferred from the animal to the environment is reduced and in extreme situations may actually be reversed so that the animal is gaining heat.

Management strategies such as altering metabolizable energy intake and providing shade structures for the animals to reduce heat stress have been explored and are viable options to beef producers. Use of sprinklers to apply water to the cattle and mound in the pen is another option. While sprinkling systems have been extensively used and researched in dairy, poultry and swine operations, few studies exist examining their effect on feedlot animals in the High Plains. Therefore, the objective of this study was to determine the effects of water application to feedlot mounds

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during the summer on performance and behavior of feedlot steers. Changes in tympanic temperatures of the animals and microclimatic conditions of the mounds during water application were examined.

Procedure

Ninety-six *Bos taurus*, (predominantly Angus and Angus x Hereford) yearling steers were used for this study. Upon initiation of the trial (June 23, 1999) steers were implanted with Synovex-Plus® and weighed with the average body weight on two consecutive days used as initial weight of the steers. Steers were allotted to one of 12 pens based on initial weight and allowed *ad libitum* access to a 65 Mcal NEg/cwt finishing diet which contained (DM basis): 84% dry rolled corn, 7.5% alfalfa hay, 2% soybean meal, 2% dry supplement, 4.5% liquid supplement. Four replicates were assigned to each of three treatments (TRT); 1) control; 2) water applied to mounds between 1000-1200 hr (AM); and 3) water applied to mounds between 1400-1600 hr (PM). Water was applied to the AM and PM mounds using Rainbird Pop-Up Sprinklers® when predicted mean daily temperature-humidity index was > 74. This resulted in water being applied on 23 days of the 82-day study. Water flow was controlled using manual valves and a water flow meter so as to supply 9 gal/hd/day. A semi-circular area was wetted to provide 26 ft^2 of wetted surface per animal. Time of water application was controlled using a two-cycle automatic valve.

Daily feed and water intakes were recorded. Body weights were obtained on day 34 and at the termination of the trial (day 82; Sept. 13, 1999). On day 83 steers were transported to a commercial slaughter facility. Hot carcass weight, fat thickness, marbling score and yield grade were obtained.

An automated weather station in the center of the facility compiled minute by minute monitoring of temperature (Ta), relative humidity (RH), black globe temperature (BGT), wind speed and wind direction into hourly observations. Temperature humidity and black globe-humidity indices (THI and BGTHI, respectively) were calculated hourly and averaged daily using the weather station data. The THI equation is defined as:

$$THI = Ta - (.55 - (.55 * (RH / 100)) * (Ta - 58)$$

The BGTHI is determined by substituting BGT for Ta in the equation. Black globe is more comprehensive in its evaluation of weather conditions because it incorporates the effects of wind speed and solar radiation along with temperature and humidity.

Climatic conditions of the mounds were recorded on days 30 through 33 using HOBO Pro data loggers. Loggers placed at heights of 6" and 42" on fence posts bisecting the mounds lengthwise recorded Ta and RH every fifteen minutes. For analytical purposes, readings at 0700 – 0800, 0930 – 1030, 1200 – 1300, 1430 – 1530, 1700 – 1800, and 1930 – 2030 hr were averaged to provide six observations per day. Radiation shields were positioned around the loggers to prevent exposure to direct sunlight and contact with water during sprinkling. Wire cages were positioned around the shields to prevent animal tampering. Soil temperatures of the mounds were measured using loggers placed at a height of 24 inches and equipped with a temperature probe. The probe was inserted into the soil at a depth of .5" to monitor soil temperature; additionally the logger collected Ta at 24 inches. After analysis, there was no difference between Ta at 24 inches and 42 inches, thus the 24 inches Ta are not shown. Temperature humidity index was calculated using measurements of 6 and 42 inches.

Tympanic temperature (TT), an indicator of body temperature, was determined on 2 animals/rep/TRT (8 animals/treatment) on days 30 through 33. Temperatures were collected hourly via thermistor leads placed in the ear canal at an approximate depth of 6". At this depth the lead was very near the tympanic membrane of the steers. Thermistor leads were attached to data loggers which were secured in the ear.

Behavioral observations were made at 0900, 1300, 1700, and 2100 during three periods of hot environmental conditions accompanied by water application to mounds. These periods were classified according to the time of the trial that they occurred and their mean daily THI and BGTHI. The periods were: 1) Early Hot (days 11 –12; THI = 77, BGTHI = 81); 2) Late Hot (days 21 – 22;

Table 1. Effect of morning and evening mound wetting on feedlot performance of yearling steers.

	Treatments[a]				Contrast P-values[b]	
Item	CON	AM	PM	SEM[c]	CON vs TRT	AM vs PM
Body weight, lb						
Day 0	1049	1047	1049	2.4	.26	.42
Day 34	1170	1173	1166	6.8	1.0	.53
Day 82[d]	1333	1351	1327	10.3	.75	.16
Dry matter intake, lb/day						
Day 0-34	21.67	22.29	22.04	.20	.30	.65
Day 34-82	24.71	25.34	25.39	.44	.26	.97
Day 0-82	23.74	24.38	24.29	.37	.25	.89
Average daily gain, lb/day						
Day 0-34	3.50	3.72	3.45	.20	.77	.39
Day 34-82	3.43	3.70	3.34	.15	.64	.15
Day 0-82	3.45	3.70	3.39	.13	.61	.13
Feed:Gain						
Day 0-34	6.22	6.04	6.43	.31	.97	.41
Day 34-82	7.12	6.91	7.63	.22	.85	.06
Day 0-82	6.87	6.61	7.19	.17	.89	.06
Water intake, gal/day						
Day 0-34	9.96	10.13	9.34	.06	.08	.01
Day 34-81	10.06	9.97	10.61	.50	.72	.43
Day 0-81	10.14	10.16	10.21	.30	.90	.92

[a]CON = control; AM = water applied to mounds between 1000 – 1200 hr; PM = water applied to mounds between 1400 – 1600 hr.
[b]Single degree of freedom orthogonal contrasts of CON vs. mean of AM and PM, and AM vs. PM.
[c]Standard error of the mean.
[d]Day 82 live weight multiplied by .96%.

THI = 76, BGTHI = 80); 3) Very Hot (days 30 – 31; THI = 78, BGTHI = 85). The Very Hot period coincided with the heat wave that affected Nebraska in July 1999. Behavioral observations made during these times included assessments of panting, pen position of the animals, and feed available in the bunk. Panting scores were assigned to each animal and consisted of the following: 0 = normal breathing; 1 = slightly elevated respiration rate; and 2 = excessive panting accompanied by salivation. Bunk scores were assigned on a pen basis and consisted of: 0 = < 10% of the days feed amount left in bunk; 1 = 10 – 50% of the days feed remaining; 2 = > 50% of the days feed remaining in the bunk.

Performance and carcass data were analyzed using the GLM procedures of SAS (1986) with the model including the fixed effects of TRT and replicate. Single degree of freedom orthogonal contrasts were used to determine differences among treatments. The contrasts used were CON vs. AM and PM and AM vs. PM with a P-value < .10 being considered significant. Behavior data was analyzed using Chi-square test with a mean panting and bunk score determined for each treatment. Tympanic temperatures and climatic conditions of the mounds were analyzed using repeated measures.

Results

Overall performance during the trial was not affected by water application to the mounds (Table 1). However, feed conversion was improved (P < .10) for AM *vs.* PM from day 34 until the termination of the trial. This difference subsequently resulted in AM steers having improved (P < .10) feed conversions over the entire feeding period. Water intake was affected by TRT with AM steers consuming significantly more water from day 0 – 34 than PM steers. Carcass characteristics were not affected by TRT (data not shown).

Panting scores did not differ at any observation during Early Hot or Late Hot environmental periods (data not shown). Panting scores did not differ at 0900, 1300 or 2100 during the Very Hot period. However, at 1700, mean panting score for PM cattle was lower than CON with AM being intermediate. Scores were 1.92, 1.83, and 1.59 for CON, AM and PM, respectively.

Bunk scores were not affected by treatment during Early, Late or Very Hot environmental periods. Although not significant, there was a slight numeric trend for PM steers to have slightly lower bunk scores at 1300, 1700 and 2100, thus PM steers tended to consume more feed prior to these times during the Very Hot period.

A TRT by position by time interaction (P < .01) was found for mound temperatures, thus data were analyzed within position and time and are shown in Figures 1 and 2. Soil temperatures (Figure 1) of CON mounds were higher (P < .01) than AM and PM at all times and reached a maximum of 111.5 °F at 1500. Mounds wetted in the afternoon were cooler overnight than AM mounds as evidenced by their lower (P < .05) temperatures at 0730 (75.6 vs. 74.8 ± .2 °F). Temperatures of AM and PM mounds were similar at 1000 (avg. = 79.3 °F) and 1230 hr (avg. = 86.2); however, PM mounds were lower than AM at 1500, 1730, and 2000.

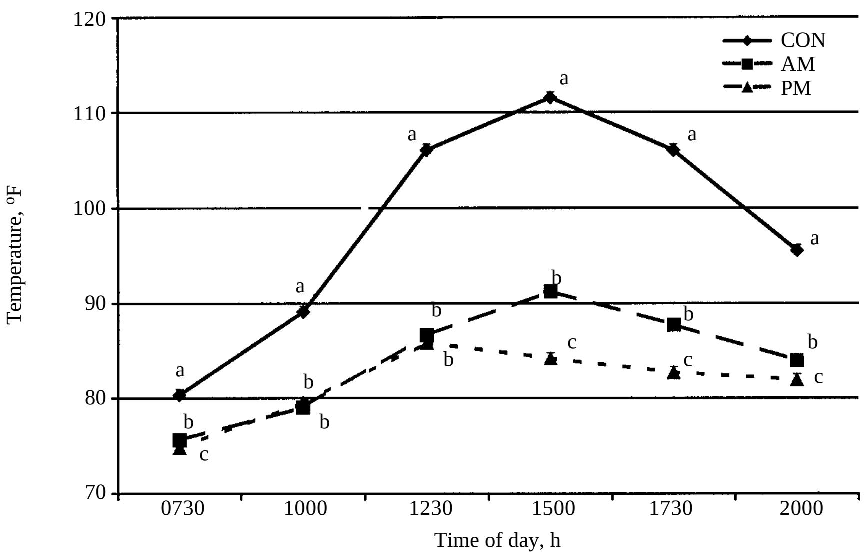

Figure 1. Effect of water application to feedlot mounds on soil temperature. [abc]Values within a time differ (P < .05).

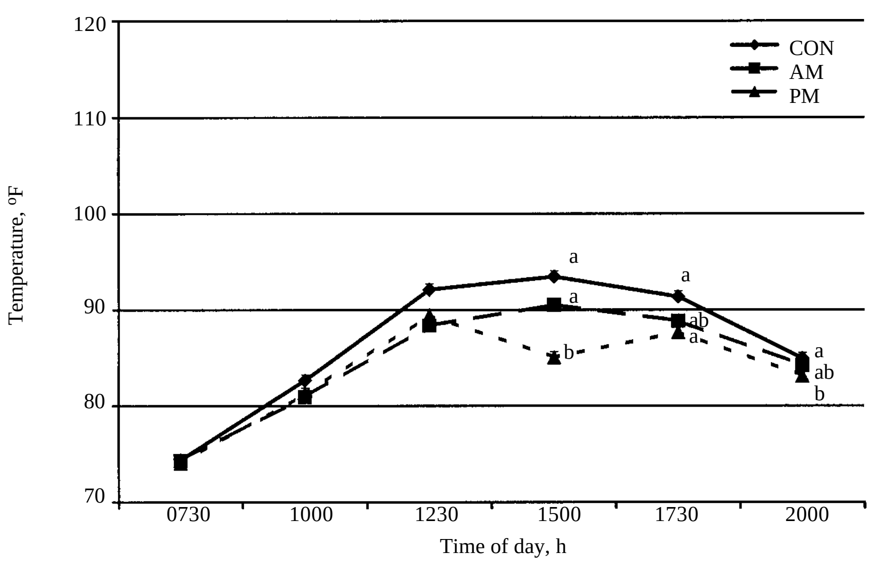

Figure 2. Effect of water application to feedlot mounds on ambient air temperature at a height of 42 inches. [ab]Values within a time differ (P < .05).

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Temperatures at 6" (data not shown) were similar across TRT at 0730, 1000 and 1230 and averaged 74.4 ± .2, 80.3 ± 1.0 , and 91.5 ± 2.4 °F, respectively. At 1500, PM mounds were lower than AM and CON and continued to be lower than CON at 1730 and 2000. Temperatures at 42 inches (Figure 2) followed a similar trend with no TRT effect at 0730, 1000, and 1230, but PM mounds were again lower than AM and CON at 1500 and continued to be lower than CON at 1730 and 2000 with AM being intermediate.

Relative humidities above the mounds (Figure 3) did not differ (P > .10) by position (height above mound), therefore position data were pooled. The TRT by time interaction was significant (P < .01), thus means within a time were compared as previously described for temperature. As expected, water application increased RH of the mounds. Treatment mounds had similar RH except at 1500 when PM mounds were higher (P < .05; 70.21 vs. 60.78). This increase in RH of the PM mounds is likely due to the time of measurement coinciding with sprinkling time. Although TRT and CON mounds were different at 2000, RH for all mounds was similar at 0730, suggesting that RH was similar during the overnight hours.

Temperature-humidity indices of the mounds at the various time points are presented in Figure 4. Like RH, position at which the reading was obtained was not significant, thus results were pooled for analysis. The TRT by time interaction was significant (P < .01), thus means within time are separated by least significant difference. The THI is derived from both ambient temperature and humidity and has been suggested to be more indicative of the actual heat loads the animal is experiencing as opposed to temperature or humidity alone. Temperature-humidity indices only differed between treatments at the 1500 and 1730 readings. At 1500, PM mounds, despite having significantly higher RH, had a lower THI than both CON and AM mounds (85.0, 84.12, and 81.26 for CON, AM, and PM respectively). At 1730, PM THI was still lower than CON with AM being intermediate (84.0, 83.2, and 82.2 for CON, AM, and PM, respectively).

Tympanic temperatures (TT) of the steers are presented in Figure 5. Treatment by time interaction was significant (P < .001). Steers in the AM treatment had lower (P < .05) TT than CON and PM cattle beginning at 2300 and lasting through 1000. Nighttime cooling of cattle is essential in the maintenance of homeothermy. Low TT may be indicative of a mechanism by which the heat capacity of animals is increased, thus enabling them to tolerate higher daytime temperatures. Control and PM cattle had similar TT except at 1700, when PM had lower (P < .05) TT than CON and AM steers. Overall TT were 103.2, 102.7 and 103.2 ± .2 °F for CON, AM, and PM steers, respectively. During the corresponding time period in which TT was measured, DMI for the TRT averaged 16.83, 16.07 and 17.56 ± .77 for CON, AM, and PM respectively. The lower DMI of the AM cattle may have contributed to their lower TT.

Application of water to feedlot mounds is a viable option to provide a cool area in a pen where cattle can seek

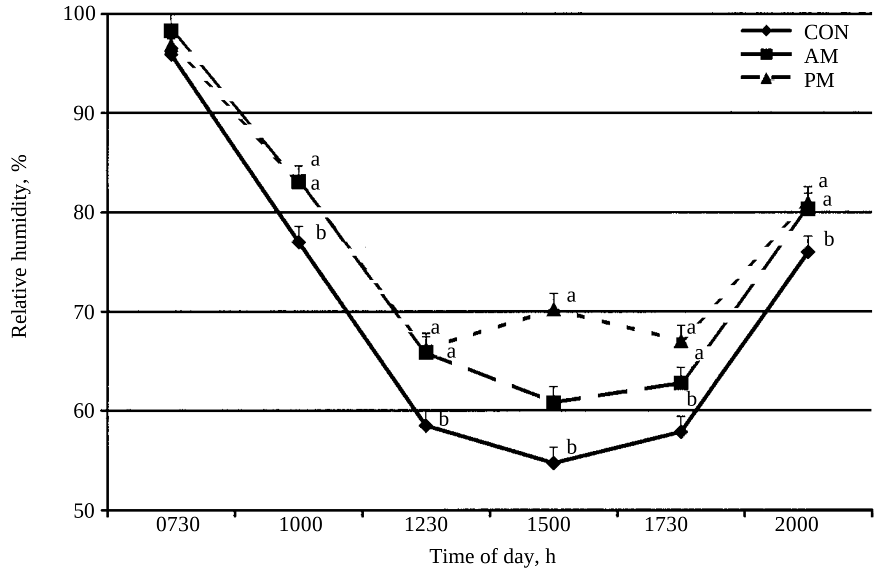

Figure 3. Effect of water application to feedlot mounds on mean relative humidity.[ab]Values within a time with different superscripts differ (P < .05).

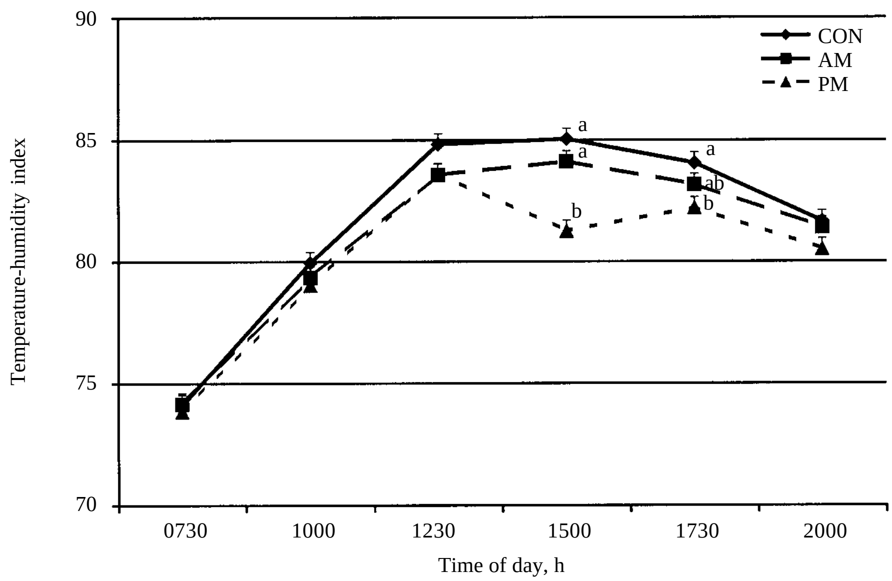

Figure 4. Effect of water application to feedlot mounds on mean temperature-humidity index. [ab]Values within a time with different superscripts differ (P < .05).

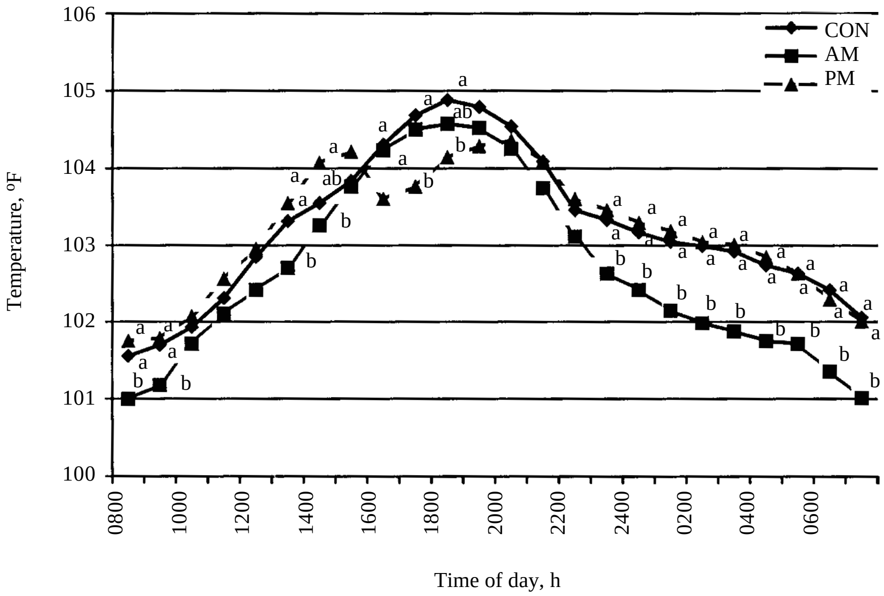

Figure 5. Effect of water application to feedlot mounds on tympanic temperature of steers. [ab]Values within a time with different superscripts differ ($P < .05$).

relief from heat stress conditions. Although RH over the mound is increased, the decrease in microclimate temperature associated with water application results in either no effect or a concomitant lowering of THI. The decrease in temperature is significant in allowing for a maximization of the heat gradient between animal and environment in order to allow greater heat dissipation. Our performance and TT data suggest preventing cattle from getting too hot during the day by providing external cooling in the morning is superior to providing external cooling in the afternoon. However, providing external cooling in the afternoon tended to enhance intake during very hot environmental conditions.

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The Relationship of the Characteristics of Feedlot Pens to the Percentage of Cattle Shedding *Escherichia coli* O157:H7 Within the Pen

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The food-borne pathogen *Escherichia coli* O157:H7 was commonly found in pens of feedlot cattle, and the percentage of cattle shedding the organism may have been influenced by the pen environment.

Summary

This study was designed to discover relationships between characteristics of feedlot pens and the percentage of cattle shedding Escherichia coli O157:H7. Twenty-nine pens from five Midwestern feedlots were each sampled once between June and September, 1999. Feces were collected from all cattle in each pen. E. coli O157:H7 was isolated from the feces of 714 of 3162 cattle tested (23%), including at least one animal from each of the 29 pens. Pen prevalence did not differ between feedyards, but did vary widely within feedyards. Muddy pens were more likely to have a higher pen prevalence than normal pens.

Introduction

Escherichia coli bacteria are commonly found as normal inhabitants of the intestinal tracts of humans and animals. Unfortunately, some strains including *E. coli* O157:H7, though generally harmless for cattle, carry traits that allow them to cause serious food-borne disease in humans.

Many segments of the food industry have adopted the principles of hazard-analysis-critical-control-points (HACCP) to minimize the likelihood that food will be contaminated with potentially dangerous pathogens. Unfortunately, there is insufficient knowledge of the epidemiology and

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ecology of *E. coli* O157:H7 to design and implement HACCP-based food safety programs in cattle feedyards.

Cattle in feedlots rarely are handled as individuals. Most conceivable control points for reducing human food-borne pathogens in feedlot cattle would be directed towards pens of cattle. Therefore, epidemiologic studies with the objective of identifying manageable factors (control points) to reduce human food-borne pathogens in the feedlot should relate the characteristics and pathogen status of managed groups of cattle (pens), rather than characteristics of cattle as individuals. The objective of this study was to describe the percentage of cattle shedding *E. coli* O157:H7 in feces within Midwestern feedlot pens and to identify potential risk factors for pen prevalence.

Procedure

Study design

The study design was cross-sectional observational at the level of the feedyard pen. The percentage of cattle within a pen shedding detectable levels of E. coli O157:H7 was described and compared to concurrent characteristics of the feedlot pen relating to the cattle and the pen environment. Approximately 30 g of feces was collected from the rectums of all cattle within each pen while they were restrained in a handling chute for routine management procedures (re-implanting). Concurrent samples were collected of water from water tanks, and partially consumed feed from feedbunks of the same pens. Concurrent information was collected about characteristics of the pen that may be risk factors for the prevalence of cattle shedding *E. coli* O157:H7. These factors included number of cattle, days on feed, average body weight, class and sex of cattle, culture results from water or feed, water-tank temperature and pH, and subjective assessments of pen condition and water-tank cleanliness.

Source of cattle

Five feedyards, typical of commercial feedlots in the region, were asked to voluntarily participate in the study. The one time cattle capacity in these feedyards ranged from 3,000 to 12,000 head; approximately 40,000 head collectively in pens of 50 to 300 head. Pens were open-dirt lots, maintained by scraping, typically once per month. The feedlots involved in this study fed primarily dry-rolled corn, high-moisture corn, wet corn gluten feed, wet distillers grains, alfalfa hay, corn silage, and other byproducts. Cattle pens were selected from the 5 commercial feedyards at the time of routine re-processing. Pens were bypassed, or pens with fewer cattle were chosen for sampling, during weeks when more pens were available than could be managed by the culturing capacity of the laboratories. Sampled pens ranged from 36 to 231 (median 107) cattle. At sampling, cattle had been in the feedyards 19 to 108 (median 51) days and the mean body weight per pen ranged from 764 to 1175 lbs (median 930 lbs).

Microbiology

Culture methods were specific to the type of sample but included selective enrichment and immunomagnetic separation. Isolates were confirmed by standard methods including PCR. Methods for recovery of *E. coli O157:H7* from feces were modifications of those recently reported (Laegreid et al., 1999. Epidemiol Infect. pp291-298).

Statistical methods

The dependent variable was the pen-prevalence of *E. coli* O157:H7 defined as the percentage of cattle within a pen from which the organism was isolated from feces. The correlation between the magnitude of pen-prevalence of *E. coli*

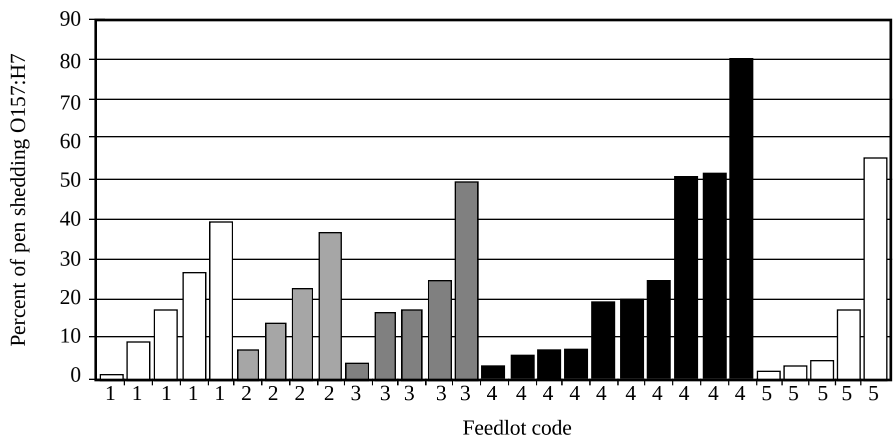

Figure 1. Percentage of cattle shedding detectable *Escherichia coli* O157:H7 in each of 29 pens of feedlot cattle in five Midwestern feedyards. Prevalence levels of fecal-shedding for individual pens are represented by bars arranged in order of increasing prevalence by feedyards of origin.

Table 1. Continuous or ordinal variables describing 29 feedlot pens from 5 Midwestern US feedyards and the correlation of the variable to the percentage of cattle within pens found shedding *Escherichia coli* O157:H7 in the feces.

Variable	Range of values (Median)	Spearman's rank correlation coefficient	P-value
Pen size	336-231 (107)	r = 0.08	0.67
Days in the feedyard	19-108 (51)	r = -0.21	0.28
Average body weight	764-1175 (930)	r = 0.00	1.00
Temperature of water in tank	53.7-67.5 (61.1)	r = -0.17	0.37
pH of water in tank	6.2-8.2 (7.2)	r = -0.10	0.62
Cleanliness of water in tank	1-5 (3)	r = -0.02	0.93
pH of feed in bunk	4.2-7.3 (4.8)	r = -0.11	0.55

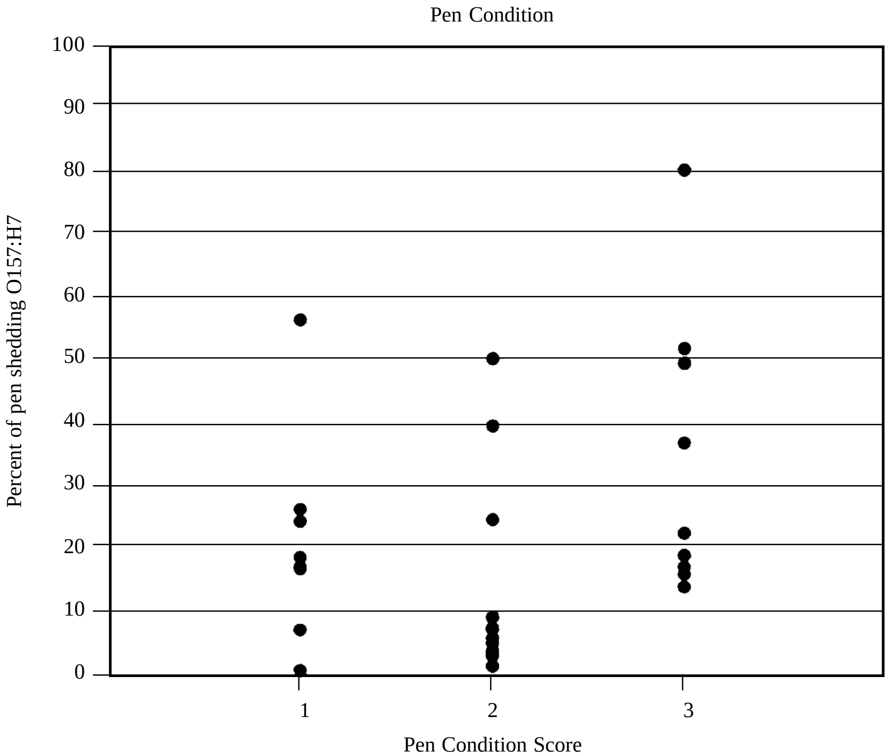

Figure 2. Percentage of cattle shedding detectable *Escherichia coli* O157:H7 in pens subjectively classified by pen environment as: 1-dry and dusty, 2-normal condition, 3-wet and muddy. Compared to pens with normal environmental conditions, pens classified as wet and muddy had significantly greater pen prevalence of *E. coli* O157:H7.

O157:H7 (rank order of pen-prevalence) and variables representing pen characteristics which were at least ordinal was tested using Spearman's rank correlation. Association of the magnitude of pen-prevalence with categorical variables was tested using non-parametric methods.

Results

E. coli O157:H7 was isolated from the feces of 714 of 3162 cattle tested (23%), including at least one animal from each of the 29 pens. The pen prevalence of cattle shedding detectable levels of the organism ranged from 0.7% to 79.8% (median 17.1%). Feedyards did not differ by pen prevalence (Kruskal-Wallis P=0.81); however, within each feedyard the pen prevalence differed widely (chi square P<0.001; Figure 1).

E. coli O157:H7 was recovered from the water tanks of seven pens and the feed from the bunk of one pen. Pen prevalence was not associated with recovery of the agent from feed (Wilcoxon rank sums P=0.31), or water (Wilcoxon rank sums P=0.15). Pen prevalence was not correlated with the temperature, pH, or cleanliness of water from the water tanks, or pH of the feed, number of cattle, mean body weight or number of days in the feedyard (Table 1).

The condition of the pen surface, subjectively evaluated as dry, normal, or wet, was associated with the level of pen prevalence (Kruskal-Wallis P<0.05; Figure 2). Specifically, wet pen conditions were associated with higher pen prevalence than pens in normal condition (Wilcoxon rank sums, P=0.01).

The prevalence of fecal shedding within feedlot cattle herds and pens has been reported to be low. However, the reliability of *E. coli* O157:H7 prevalence estimates in cattle may vary by the diagnostic method employed, the number of cattle sampled and the type of samples collected. The overall 23 percent of fecal shedding observed in this study is consistent with other reports suggesting that at times the organism may be widespread in beef cattle populations. For example, in a recent Canadian study, the organism was recovered from 19.7 percent of fecal samples collected at slaughter from yearling cattle and cull cows during the summer months (Van Donkersgoed et al. 1999 Canadian Vet J. pp 332-338).

The pen prevalence of fecal shedding did not differ between the five feedyards. This finding suggests that *E. coli* O157:H7 may be ubiquitous to feedlot cattle populations. In a multistate cross-sectional study, researchers cultured the feces of 120 cattle each (4 pens x 30 fecal pats) in 100 feedyards (Hancock et al. 1997 J Food Prot. pp 462-465). This sampling strategy may prevent detection of low prevalence pens. Despite a low overall prevalence of shedding (1.6%), *E. coli* O157:H7 was found in 61% of the feedyards surveyed. Other surveys, using serology (Laegreid et al. 1998 Conf Res Workers Anim Dis P26) and bacterial culture of feces (Sargeant et al. 1998 Conf Res Workers Anim Dis Abstract 41), suggest that exposure to *E. coli* O157:H7 is widespread and most beef cattle have been exposed to the organism before weaning. Because of commingling, widespread exposure of cattle to *E. coli* O157:H7 after arrival in large cattle feedlots is plausible, at least during certain seasons. Cattle recently arriving in the feedyard have been demonstrated to be at greater risk for shedding *E. coli* O157 than cattle on feed longer (Dargatz et al. 1997 J Food Prot pp 466-470).

All pens we observed had some cattle shedding the organism in the feces. In spite of the apparent ubiquity of the organism, the pen-prevalence of cattle shedding *E. coli* O157:H7 varied greatly within each feedyard. Pens with high and low prevalence of fecal shedding were observed in each feedyard. Factors that explain the variability in pen-prevalence of *E. coli* O157:H7 fecal shedding may be risk factors that could be managed as control points in a HACCP-based feedlot production food safety program.

The environmental condition of the pen was the only pen characteristic that was associated with pen prevalence.

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Pens with the greatest percentage of cattle shedding *E. coli* O157:H7 were more likely to be wet and muddy at the time of sample collection. Pens with dusty conditions were intermediate in the percentage of cattle shedding the organism. The association between the environmental condition of a pen and the percentage of cattle shedding *E. coli* O157:H7 seems plausible. Compared to the normal pen conditions, muddy or dusty conditions would be expected to facilitate fecal-oral transmission of enteric agents because of greater opportunity for the agent to move with water or dust particles.

It is unlikely that selection bias was introduced by voluntary recruitment of the feedyards or selection of cattle pens by convenience. There was no prior knowledge of the *E. coli* O157:H7 status of any of the feedyards. Pens were selected for inclusion in the study with consideration for the feedyards' re-implanting schedule and the workload of the laboratories. When there was an option, pens with fewer cattle were preferentially chosen for study to minimize costs. Pens were selected without knowledge of the results from previous pens in the feedyards.

The results of this study suggest that *E. coli* O157:H7 should be considered an ubiquitous organism in pens of feedlot cattle and that factors in the pen environment may help to explain the prevalence of cattle shedding the organism. The limited time-period of the study (summer months) and the cross-sectional nature of the study did not permit observing the effect of time dependent variables on the outcome of pen prevalence. It would be interesting to observe changes in pen prevalence over time as pen conditions change.

A Diagnostic Strategy to Classify Pens of Feedlot Cattle by the Prevalence of *Escherichia coli* O157:H7 Fecal Shedding

David Smith
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Mark Blackford
Rodney Moxley
Jeff Gray
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Todd Milton
Terry Klopfenstein[1]

This diagnostic strategy can be used in food-safety research or as a monitoring tool in animal production food-safety programs to classify feedlot pens by the percentage of cattle shedding *Escherichia coli* O157:H7.

Summary

This study evaluated two pen testing strategies to predict the percentage of cattle in a pen shedding detectable E. coli O157:H7. Culture of a composite fecal sample most accurately detected pens with 37% or more cattle shedding E. coli O157:H7 in feces. A new pen test device most accurately detected pens with 16% or more individuals shedding. The likelihood of detecting E. coli O157:H7 with either method increased as pen prevalence increased. If both pen-level test methods were used together, pens could be classified as high, medium or low prevalence with less labor and expense than testing individual cattle.

Introduction

The principles of hazard-analysis-critical-control-points (HACCP) were developed to minimize the likelihood that food will be contaminated with potentially dangerous pathogens. Ideally food-safety would be maximized if HACCP principles were applied at all levels of food production and processing. Unfortunately, there is insufficient knowledge of the epidemiology and ecology of *E. coli* O157:H7 to design and implement HACCP-based food safety programs in cattle feedyards.

Research or development of on-farm HACCP programs to control *E. coli* O157:H7 in feedlot production systems have been hampered by difficulty in determining the infection status of cattle at any point in time. The difficulty in diagnosis results because infection with *E. coli* O157:H7 in cattle occurs without clinical signs, except in calves, and because there is a lack of field-validated methods to monitor livestock for food safety pathogens.

Determining if individual live cattle are shedding *E. coli* O157:H7 is expensive and impractical. For example, culture of the feces from most, if not all, animals in a feedlot pen requires considerable labor and supplies. Handling finished cattle prior to shipping is not desirable because of the loss in value to cattle due to shrink, dark cutters and bruising. It may be possible to control *E. coli* O157:H7 in feedlots without knowing the infection status of individual cattle because control points or interventions for reducing human foodborne pathogens in feedlot cattle would most likely be directed towards pens of cattle. Therefore, the *E. coli* O157:H7 status of pens of feedlot cattle is an important outcome for feedlot production food safety research and HACCP monitoring.

Research and development of HACCP-based feedlot food safety programs could advance if pens of cattle, rather than individuals, could be accurately and economically classified by

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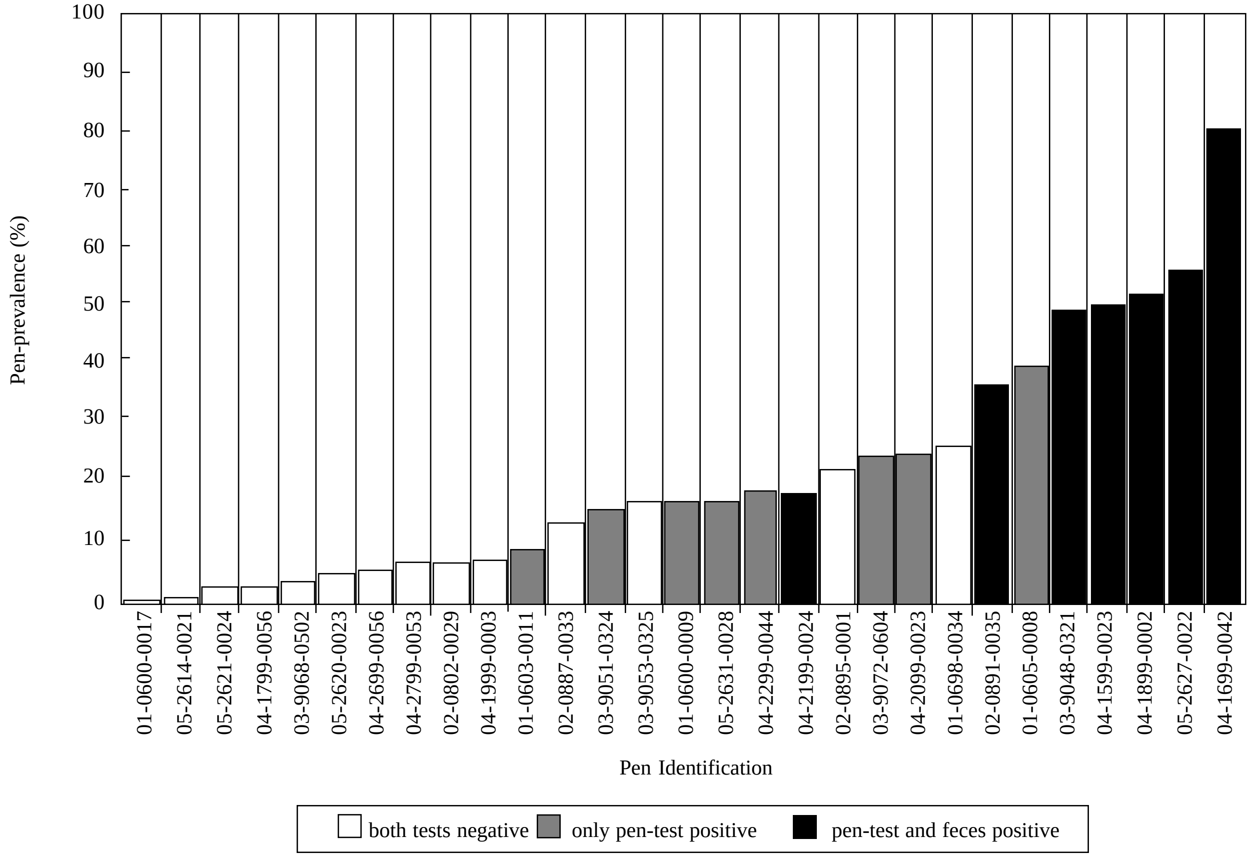

Figure 1. The relationship between the *Escherichia coli* O157:H7 culture results of the pen-test device, a composite fecal sample collected from the pen and the percent of cattle in the pen shedding detectable levels of the organism in rectal feces.

the level of fecal shedding of *E. coli* O157:H7. Such a "pen-test" could serve as a monitoring tool in feedlot production food-safety programs, and would allow researchers to test potential interventions, or look for feedlot production methods related to the presence or absence of food-borne pathogens. The objective of this study was to evaluate diagnostic strategies to efficiently identify pens of feedlot cattle with a high prevalence of cattle shedding *E. coli* O157:H7.

Procedure

Twenty-nine feedlot pens from five Midwestern feedlots, ranging in size from 36 to 231 (median 107) cattle, were each studied once between June and September, 1999 (Smith et al. 2001 Beef Report). Seven pen-test devices that cattle could rub, lick or chew were placed in the pens the evening prior to sample collection. The morning of sampling, feces were collected from the rectums of all cattle in each pen and concurrent samples were collected of pen-test devices and a single composite sample of 20 fresh fecal pats from the pen surface. Culture methods were specific to the type of sample but included selective enrichment and immunomagnetic separation. Isolates were confirmed by standard methods including PCR. Non-parametric statistical methods were used to test either rank differences or rank correlations between pen-level classifications and the results of individual animal testing.

Results

Escherichia coli O157:H7 was isolated from at least one animal in each of the 29 pens. The percentage of cattle shedding detectable levels of the organism within a pen ranged from 0.7% to 79.8% (median 17.1%). *E. coli* O157:H7 was recovered from at least one pen-test device from 15 pens and from the composite fecal samples of eight pens (Figure 1). Recovery of *E. coli* O157:H7 from at least one pen test device or from the composite fecal sample was most likely to occur from the pens with higher prevalence (Wilcoxon rank sums P=0.001).

The pen-test devices and composite feces were evaluated singly as diagnostic tools to differentiate high prevalence pens from low prevalence pens. The new pen-test device most accurately detected as positive (greatest percentage of pens classified correctly) pens with 16% or greater prevalence (pen-level sensitivity = 82%, pen-level specificity = 92%). Culture of composite feces most accurately detected as positive pens with a 37% percent or higher prevalence (pen-level sensitivity = 86%, pen-level specificity = 91%).

Information from culture of the pen-test devices and the composite feces was combined to classify pens by three levels of fecal shedding prevalence. Pens were classified as high prevalence if *E. coli*

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O157:H7 was recovered from the composite fecal sample; pens were classified as medium prevalence if the organism was recovered from the device, but not from the composite feces; pens were classified as low prevalence if the organism was not recovered from the device or the composite feces. This classification scheme correlated well (Spearman's r = 0.76, P<0.0001) with the pen-prevalence determined by culturing the feces from individual cattle. Pens classified as high prevalence had significantly higher rankings in pen-prevalence than pens classified as medium prevalence (P=0.05) or low prevalence (P=0.0006), and pens classified as medium prevalence had significantly higher rankings in pen-prevalence than pens classified as low prevalence (P=0.005).

The premise of the pen-test was to culture a few devices from which many cattle in a pen could have contributed organisms. Culture of the pen-test devices alone or in parallel with culture of a composite fecal sample may be a diagnostically efficient strategy to characterize *E. coli* O157:H7 fecal shedding in feedlot pens. This diagnostic strategy may be useful as a research tool or as a monitoring tool in the development of animal production food safety programs.

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Influence of Restricted Intake and Reduced Dietary Starch on Colonic pH and *E. coli* Prevalence

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David Smith
Spring Younts[1]

> A finishing diet low in starch increased fecal pH, lowered VFA, and reduced numbers of acid-resistant *E. coli* shed in the feces.

Summary

Ninety feedlot steers were used to test the effects of reducing dietary starch and intake on colonic pH, VFA, total and acid-resistant coliform and ***E. coli*** *populations, and* ***E. coli*** *O157:H7 shedding. When corn bran and wet corn gluten feed (WCGF), or high moisture corn and WCGF were substituted for dry rolled corn, colonic pH increased while VFA concentration decreased. The corn bran and WCGF diet reduced acid-resistant* ***E. coli*** *shedding. Restricting intake increased colonic pH and decreased VFA concentration, but did not affect acid-resistant* ***E. coli*** *shedding. Prevalence of* ***E. coli*** *O157:H7 was not affected by diet or intake.*

Introduction

Enterohemorrhagic *Escherichia coli* O157:H7 is a bacterium found commonly in the intestinal tract of livestock that can cause severe illness and death in humans. More than 100 outbreaks of *E. coli* O157:H7 have been reported since 1982, 52% of which have been linked to foods derived from cattle.

Besides its ubiquitous distribution in livestock, other noteworthy characteristics of *E. coli* O157:H7 are its low infective dose for humans and its acid resistance. Because it can thrive under low pH conditions, undigested feed that is fermented in the colon may facilitate growth of *E. coli* O157:H7 and ultimately increase the numbers of the organism being shed in the feces.

High grain finishing diets may result in large amounts of undigested starch reaching the colon. Because of this, it has been suggested that feeding hay instead of grain would decrease the amount of starch reaching the colon, increase colonic pH and decrease the numbers of acid-resistant *E. coli* being shed in the feces. In 1998, it was reported that switching cattle from a grain-based diet to hay four days prior to slaughter reduced the prevalence of both generic and acid resistant *E. coli.* A similar study conducted at the University of Nebraska confirmed these results. When steers consuming dry-rolled corn, high-moisture corn, or wet corn gluten feed were switched to alfalfa hay for five days, acid-resistant *E. coli* populations in the feces were reduced by 99% (2000 Nebraska Beef Report, pp. 39-41).

Feeding hay at the end of the feeding period may not be a feasible management practice for cattle feeders. However, if reducing the amount of fermentation in the colon is the key to reducing the numbers of acid-resistant *E. coli* being shed in the feces, more practical approaches may be available. High moisture corn, wet corn gluten feed (WCGF) and corn bran are feedstuffs used commonly in Nebraska feedlots, and each would be expected to result in less undigested starch reaching the colon. Therefore, the objectives of this trial were to determine the effect of

Table 1. Composition of diets.

Ingredient, %DM	Treatment		
	High	Med	Low
Dry rolled corn	81.55	—	—
High moisture corn	—	43.75	—
Corn bran	—	—	43.75
Wet corn gluten feed	—	43.75	43.75
Alfalfa hay	7.50	7.50	7.50
Molasses	3.00	—	—
Supplement	7.95	5.00	5.00

Table 2.Effect of diet on colonic digesta samples.

Item	Dietary treatment[a]		
	High	Med	Low
Colonic pH	6.90[c]	7.25[d]	7.52[e]
VFA, mMol/g feces	188.01[f,g]	193.95[f]	150.43[g]
Total coliform, $\log_{10}$[b]	5.52	4.78	5.43
Acid resistant coliform, $\log_{10}$[b]	4.28[c]	2.98[d]	2.64[d]
Total *E. coli*, $\log_{10}$[b]	6.81[c]	5.71[d]	6.35[c]
Acid resistant *E. coli*, $\log_{10}$[b]	4.69[f]	4.06[g]	3.86[g]

[a]High = dry rolled corn, Med = high moisture corn and WCGF, Low = corn bran and WCGF.
[b]Bacterial numbers shown in $\log_{10}$ colony forming units / g feces.
[c,d,e] Means within a row differ ($P < .01$).
[f,g] Means within a row differ ($P < .05$).

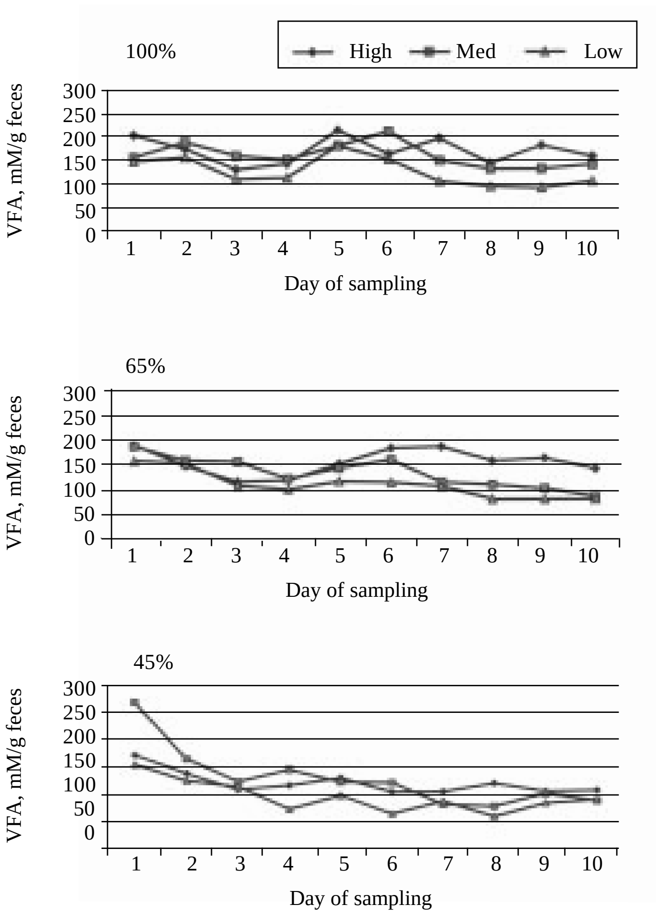

Figure 1. Effect of day on colonic VFA concentration within intake level. DRC = dry-rolled corn, HMC = high-moisture corn and wet corn gluten feed, and Bran = corn bran and wet corn gluten feed. 100% = ad libitum, 65% and 45% = intake restricted to 65% and 45% of ad libitum, respectively.

replacing dry-rolled corn with either high-moisture corn and WCGF or corn bran and WCGF on colonic pH and volatile fatty acid concentration, as well as coliform bacteria and *E. coli* being shed in feces. Additionally, we wished to determine the effects of limiting intake of each of these diets. Treatment diets were fed at the end of the finishing phase, with the objective being to reduce shedding of *E. coli* prior to arrival at the packing plant without hampering performance.

Procedure

Ninety crossbred steers (BW = 1198 lb) were used to test the effects of finishing diet and level of intake on colonic pH and VFA content, as well as coliform bacteria and *E. coli* shedding. The project was designed as a 3 x 3 factorial, with three diets offered at three levels of intake. Calves were randomly assigned to treatment and allotted to one of 18 pens (5 head/pen; 2 pens/ treatment). Treatment diets (Table 1) were formulated to supply varying amounts of unfermented starch reaching the colon, and were based on dry-rolled corn (High), high-moisture corn and wet corn gluten feed (Med), or a combination of corn bran and wet corn gluten feed (Low). Diets were offered free choice (100%), or restricted to either 65% or 45% of full consumption for 10 days. Cattle were penned together within diet type for 14 days prior to initiation of the trial to establish ad libitum levels of intake. Fecal samples were collected from the rectum of each individual on ten consecutive days, and analyzed for pH, acetate, butyrate, isobutyrate, propionate, isovalerate and total VFA concentration. Total coliform bacteria, total *E. coli*, and acid-resistant coliforms and *E. coli* were quantified. The presence of *E. coli* O157:H7 was also determined.

Results

Analysis of fecal samples collected on day 1 (Table 2) represent the effect of ad libitum consumption of the treatment diets. Cattle consuming diets containing

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WCGF had higher ($P < .01$) colonic pH values than those on a DRC-based finishing ration. Replacing HMC with corn bran further raised ($P < .01$) colonic pH. Volatile fatty acid concentration of colonic digesta did not differ ($P > .05$) between the DRC and HMC-based diets. The corn bran diet did reduce ($P < .05$) the amount of VFA in the colon.

The total number of coliform bacteria isolated from rectal grab samples collected on day 1 did not differ ($P > .05$) between diets. Acid-resistant coliforms were reduced ($P < .01$) by the inclusion of WCGF. The total number of *E. coli* cultured was lower ($P < .01$) for cattle consuming the HMC diet compared to the other treatments, and the corn bran treatment tended ($P = .06$) to be lower than DRC. The number of acid-resistant *E. coli* being shed in the feces was lower ($P < .05$) in samples collected from calves consuming diets containing WCGF.

Once intake restrictions were imposed, level of intake significantly ($P < .01$) influenced colonic pH. Cattle on ad libitum intake had an average colonic pH of 7.29. That increased to 7.35 and 7.46 for 65% and 45% restriction, respectively. Because of the inclusion of limestone in the diets, and its potential to act as a buffer in the colon, colonic VFA concentration may be a better indicator of microbial activity in the hind gut, rather than pH. Restricting intake decreased ($P < .01$) the amount of VFA from 150, to 131, and 110 mMol/g, for 100%, 65, and 45% intake, respectively. Intake level did not ($P = .83$) affect the numbers of acid-resistant *E. coli* being shed in feces.

The number of calves shedding *E. coli* O157:H7 ranged from 0% to 18% over the 10-day sampling period, and prevalence was not affected by diet. Level of intake also had no significant impact on O157:H7, though numerical differences were evident. Across days and diets, 12% of ad libitum, 14% of 65% intake, and 5% of 45% intake calves were positive for O157:H7. In order for treatments to yield statistical differences in the presence or absence of *E. coli* O157:H7, it may be necessary to have larger sample sizes than the numbers used in this study.

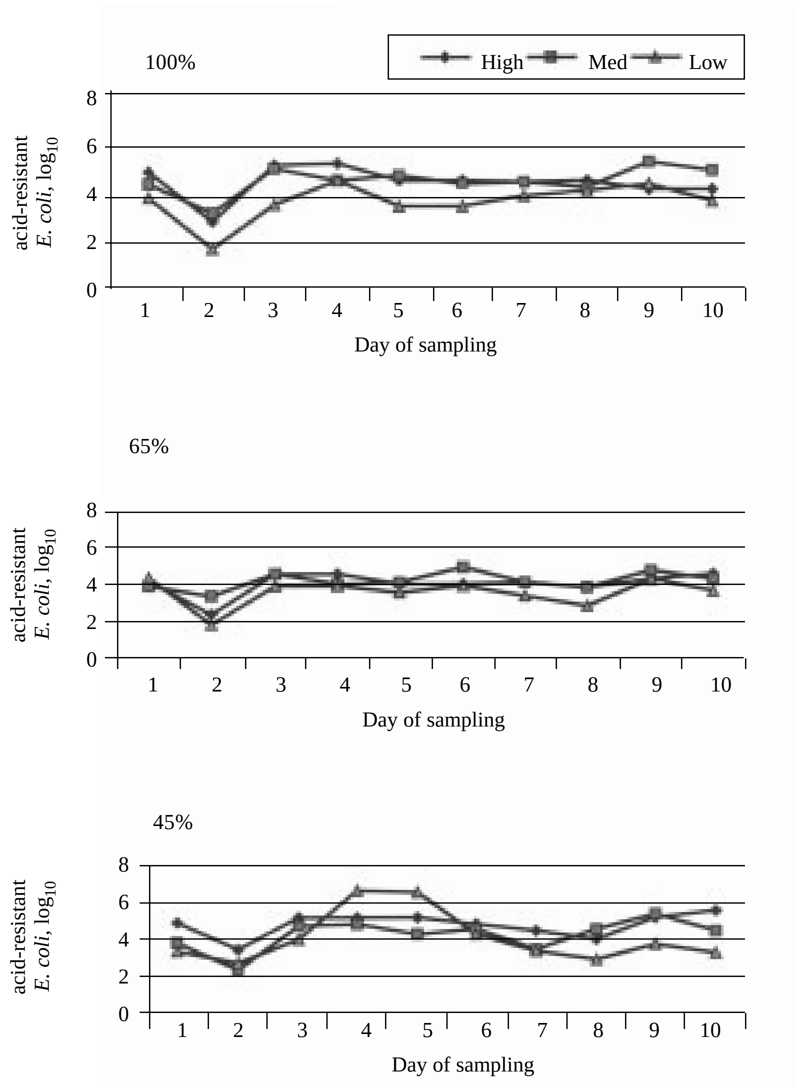

Figure 2. Effect of day on acid-resistant *E. coli* numbers cultured from colonic digesta. DRC = dry-rolled corn, HMC = high-moisture corn and wet corn gluten feed, and Bran = corn bran and wet corn gluten feed. 100% = ad libitum, 65% and 45% = intake restricted to 65% and 45% of ad libitum, respectively.

Replacing dry-rolled corn with high-moisture corn and WCGF, or corn bran and WCGF raised colonic pH and reduced VFA concentrations in feedlot steers. Restricting intake to 65% and 45% of ad libitum had a similar effect. A WCGF and corn bran-based diet tended to reduce numbers of acid-resistant *E. coli* shed in the feces. Prevalence of *E. coli* O157:H7 in feces was not affected by diet or level of intake.

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Phosphorus and Nitrogen-Based Beef Cattle Manure or Compost Application to Corn

Bahman Eghball[1]

Nitrogen and phosphorus-based manure and compost applications resulted in similar corn yields across four years but soil P accumulation was much greater for N-based than P-based application.

Summary

This study was conducted to evaluate effects of P and N-based manure and compost applications on corn yield and soil P level. Annual or biennial manure or compost application resulted in corn grain yields similar to those with chemical fertilizer application. P-based manure or compost application resulted in similar corn grain yield but significantly less soil P build-up than N-based treatments. Estimated N availability was 40% for manure and 15% for compost in the first year and was 18% for manure and 8% for compost in the second year after application.

Introduction

Beef cattle feeding is concentrated in the Central and Southern Great Plains. At any one time, there are at least 10 million head of beef cattle on feed in the United States. Approximately 585,000 tons of N, 173,000 tons of P and 530,000 tons of K are excreted annually in this beef feedlot manure. Carbon in manure is likely to have far greater value than the nutrients it contains if applied to a low organic matter or eroded soil.

Composting manure is a useful method of producing a stabilized product that can be stored or spread with little odor, weed seeds, pathogens, or fly breeding potential. Composting also has some disadvantages. Study conducted by the author indicated 20-40% loss of total N and 46-62% loss of total C during composting of beef cattle feedlot manure, as well as significant losses of K and Na (> 6.5% of total K and Na) in runoff from composting windrows during rainfall.

Manure or compost application to provide for corn N requirements may greatly increase soil levels of P since the N:P ratios of beef cattle feedlot manure and composted manure are significantly smaller than N:P uptake ratios of most crops. The N:P ratio for feedlot manure is about 2.5 and is 2 for composted manure while N:P grain uptake ratios of winter wheat, corn, and grain sorghum are around 4.5, 5.9, and 4.5, respectively. The increase in soil P level can increase P loss in runoff, which has been associated with eutrophication (algae bloom and oxygen depletion) of rivers and lakes. The objective of this study was to evaluate the effects of application frequency and N and P-based rates of manure and compost application on corn grain yield and soil P level.

Procedure

A dryland experiment was initiated in 1992 on a Sharpsburg silty clay loam soil under dryland conditions at the University of Nebraska Agricultural Research Center near Mead, Neb. The study area had a Bray and Kurtz No.1 soil P test of 69 ppm, which is considered very high in Nebraska, and a pH of

Table 1. Characteristics of beef cattle feedlot manure and composted feedlot manure applied in four years at Mead, NE. Nutrients and ash contents are on dry weight basis.

Year and source	Total N	Total P	Ash	Water content	NO_3-N	NH_4-N	EC†	pH†
	%				ppm		m mho/cm	
1992								
Manure	0.79	0.23	84.4	19.5	30	1263	4.6	7.3
Compost	1.10	0.42	80.8	33.2	117	169	7.4	7.7
1993								
Manure	1.02	0.50	71.5	53.9	17	480	5.2	8.8
Compost	0.77	0.32	79.6	40.3	38	33	2.2	8.3
1994								
Manure	1.56	0.33	59.1	20.0	11	365	5.4	8.2
Compost	0.76	0.41	84.9	34.0	383	55	6.1	7.2
1995								
Manure	1.30	0.32	67.7	25.1	130	898	3.8	7.3
Compost	0.78	0.31	79.8	15.0	294	97	6.0	7.7

†Electrical conductivity (EC) and pH were determined on 2:1 water to dry manure or compost ratio.

Table 2. Composted and non-composted manure dry weight application in four years at Mead, Neb.

Treatment	Dry weight 1992	1993	1994	1995
	tons/acre			
Manure for N	20.9	8.3	5.4	6.5
Manure for P	12.6	2.9	2.9	1.2
Manure for N / 2Y†	41.9	—	16.2	—
Manure for P / 2Y	25.2	—	8.8	—
Compost for N	15.4	22.1	11.2	16.2
Compost for P	6.9	4.6	2.4	1.3
Compost for N / 2Y	31.0	—	33.6	—
Compost for P / 2Y	13.8	—	7.1	—
Fertilizer	—	—	—	—

†2Y indicates biennial manure or compost application.

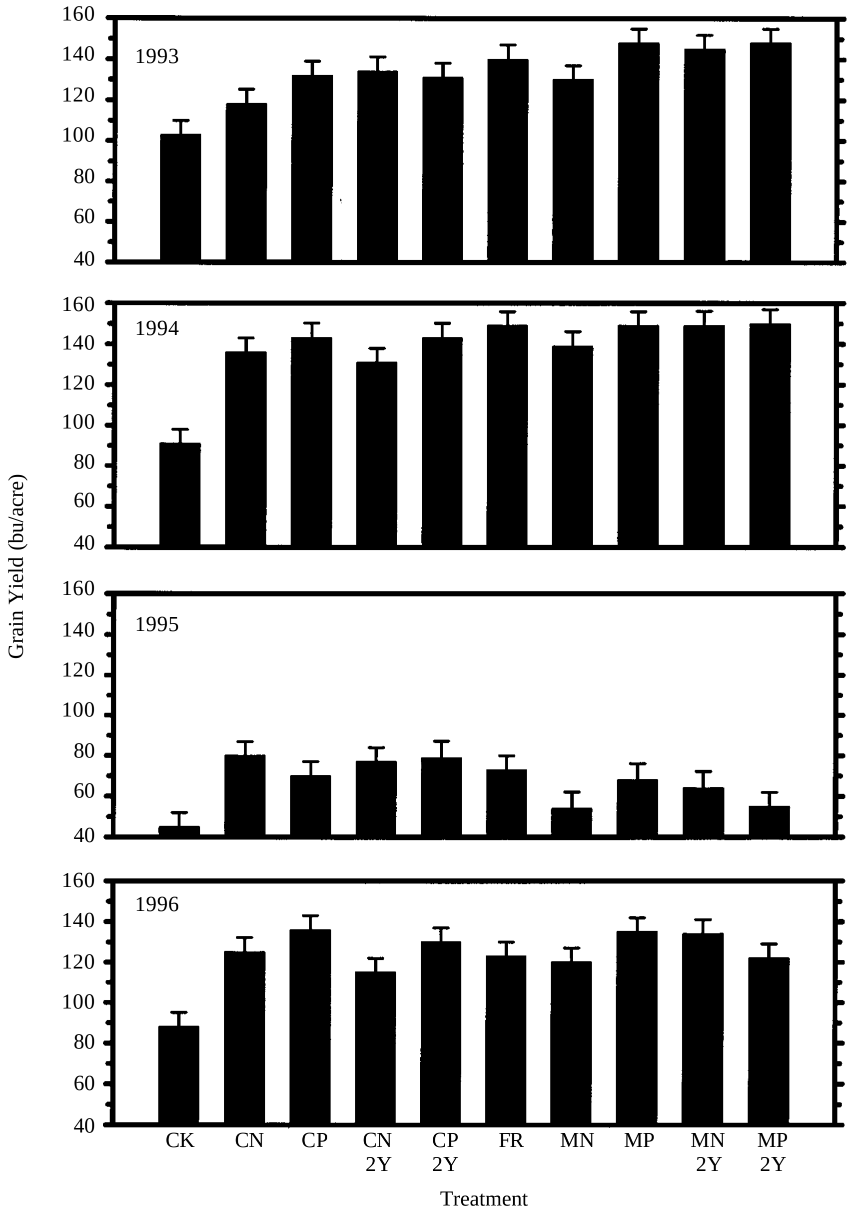

Figure 1. Corn grain yield for ten treatments in four years at Mead, Neb. Each vertical bar is standard deviation of that mean. CN is N-based compost, CP is P-based compost, MN is N-based manure, MP is P-based manure, FR is fertilizer, CK is check, and 2Y indicates biennial application.

6.2 in the top 6 inches. The experimental design was a randomized complete block with four replications. The 10 treatments applied included annual or biennial manure or compost application based on N or P removal of corn (135 lb N/acre and 53 lb P_2O_5/acre for an expected yield level of 150 bu/acre) and fertilized and unfertilized checks. Fertilizer application was made in the spring each year. If necessary, the P-based treatments (annual or biennial application) also received N fertilizer as ammonium nitrate (34-0-0, N-P-K) in the spring so that a total of 135 lb N/acre was available to the crop.

Beef cattle feedlot manure (collected in November) and composted feedlot manure were applied in November 1992 based on the assumption that 40, 20, 10 and 5% of the N and P in manure or compost will become plant available in the first, second, third and fourth year after application, respectively. The first year N availability assumption from compost was found to be too high so availability assumptions were changed to 20, 20, 10, 5% in the first, second, third and fourth year after compost applications in 1993, 1994 and 1995. Biennial manure or compost applications were made to provide 135 lb N/acre for N-based and 53 lb P_2O_5/acre for P-based rates in the second year after application based on the assumptions given above. Residual N and P values from previous years were considered when manure or compost were applied.

Manure or compost application was made in late autumn (November or December) after corn harvest. Manure and compost were applied by hand to plots 40 feet long and 15 feet wide (six corn rows). The characteristics and amounts of manure and compost applied for each treatment are given in Tables 1 and 2. Manure and compost were applied and disked-in within two days after application. Corn (Pioneer 3394) was planted at a seeding rate of 19,000 seeds/acre and a row spacing of 30 inches. The planting dates were May 21, 1993, May 10, 1994, May 24, 1995, and May 21, 1996. Corn was harvested by hand in October (middle 2 rows, 20 feet long) of each year and grain yield determined. The reported yields are adjusted to 15.5% moisture content.

Soil samples were collected from all plots each year after harvest. The surface soil (0 to 6 inches) samples were analyzed for Bray and Kurtz No.1 soil P test to evaluate the effects of manure, compost and fertilizer application on the soil P level. The amounts of rainfall from June 1 to Aug. 31 for the above years were 23.4, 15.9, 4.2, and 8.5 inches for 1993, 1994, 1995 and 1996, respectively.

Results

Grain yield

There was a significant year by treatment interaction for corn grain yield. The relative differences among treatments were different for each year (Figure 1). Grain yields for all treatments were greater than the check. Grain yields for the manure and compost treatments were similar to those for the fertilizer treatment in all four years (Figure 1). This indicates that annual or biennial

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manure or compost application can provide added nutrients to corn, similar to fertilizer application, with added benefits of organic matter and micro-nutrients addition to the soil. Phosphorus-based manure or compost application, with additional N as fertilizer, produced similar corn grain yields to those for the N-based and fertilizer treatments.

Nitrogen use efficiency was greater for manure than compost application. The estimated first-year N availability from manure N was 40%, and was 15% for compost application. Second-year N availability estimation was 18% for manure and 8% for compost application. Nitrogen availability from compost was less than the expected 20%. Small fractions of N are available in the third and fourth year after application (usually <10%). The manure or compost N remaining after the fourth year become a portion of soil-N and a small fraction becomes plant available each year.

Soil Phosphorus

The results indicate that surface soil (top 6 inches) phosphorus level was greatest for the biennial N-based compost application and was least for the check plot (Figure 2). There was a significant year by treatment interaction for soil P level. Soil P levels for all N-based treatments were greater than those for the check plots (Figure 2). Annual P-based manure and compost application had P levels that were similar to the original soil P level of 69 ppm even after four years of manure and compost application.

Even though the N-based manure and compost treatments had soil P levels similar to those for the fertilizer treatment in 1993, they had higher soil P levels than the fertilizer treatment in later years (Figure 2). Biennial P-based manure or compost application resulted in greater soil P build-up than did annual P-based manure or compost applicature. This is because of the greater amount of manure or compost applied every other year. Nitrogen-based manure or compost application resulted in available soil P levels that were significantly greater than those for the P-based manure or compost application, fertilizer, or check treatments. After four years of application, annual P-based manure or compost treatments had soil P levels similar to the original soil P level before treatment application.

Phosphorus-based manure or compost application strategy can increase the distance manure and compost need to be hauled and hence increase the application cost. Therefore, P-based application should be used in sites vulnerable to P runoff losses. A recently developed P Risk Assessment Index can be used to determine which sites are vulnerable to P runoff losses. Nitrogen-based manure and compost applications can be used in areas where the potential for P runoff loss is minimal.

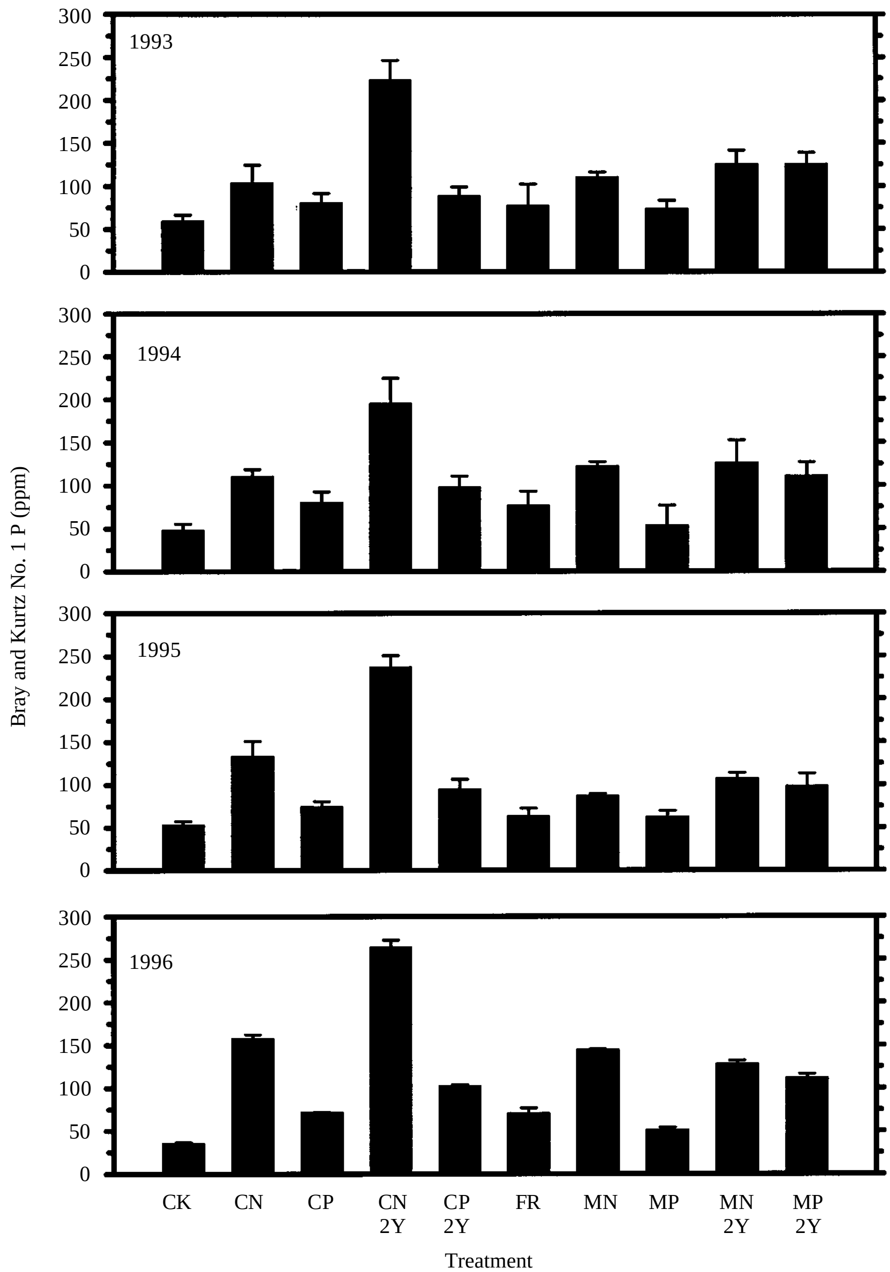

Figure 2. Surface soil (0-6 in) P levels for ten treatments in four years at Mead, Neb. Each vertical bar is standard deviation of that mean. CN is N-based compost, CP is P-based compost, MN is N-based manure, MP is P-based manure, FR is fertilizer, CK is the check, and 2Y indicates biennial application.

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Composting of Feedlot and Dairy Manure: Compost Characteristics and Impact on Crop Yields.

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Compost fertilization increased yields of irrigated corn and soybeans, dryland corn, wheat, and grain sorghum. The increased yield offset application costs for all crop rotations except soybeans.

Summary

Since 1993, approximately 17,600 tons of beef feedlot and dairy compost have been spread on 1,100 acres. Crop yields were measured to determine the impact of a one-time compost application by using no-compost check strips in large-scale production fields. Adding compost to irrigated corn, irrigated soybeans, and dryland corn acres significantly increased yields, with four-year average increases of 2.3, 1.5, and 2.7%, respectively. For all crops measured, the response to compost was greatest the first year following application and declined linearly in subsequent years. The increased yield from compost application offsets spreading costs using average prices for crops.

Introduction

Managing manure and nutrients is becoming increasingly important for agricultural producers. For these reasons, numerous projects were initiated at the University of Nebraska to help producers become more aware of the challenges with managing manure, and also the costs associated with nutrient management. The primary focus of this article is to summarize compost characteristics and average yield responses from a one-time compost application to irrigated corn and soybeans, or dryland corn, soybeans, wheat and grain sorghum.

Procedure

Composting was initiated in 1993 to handle manure from the 1500-head research beef feedlot and the 150-cow dairy at the University of Nebraska Agricultural Research and Development Center near Mead, Neb. Since then, compost as a waste management system has been evaluated by determining costs of composting, costs of spreading, nutrient recoveries during composting and yield impacts from compost amendment to soil. Research progress reports have been provided in previous beef reports (1996 Nebraska Beef Report, pp. 77-79; 1997 Nebraska Beef Report, pp. 88-91). However, until this past year, sufficient replication for detailed summaries of crop yield impacts from compost amendment were unavailable.

Yield differences from treatments were evaluated using both increased revenue and cost of treatments. Corn price was based on Nebraska Agricultural Statistics Service for marketing years from 1992 to 1998 or $2.50 per bushel. The soybean price was also based on Nebraska Agricultural Statistics Service for marketing years from 1992 to 1998 which is $6.05 per bushel.

Composting was done in windrows during the summer months (May to October) and was dependent on manure supply and timing. Once windrows were formed, samples were collected from random locations. Compost was considered finished when windrows no longer produced heat two to seven days after turning. Dairy manure was amended at the time of windrow formation with organic residue that varied from year to year. In 1998 and 1999, feedlot compost was amended with organic residue to increase carbon content and the C:N (carbon:nitrogen) ratios. After complete composting, windrows were again sampled. Samples were composited by time and by windrow and analyzed for DM, OM , N (nitrogen), P (phosphorus), K (potassium), and most mineral elements. Nitrogen recoveries were calculated using total ash as an internal marker and the following equation:

Nitrogen recovery = 100 x [(% ash before ÷ % ash after) x (% N after ÷ % N before)]. Ash and N concentrations are on a DM-basis.

Since 1993, approximately 1100 acres have received compost through this research project. Check strips, where no compost was applied, have been maintained in large-scale production fields by GPS/GIS technology to ensure strip identity and integrity. Yield data have been collected and summarized for compost produced from 1993 to 1998. Until 1997, compost application was targeted at 10 tons (as-is) per acre. In 1998 and 1999, compost application was increased to 20 tons (as-is) per acre. Fields were chosen based on Bray-P1 soil phosphorus test less than 15 ppm as the critical soil test value, and the availability of compost.

Yields were determined by collection of total weight from check strips (Figure 1) by using a 550 bu Brent (model 672) grain cart equipped with J-star load cells, or by truck scale. When weighing capability was unavailable, yields were determined by calibrated yield monitors (Agleader PF3000) from grain combines. Most of the corn yields and 50% of soybean yields were determined with weights from the grain cart, with the remaining soybean yields determined using yield monitors. Fields were

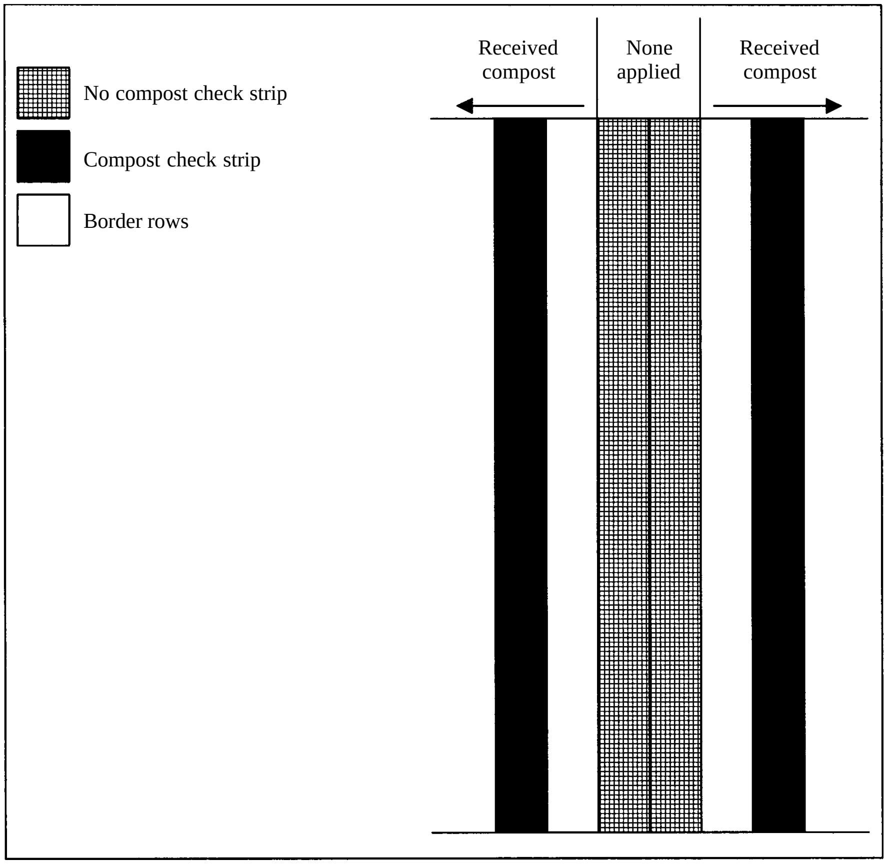

Figure 1. Diagrammatic representation of check strips for yield comparisons between compost treatment versus no compost treatment. Each strip represents an 8-row (20 foot) width which matches planting and harvest equipment.

Table 1. Compost nutrient composition and tonnage for 1993 to 1999. The year represents the summer that composting occurred.

Feedlot compost			Lb per ton of DM		
	Tons(as-is)	DM, %	N	P	N recovery
1993	2700	83.2	.2	6.7	
1994	600	77.3	16.0	10.0	64-77
1995	450	82.9	13.4	6.8	
1996	1450	77.4	16.1	14.5	84
1997	560	76.1	18.8	10.3	61
1998	1425	82.8	7.1	9.2	89
1999	900	71.8	13.6	8.0	84
average	1155	78.8	12.9	9.4	
Dairy compost			Lb per ton of DM		
	Tons(as-is)	DM, %	N	P	
1993	1955		9.0	9.0	
1994	1500	65.5	17.6	13.0	
1995	1360	77.9	15.3	11.9	
1996	965	70.5	20.1	14.2	
1997	1180	66.5	22.1	13.3	
1998	1865	73.9	19.0	14.2	
1999	690	77.0	20.0	8.9	
average	1360	71.9	17.6	12.0	

managed similarly in terms of crop, variety or hybrid, irrigation, N fertilization and planting/harvesting dates. No commercial P was applied.

To account for variation from field to field, field and compost treatment were included in the yield model. Most fields (majority of the data) were maintained on either an irrigated, no-till corn-soybean rotation or a non-irrigated, no-till corn-soybean rotation. Some data were collected on non-irrigated, no-till wheat and grain sorghum crops. Data were analyzed within each crop by year from application time, i.e. whether one, two, three and four or more years from compost amendment, using proc GLM in SAS.

Results

Compost production

Nitrogen concentration is usually an indicator of compost quality and soil contamination. In 1993 and 1998, feedlot compost was lower in quality (Table 1). Those years were associated with unusually wet springs and therefore pens were cleaned and more soil unavoidably removed. Total tonnage was also relatively high those years which is further evidence that more soil was removed. Animal capacity was unchanged and therefore more manure would not be associated with animal production. Averaging across the seven years, the 1500-head feedlot produced an average of 1,155 tons (as-is) annually of finished compost that contained 12.9 lb of N and 9.4 lb of P per ton of DM. Dry matter concentration averaged 78.8%. Therefore, 10.2 lb of N and 7.4 lb of P were produced per ton of as-is compost. Converting P to a P_2O_5 basis leads to 16.9 lb of P_2O_5 per ton of as-is compost from the feedlot. Using the average N concentration of 10.2 lb, the value of N is $1.14 per ton (as-is) assuming N is priced at $0.112 per lb ($NH_3$ = $185 per ton equivalent, based on 2000 prices). Similar calculations for P suggests that the value of P is $4.97 per ton (as-is) assuming $0.294 per lb of P_2O_5 (11-52-0 = $330 per ton equivalent).

Dairy compost was relatively consistent across years and was generally higher quality based on N concentration due to manure production and handling differences relative to feedlot manure. Dairy manure was hauled "fresh" to the compost yard daily, and stored. Differences exist between fresh dairy manure and feedlot manure; however, manure

(Continued on next page)

collected fresh from feedlot animals would produce compost similar to dairy compost rather than typical feedlot compost from manure collected on open-dirt pens. In the summer, manure was placed in windrows and mixed with organic residue. As a result, soil contamination was much lower and compost tonnage was more constant. Beginning in 1999, less manure was hauled to the compost yard due to direct applications of fresh dairy manure on other ARDC acres. Averaged across the seven years, the 150-cow dairy produced 1,360 tons (as-is) annually of finished compost that contained 17.6 lb of N and 12.0 lb of P per ton of DM. Dry matter concentration averaged 71.9%. Therefore, 12.6 lb of N and 8.6 lb of P were produced per ton of as-is compost. Converting P to a P_2O_5 basis leads to 19.8 lb of P_2O_5 per ton of as-is compost from the dairy. Using the average N concentration of 12.6 lb, the value of N is $1.41 per ton (as-is) assuming N is priced at $0.112 per lb. Similar calculations for P suggests that the value of P is $5.82 per ton (as-is) assuming $0.294 per lb of P_2O_5.

During composting, energy is required in the form of carbon (organic matter) to maximize N recovery. Therefore, a critical measure in manure is the carbon to nitrogen (C:N) ratio. That ratio in feedlot manure is usually 12:1 whereas optimal C:N ratios are 25:1 or greater. The consequences of low C:N ratios are greater N losses. Table 1 contains N recovery ranges for feedlot compost in these studies. N recovery is variable but ranges from 60 to 90%, which suggests that the majority of N is transformed from inorganic N to organic N. Once applied, organic N should be more stable than that in manure and eventually be used by the growing crops.

Table 2. Yield responses (bu/acre) from compost treatment on irrigated and dryland corn.

Years[a]	-comp	+comp	diff (bu)	diff (%)	fields	SE	P=
Irrigated							
1	148.1	157.0	8.9	6.0	6	1.65	.01
2	154.5	158.3	3.8	2.5	4	.88	.06
3	169.6	169.3	-0.3	-0.1	4	.31	.54
4+	198.0	199.6	1.6	0.8	5	.80	.25
overall avg	167.6	171.1	3.6	2.3			
Dryland							
1	124.7	134.7	10.0	8.0	5	2.20	.04
2	104.9	106.9	2.0	1.9	12	.94	.16
3	179.5	180.9	1.4	0.8	3	.65	.27
4	133.4	135.5	2.1	1.6	9	.76	.08
4+	142.8	144.5	1.7	1.2	13	7.01	.87
overall avg	136.7	140.1	3.4	2.7			

[a]Years is the number of years following a one-time compost application, -comp is treatment not receiving compost, +comp is treatment receiving compost, differences in bushels and percentage calculated as +comp minus -comp divided by -comp treatment, fields is a measure of replication, SE is the standard error of the mean, and P= is the probability that the +comp and -comp treatments are equal when variation due to fields is accounted for.

Table 3. Yield responses (bu/acre) from compost treatment on irrigated and dryland soybeans.

Years[a]	-comp	+comp	diff (bu)	diff (%)	fields	SE	P=
Irrigated							
1	60.0	61.3	1.3	2.2	3	.24	.06
2	61.5	62.7	1.2	2.0	4	.31	.54
3	58.9	59.7	0.8	1.4	4	.49	.32
4+	61.2	61.3	0.1	0.2	5	.59	.96
overall avg	60.4	61.3	0.9	1.5			
Dryland							
1	52.0	52.3	0.3	0.6	3	1.70	.90
2	50.5	51.9	1.4	2.8	3	1.09	.45
3	43.2	43.6	0.4	0.9	6	.87	.79
4+	58.3	58.6	0.3	0.5	14	1.25	.86
overall avg	51.0	51.6	0.6	1.2			

[a]Years is the number of years following a one-time compost application, -comp is treatment not receiving compost, +comp is treatment receiving compost, differences in bushels and percentage calculated as +comp minus -comp divided by -comp treatment, fields is a measure of replication, SE is the standard error of the mean, and P= is the probability that the +comp and -comp treatments are equal when variation due to fields is accounted for.

Crop yields

Adding compost to irrigated acres improved ($P < .10$) corn yields in the first and second years following application (Table 2). Yields were increased by 8.9 bushels, which was 6% the first year and by 3.8 bushels or 2.5% the second year. Ten fields were planted with corn those two years. After the second year, compost treatment had no impact ($P > .25$) on corn yield. Assuming a 3.6 bushel increase in corn yield each year for four years (based on overall average response), then compost treatment increases gross returns by $36 per acre if average price for corn is $2.50 per bushel for those four years (3.6 bushels x 4 years x $2.50 per bushel). If application costs average $2.50 per ton (based on previous calculations; 1997 Nebraska Beef Report, pp. 88-91), then total spreading costs are $25 per acre for 10 tons per acre application rates or $50 if 20 tons per acre are applied. Application costs are variable and dependent on size of operation and distance traveled. We used an average, but individual producers would need to assess their application costs. Most of the yield data presented here follows an application rate of 10 tons per acre (five of the six years). In these calculations, only four years were used in the economic calculations to obtain conservative estimates, whereas some of these fields received compost six years earlier. Therefore, total income would be increased by approximately $11 per acre if compost is used on irrigated corn ground.

Adding compost to non-irrigated corn acres increased ($P < .04$) yields by 10 bushels or 8% the first year after application. In subsequent years, the impact of adding compost was not statistically significant except for the fourth year after compost application. Based on the results in Table 2, compost

Table 4. Crop yield responses (bu/acre) from compost treatment on dryland wheat and grain sorghum yields.

Years[a]	-comp	+comp	diff (bu)	diff (%)	fields	SE	P=
Wheat							
1	36.6	41.0	4.4	12.0	5	1.01	.04
Grain sorghum							
1,3,5	115.9	118.5	2.6	2.2	5	.66	.04

[a]Years is the number of years following a one-time compost application, -comp is treatment not receiving compost, +comp is treatment receiving compost, differences in bushels and percentage calculated as +comp minus -comp divided by -comp treatment, fields is a measure of replication, SE is the standard error of the mean, and P= is the probability that the +comp and -comp treatments are equal when variation due to fields is accounted for.

treatment numerically increased dryland corn yields in every year measured (up to six years); however, variation from year to year was probably due to precipitation differences. With variable yields due to weather effects during different years, effects due to compost application were not distinguishable. Biologically, a 1 to 2 percent improvement in yields observed during the second to fourth year is significant. If yield is increased 3.4 bushels due to compost treatment, then gross income is increased by $34 (3.4 bushels x 4 years x $2.50 per bushel). With similar calculations as in the irrigated corn example, net income would be increased by approximately $9 per acre if compost is applied at a rate of 10 tons per acre to dryland corn.

When soybeans were planted on irrigated acres, compost treatment increased ($P < .06$) yields by 1.3 bushels or 2.2% the first year (Table 3). In subsequent years, compost treatment did not statistically increase yields ($P > .32$). Yield improvements decreased linearly with year from application based on percent improvements from 2.2% (year 1) to 0.2% (years 4 and 5). Performing similar economic calculations with the soybeans as with the corn and an average yield improvement of 0.9 bushels, applying compost added about $21.50 return per acre (0.9 bushels x 4 years x $6.05). The differences in yield alone from compost application to irrigated soybeans does not offset the average application costs ($25) in this study. Because soybean yields are lower than those of corn in bushels per acre (60 versus 168), yield differences are more difficult to assess.

With non-irrigated soybeans, compost treatment did not result in statistical differences in yield (Table 3) when compared with the no-compost treatment. During each year from application, yields were increased by compost application. The overall average increase above the no-compost treatment was 1.2% or 0.6 bushels. Only three fields were used to measure dryland soybean yields in the first and second years following application. These fields were planted to other crops, either corn, wheat, or grain sorghum. If more observations were available, then the numerical differences may be significant. Based on the standard errors, variation in yields on dryland soybeans is greater than variation in yields from irrigated acres. The increased variation in dryland situations is presumably related to precipitation differences and the subsequent impact that weather has on yields. This trend is similar when corn is grown on dryland acres (Table 2).

On some of the non-irrigated acres previously discussed, wheat was grown the first year after spring application of compost. Wheat yield was influenced more than any other crop by compost treatment. Spreading compost on wheat acres increased ($P < .04$) yield by 12% or 4.4 bushels per acre the first year after application (Table 4). With the wheat crop, corn silage was harvested in September and compost applied just prior to wheat planting. When grain sorghum was grown on compost-treated acres, yield was increased ($P < .04$) by 2.2 percent or 2.6 bushels compared to the no-compost treatment. The yield response for grain sorghum was averaged across one, three, and five years following the one-time application of compost.

In summary, yields were increased when compost was applied to irrigated corn and soybeans, dryland corn, dryland wheat, and dryland grain sorghum. The economic returns were greatest for corn and covered costs associated with spreading. The costs associated with composting ($1.50 per ton based on 1997 Nebraska Beef Report, pp. 88-91) are not included in the economic returns. However, the value of nutrients in compost in this study were also not included nor were the costs associated with disposal of manure. In this project, N fertilization was not reduced in the compost treated strips. Thus all the reported increases in yields and income were over and above the yields from crops receiving the recommended N fertilizer rates based on soil tests. There would be some cost savings if N fertilization were reduced on compost-treated fields, assuming compost will provide a portion of crop available N. Because N fertilization was held constant, we conclude that the yield response is probably due to P but other nutrients might have influenced yield. Whether yield improvements result from added P, OM, K, or other nutrients is not known, only that there is a benefit from one of these or a combination.

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Consumer Acceptance and Value of Strip Steaks Differing in Marbling and Country-of-Origin

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Consumers found high marbled beef and domestic beef more acceptable in palatability than low marbled beef and Argentine beef and generally were willing to pay more for more acceptable products.

Summary

Consumers (72.6%) visually preferred low marbled steaks. However, high marbled steaks were rated more juicy, tender and desirable in flavor and overall acceptability than low marbled steaks. Based on auction bids, consumers in Chicago (but not San Francisco) were willing to pay more for high marbled steaks than low marbled steaks. Domestic steaks were rated higher in all sensory attributes than Argentine steaks. Consumers in both locations were willing to pay more for domestic steaks than Argentine steaks. Although most consumers visually prefer low marbled steaks, most consumers find high marbled steaks to be more acceptable in sensory characteristics.

Introduction

Current research involving the sensory characteristics of beef has focused on consumer acceptance of beef tenderness and the value consumers place on tenderness. However, an improvement in beef tenderness alone may not be sufficient to increase overall consumer acceptance of beef. In this study, factors affecting beef flavor were studied to discover the importance of beef flavor on consumer acceptance and the value consumers place on flavor.

Marbling has been used in the meat industry as a visual indicator of beef palatability; therefore, strip loins differing in marbling level, but similar in tenderness, were used to investigate the effect of marbling on consumer acceptance. In addition, Argentine beef has been said to have a unique flavor (due to grass feeding and longer aging periods), so Argentine and domestic strip loins, of similar marbling level and tenderness, were used to determine consumer acceptance of beef from Argentina and the United States. Finally, experimental auction procedures were used to determine the value consumers placed on beef that differed in marbling level and country-of-origin.

Procedure

Selection of Strip Loins

Strip loins of two quality grades (Select and Upper 2/3 Choice) and of two countries (United States and Argentina) were purchased and shipped to the University of Nebraska-Loeffel Meat Laboratory. Each strip loin was assigned a random, three-digit code. The strip loins were aged for nine days at 32°F, and subsequently frozen. The strip loins were later cut into steaks, and the steaks were labeled in ascending order from anterior to posterior.

Steak 1 (the most anterior steak) was used for an objective tenderness determination, and steak 2 was held in reserve. Thawed steaks were cooked on a table-top broiler to an internal temperature of 160°F. The steaks were allowed to cool prior to coring with an automated coring device. Cores (1/2 inch diameter) were then sheared to determine Warner-Braztler shear force using an Instron Universal Testing Machine. For the marbling comparison, high marbled (upper 2/3 Choice) and low marbled (Select) strip loins with similar ($P>0.05$) Warner-Bratzler shear force values were paired for sensory evaluation, while steaks for the country-of-origin comparison were paired based on similar ($P>0.05$) Warner-Braztler shear force values and similar ($P>0.05$) marbling scores. In the country-of-origin comparison, all pairs were within the Select quality grade. Aging of Argentine beef was not under experimental control, and the exact aging period was unknown. However, information provided by the Argentine supplier indicates that the beef was aged for at least 30 days which assures that the Argentine beef was aged for a longer period than the domestic beef (nine days). Therefore, time of aging may contribute to the unique flavor of the Argentine beef used in this study. Efforts to minimize variation due to tenderness within each pair for the marbling comparison and to minimize variation due to both tenderness and marbling within each pair for the country-of-origin comparison add to the uniqueness of the study.

Selection of consumers

Consumers in two locations (Chicago and San Francisco) were screened over the telephone in order to qualify for the study. To be eligible, consumers had to meet three criteria. They had to be between the ages of 19 and 59, be the primary grocery shopper of the household and be willing to consume beef. In addition to these requirements, efforts were made to balance the selected consumers in regard to age, level of beef consumption, gender, economic category, and ethnicity. In each city, 12 panels were scheduled over a three-day period with a target of 12 consumers per panel.

Taste panel procedures

Prior to the taste panels, selected consumers were mailed a consent form and a survey to discern the consumer's

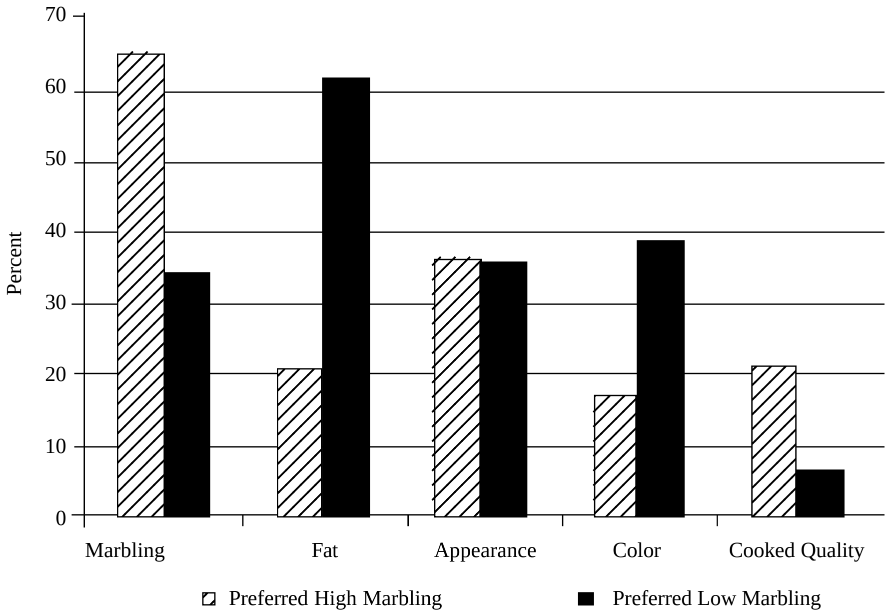

Figure 1. Percentage of selection criteria listed by each preference group.

eating preferences, meat purchasing behaviors and other demographic characteristics. The consumers brought these forms with them and were paid for their participation upon arrival ($25 in Chicago and $35 in San Francisco). Consumers were compensated with amounts comparable to other test marketing facilities in the respective cities.

Next, consumers were asked to visually evaluate a pair of steaks in a retail display case. Steaks of different marbling level (upper 2/3 Choice and Select) were purchased at local retail stores in each location. The steaks were packaged similarly and were labeled with four-digit random number codes. Consumers were asked to choose the steak that they would purchase if shopping in a grocery store, list the selection criteria they used to choose the steak and provide the price that they were willing to pay for each steak.

Then, the experimental auction procedures were explained. Consumers were informed that in each auction they would be bidding for a one-pound package (consisting of two frozen steaks) from the same strip loins as the samples in the taste panels. In each auction, there would be three winners, each receiving a one-pound package of steak. The auction method used was a Vickery auction, which is a silent, sealed-bid auction. Two practice auctions were conducted using the visual evaluation steaks. The consumers then evaluated a warm-up steak sample and a third practice auction was conducted. The practice auctions were simply used to acquaint the consumers with the auction procedures; the products used in these auctions were not purchased by the winning bidders.

Taste panel sample preparation

Paired strip loins were randomly assigned to taste panels. For the marbling comparison, each taste panel was assigned two matched pairs and for the country-of-origin comparison, one matched pair was assigned. Frozen steaks were shipped to the taste panel facilities. Steaks 3, 4 and 5 from each strip loin were used for taste panel samples. These steaks were thawed at refrigeration temperatures for about 24 hours prior to cooking. The steaks were then cooked to 160°F and cut into small rectangles for sensory evaluation. Steaks 6-11 remained frozen and were used in the auctions.

Consumers used an eight-point hedonic scale to rate taste panel samples for juiciness (1=extremely dry, 8=extremely juicy), tenderness (1= extremely tough, 8=extremely tender), flavor and overall acceptability (1= extremely undesirable, 8=extremely desirable). After evaluating each pair of samples, consumers had the opportunity to participate in an auction for steaks from the same strip loin as the samples they tasted. This procedure was performed three times (two marbling comparisons and one country-of-origin comparison).

Statistical analysis

Consumers in experimental auctions tend to bid amounts that do not reflect the market value of the products. Using a Vickery auction, instead of focusing on the absolute bids for the products differing in marbling or country-of-origin, the analysis focuses on the differential between the two bids, which better reflects the value consumers place on the products. Price data were analyzed using the mixed procedure of SAS and visual preference data were analyzed using the chi square procedure in SAS.

Results

In regard to panel demographics, a total of 248 consumers participated in the study (124 in each location). In Chicago, the panels consisted of 102 females and 22 males, while in San Francisco, 96 females and 28 males participated. In both locations, most consumers were between the ages of 30 and 59, and consumed beef 1-4 or more times per week. Their yearly incomes ranged from $10,000-100,000 or more/ year. Most of the consumers were Caucasians.

There was a significant difference in visual preference with 72.6% of consumers preferring the low marbled steak. Selection criteria were categorized into five main categories: marbling, fat, color, appearance and cooked quality (Figure 1). A majority of consumers (61.6%) who preferred low marbling listed fat as a selection criteria, while a majority of consumers (65.4%) who preferred high marbling listed marbling as a selection criteria. It appears that visual preference for steaks differing in marbling is influenced by consumer perception of marbling as a negative factor (high fat content) or a positive factor (increases flavor and juiciness).

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In regard to price, there was a significant interaction between visual preference and marbling level. Consumers who preferred the high marbled steak were willing to pay $0.75/lb more (P<0.01) for the high marbled steak (Table 1). Consumers who preferred the low marbled steak were willing to pay $1.12/lb more (P<0.01) for the low marbled steak. Consumers placed a higher value on the steak (high or low marbled) that they preferred, based on visual assessment. It appears that consumers who are concerned about fat content place a higher value on low marbled steaks than consumers who want to purchase a steak with high eating quality place on high marbled steaks.

In the taste panel evaluations, consumers rated high marbled steaks more (P<0.01) desirable in flavor as well as more (P<0.01) juicy and more (P<0.05) tender (Table 2). Although pairs were matched based on Warner-Bratzler shear force values, consumers perceived differences in tenderness. It is not surprising that objective and subjective evaluations of tenderness are different. Finally, consumers rated high marbled steaks as being more (P<0.01) desirable overall. Consumers in Chicago were willing to pay $0.23 more (P<0.05) for high marbled steaks than low marbled steaks (Table 3), while consumers in San Francisco were only willing to pay $0.09 more (P>0.05) for high marbled steaks than low marbled steaks. Consumers in both locations rated high marbled steaks higher in all sensory attributes; however, only consumers in Chicago were willing to pay significantly more for the high marbled steaks, based upon palatability characteristics. There are likely a variety of reasons that consumers in Chicago and San Francisco valued high and low marbled beef differently. Even so, marbling is clearly an important factor that affects beef palatability. Consumers need to be aware of the importance of marbling, and that they are likely to find high marbled steaks more acceptable than low marbled steaks.

Consumers found the domestic steaks to be more (P<0.01) desirable in flavor and rated domestic steaks higher (P<0.01) in juiciness, tenderness and overall acceptability (Table 4). Consumers in Chicago were willing to pay $0.89 more (P<0.01) for domestic steaks than Argentine steaks, and consumers in San Francisco were willing to pay $0.48 more (P<0.01) for domestic steaks than Argentine steaks (Table 5). The Argentine beef used in this study was imported from a supplier that used grass-fed cattle and a long aging period. Grass-fed beef tends to have a different flavor profile than grain-fed beef, which is more typical of commercial beef in the United States. Length of aging also will affect the flavor of beef, and the Argentine beef was aged longer than most beef in the United States. With both of these factors contributing to the flavor of the Argentine beef, it is not surprising that consumers found a substantial difference in flavor between the two products. While the flavor of Argentine beef may be unique, the consumers in this study found domestic beef to be more acceptable and placed a higher value on domestic beef.

Table 1. The value consumers place on steaks differing in marbling level based on visual evaluation ($/lb).

	Price for high marbled steak	Price for low marbled steak	Differential	P-Value
Preferred high marbling	$3.77	$3.02	$0.75	<0.01
Preferred low marbling	$2.98	$4.10	$1.12	<0.01

Table 2. Taste panel ratings for high and low marbled steaks.

Attribute[a]	High marbled steaks	Low marbled steaks	P-value
Flavor rating	5.60	5.30	<0.01
Juiciness rating	4.94	4.47	<0.01
Tenderness rating	5.45	5.26	<0.05
Overall acceptability rating	5.37	5.06	<0.01

[a] Samples rated using an 8-point hedonic scale (8=extremely desirable, juicy, tender, desirable; 1=extremely undesirable, dry, tough, undesirable).

Table 3. The value consumers place on high and low marbled steaks based on experimental auction bids ($/lb).

	High marbled steak bid	Low marbled steak bid	Differential	P-value
Chicago	$2.38	$2.16	$0.23	<0.05
San Francisco	$2.70	$2.61	$0.09	>0.05

Table 4. Taste panel ratings for Argentine and domestic steaks.

Attribute[a]	Domestic steaks	Argentine steaks	P-value
Flavor rating	5.82	4.60	<0.01
Juiciness rating	4.94	4.47	<0.01
Tenderness rating	5.79	5.14	<0.01
Overall acceptability rating	5.64	4.57	<0.01

[a]Samples rated using an 8-point hedonic scale (8=extremely desirable, juicy, tender, desirable; 1=extremely undesirable, dry, tough, undesirable).

Table 5. The value consumers place on domestic and Argentine steaks based on experimental auction bids ($/lb).

	Domestic steak bid	Argentine steak bid	Differential	P-Value
Chicago	$2.63	$1.74	$0.89	<0.01
San Francisco	$2.59	$2.10	$0.48	<0.01

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Physical and Chemical Properties of 39 Muscles from the Beef Chuck and Round.

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Chris Calkins[1]

Variation among the muscles of the beef chuck and round are profound. Physical and chemical properties of these muscles were shown to be affected the most by quality grade.

Summary

Twenty-seven and 12 muscles, respectively, from the chuck and round were analyzed for objective color, expressible moisture, emulsion capacity, pH, total collagen content total heme-iron content, and proximate composition. Observations of these physical and chemical properties showed a vast range of results. The range in data reveal the variation within and among muscles. Knowledge of this variation can lead to proper usage, thereby increasing value of the beef chuck and round. Quality grade had the most pronounced effects, whereas yield grade and weight showed fewer effects on these traits across all 39 muscles.

Introduction

With the increasing popularity of value-added products and the decline in value of the beef chuck and round (20 - 25% over a five-year period), it's necessary to characterize the muscles from these two primals. Muscle has unique physical and chemical properties, which when known and understood can allow for development of value-added products. Information (physical and chemical properties) of many muscles within the chuck and round was lacking until this study was undertaken. It is also important to describe the effects of quality grade, yield grade, and weight of carcass on these properties. Therefore, the objectives of this study were to determine the physical and chemical properties of 39 muscles from the beef chuck and round and the effects of quality grade, yield grade, and weight on these properties.

Procedure

Ninety-four chucks and 94 rounds were selected at the IBP Inc., Dakota City, Neb. plant based on quality grade (upper 2/3 Choice, low Choice, and Select), yield grade (1, 2, 3, and 4 and 5 together), and carcass weight (550 - 650 lb and 850 - 950 lb). Twenty-seven and 12 muscles, respectively, were dissected from chucks and rounds. Each individual muscle was then trimmed of all external fat and connective tissue. Objective color (L*, a*, and b* values) was observed using a Hunter Lab Mini Scan device with a 1- inch port. Expressible moisture, a method of measuring water holding capacity, was measured as the percentage of moisture lost due to centrifugation. Muscle pH was determined using a pH meter with a spear tip combination electrode. Emulsion capacity, which determines the amount of oil a specific muscle/protein system can bind, was expressed as mL oil bound/2.5g of lean tissue. Total collagen measures the amount of connective tissue within a given muscle. It was quantified by measuring the total content of hydroxyproline in a sample, which is related to collagen. Total collagen was expressed as mg of collagen/g of lean tissue. Total heme-iron measures the amount of myoglobin and hemoglobin within a given muscle. Acetone and hydrochloric acid were used to separate myoglobin and hemoglobin from the sample. This solution then was read using a spectrophotometer; results were expressed in parts per million (ppm). Proximate composition (fat, moisture and ash) was determined using Soxhlet ether extraction procedures and a LECO Thermogravimetric Analyzer (a continuous weighing and heating device). Fat, moisture and ash were expressed as mg/g (%) of lean tissue. Data were analyzed statistically using mixed and least square means procedures.

Results

Across all 39 muscles, variation was evident in all analyzed physical and chemical properties (Tables 1 - 4). Objective color (L*, a*, and b*) values represent a color scale. The higher the L* (ranging from 0 = black to 100 = white), the lighter the muscle. As a* (ranging from negative 60 = green to positive 60 = red) increases, the muscle becomes more red. As b* (ranging from negative 60 = blue to positive 60 = yellow) increases, the muscle becomes more yellow. The overall means and standard deviations observed for L*, a*, and b* were 41.06 $\pm$ 4.55, 29.57 $\pm$ 4.05, and 22.78 $\pm$ 4.32, respectively. The measurement of objective color can be correlated to other chemical properties such as pH and total heme-iron, which together can be related to the shelf-life of a specific muscle and the ultimate color of a processed product.

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Table 1. Properties of chuck muscles.

Muscle	Emulsion capacity (mL oil/2.5g) Mean	(s.d.)	Expressible Moisture (%) Mean	(s.d.)	L* - value Mean	(s.d.)	a* - value Mean	(s.d.)	b* - value Mean	(s.d.)
Biceps brachii	169.71	(14.7)	37.52	(4.22)	38.56	(3.56)	28.65	(3.75)	21.85	(4.32)
Brachiocephalicus omo-transversarius	172.13	(18.1)	37.57	(5.95)	42.66	(2.70)	28.79	(3.27)	21.61	(3.34)
Brachialis	176.61	(20.6)	37.62	(5.41)	38.87	(4.03)	28.08	(3.74)	20.41	(4.28)
Cutaneous omo-brachialis	179.37	(27.3)	34.85	(8.17)	52.08	(5.63)	19.51	(4.54)	14.68	(4.45)
Complexus	175.10	(17.1)	36.34	(5.31)	40.58	(2.47)	31.10	(3.00)	23.69	(3.56)
Deltoideus	173.07	(15.1)	38.56	(4.62)	43.80	(3.68)	27.47	(3.33)	20.71	(3.39)
Deep pectoral	175.53	(20.6)	37.46	(4.57)	41.31	(3.08)	29.79	(3.23)	22.56	(3.52)
Dorsalis oblique	175.04	(19.3)	37.59	(4.52)	43.35	(2.64)	30.09	(3.34)	22.79	(3.72)
Infraspinatus	171.45	(15.0)	37.63	(4.70)	38.85	(2.60)	31.25	(3.08)	24.82	(3.64)
Intertransversales	174.26	(14.9)	35.84	(5.24)	39.30	(4.04)	29.98	(3.17)	22.82	(3.71)
Latissimus dorsi	175.02	(19.6)	37.82	(5.15)	41.51	(3.50)	29.07	(4.03)	22.05	(4.35)
Longissimus capitus et Atlantis	175.15	(14.9)	37.19	(5.31)	39.71	(3.83)	29.90	(4.17)	22.63	(4.57)
Longissimus costarum	174.15	(18.3)	34.85	(5.90)	40.01	(4.31)	27.08	(3.77)	19.90	(3.84)
Longissimus dorsi	173.70	(16.8)	37.76	(4.27)	40.55	(3.03)	31.13	(3.46)	23.98	(4.00)
Levatores costarum	174.86	(19.7)	36.94	(5.28)	39.33	(3.87)	29.14	(3.62)	22.34	(3.88)
Multifidus/Spinalis dorsi	168.49	(17.0)	36.38	(5.47)	38.08	(3.34)	30.60	(3.87)	23.20	(4.94)
Rhomboideus	173.67	(16.2)	36.42	(4.77)	41.35	(3.04)	28.43	(3.48)	20.99	(3.90)
Scalenus dorsalis	170.82	(19.7)	37.51	(4.73)	44.61	(3.67)	29.55	(3.72)	21.74	(3.92)
Serratus ventralis	177.25	(16.4)	37.20	(5.72)	39.64	(2.98)	31.42	(2.87)	24.61	(3.49)
Splenius	179.35	(19.6)	36.34	(6.53)	40.49	(2.88)	29.40	(3.78)	21.98	(4.19)
Superficial pectoral	172.12	(15.9)	35.92	(5.52)	44.09	(3.75)	28.10	(3.06)	20.78	(3.07)
Subscapularis	173.06	(14.4)	37.85	(4.64)	38.65	(4.09)	30.30	(2.86)	23.45	(3.46)
Supraspinatus	178.80	(17.9)	38.73	(4.95)	40.82	(3.35)	30.92	(3.03)	23.83	(3.51)
Teres major	178.89	(24.1)	37.12	(4.83)	41.48	(3.75)	29.98	(3.74)	23.02	(4.21)
Tensor fascia antibrachii	173.10	(17.8)	37.92	(4.73)	42.47	(3.17)	28.03	(3.86)	20.40	(4.11)
Trapezius	175.24	(25.0)	35.64	(5.07)	44.89	(4.69)	25.65	(4.64)	18.44	(5.41)
Triceps brachii	169.64	(19.7)	36.41	(20.20)	39.47	(2.80)	31.50	(3.62)	24.78	(4.38)

Table 2. Properties of chuck muscles.

Muscle	Total Collagen (mg/g) Mean	(s.d.)	Heme – Iron (ppm) Mean	(s.d.)	pH Mean	(s.d.)	Fat (mg/g) Mean	(s.d.)	Moisture (mg/g) Mean	(s.d.)	Ash (mg/g) Mean	(s.d.)
Biceps brachii	13.14	(7.32)	24.70	(2.88)	5.79	(0.33)	6.79	(2.17)	72.74	(1.66)	1.07	(0.19)
Brachiocephalicus omo-transversarius	11.28	(6.48)	16.86	(3.12)	5.75	(0.31)	6.40	(2.14)	73.10	(1.47)	1.14	(0.18)
Brachialis	11.81	(4.36)	23.84	(2.85)	5.76	(0.30)	4.04	(1.23)	75.41	(1.19)	1.43	(0.22)
Cutaneous omo-brachialis	10.72	(5.68)	15.20	(6.47)	5.81	(0.32)	14.03	(4.19)	64.88	(6.70)	1.04	(0.19)
Complexus	12.59	(4.68)	22.14	(2.13)	5.76	(0.33)	8.37	(1.88)	72.02	(1.48)	1.48	(0.08)
Deltoideus	13.57	(8.13)	16.72	(2.09)	5.77	(0.33)	6.45	(1.75)	73.32	(1.71)	1.23	(0.17)
Deep pectoral	10.56	(4.67)	19.90	(3.25)	5.73	(0.32)	5.49	(1.93)	72.66	(1.32)	1.41	(0.23)
Dorsalis oblique	10.13	(3.84)	18.35	(2.18)	5.88	(0.37)	9.07	(2.32)	71.91	(1.89)	1.12	(0.18)
Infraspinatus	8.72	(3.33)	23.55	(2.87)	5.78	(0.32)	9.18	(2.54)	70.81	(2.05)	1.08	(0.11)
Intertransversales	13.82	(5.55)	23.39	(2.92)	5.77	(0.34)	8.56	(2.45)	71.86	(1.96)	1.03	(0.14)
Latissimus dorsi	12.53	(7.67)	18.37	(2.94)	5.74	(0.32)	5.99	(1.51)	72.34	(1.41)	1.23	(0.16)
Longissimus capitus et Atlantis	11.87	(7.62)	21.44	(3.83)	5.79	(0.32)	6.49	(1.92)	73.23	(1.37)	1.07	(0.12)
Longissimus costarum	13.39	(8.19)	23.00	(3.40)	5.86	(0.33)	10.06	(3.48)	69.65	(2.75)	1.08	(0.20)
Longissimus dorsi	14.49	(9.07)	22.02	(4.48)	5.71	(0.27)	7.74	(1.95)	70.52	(1.58)	1.20	(0.14)
Levatores costarum	8.87	(4.40)	21.77	(1.96)	5.86	(0.32)	9.86	(2.45)	70.39	(1.95)	1.09	(0.17)
Multifidus/Spinalis dorsi	16.20	(11.71)	24.93	(2.45)	5.80	(0.41)	14.22	(2.67)	68.04	(2.11)	1.01	(0.21)
Rhomboideus	12.27	(5.09)	20.69	(3.45)	5.82	(0.32)	6.35	(1.93)	72.08	(1.43)	1.38	(0.15)
Scalenus dorsalis	10.06	(4.26)	15.75	(1.99)	5.75	(0.34)	9.11	(3.11)	71.22	(2.53)	0.98	(0.18)
Serratus ventralis	8.78	(3.82)	24.33	(3.13)	5.81	(0.28)	12.21	(3.05)	68.77	(2.43)	1.02	(0.11)
Splenius	11.16	(9.16)	19.37	(3.18)	5.71	(0.29)	4.35	(1.44)	74.43	(1.39)	1.33	(0.24)
Superficial pectoral	8.21	(4.90)	20.15	(4.97)	5.77	(0.27)	10.66	(2.90)	69.79	(2.29)	1.10	(0.09)
Subscapularis	10.64	(6.11)	20.55	(2.39)	5.85	(0.33)	4.60	(1.26)	73.21	(1.19)	1.31	(0.20)
Supraspinatus	17.77	(11.00)	21.47	(3.25)	5.82	(0.32)	4.95	(1.08)	74.29	(0.95)	1.37	(0.15)
Teres major	11.33	(3.74)	19.94	(2.33)	5.72	(0.34)	5.25	(1.29)	73.54	(1.11)	1.23	(0.31)
Tensor fascia antibrachii	9.95	(5.36)	14.74	(2.91)	5.79	(0.37)	4.57	(1.36)	74.08	(1.16)	1.24	(0.15)
Trapezius	8.85	(4.90)	16.03	(3.19)	5.82	(0.33)	8.65	(1.91)	71.62	(2.06)	0.93	(0.11)
Triceps brachii	9.97	(3.84)	21.53	(2.43)	5.78	(0.38)	5.65	(1.55)	73.23	(1.27)	1.44	(0.17)

Table 3. Properties of round muscles.

Muscles	Emulsion capacity (mL oil/2.5g)		Expressible Moisture (%)		L* - value		a* - value		b* - value	
	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)
Adductor	172.73	(17.9)	38.89	(4.41)	42.32	(4.08)	31.09	(3.71)	25.47	(3.00)
Biceps femoris	171.33	(16.5)	38.27	(6.09)	41.38	(2.78)	32.14	(2.61)	26.55	(2.62)
Gluteus medius	176.76	(21.2)	37.78	(4.72)	44.53	(3.55)	27.74	(4.42)	22.47	(3.14)
Gracilis	175.33	(18.8)	38.52	(4.99)	36.15	(2.92)	30.89	(3.05)	23.48	(3.54)
Pectineus	175.51	(18.8)	38.24	(5.20)	42.10	(4.54)	31.96	(2.14)	25.44	(2.51)
Rectus femoris	174.12	(19.5)	38.12	(4.89)	41.08	(3.01)	30.29	(3.32)	25.16	(2.38)
Sartorius	171.75	(20.0)	39.33	(4.66)	40.79	(3.07)	29.10	(3.13)	21.39	(3.15)
Semimembranosus	178.62	(23.7)	38.68	(4.48)	39.44	(2.96)	32.56	(2.53)	27.00	(2.57)
Semitendinosus	175.29	(17.1)	37.87	(4.11)	44.39	(3.11)	30.06	(2.23)	24.27	(2.11)
Vastus intermedius	173.25	(20.4)	37.84	(5.09)	35.22	(2.99)	30.16	(1.81)	23.32	(2.27)
Vastus lateralis	172.84	(16.1)	39.06	(4.24)	39.45	(2.75)	31.95	(2.35)	25.65	(2.70)
Vastus medialis	169.19	(12.8)	38.50	(4.23)	35.38	(3.53)	31.03	(2.65)	24.26	(3.51)

Table 4. Properties of round muscles.

Muscles	Total Collagen (mg/g)		Heme – Iron (ppm)		pH		Fat (mg/g)		Moisture (mg/g)		Ash (mg/g)	
	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)
Adductor	12.31	(11.89)	22.57	(2.70)	5.76	(0.30)	4.57	(1.21)	72.86	(0.87)	1.49	(0.23)
Biceps femoris	12.36	(8.32)	22.43	(3.48)	1.69	(0.30)	6.86	(1.65)	71.61	(1.29)	1.29	(0.17)
Gluteus medius	11.80	(5.77)	19.76	(2.57)	5.76	(0.34)	5.94	(1.69)	71.44	(1.51)	1.40	(0.16)
Gracilis	15.20	(7.92)	24.31	(4.22)	5.76	(0.31)	3.93	(1.24)	74.78	(1.06)	1.51	(0.17)
Pectineus	12.97	(6.71)	21.28	(2.64)	5.84	(0.30)	3.16	(0.83)	74.45	(0.83)	1.56	(0.18)
Rectus femoris	11.06	(4.23)	19.60	(3.10)	5.72	(0.32)	5.11	(1.79)	73.33	(1.22)	1.50	(0.17)
Sartorius	10.49	(3.39)	19.40	(2.87)	5.75	(0.30)	3.14	(1.29)	74.69	(1.11)	1.54	(0.27)
Semimembranosus	10.40	(4.91)	21.22	(3.29)	5.74	(0.31)	4.36	(1.24)	72.79	(0.78)	1.75	(0.26)
Semitendinosus	11.56	(6.20)	14.65	(2.16)	5.72	(0.30)	4.08	(0.90)	73.27	(0.77)	1.53	(0.15)
Vastus intermedius	9.89	(3.46)	27.27	(2.92)	5.87	(0.40)	8.43	(2.56)	72.91	(1.77)	0.98	(0.11)
Vastus lateralis	12.71	(5.39)	20.29	(3.18)	5.77	(0.30)	4.44	(1.15)	73.54	(0.97)	1.53	(0.26)
Vastus medialis	14.92	(8.75)	25.45	(3.58)	5.78	(0.28)	4.35	(1.27)	75.02	(1.14)	1.47	(0.33)

The mean and standard deviation for expressible moisture was observed to be 37.50 ± 5.15%. Expressible moisture (along with pH) can reveal a good understanding of protein functionality. Knowledge of the amount of moisture lost due to centrifugation allows product developers to use technologies to minimize the loss of moisture (loss of yield and palatability).

The mean and standard deviation of pH was observed to be 5.78 ± 0.32. Muscle pH as previously mentioned reveals a better understanding of protein functionality. As muscle pH increases, expressible moisture decreases. However, higher pH meat appears to be darker in color (lower L* values) and also tends to have a shorter shelf-life.

The mean and standard deviation for emulsion capacity were observed to be 174.2 ± 18.8 mL oil bound/2.5 g of lean tissue. This property of muscle can also characterize a specific muscle, as higher amounts of oil bound in a protein system can be related to the amount of salt-soluble protein (major binding protein) within that system. Such information can allow for increased yield and therefore increased profit in the production of sausage-type products.

The mean and standard deviation of total collagen was 11.69 ± 6.54 mg/g of lean tissue. This property of muscle can be related to the tenderness and texture of meat.

The mean and standard deviation for total heme-iron was 20.78 ± 4.43 ppm. Total heme-iron can reveal information about a muscle's physical appearance (appearance to the eye), which is a major factor in consumer acceptance. The concentration of these color pigments is also an important determinant of processed meat color.

Fat, moisture and ash had mean percentages and standard deviations of 6.86 ± 3.45, 72.28 ± 2.83, and 1.26 ± 0.28, respectively.

To envision the variation between these 39 muscles, each muscle was categorized for each trait into three groups — desirable (white), intermediate (gray), or undesirable (black). These charts (Tables 5 and 6) show specific physical and chemical properties (fat, pH, expressible moisture, emulsion capacity, total heme-iron, and total collagen) which provide a quick, overall picture of a particular muscles' characteristics. This can be useful in selection of candidate muscles for value-added products.

Through investigation of the effects of quality grade, yield grade and weight on the physical and chemical properties, quality grade was the effect that was most frequently significant ($P < .05$). Across all physical and chemical properties, 2 to 31, 1 to 9, and 0 to 8 muscles out of 39 showed an effect due to quality grade, yield grade, and weight, respectively. For muscles with a significant quality grade effect, moisture (19 of 23 muscles) and ash (6 of 15 muscles) decreased while fat (26 of 31 muscles) and pH (7 of 16 muscles) increased with an increase in quality grade. It was also observed that properties showing an increase with an increase in quality grade were fat (26 out of 31 muscles) and pH (7 out of 16 muscles).

(Continued on next page)

Table 5. Classification of beef chuck muscles by trait.

	Fat	pH	Expressible Moisture	Emulsion Capacity	Heme-Iron	Total Collagen
Biceps brachii	Light gray	Light gray	Light gray	Dark gray	Light gray	Light gray
Brachiocephalicus omot.	Light gray	Light gray	Light gray	Light gray	Light gray	Light gray
Brachialis	White	Light gray	Light gray	White	Light gray	Light gray
Cutaneous omo brachialis	Dark gray	Light gray	White	White	Dark gray	Light gray
Complexus	Light gray	Light gray	Light gray	White	Light gray	Light gray
Deep pectoral	Light gray	Light gray	Light gray	White	Dark gray	Light gray
Deltoideus	Light gray	Light gray	Dark gray	Light gray	Dark gray	Light gray
Dorsalis oblique	Light gray	White	Light gray	White	Dark gray	Light gray
Infraspinatus	Light gray	Light gray	Light gray	Light gray	Light gray	White
Intertransversales	Light gray	Light gray	White	Light gray	Light gray	Light gray
Latissimus dorsi	Light gray	Light gray	Light gray	White	Dark gray	Light gray
Longissimus cap. et Atlantis	Light gray	Light gray	Light gray	White	Light gray	Light gray
Longissimus costarum	Dark gray	White	White	Light gray	Light gray	Light gray
Longissimus dorsi	Light gray	Light gray	Light gray	Light gray	Light gray	Light gray
Levatores costarum	Light gray	White	Light gray	Light gray	Light gray	White
Multifidus and spinalis dorsi	Dark gray	White	Light gray	Dark gray	Light gray	Dark gray
Rhomboideus	Light gray	White	Light gray	Light gray	Light gray	Light gray
Scalenus dorsalis	Light gray	Light gray	Light gray	Light gray	Dark gray	Light gray
Serratus ventralis	Dark gray	White	Light gray	White	Light gray	White
Splenius	White	Light gray	Light gray	White	Dark gray	Light gray
Superficial pectoral	Dark gray	Light gray	White	Light gray	Light gray	White
Subscapularis	White	White	Light gray	Light gray	Light gray	Light gray
Supraspinatus	White	White	Dark gray	White	Light gray	Dark gray
Tensor fascia antibroachii	White	Light gray	Light gray	Light gray	Dark gray	White
Teres major	Light gray	Light gray	Light gray	Light gray	Dark gray	Light gray
Trapezius	Light gray	White	White	White	Dark gray	White
Triceps brachii	Light gray	Light gray	Light gray	Dark gray	Light gray	White

The white cells represent fat <5%, pH >5.8, WHC (expressible moisture) <36%, bind >175 mL, heme-iron >25 ppm, collagen <01 mg/g, while the dark gray cellsrepresent fat >10%, pH <5.7, WHC >38%, bind <170 mL, heme-iron <20 ppm, collagen >15 mg/g. The values represented by the light gray cells are intermediate.

Table 6. Classification of beef round muscles by trait.

	Fat	pH	Expressible Moisture	Emulsion Capacity	Heme-Iron	Total Collagen
Adductor	White	Light gray	Dark gray	Light gray	Light gray	Light gray
Biceps femoris	Light gray	Dark gray	Dark gray	Light gray	Light gray	Light gray
Gluteus medius	Light gray	Light gray	Light gray	White	Dark gray	Light gray
Gracilis	White	Light gray	Dark gray	White	Light gray	Dark gray
Pectineus	White	White	Dark gray	White	Light gray	Light gray
Rectus femoris	Light gray	Light gray	Dark gray	Light gray	Dark gray	Light gray
Sartorious	White	Light gray	Dark gray	Light gray	Dark gray	Light gray
Semimembranosus	White	Light gray	Dark gray	White	Light gray	Light gray
Semitendinosus	White	Light gray	Light gray	White	Dark gray	Light gray
Vastus intermedius	Light gray	White	Light gray	Light gray	White	White
Vastus lateralis	White	Light gray	Dark gray	Light gray	Light gray	Light gray
Vastus medialis	White	Light gray	Dark gray	Light gray	White	Light gray

The white cells represent fat <5%, pH >5.8, WHC (expressible moisture) <36%, bind >175 mL, heme-iron >25 ppm, collagen <01 mg/g, while the dark gray cellsrepresent fat >10%, pH <5.7, WHC >38%, bind <170 mL, heme-iron <20 ppm, collagen >15 mg/g. The values represented by the light gray cells are intermediate.

Significant ($P < .05$) yield grade effects were seldom linear, reflecting inconsistent trends as yield grade increased or decreased.

Moisture (4 out of 5 muscles), L* value (7 out of 7 muscles), a* value (8 out of 8 muscles), b* value (6 out of 6 muscles), and expressible moisture (5 out of 6 muscles) increased with an increase in weight of carcass. However, pH (4 out of 4 muscles), fat (4 out of 5 muscles), and emulsion capacity (5 out 5 muscles) decreased with an increase in weight of carcass. Total collagen showed no effect across all 39 muscles due to weight.

These data indicate a vast amount of variation in physical and chemical properties among muscles of the beef chuck and round. Knowledge of these properties now allows individual muscles to be identified and utilized for production of value-added products.

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Fiber Type Composition of the Beef Chuck and Round

Kevin Kirchofer
Chris Calkins[1]

There is wide variability in fiber types of beef chuck muscles. This would be expected to create different processing characteristics which influence optimal muscle use in value-added products.

Summary

The fiber type composition of 38 muscles of the beef chuck and round was studied to facilitate optimal muscle use in value-added products. Select grade chucks and rounds (n=4 each) were used. Muscles containing greater than 40% β-red fiber numbers were classified as red; greater than 40% α-white were classified as white. All others were classified as intermediate. Nine of 12 round muscles were white, while chuck muscles were equally dispersed between red (10 of 26), intermediate (9 of 26), and white (7 of 26), indicating variation among muscles of the chuck, which may create differences in processing characteristics.

Introduction

There is a relationship between ultimate meat quality and muscle fiber type composition. Muscles with increased α white (αW) fibers have more connective tissue, less intramuscular fat, and are less tender than muscles with more β-red (βR) fibers. Not only do individual muscles differ in fiber type composition, but muscle fiber types within a specific muscle may be affected by breed, sex, time on feed and maturity.

Muscle fiber types have been reported for many of the larger muscles of the beef carcass. Little attention has been given to the smaller muscles that comprise the chuck and the round. With many of these muscles going to further processing, there is a need for a fiber type profile of these muscles. The objective of this study was to characterize the histochemical muscle fiber type of 23 muscles of the beef round and 26 muscles of the beef chuck to help in the application of muscles into value-added products through the use of further processing.

Procedure

Select-grade chucks and rounds (n=4 each) were chosen representing two weight ranges (550-650 lbs, and 800-900 lbs) and two yield grades (yield grade 1 and 3). Twelve muscles of the beef round and 26 muscles of the beef chuck were fabricated and sampled. Muscle samples were frozen in liquid nitrogen within nine days post mortem and subsequently stored at -112°F until histochemical analysis was performed.

One cubic centimeter of frozen tissue was mounted on a cryostat chuck in such a manner to set muscle fibers perpendicular to the cutting blade. The mounted cubes were allowed to equilibrate to -4.0°F before being sliced to a thickness of 12 μm on a cryostat. The slices were mounted on slides and allowed to equilibrate to room temperature before being stained.

Muscle sections were stained according to a simultaneous staining technique, which included a stain for succinic dehydrogenase activity and a stain for acid-active adenosine triphosphatase activity after acid incubation. Cover slips were permanently mounted over the stained tissue to enable fiber classification.

Fibers were classified on the basis of stain reactions: β-red fibers stained dark brown, α-red fibers were clear in the middle and surrounded by a blue ring, and α-white fibers were clear. Fiber numbers were calculated by examining a minimum of 500 muscle fibers from muscle bundles containing at least 50 fibers per bundle. Muscle fiber percentage was calculated by counting the total number of each fiber type, dividing by the total number of fibers counted, and multiplying the quotient by 100:

Fiber Number (%) = Fiber Number (β-red, α-red, or α-white) / Total Fiber Number * 100.

Muscles were classified as red, intermediate, or white on the basis of the average muscle fiber number (%). Muscles were classified as red if they

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Table 1. Muscle fiber type characteristics of red[a] muscles.

MUSCLE	Trait	β-Red Mean	β-Red (S.E.[b])	α-Red Mean	α-Red (S.E.[b])	α-White Mean	α-White (S.E.[b])
Trapezius	Number (%)	62.56	(3.72)	21.48	(3.08)	15.96	(2.97)
	Diameter (μm)	34.98	(0.77)	40.92	(0.91)	46.53	(0.89)
	Area (μm^2)	991.81	(42.70)	1364.04	(62.87)	1751.72	(65.06)
	Percent Area	51.94	(1.26)	24.84	(1.36)	23.23	(1.47)
Brachialis	Number (%)	61.93	(2.14)	28.98	(1.98)	9.10	(1.45)
	Diameter (μm)	33.78	(0.80)	38.72	(0.95)	47.83	(0.79)
	Area (μm^2)	935.37	(44.52)	1228.69	(57.93)	1826.27	(61.16)
	Percent Area	51.43	(0.89)	32.42	(1.06)	16.14	(1.38)
Multifidous & spinalus dorsi	Number (%)	60.19	(1.90)	22.12	(2.94)	17.69	(1.69)
	Diameter (μm)	30.57	(0.65)	38.04	(0.91)	48.41	(0.89)
	Area (μm^2)	751.88	(31.51)	1191.37	(54.92)	1875.69	(67.84)
	Percent Area	43.06	(0.91)	24.91	(1.15)	32.03	(1.34)
Biceps brachii	Number (%)	58.71	(1.98)	22.73	(1.06)	18.56	(3.02)
	Diameter (μm)	35.97	(0.78)	38.24	(0.78)	49.40	(0.77)
	Area (μm^2)	1044.19	(45.61)	1173.31	(48.21)	1944.99	(60.08)
	Percent Area	48.72	(0.95)	21.70	(1.17)	29.58	(1.29)
Intertransversales	Number (%)	52.51	(5.84)	25.16	(3.44)	22.33	(4.61)
	Diameter (μm)	33.49	(0.88)	42.56	(0.80)	43.28	(0.81)
	Area (μm^2)	935.11	(48.73)	1503.14	(54.59)	1537.00	(57.12)
	Percent Area	40.09	(1.03)	29.48	(1.26)	30.43	(1.29)
Complexus	Number (%)	51.59	(5.95)	22.93	(1.34)	25.48	(5.18)
	Diameter (μm)	31.01	(0.69)	41.65	(1.02)	47.54	(0.91)
	Area (μm^2)	774.79	(34.31)	1424.84	(68.80)	1811.30	(68.68)
	Percent Area	33.92	(1.02)	27.31	(1.01)	38.77	(1.26)
Levatores costarum	Number (%)	46.87	(2.65)	26.23	(4.21)	26.90	(1.94)
	Diameter (μm)	37.36	(0.92)	53.67	(1.11)	55.44	(1.10)
	Area (μm^2)	1141.65	(56.51)	2387.26	(97.39)	2520.63	(98.61)
	Percent Area	29.34	(0.85)	33.45	(1.06)	37.21	(1.25)
Infraspinatus	Number (%)	46.64	(3.04)	28.51	(2.72)	24.85	(3.55)
	Diameter (μm)	36.69	(0.84)	44.31	(0.91)	52.89	(0.98)
	Area (μm^2)	1143.30	(51.67)	1623.98	(67.05)	2289.55	(86.77)
	Percent Area	32.86	(0.64)	29.82	(1.05)	37.32	(1.24)
Brachiocephalicus omotranversarius	Number (%)	42.22	(1.24)	28.32	(1.01)	29.46	(1.21)
	Diameter (μm)	34.85	(0.76)	44.90	(0.95)	54.25	(0.87)
	Area (μm^2)	987.40	(42.04)	1621.15	(67.56)	2353.15	(76.67)
	Percent Area	26.49	(0.77)	29.44	(1.18)	44.07	(1.24)
Longissimus capitus et Atlantis	Number (%)	40.99	(4.20)	27.87	(1.30)	31.14	(4.16)
	Diameter (μm)	34.35	(0.78)	40.99	(0.92)	49.11	(0.95)
	Area (μm^2)	954.54	(43.40)	1357.75	(61.23)	1939.91	(74.79)
	Percent Area	28.59	(0.92)	28.20	(1.16)	43.21	(1.18)

[a]Muscles containing greater than 40% β - Red fiber numbers were classified as red.
[b]Standard error of the fiber type traits by muscle.

had more than 40% β-red fibers. White muscles had more than 40% α-white fibers, and all other muscles were classified as intermediate muscles.

Fiber diameters were found by capturing photomicrographs with a black and white, monochrome camera mounted on a light microscope. A minimum of 50 diameters of each fiber type (β-red, α-red, and α-white) were measured with the help of computer software. Muscle fiber area was calculated from the fiber diameters: $A = \pi (diameter/2)^2$. Percent area was calculated for each fiber type by first multiplying the average fiber type number by the average of the fiber area for a specific muscle, next, dividing by the total area, and finally, multiplying the quotient by 100:

%A = (Average Fiber Area * Average Fiber Number (%) / Total Area) *100.

The analysis of variance included muscle and carcass weight group as main effects. Significant (P< .05) interactions were separated using contrasts to test for linearity.

Results

Tests of the interaction of carcass weight group and muscle and tests of the effect of carcass weight group on muscle fiber type characteristics were not significant for any of the characteristics studied (P> .05). The effect of muscle on fiber type characteristics was always significant (P<.002). Data were pooled by muscle, and means were calculated for fiber number (%), diameter, area and percentage area. Means are presented by muscle classification in Tables 1, 2, and 3.

Based on the literature, we anticipated fiber-type characteristics would be significantly influenced by carcass weight, although this is indirectly associated with an animal's ultimate size and age at slaughter. Because animals used

Table 2. Muscle fiber type characteristics of intermediate[a] muscles.

		β-Red		α-Red		α-White	
MUSCLE	Trait	Mean	(S.E.[b])	Mean	(S.E.[b])	Mean	(S.E.[b])
Vastus lateralis	Number (%)	22.18	(4.53)	37.95	(7.99)	39.87	(5.02)
	Diameter (μm)	36.49	(0.94)	46.84	(1.03)	56.21	(1.11)
	Area (μm^2)	1086.48	(55.51)	1770.50	(78.74)	2529.68	(98.97)
	Percent Area	12.42	(0.95)	35.24	(1.19)	52.34	(1.16)
Subscapularis	Number (%)	39.48	(3.30)	33.05	(3.70)	27.47	(1.16)
	Diameter (μm)	33.69	(0.75)	39.41	(0.84)	53.80	(0.97)
	Area (μm^2)	916.25	(40.29)	1252.60	(53.29)	2311.24	(83.46)
	Percent Area	25.63	(1.09)	29.23	(1.17)	45.14	(1.16)
Triceps brachii	Number (%)	33.50	(1.48)	31.89	(2.10)	34.61	(2.09)
	Diameter (μm)	33.80	(0.85)	43.07	(0.93)	52.50	(1.20)
	Area (μm^2)	939.40	(45.85)	1497.66	(63.53)	2233.62	(99.82)
	Percent Area	20.14	(0.50)	31.17	(0.99)	48.69	(1.15)
Superficial pectoral	Number (%)	38.21	(4.28)	31.26	(3.83)	30.53	(2.24)
	Diameter (μm)	37.61	(0.97)	53.58	(1.31)	63.77	(1.06)
	Area (μm^2)	1150.78	(58.51)	2361.57	(115.13)	3287.19	(109.33)
	Percent Area	20.95	(1.06)	32.77	(1.04)	46.28	(1.15)
Teres major	Number (%)	37.06	(2.13)	30.73	(2.15)	32.21	(3.65)
	Diameter (μm)	29.25	(0.72)	34.62	(0.73)	47.42	(0.94)
	Area (μm^2)	694.32	(33.65)	964.08	(39.37)	1818.12	(69.70)
	Percent Area	23.35	(0.78)	26.39	(0.86)	50.25	(1.15)
Supraspinatus	Number (%)	35.74	(3.09)	30.57	(4.39)	33.69	(7.31)
	Diameter (μm)	35.65	(0.89)	49.81	(1.18)	56.26	(1.16)
	Area (μm^2)	1062.91	(51.53)	2100.65	(102.24)	2596.66	(106.41)
	Percent Area	20.96	(0.98)	32.30	(1.11)	46.74	(1.15)
Serratus ventralis	Number (%)	36.50	(4.96)	28.92	(2.58)	34.58	(7.50)
	Diameter (μm)	32.83	(0.92)	44.25	(1.08)	50.11	(0.99)
	Area (μm^2)	896.94	(49.65)	1693.07	(81.88)	2038.60	(79.76)
	Percent Area	23.26	(1.05)	30.31	(1.06)	46.43	(1.15)
Vastus medialis	Number (%)	34.71	(7.66)	27.88	(2.82)	37.40	(8.84)
	Diameter (μm)	36.25	(0.71)	51.72	(1.06)	60.83	(1.12)
	Area (μm^2)	1063.70	(41.48)	2177.65	(88.76)	3007.83	(110.90)
	Percent Area	19.34	(0.56)	30.14	(1.05)	50.51	(1.14)
Longissimus costarum	Number (%)	37.22	(4.24)	27.37	(2.74)	35.41	(3.62)
	Diameter (μm)	29.24	(0.67)	39.97	(0.94)	41.20	(0.67)
	Area (μm^2)	697.05	(31.33)	1320.43	(60.91)	1372.75	(45.06)
	Percent Area	24.47	(0.92)	31.59	(1.02)	43.94	(1.14)
Sartorius	Number (%)	34.16	(2.46)	26.29	(2.40)	39.55	(1.79)
	Diameter (μm)	28.76	(0.69)	35.82	(0.75)	44.18	(0.73)
	Area (μm^2)	670.66	(31.40)	1033.59	(42.51)	1557.20	(51.21)
	Percent Area	20.63	(0.61)	24.57	(1.05)	54.79	(1.12)
Deep pectoral	Number (%)	37.62	(2.41)	25.27	(4.32)	37.11	(6.11)
	Diameter (μm)	27.70	(0.61)	34.60	(0.70)	44.08	(0.68)
	Area (μm^2)	625.02	(27.01)	971.52	(38.59)	1554.78	(47.84)
	Percent Area	22.45	(0.80)	23.79	(0.76)	53.76	(1.12)
Splenius	Number (%)	38.91	(0.37)	23.81	(1.21)	37.28	(0.98)
	Diameter (μm)	31.90	(0.84)	41.39	(1.35)	42.47	(0.94)
	Area (μm^2)	832.29	(43.42)	1447.69	(93.59)	1473.83	(64.92)
	Percent Area	27.29	(0.91)	27.70	(0.80)	45.01	(1.12)

[a]Muscles not classified as red or white were classified as intermediate.
[b]Standard error of the fiber type traits by muscle.

in this experiment were all taken from animals of the same carcass maturity, it was thought that the ultimate size of the animals from the two different carcass weight groups would significantly influence the muscle fiber type profile. No significant differences were noted for the weight of the carcass; this likely can be attributed to small sample numbers per weight group (n=2).

There were nine of 12 muscles from the round that were classified white. The three muscles from the round that were not classified as white (*Vastus medialis*, *Vastus lateralis*, and *Sartorious*) were all classified as intermediate. In contrast, muscles of the chuck were evenly dispersed between red (10 of 26), intermediate (9 of 26), and white (7 of 26).

An even distribution of muscle fiber type profiles found in muscles from the chuck would suggest a large variability in processing characteristics of muscles of the beef chuck. Conversely, muscles of the beef round may be considered similar, and may not contain as wide a variability in processing characteristics as muscles from the beef chuck.

[1]Kevin Kirchofer, graduate student. Chris Calkins, Professor, Animal Science, Lincoln. This project was funded by beef producers through their $1/head checkoff and produced for the Cattlemen's Beef Board and State Beef Councils.

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Table 3. Muscle fiber type characteristics of white[a] muscles.

MUSCLE	Trait	β-Red Mean	β-Red (S.E.[b])	α-Red Mean	α-Red (S.E.[b])	α-White Mean	α-White (S.E.[b])
Vastus intermedius	Number (%)	29.62	(5.69)	9.42	(0.85)	60.96	(5.27)
	Diameter (µm)	38.33	(0.80)	50.02	(1.02)	62.91	(1.46)
	Area (µm^2)	1183.68	(48.69)	2016.41	(82.65)	3202.96	(146.93)
	Percent Area	15.08	(1.27)	8.16	(1.01)	76.76	(1.12)
Gluteus medius	Number (%)	19.52	(0.80)	24.85	(2.00)	55.63	(2.57)
	Diameter (µm)	36.05	(0.85)	42.67	(1.05)	49.82	(1.11)
	Area (µm^2)	1067.63	(49.60)	1478.70	(72.70)	1998.75	(88.01)
	Percent Area	12.82	(0.99)	22.20	(1.00)	64.98	(1.09)
Tensor fascia antibrachii	Number (%)	18.96	(0.68)	30.79	(3.01)	50.25	(2.82)
	Diameter (µm)	30.92	(0.82)	36.56	(0.67)	50.63	(0.89)
	Area (µm^2)	783.87	(42.32)	1076.52	(39.61)	2061.26	(72.50)
	Percent Area	10.02	(0.69)	22.47	(0.92)	67.51	(1.06)
Semitendinosus	Number (%)	24.30	(1.97)	25.99	(1.59)	49.71	(3.27)
	Diameter (µm)	37.88	(0.87)	46.86	(0.88)	60.86	(1.22)
	Area (µm^2)	1161.68	(52.20)	1787.13	(67.92)	2982.32	(121.95)
	Percent Area	13.12	0.66	20.99	0.87	65.89	(1.06)
Biceps femoris	Number (%)	21.72	(1.90)	29.00	(2.31)	49.28	(4.02)
	Diameter (µm)	34.25	(0.78)	46.96	(0.94)	59.46	(1.12)
	Area (µm^2)	956.01	(42.76)	1778.44	(69.96)	2873.14	(106.18)
	Percent Area	10.47	(1.04)	25.16	(0.96)	64.36	(1.05)
Deltoideus	Number (%)	24.84	(3.11)	28.49	(2.24)	46.67	(3.93)
	Diameter (µm)	30.91	(0.81)	38.97	(0.85)	54.71	(1.09)
	Area (µm^2)	780.22	(40.26)	1229.39	(55.16)	2410.05	(96.26)
	Percent Area	11.93	(0.68)	21.74	(0.80)	66.33	(1.05)
Scalenius dorsalis	Number (%)	30.25	(4.00)	23.34	(1.74)	46.42	(4.79)
	Diameter (µm)	24.01	(0.57)	33.26	(0.65)	41.77	(0.77)
	Area (µm^2)	467.05	(21.84)	887.76	(34.74)	1395.26	(51.82)
	Percent Area	14.78	(0.89)	21.19	(0.83)	64.03	(1.04)
Rectus femoris	Number (%)	23.89	(1.43)	29.71	(3.46)	46.40	(3.85)
	Diameter (µm)	32.48	(0.74)	41.57	(0.79)	47.56	(0.89)
	Area (µm^2)	862.22	(39.74)	1405.30	(52.99)	1822.77	(68.55)
	Percent Area	14.31	(0.70)	28.60	(1.05)	57.09	(1.01)
Semimembranosus	Number (%)	26.25	(1.18)	28.63	(2.02)	45.12	(2.39)
	Diameter (µm)	38.58	(0.88)	43.71	(0.97)	46.96	(1.03)
	Area (µm^2)	1241.99	(54.43)	1546.12	(66.73)	1849.35	(76.95)
	Percent Area	21.11	(0.57)	28.51	(0.83)	50.37	(1.00)
Pectineus	Number (%)	31.84	(5.88)	23.59	(3.88)	44.56	(4.79)
	Diameter (µm)	35.17	(0.74)	42.45	(0.92)	53.52	(1.08)
	Area (µm^2)	1001.18	(41.73)	1449.57	(60.74)	2314.59	(92.99)
	Percent Area	19.85	(0.89)	20.98	(0.83)	59.16	(0.98)
Rhomboidus	Number (%)	32.27	(2.67)	23.39	(2.10)	44.34	(4.16)
	Diameter (µm)	31.78	(0.90)	40.56	(1.19)	47.06	(0.91)
	Area (µm^2)	834.34	(46.91)	1370.85	(80.39)	1789.47	(69.34)
	Percent Area	19.86	(0.64)	22.92	(0.80)	57.22	(0.98)
Latissmus dorsi	Number (%)	26.88	(3.44)	28.98	(1.32)	44.14	(4.46)
	Diameter (µm)	32.60	(0.77)	39.43	(1.00)	47.66	(0.94)
	Area (µm^2)	859.65	(38.95)	1269.69	(62.43)	1823.71	(70.99)
	Percent Area	16.98	(0.72)	26.42	(0.40)	56.60	(0.97)
Dorsalis oblique	Number (%)	34.16	(3.10)	21.94	(2.90)	43.90	(3.85)
	Diameter (µm)	26.87	(0.64)	34.61	(0.67)	44.58	(0.82)
	Area (µm^2)	585.57	(27.22)	963.07	(37.54)	1622.82	(59.02)
	Percent Area	18.93	(1.29)	19.45	(1.11)	61.62	(0.93)
Longissimus dorsi	Number (%)	35.01	(1.43)	21.76	(3.37)	43.22	(4.41)
	Diameter (µm)	41.92	(0.91)	54.84	(1.13)	60.68	(1.26)
	Area (µm^2)	1429.91	(60.92)	2431.66	(98.11)	2981.95	(125.64)
	Percent Area	22.28	(1.35)	22.92	(1.03)	54.80	(0.90)
Adductor	Number (%)	29.25	(2.99)	28.24	(3.86)	42.51	(1.87)
	Diameter (µm)	34.57	(0.85)	40.57	(0.90)	47.88	(1.01)
	Area (µm^2)	973.05	(46.79)	1325.44	(58.64)	1846.65	(77.41)
	Percent Area	19.86	(1.18)	26.49	(0.86)	53.65	(0.84)
Gracilis	Number (%)	24.42	(4.12)	33.87	(4.60)	41.71	(3.06)
	Diameter (µm)	31.27	(0.63)	36.47	(0.76)	41.73	(0.76)
	Area (µm^2)	829.71	(32.68)	1078.56	(44.25)	1399.42	(51.28)
	Percent Area	16.17	(1.37)	32.08	(1.30)	51.75	(0.61)

[a]Muscles containing greater than 40% α-white fiber numbers were classified as white.
[b]Standard error of the fiber type traits by muscle.

The Effects of Post-Harvest Time and Temperature on Glycolytic Potential of Beef Muscle.

Dana J. Hanson
Chris Calkins[1]

Post mortem temperature has little effect on the extent of glycolysis in beef muscle. The time of post mortem sampling can impact glycolytic potential values in beef longissimus muscle.

Summary

The objectives of this study were to determine if post mortem temperature affects extent of glycogen metabolism and if sampling time influences glycolytic potential values in muscle. Beef longissimus muscles entered rigor mortis at two different temperatures and were sampled at 45 minutes post mortem, rigor mortis and 24 hours post mortem to determine the glycolytic potential of the muscle. Post mortem temperature had little effect on the glycolytic potential of beef muscle. Glycolytic potential values from samples removed early post mortem were underestimated when compared to samples taken at 24 hours post mortem.

Introduction

Glycolytic potential is a procedure that is commonly used to estimate the ability of muscle to generate lactic acid. Ante-mortem muscle glycogen levels can also be estimated. Knowledge of a muscle's glycolytic potential can help studies on dark cutting beef and other quality defects. It often is assumed that sampling time is not an important consideration, because the glycolytic potential procedure measures glycogen and some of its degradation products; glucose-6-phosphate and lactic acid. There are a number of intermediate products of glycolysis that are not quantified; their omission might influence the glycolytic potential value.

Temperature also may have an impact on the extent of glycogen breakdown, post mortem. This may affect the overall quantities of lactic acid and residual glycogen in muscle used to determine glycolytic potential. The objective of this study was to determine if temperature and time of muscle sampling affects glycolytic potential values of beef longissimus muscle.

Procedure

The right and left sides from 10 steers were randomly assigned to warm (86°F) or cold (32°F) temperature treatments. For the warm temperature treatment, full, bone-in strip loins were removed immediately after slaughter and held at 86°F until rigor (ca. 6 h); then these samples were moved to 32°F. Cold-temperature loins remained within the carcasses, which were stored at 32°F. Longissimus muscle pH was measured every hour to determine rigor (defined as two consecutive pH readings within 0.1 unit). Samples for lactic acid, glycogen and glycolytic potential (mmol/kg) were removed 45 minutes post mortem, at rigor, and 24 hours post mortem. Glycolytic potential is a procedure that measures the potential for lactic acid production by the muscle. Knowledge of glycogen, glucose-6-phosphate, and lactic acid concentrations (determined enzymatically) allows glycogen levels to be calculated because each molecule of glycogen generates two molecules of lactic acid. These sample were frozen in liquid nitrogen and stored at -112°F until further analysis. Three, 1-inch thick steaks were cut from each loin section to be used for Warner-Bratzler shear determination after one, seven and 14 days of aging. Steaks were cooked on table-top broilers to 158°F prior to cooling for removal of 1/2-inch cores.

Results

Longissimus muscle pH did not differ between hot- and cold-treated muscle at 24 hours ($P<.05$). The rate of pH decline was different among the temperature treatments, but this had no effect on the final values. These pH data are summarized in Table 1.

With the exception of lactic acid levels ($P< .05$) at 24 h, temperature at storage (warm vs cold) had no significant effects on lactic acid, glycogen and glycolytic potential at 45 minutes post-mortem (Table 2), at the point of rigor development (Table 3), or 24 hours post mortem (Table 4). Clearly storage

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Table 1. Mean pH values at three different times post mortem for beef longissimus muscle held at two different temperatures post mortem.

Sampling Time	Warm[a]	Cold [b]	P value
45 min post mortem	6.6 ± .21	6.8 ± .13	.02
Estimated rigor [c]	5.3 ± .05	5.5 ± .19	< .01
24 h post mortem	5.4 ± .04	5.4 ± .09	.43

[a] Warm = 86ºF.
[b] Cold = 32ºF.
[c] Estimated rigor = the time when consecutive, hourly pH readings were within 0.1 unit.

Table 2. Pre-rigor glycogen, lactate, and glycolytic potential values for beef longissimus muscle held at two different temperatures post mortem.

Sampling Time	Warm[a]	Cold [b]	P value
Glycogen [c], mmol/kg	58.6 ± 7.0	62.6 ± 8.7	.35
Lactate, mmol/kg	48.2 ± 11.4	46.1 ± 5.3	.64
Glycolytic potential [d]	165.4 ± 16.8	171.3 ± 15.4	.40

[a]Warm = 86ºF.
[b]Cold = 32ºF.
[c]Glycogen = ([glycogen] + [glucose] + [glucose-6-phosphate]).
[d]Glycolytic Potential (mmol of lactate equivalents / kg of wet tissue). This is determined as (2 x glycogen) + lactate concentrations.

Table 3. Glycogen, lactate, and glycolytic potential values at rigor onset for beef longissimus muscle held at two different temperatures post mortem.

Sampling Time	Warm[a]	Cold [b]	P value
Glycogen [c], mmol/kg	42.1 ± 9.7	43.8 ± 7.3	.41
Lactate, mmol/kg	128.1 ± 5.7	130.2 ± 8.3	.54
Glycolytic potential [d]	212.3 ± 21.2	217.8 ± 21.4	.37

[a]Warm = 86ºF.
[b]Cold = 32ºF.
[c]Glycogen = ([glycogen] + [glucose] + [glucose-6-phosphate]).
[d]Glycolytic Potential (mmol of lactate equivalents / kg of wet tissue). This is determined as (2 x glycogen) + lactate concentrations.

Table 4. Post mortem (24 h) glycogen, lactate, and glycolytic potential values for beef longissimus muscle held at two different temperatures post mortem.

Sampling Time	Warm[a]	Cold [b]	P value
Glycogen [c], mmol/kg	42.3 ± 10.0	39.8 ± 9.9	.19
Lactate, mmol/kg	134.0 ± 6.6	140.6 ± 7.0	.05
Glycolytic potential [d]	221.6 ± 19.8	220.1 ± 18.9	.86

[a]Warm = 86ºF.
[b]Cold = 32ºF.
[c]Glycogen = ([glycogen] + [glucose] + [glucose-6-phosphate]).
[d]Glycolytic Potential (mmol of lactate equivalents / kg of wet tissue). This is determined as (2 x glycogen) + lactate concentrations.

Table 5. Warner-Bratzler shear (lb) values at three different aging times for beef longissimus muscle held at two different temperatures post mortem.

Sampling Time	Warm[a]	Cold [b]	P value
1 day of aging	11.5 ± 1.3	10.6 ± 1.5	.03
7 days of aging	9.9 ± 1.2	8.2 ± .84	< .01
14 days of aging	9.9 ± 1.3	7.5 ± 1.2	< .01

[a] Warm = 86ºF.
[b] Cold = 32ºF.

temperature (or temperature at rigor) has little influence on the extent of post mortem glycolysis.

Time of storage altered the calculated glycolytic potential in this study. These values increased from 165.4 to 221.6 mmol/kg over a 24-hour period ($P < .05$) in warm-treated muscle and from 171.3 to 220.1 in cold-treated muscle. Values at 24 hours for warm versus cold muscle were not different ($P = .86$). These data suggest that glycolytic potential will be underestimated if muscle samples are taken at 45 minutes post mortem. It is likely that substrate (glycogen) is caught in the various stages of glycolysis. These intermediate products of glycolysis are not measured by the glycolytic potential assay. It appears that pre-rigor muscle samples intended for determination of glycolytic potential should be allowed to fully metabolize prior to measurement.

In this study, warm treatment was associated with elevated ($P < .05$) shear force values at one, seven and 14 days of aging compared to cold-treated muscle. Perhaps the more rapid rate of pH decline in warm-treated muscle did not allow sufficient time for proteolytic enzymes to break down the muscle ultra structure before the ultimate pH was achieved. The mean pH values after six hours post mortem for cold-treated muscle were higher ($P < .01$) than the warm treated-muscle, 5.54 vs 5.33, respectively. The proteolytic enzymes may have been irreversibly denatured by the low pH, high temperature condition, which would explain the lack of tenderness improvement on days 7 and 14 for the warm-treated muscle.

It can be concluded that temperature has little effect on the extent of post mortem glycolysis in muscle. Measuring glycolytic potential prior to rigor mortis underestimates glycogen by 10-15%. This may be due to the concentration of intermediate products of glycolysis. Muscle samples for determination of glycolytic potential should be taken after rigor to avoid underestimation of glycogen in beef longissimus muscle.

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[1]Dana J. Hanson, graduate student; Chris Calkins, professor, Animal Science, Lincoln.

The Role of Muscle Glycogen in Dark Cutting Beef.

Dana J. Hanson
Chris Calkins
Kevin Kirchofer[1]

Pre- slaughter glycogen levels need to be greater than 80 mmol/kg to prevent the dark cutting beef condition.

Summary

Dark cutting beef occurs when muscle glycogen levels are depleted prior to slaughter. Without glycogen, lactic acid is not produced in post-mortem muscle, causing a higher than normal muscle pH. This research was conducted to identify the threshold level of glycogen where the dark cutting condition is likely to occur. These data from muscles varying widely in pH suggest that muscle glycogen levels need to be at or above 80 mmol/kg to prevent the dark cutting beef condition.

Introduction

Carbohydrates are stored as glycogen in muscle. Glycogen provides energy for the muscle cell to function. This carbohydrate, through conversion to lactic acid, facilitates the normal pH drop that occurs when muscle is converted to meat after slaughter. Glycogen that has been stored in the muscle continues to be metabolized post mortem. This degradation of glycogen produces lactic acid and causes the pH of the muscle to drop.

Normally, muscle glycogen concentrations are sufficient to drive the pH of the muscle to approximately 5.6. If the animal has been exposed to a large amount of stress (harsh weather, excessive exercise, lack of water or feed, mixing with unfamiliar animals, or estrus) prior to slaughter, the amount of glycogen in the muscle can be severely reduced. In this case, dark cutting beef can occur. This is due to the lack of glycogen needed to facilitate a drop in muscle pH after death. Dark cutting beef has a pH greater than 5.8 and can be as high as 6.9. This muscle is dark in color, undesirable in flavor, and more susceptible to microbial spoilage. As a result, prices paid to producers are severely reduced when this condition occurs.

There are limited data regarding muscle glycogen concentrations needed to prevent the dark cutting beef condition. The objective of this study was to determine the level of pre-slaughter glycogen that is required to prevent dark cutting beef. This information may be helpful in designing strategies to reduce the occurrence of this condition.

Procedure

Dark cutting and normal colored muscle samples (n=180) were collected from two major packers in the state of Nebraska. These sample were obtained by removing approximately 100 g from the 12th rib region of beef carcasses 2 - 4 days post mortem. Color scores (L*, measures the relative lightness and darkness of a color; a*, measures the relative greenness to redness color of a sample; b*, measures the relative yellowness to blueness of a color) were also taken just prior to removal of the sample. Samples with high fat content (> 6.0 %) were removed from the original data set. It was concluded that high fat samples cause an overestimation of L* value due to the amount of white color provided by the fat in the sample. A visual color scale was used to classify samples (n=121) based on the dark to normal color range of the muscle. A score of 1 represented a normal-appearing muscle and 5 represented extremely dark muscle. Samples were frozen on dry ice and stored at - 22 F before analysis for glycolytic potential (glycogen content) and pH. Glycolytic potential is a procedure that measures the total amount of lactic acid produced by the muscle as well as the glycogen remaining in the system. The lactic acid values can be converted to glycogen because each molecule of glycogen generates two molecules of lactic acid. These data essentially indicate the amount of glycogen that was present in the muscle system before death. Regression analysis was used to determine the relationship between glycogen concentration and pH. The characteristics for each color score were evaluated by analysis of variance. Means were then separated using t-tests.

Results

The data collected revealed a significant quadratic relationship (Figure 1) between pre-slaughter glycogen levels and pH (R^2 = .83, root mean square error = 8.6.), where ultimate pH decreased with increasing glycogen level. Figure 1 also shows the relationship of residual glycogen to pH (R^2 = .63, root mean square error = 7.7). A very strong linear relationship exists between muscle glycogen concentration and pH for pH values above 5.6. In this pH range, residual glycogen levels appear to consistently reach about 12 mmol/kg. For this part of the curve, post-mortem conversion of muscle glycogen to lactic acid seems to continue until this baseline level of glycogen remains. The result is a steady decline in pH with increasing levels of muscle glycogen at slaughter.

Below pH 5.6, however, the relationship of ante-mortem muscle glycogen to pH is dramatically different. In this

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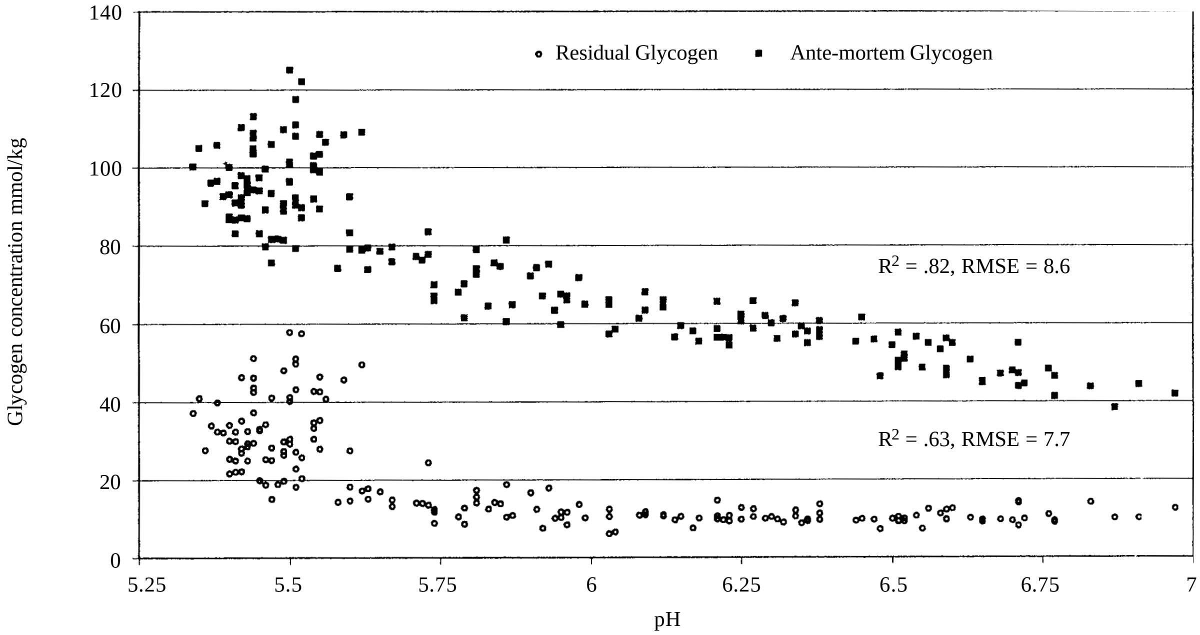

Figure 1. Comparison of estimated and residual glycogen in a population of normal and dark cutting beef.

Table 1. Mean values for pH, L*, a*, b*, residual glycogen, and ante-mortem glycogen separated by visual color score [a].

	Visual Color Score				
	1	2	3	4	5
n	59	5	26	26	5
Ultimate muscle pH	5.47[a]	5.73[b]	6.05[c]	6.31[d]	6.72[e]
L* [b]	34.63[a]	34.40[a]	34.09[a]	31.39[b]	25.41[c]
a* [c]	33.97[a]	29.09[b]	28.41[b]	27.11[b]	26.58[b]
b* [d]	29.02[a]	24.94[b]	23.79[b]	22.13[bc]	20.04[c]
Residual glycogen, mmol/kg	33.01[a]	22.93[b]	14.36[c]	12.01[c]	11.74[c]
Ante-mortem glycogen, mmol/kg	96.35[a]	80.17[b]	66.94[c]	58.82[d]	48.48[d]

[abcd]Means within a row with unlike superscripts differ (P<.05).
[a]Color score, 1 = normal muscle color ; 5 = extreme dark cutting beef color.
[b]Lightness: 0 = black, 100 = white.
[c]Red to green: - 60 = green, + 60 = red.
[d]Blue to yellow: - 60 = blue, + 60 = yellow.

situation, glycogen levels above 80 mmol/kg do not result in consistently lower pH values. In fact, residual glycogen levels in post mortem muscle increase. These values are not lowered to the 12 mmol/kg level noted at pH values above 5.6. The apparent reason is that pH values below 5.6 seem to inactivate the enzymes responsible for glycogen degradation. Thus, muscle glycogen levels at death of 80 mmol/kg or more are sufficient to reduce ultimate pH levels in post-mortem muscle and avoid the dark cutting condition.

Muscle L*, a* and b* values had significant curvilinear relationships (data not shown) to pH (R^2=.34, .64 and .60, respectively). These relationships were lower than expected. The L*, a* and b* readings represent a point in a three-dimensional color system. For example, two samples may have identical L* and a* readings yet one sample may appear to have an orange hue while the other appears purple. Each color occupies a certain point within the 3-D color space. Drawing conclusions from a single parameter (L*, a*, b*) should be made with caution. Visual color scores in this study proved to be a more effective means in which to segregate carcasses based on their overall color.

Means from the visual color scale are presented in Table 1. The visual color scale was used to classify beef carcasses based on the perceived severity of dark cutting. Significant differences (P<.05) among visual categories were noted for pH. All glycogen levels were significantly different from each other (P<.05), except those for scores 4 and 5 (P = .08). These data suggest that visual assessment of color can be effective in classifying dark cutting beef. Currently, the USDA grading system uses this type of subjective measure of color to classify dark cutters. These data suggest that this approach is viable.

Results from this study indicate that the dark cutting condition is more likely to occur when muscle glycogen levels are below 80 mmol/kg. With this information, management strategies prior to slaughter could be developed to reduce the incidence of dark cutting beef.

[1]Dana J. Hanson and Kevin Kirchofer, graduate students; Chris Calkins, professor, Animal Science, Lincoln. This project was funded by beef producers through their $1/head checkoff and produced for the Cattlemen's Beef Board and State Beef Councils.

Dietary Conjugated Linoleic Acids (CLA) and Body Fat Changes

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Conjugated linoleic acid consumption by mice reduced body fat. A parallel effect is implied for humans that consume beef.

Summary

A mixture of CLA isomers was fed to mice at 0, 1, and 2% of the diet for 5, 12, or 14 days. Dietary CLA caused a reduction of body fat approaching 50% but did not cause a loss of total body weight. Mice fed CLA also experienced programmed cell death (apoptosis) of fat cells. Certain (not all) CLA isomers are natural components of beef and dairy products but not other foods. Therefore, these observations prompt speculation of an additional health benefit, reduced adiposity — to humans that eat ruminant-derived foods.

Introduction

Conjugated linoleic acids (CLA) are produced by anaerobic ruminal metabolism and subsequent animal metabolism. Consequently, ruminant animal fats contain substantial CLA (~.5%) and are by far the predominant source of CLA in the human diet. Initial investigations revealed cancer-preventing effects of CLA. Others have reported that feeding CLA to mice for 6 weeks can increase energy expenditure and reduce body fat. The mechanism by which CLA mediate these effects is uncertain, but there is evidence that CLA influence expression of fat metabolizing genes. The objective of our research was to determine effects of feeding CLA to mice on energy expenditure, feed intake, body fat and apoptosis in white adipocytes. The rationale is that the response of mice to dietary CLA may predict the response of humans to dietary beef or dairy fats.

Procedure

Diets

Conjugated linoleic acid was mixed into a purified base diet. Soy oil was replaced (1:1) with CLA to create diets of 0, 1 and 2% CLA. This CLA is a mixture of isomers with approximately 44% being the type (c9/t11) that predominates in ruminant fats, and 41% is t10/c12.

Experiment 1

Ninety 10- to 12-wk-old male mice were housed individually at 22° C and randomly assigned to one of the three experimental diets. Feed intake and body weight were measured daily. Direct calorimetry was used to measure heat loss during a four-hour period beginning at 1700 on day 9 for each replicate. On the day of calorimetry, feed was unavailable from 1200 until 1900. Thus, heat loss was determined in the fasted and in the refed state for each animal. Heat loss was determined at one-minute intervals and collected every 30 minutes for two hours in each state. Water was not available in the calorimeter chambers. Three days after calorimetry, between 0800 and 1000, mice were sacrificed by CO_2 asphyxia. Brown, epididymal and retroperitoneal fat pads and livers were removed and weighed. Twenty-one retroperitoneal fat pads were analyzed for apoptosis (programmed cell death) by a DNA laddering assay.

Experiment 2

Twenty obese M16 strain retired male breeders were randomly assigned to one of three CLA diets: 1) 0% for 12 days; 2) 2% for 14 days; and 3) 0% for 9 days followed by 2% for 5 days. Body fat, body weight, and apoptosis were assayed as in experiment 1.

Results

Experiment 1

Feed intake (g/day) by mice fed 0, 1, and 2% CLA for 12 days was 5.0, 4.7, and 4.4 (SE = .11; $P < .05$) respectively. Despite consuming less feed, the mice fed 1 and 2% CLA expended as much energy as the controls. After consuming CLA for 12 days, mice had considerably less body fat than contemporaries which were not fed CLA (Figure 1). The fat cells from mice fed 2% CLA presented more apoptosis than cells from control mice ($P < .10$).

Experiment 2

Consumption of 2% CLA diet for either five or 12 days caused a significant loss of body fat in all of the depots measured (Figure 2). In spite of this

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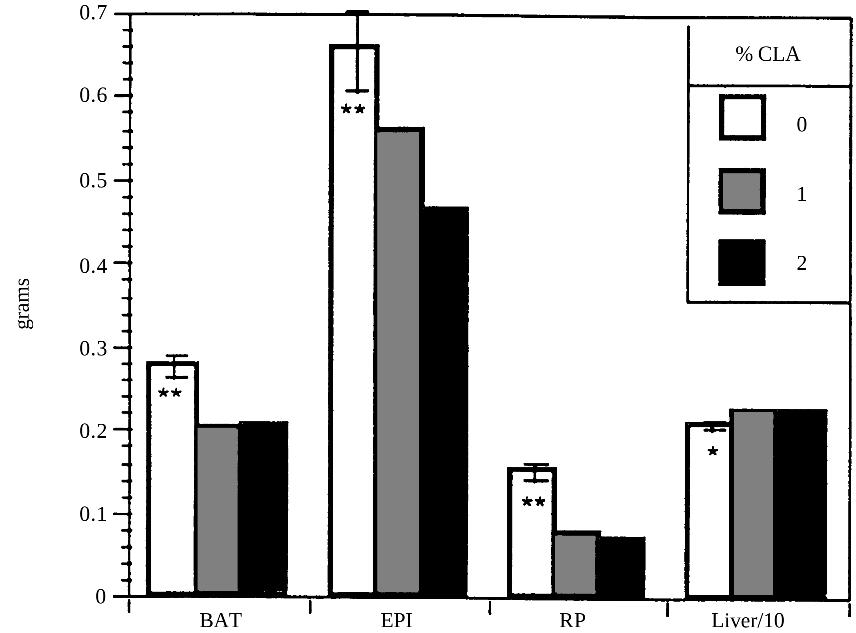

Figure 1 Experiment 1 Weight of Brown (BAT), Epididymal (EPI), and Retroperitoneal (RP) Fat Pads, and of Liver (scaled to 10% of actual weight). **CLA effect (P<.01). *CLA effect (P<.10). Error bars represent SEM.

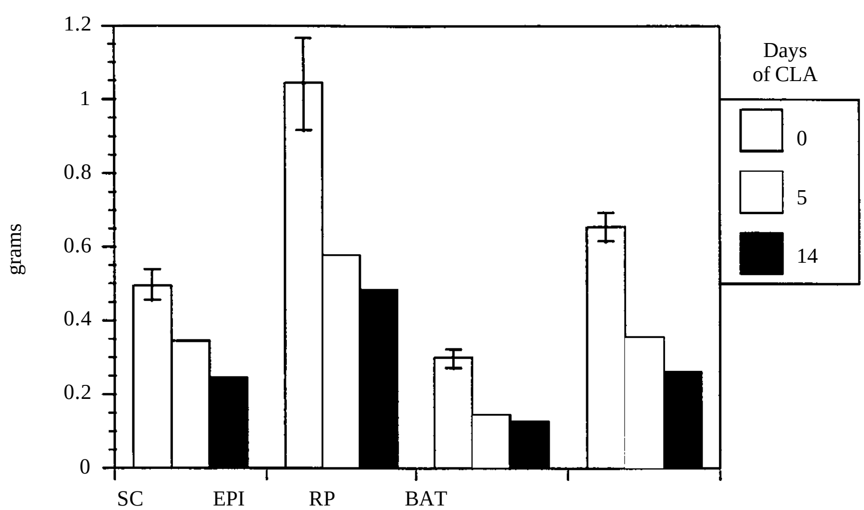

Figure 2. Experiment 2 Weight of Subcutaneous (SC), Epididymal (EPI), Retroperitoneal (RP), and Brown (BAT), Fat Pads. **CLA effect (P<.01). Error bars represent SEM.

loss of body fat, total body weight increased in animals fed CLA versus control (P < .05). Consistent with the results of experiment 1, analysis of retroperitoneal fat pads indicated that dietary CLA caused programmed cell death in fat cells (P < .03).

In conclusion, feeding mixed isomers of conjugated linoleic acid to mice causes a rapid (within 5 d) loss of body fat, no loss of total body weight, and appears to cause apoptosis of fat cells. Perhaps this apoptosis mediates the specific loss of body fat caused by CLA consumption.

It is inviting to hypothesize that ruminant animal-derived human foods can provide an anti-obesity benefit. This conclusion cannot be drawn with much certainty at the moment. Although ruminant fats are the only significant source of CLA in the human diet, most of the CLA in ruminant fat is c9/t11. Our experimental CLA mixture contained nearly as much t10/c12 as it did c9/t11. Therefore, the effect we observed in mice could be due to an isomer of CLA which is not predominant in any food. Furthermore, there is a question about whether the amount of CLA necessary to cause a benefit could be supplied by a relatively normal diet. Certainly, the amount of CLA which we fed mice (1% and 2%) couldn't be obtained naturally given that beef and milkfat are .5% CLA. However, some research conducted at the University of Georgia indicates that .25% CLA causes a loss of body fat in rats. We have not tested such low concentrations.

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Changes to the Purine Assay Improve Purine Recovery and Assay Precision

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Modifications of the purine assay improved recovery of purines, increased assay precision, and accounted for particle-attached bacteria.

Summary

Three experiments tested modifications of the purine assay designed to improve estimation of microbial crude protein supply. In Experiment 1, changing hydrolysis conditions from 12 normal perchloric acid to 2 normal increased purine recovery and lowered the coefficient of variation. In Experiment 2, phosphate buffer yielded greater recovery of purines than acetate buffer and using the extraction solution as a wash was less variable than silver nitrate in .005 molar hydrochloric acid. In Experiment 3, purine nitrogen:total microbial nitrogen ratios for five forages were determined by incubating NDF in situ and analyzing them before and after neutral detergent extraction.

Introduction

The original purine assay has two problems. First, the current method of isolating rumen microbes, known as differential centrifugation, may not yield a representative proportion of particle-attached microorganisms. Therefore, the measured purine nitrogen:total microbial nitrogen ratio of those microbes may not be accurate. Second, purine recovery and the precision associated with that recovery are poor. Two laboratories (in Germany and at Ohio State University) have proposed separate modifications to the assay that improve recovery of purines. The objectives of this research were to develop a method of estimating the purine nitrogen:total microbial nitrogen ratio of particle-attached microorganisms and to investigate the effect combinations of these modifications have on purine recovery and precision.

Procedure

Three experiments were conducted. Samples for Experiments 1 and 2 were collected from five ruminally and duodenally fistulated steers (ave wt. = 800 lb) that were fed alfalfa hay and smooth bromegrass hay for seven days each. Cattle were fed hay ad libitum for six days and omasal, duodenal and fecal samples were collected on the seventh day. All samples were lyophilized and ground by Wiley mill to pass through a .008" screen. Experiment 3 was an in situ experiment that used both the alfalfa and smooth bromegrass hays from the previous experiments as well three other hays: switchgrass hay, high-quality meadow hay and low-quality meadow hay. The quality of these forages is described in Table 1.

In Experiment 1, the 10 omasal samples were used. The objective was to test the effect of perchloric acid concentration on purine recovery within the original protocol of Zinn and Owens. Treatments were 12 or 2 normal perchloric acid. In Experiment 2, the effects of buffer type and wash solution within the Zinn and Owens procedure were tested in a 2 x 2 factorial arrangement. Samples tested were the duodenal samples that correspond to the same sampling time as the omasal samples in Experiment 1. Buffers tested were .2 molar acetic acid and .2 molar ammonium phosphate. Wash solutions tested were .005 molar silver nitrate and the original precipitation solution of the procedure. The perchloric acid used in Experiment 2 was 2 normal.

In Experiment 3, the objective was to estimate the purine nitrogen:total microbial nitrogen ratio of particle-attached rumen microorganisms. Neutral detergent fiber (NDF) was generated for each forage and dried NDF was incubated in situ for 12 hours. Three bags each were incubated in a steer fed 2% of body weight of smooth bromegrass (8% CP) and another steer fed 2% of body weight of a diet containing 70% of the DM as that smooth bromegrass hay and 30% of the DM as a 50:50 blend of dry-rolled corn and soybean meal. Nitrogen and purine concentrations were measured on the NDF before ruminal incubation and on the in situ residue both before and after neutral detergent extraction.

Results

Results of Experiment 1 are shown in Table 2. Use of 2 normal perchloric acid increased purine recovery over the standard 12 normal acid. Estimates of microbial crude protein concentration increased from 2.23% to 7.43% of the DM. The less concentrated acid also lowered the coefficient of variation (CV), an estimation of the method's error rate, from 14.87% (when 12 normal acid was used) to 3.14%. These results are in agreement with two other research publications. The more concentrated acid generates chemicals in the sample that interfere with the detection of purines, thereby reducing purine concentrations. This effect occurs only when NDF is present in the sample; this

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Table 1. Quality of hays used in experiments.

Forage	CP[a]	UIP	NDF
Alfalfa	22.4	4.0	32.8
Smooth bromegrass	7.8	3.2	63.3
Switchgrass	4.5	2.4	73.2
High-quality meadow hay	8.7	3.5	62.3
Low-quality meadow hay	8.6	2.7	62.9

[a]CP, UIP (in situ NDIN procedure), and NDF on a DM basis.

Table 2. Effect of acid concentration on purine recovery (Experiment 1).

	perchloric acid normality			
Item	2 N	12 N	SEM	*P*-value
MCP[a]	7.43[c]	2.23[d]	.51	.0001
C.V.[b]	3.14[c]	14.87[d]	2.61	.0053

[a]Microbial crude protein (DM basis), as estimated by purines (purine nitrogen:total nitrogen ratio assumed to be .2).
[b]Coefficient of variation for MCP estimates, % of mean value.
[c,d]Means within a row with different superscripts differ (*P*-value shown).

Table 3. Effects of buffer and wash solution type on purine recovery (Experiment 2).

	acetate buffer		phosphate buffer		Effects[a]		
	AGNO3[b]	ORIGINAL	AGNO3	ORIGINAL	buffer	wash	buffer *wash
MCP[c]	1.39	1.91	5.39	6.74	.0001	.003	.16
CV[d]	6.87	12.60	9.85	2.83	.210	.812	.02

[a]P-values for effects listed.
[b]AGNO3 is silver nitrate wash solution; original is the same wash solution as is used for the extraction.
[c]Microbial crude protein (DM basis), as estimated by purines (purine:N ratio assumed to be .2).
[d]Coefficient of variation for MCP estimates, % of mean value.

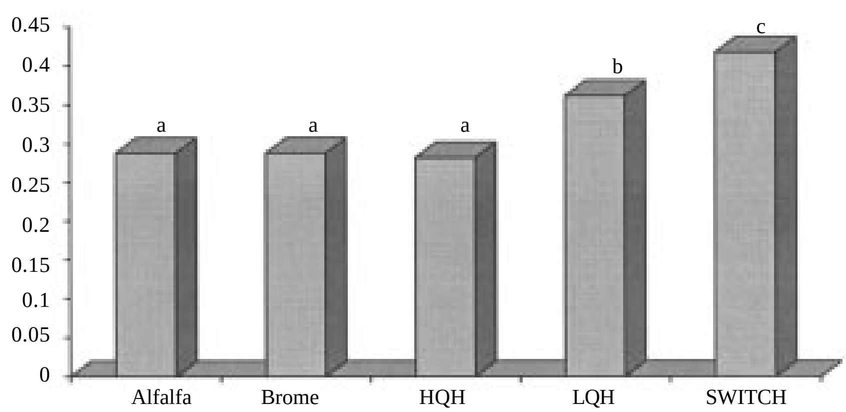

Figure 1. Purine nitrogen:total microbial nitrogen ratio of particle-associated rumen microorganisms on NDF of different forages (Experiment 3). HQH, LQH, SWITCH = high and low-quality meadow hay, and switchgrass, respectively.
[a,b,c]Bars within unlike letters differ ($P \leq .06$).

is the case with omasal and duodenal samples. The reduction of CV when weaker acid is used is also beneficial, as the standard purine assay is known to be variable. Finally, use of weaker acid also makes the assay safer because samples will be less prone to explode.

In Experiment 2, phosphate buffer increased purine recovery when compared to acetate buffer (Table 3). The use of the original precipitation solution as a wash solution also resulted in a significantly greater purine recovery than did the silver nitrate solution. There was no effect of buffer type or wash solution on the CV of the MCP estimate (Table 3). Therefore, the combination of phosphate buffer and the original precipitation solution for washing the sample pellet should be used to achieve the maximum recovery of purines in a sample.

The purine nitrogen:total microbial nitrogen ratios measured in Experiment 3 are shown in Figure 1. There was no effect of fistulated steer diet on the ratios so the data were pooled across diets. Alfalfa, bromegrass and high-quality meadow hay were not different in terms of ratio (~.28). Low-quality meadow hay's ratio (.361) was statistically different than all forages, as was switchgrass (.417). Each of these estimates differs from the previous estimate made at UNL for bromegrass (.137; 1998 Nebraska Beef Report, pp. 90-91) but fall within the range of those estimates made at Ohio State University (ranging from .207 to .587).

Because this ratio converts purine values to MCP values, it has a substantial effect on MCP calculations. Ratio estimates are typically made by the differential centrifugation of rumen contents. This method effectively separates free-floating rumen microbes from forage particles; however, those microbes attached to forage particles tend to remain with the forage. This is problematic because a majority of the rumen microbes are attached to forage particles when forage diets are fed. If the purine nitrogen:total microbial nitrogen ratio of particle-associated microbes differs from that obtained by differential centrifugation, estimates of MCP will be inaccurate. Our data suggest the ratio is variable and can be affected by forage type. This research establishes a modified purine assay that accurately estimates the MCP concentration of a digesta sample. The improved method of estimating the purine nitrogen: total microbial nitrogen ratio that includes particle-associated microbes, a major source of microbial protein, can be used for forage diets.

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Urinary Allantoin Excretion as a Marker of Microbial Crude Protein Supply for Cattle

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Todd Milton
Terry Klopfenstein[1]

Urinary allantoin excretion can be used as an estimate of microbial crude protein supply.

Summary

Two metabolism trials evaluated urinary allantoin excretion as a noninvasive marker of microbial crude protein flow from the rumen. In the first trial, both urinary allantoin excretion and duodenal purine flow increased as alfalfa intake increased. A positive linear relationship (r^2 = .74) existed between the markers. In the second trial, an increase in the metabolizable energy supplied to the animal did not increase urinary allantoin excretion. We concluded that urinary allantoin excretion was an effective, noninvasive marker of microbial crude protein supply.

Introduction

A urine metabolite, allantoin, has received recent attention in dairy and sheep research for its potential to serve as a microbial crude protein (MCP) marker. No validation studies have been conducted that compare urinary allantoin excretion (ALLAN) to duodenal flow of MCP for beef cattle diets. Such a comparison would provide a benchmark for the use of ALLAN in field trials. It may be inaccurate to assume ALLAN is the same for all dietary conditions. The objectives of the research reported herein were: 1) to compare ALLAN to the duodenal flow of MCP measured by purines; 2) to describe the effect of increasing alfalfa hay intake on the variables in objective 1); and 3) to investigate effects of metabolizable energy supply on ALLAN.

Procedure

Six crossbred yearling steers (mean wt = 800 lb.) were fitted with ruminal and duodenal cannulae according to the guidelines of the UNL Institutional Animal Care and Use Committee. The diet fed in two metabolism trials was a single lot of alfalfa hay (DM basis): 22.4% CP, 32.8% NDF, and 26.7% ADF. A pre-trial feeding period determined the maximum level of dry matter intake that all steers would sustain without any feed refusal was 19 lb/day. In Trial 1, fractions of the maximum level were applied as treatments in a concurrent 3 x 3 Latin square arrangement: 1) 9.5 lb/day; 2) 14.3 lb/day; or 3) 19 lb/day. Periods were 21 days. Hay was fed every 2 hours by automatic feeders in an attempt to establish a steady state of fermentation in the rumen. Steers were housed in 10' x 10' box stalls and were allowed to move freely on days 1-14 of each period. On days 15-21, steers were tethered to facilitate sample collection. Duodenal samples were collected every 3 hr from 0700 to 1900 on days 15-17 and total urine collection was made on days 18-21 by abdominal funnels attached to a vacuum pump. Duodenal samples were freeze-dried and analyzed for purines as a microbial marker and acid-insoluble ash as a flow marker. Aliquots of each total urine collection were analyzed for allantoin.

Trial 2 was conducted as a follow-up to Trial 1. The following two treatments were applied over six-day periods in a crossover design: 1) 14.3 lb/day of alfalfa hay DMI plus ruminal infusion of isotonic saline; or 2) 14.3 lb/day of alfalfa hay DMI plus ruminal infusion of a sodium acetate and propionic acid solution (pH = 6.0) formulated to provide the metabolizable energy equivalent of 4.7 lb of alfalfa hay DMI. The ruminal infusions were given as pulse doses through the ruminal cannula four times daily. Cattle were tethered on days 4-6 and total urine collections were made at that time. Aliquots of urine were analyzed for allantoin.

Results

A direct comparison of the daily supplies of purines and allantoin (Figure 1) indicates there is a linear relationship between them. The fit of the line (as described by the r^2 value) implies the line does an adequate job of describing the variation between the two methods. An r^2 value of .74 can be interpreted as the line describing 74% of the variation in the data. The fact that the slope of the line (.84) is less than one indicates that not all of the daily purine flow at the duodenum is recovered in the urine as allantoin. Slopes of less than one for comparisons between post-ruminal purine flow and ALLAN have been reported in the scientific literature. The possibility exists for purines to be metabolized to derivatives other than allantoin and excreted in the urine.

The effect of alfalfa DMI on the supply of each MCP marker is shown in Figure 2. The upward slope of the regression lines for both purine and allantoin indicates an increase in alfalfa intake caused an increase in MCP marker supply. This is intuitively correct; an

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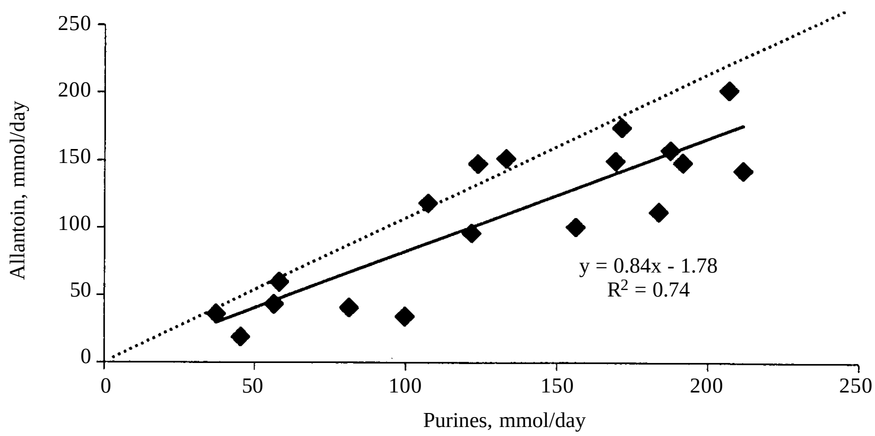

Figure 1. Comparison of duodenal purine flow and urinary allantoin excretion in beef cattle. The dotted line represents 100% recovery of purines as urinary allantoin. The solid line represents the actual recovery of purines as allantoin (equation for solid line shown on graph).

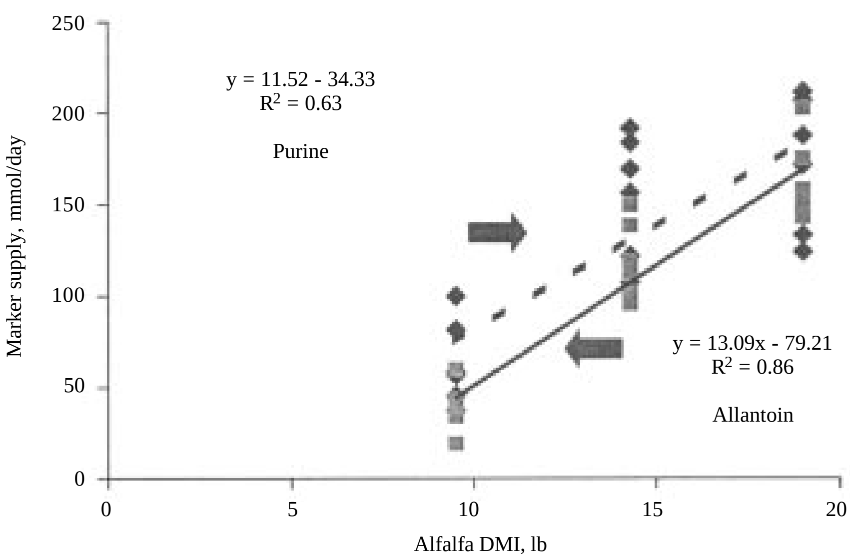

Figure 2. Effect of alfalfa dry matter intake on microbial crude protein marker supply.

increase in the TDN available for rumen fermentation should increase the amount of microbial cells and constitutive MCP markers. The degree of fit for each regression equation is also shown. The higher r^2 value for allantoin (.86) indicates it does a better job of describing the increase in MCP supply caused by additional alfalfa DMI than the does the purine assay (.63). This may be because the compound errors associated with the measurement of purine supply in duodenal samples lead to more variation in those estimates. Both an MCP marker (purine) and a duodenal flow marker (acid-insoluble ash, in this trial) are incorporated into a duodenal supply estimate, whereas a urine excretion estimate is based only on one marker (allantoin).

There was no difference in the urinary excretion of allantoin for the treatments imposed in Trial 2 (data not shown). The overall mean allantoin excretion (mmol/day) for Trial 2 was 128.3 mmol/day. This value is similar to the mean allantoin excretion (119.7 mmol/day) for the cattle fed the same level of alfalfa DMI in Trial 1. The experimental infusion of volatile fatty acids in Trial 2 was designed to provide the metabolizable energy equivalent of 4.7 lb of alfalfa DMI without allowing the rumen bacteria access to the energy. The hypothesis being tested was whether or not the additional metabolizable energy provided to the animal by the added alfalfa increased the endogenous excretion of allantoin. We conclude metabolizable energy level has no effect on endogenous allantoin excretion and all the increase in allantoin exhibited by increased alfalfa DMI in Trial 1 is due to rumen microbes. Allantoin is the product of hepatic oxidation of purines and is cleared by the kidney at a rapid rate. Intermediate products of this oxidation (such as xanthine and uric acid) do occur in the urine, but they are a small fraction of the total oxidized purines (a.k.a. purine derivatives), so we did not analyze for them. Another reason we did not analyze for the other purine derivatives is that our assay is only specific for allantoin. While other assays exist that do measure all the purine derivatives, they are more complex to perform.

We conclude there is a strong linear relationship between duodenal purine flow and urinary allantoin excretion. This relationship allows the use of allantoin as a noninvasive marker of MCP supply. Urinary allantoin excretion is a simpler method of estimating MCP supply than the duodenal purine method. Further research will focus on describing the relationship between these MCP markers and the actual amount of microbial crude protein they represent.

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[1]Ryan Mass, graduate student; D.J. Jordon and Tony Scott, technicians; Todd Milton and Terry Klopfenstein, assistant professor and professor; UNL animal science, Lincoln David Harmon, professor, University of Kentucky Animal Science, Lexington.

Evaluation of 1996 Beef Cattle NRC Model and Development of Net Energy Modifiers

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Accuracy of 1996 NRC model gain predictions may be improved by use of equations to predict appropriate net energy adjusters.

Summary

Data from 325 treatment means in 35 previous beef cattle feeding studies were used to evaluate the 1996 NRC model for accuracy of gain predictions and to develop predictions of net energy adjusters for use with the model. The model was found to inaccurately predict gain of cattle fed diets varying in ingredients and energy density. Net energy adjusters were used to achieve accurate prediction of gain for each observation and then equations were developed for predicting the level of net energy adjustment required to improve accuracy of gain prediction.

Introduction

The National Research Council's (NRC) 1996 Nutrient Requirements of Beef Cattle model has previously been shown to inaccurately predict the gain of cattle on low to medium energy diets (2000 Nebraska Beef Report, pp. 26-29). It is hypothesized that the inaccuracy in gain prediction can be attributed to the development of the net energy equations from a high energy data set that was unequally distributed (Garrett, 1980, pp. 3-7 in Energy Metabolism). Level 1 of the NRC model contains net energy adjusters that can be used to achieve accurate prediction of gain by altering the net energy values of the diets. The objective was to use previous cattle feeding data from the University of Nebraska to develop equations to predict the level of net energy adjustment required to improve accuracy of gain predictions.

Procedure

A total of 201 treatment means from 31 different growing trials and 124 treatment means from four different finishing trials conducted at the University of Nebraska and reported previously were used in evaluating gain predictions by the 1996 NRC model. The same data set was also used for developing equations to predict the level of net energy adjustment required to achieve accurate gain predictions.

Cattle weights, diets and use of implants and ionophores were used as model inputs. Energy density of diets was determined from published results, including IVDMD, or from 1996 NRC feed table TDN values. All analyses were under the assumption of thermal neutral conditions of 68°F with no wind. Final shrunk body weight (FSBW) for the finishing trials was determined from carcass weight and a common carcass dress of 63%. Data were not available for FSBW in the growing trials or body conditions score (BCS) in the growing and finishing trials, and were consequently set to a FSBW equal to the average of the finishing trials (1189 lb) for the growing trials, and a default BCS of 5 for both the growing and finishing trials. Sensitivity of gain predictions to ±10% changes in FSBW, BCS, and the DE to ME conversion of 0.82 was evaluated. The procedures of Mayer and Butler (1993, Ecological Modeling 68:21-32) were used to evaluate the accuracy and precision of gain predictions.

Subsequent to evaluation of gain predictions, the net energy adjusters were used to alter predicted gains to agree with observed gains. There are separate adjusters for NEm and NEg, with upper and lower limits of 120% and 80% of predicted NEm and NEg, respectively. Use of the model equations, but not the 1996 NRC model computer program, allowed these limits to be exceeded. Adjustment was applied equally to NEm and NEg. Resulting adjuster levels were then regressed against observed ADG, total TDN intake, and TDN concentration to develop equations for the level of adjuster required to improve accuracy of gain predictions.

Results

The data set used in evaluating the 1996 NRC model is described in Table 1. Use of implants or ionophores was found to be documented with only 6 and 62, respectively, of growing trial treatment means. All finishing trial treatments made use of implants and ionophores.

The ratio of ME to DE is about 0.80 but can range considerably depending on intake, age of animal, and feed source (NRC, 1996). With the ME to DE ratio

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Table 1. Data used in 1996 NRC model evaluation and NE adjuster equation development.

Parameter	Average	SD	Minimum	Maximum
Average weight, lb				
Growing, n=201	609.3	66.3	481.6	820.0
Finishing, n=124	958.8	69.5	731.0	1104.0
Daily gain, lb				
Growing, n=201	1.56	0.66	0.27	3.00
Finishing, n=124	3.51	0.41	2.64	4.48
DMI, lb				
Growing, n=201	14.62	3.18	8.60	20.90
Finishing, n=124	26.06	2.57	17.20	30.90
TDN, %				
Growing, n=201	61.6	7.3	42.7	75.4
Finishing, n=124	82.7	0.4	82.5	84.5
FSBW, lb				
Finishing, n=124	1188.7[a]	84.8	914.0	1369.0

[a]Value used as FSBW for growing cattle observations.

Table 2. Distribution of observations within data sets by energy density as a percent of the total.

Diet TDN, %	<53	53-72	72-80	>80
Garrett (1980)	1%	22%	65%	12%
UNL data set[a]	8.62%	48.92%	4.31%	38.15%

[a]University of Nebraska, Lincoln, n = 325.

Table 3. Sensitivity of gain predictions to changes in BCS, FSBW, or DE to ME conversion.

Parameter	Change in parameter	Change in gain prediction
BCS	+10%	-1.5%
	-10%	+1.5%
FSBW	+10%	+6.7%
	-10%	-7.0%
DE to ME conversion	+10%	+24.1%
	-10%	-24.5%

Table 4. NE adjuster equations[a] based on ADG, TDN intake, and TDN concentration.

Parameter used as X	a	SE	k	SE	b	SE
ADG[b]	0.8479	0.0669	0.2133	0.1521	0.6327	0.0962
TDN intake[c]	3.476	0.470	0.1341	0.0247	0.7705	0.0151
TDN concentration[d]	183.0	50.0	4.780	0.570	0.7628	0.0135

[a]Equations are of the form: $y = a \times 10^{(-k\,X)} + b$
[b]ADG, lb/day.
[c]TDN intake, lb/day.
[d]TDN concentration, lb/lb of DM.

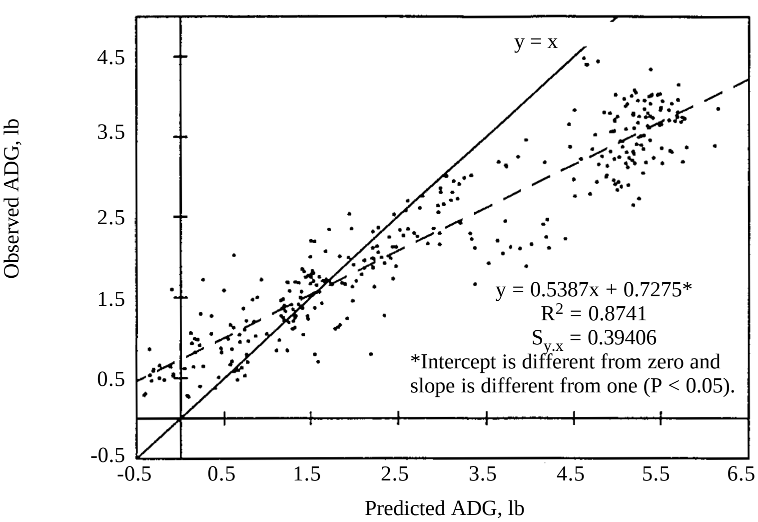

Figure 1. Accuracy of gain predictions. Each point represents a treatment mean (n=325).

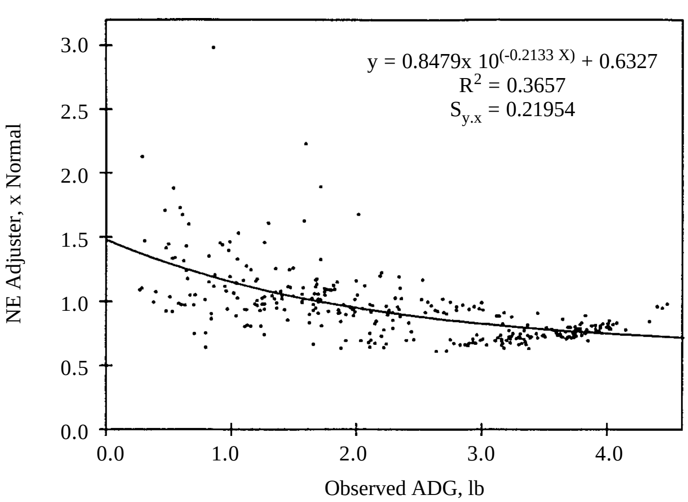

Figure 2. Prediction of NE adjuster from observed ADG. Each point represents a treatment mean (n=325).

set at 0.82, the range in ME to DE ratio in response to changing feed sources, with different levels of fiber, starch and fat, is effectively transferred into the equations that predict NEm and NEg from ME. Therefore, the range in diet energy densities used in predicting NEm and NEg from ME is particularly important. Garrett (1980) developed the equations to predict NEm and NEg from a data set with unequally distributed and high energy density, whereas this evaluation makes use of a data set with diets having a greater range in energy densities (Table 2). The data set used in this evaluation is more evenly distributed between high (>80% TDN) and moderately low (53-72% TDN) energy diets, but has relatively few observations at moderately high (72-80% TDN) and very low (<52% TDN) energy diets.

Sensitivity analysis of gain predictions to changes in FSBW, BCS, and the DE to ME conversion of 0.82 found predictions to be relatively insensitive to changes in FSBW and BCS but very sensitive to changes in the DE to ME conversion factor (Table 3). However, FSBW, BCS, and the DE to ME conversion of 0.82 are not likely to have the same relative level of variation.

Gain predictions were found to be precise with an R^2 of 0.8741, but inaccurate, as the least squares regression equation (intercept = 0.7275, slope = 0.5387) was different ($P < 0.05$) from the isopleth (intercept = 0, slope = 1) (Figure 1).

All predictions were made under thermal neutral conditions that would maximize the prediction and contribute to inaccurate prediction any time the environment was severe enough to affect performance. Therefore, over prediction of gains can be expected by assuming thermal neutral conditions. More effective modeling of environmental effects on gains by growing cattle would bring observed and predicted gains into closer agreement for rapidly gaining cattle where gains were over predicted, but would result in greater discrepancy between observed and predicted gains for slowly growing cattle where gains were under predicted.

Exponential equations were used to fit observed ADG, TDN intake, or TDN concentration to determined NE adjusters. The relationship between determined NE adjuster and ADG existed ($P < 0.05$), but was quite weak ($R^2 = 0.3657$; Figure 2). A stronger relationship ($P < 0.05$; $R^2 = 0.6441$; Figure 3) existed with TDN intake. However, use of TDN intake to predict NE adjusters will be confounded by total DMI. The strongest relationship was with TDN concentration ($P < 0.05$; $R^2 = 0.7707$; Figure 4). All equations are presented in Table 4.

The equations relating ADG, TDN intake, or TDN concentration to NE adjusters may be used to improve the accuracy of gain predictions by the 1996 NRC model. Consequently, a table of recommended adjusters (Table 5) based upon the equations derived to relate the required NE adjuster to ADG, TDN intake and TDN concentration was developed. It is important to note that the recommended NE adjusters do extend beyond the range of 80 to 120% of normal allowed by the 1996 NRC model computer program.

As an example, if a group of cattle are to be fed a diet with a TDN concentration of 65.9%, (NEm = 0.68 Mcal/lb, NEg = 0.41 Mcal/lb), the appropriate NE adjuster to enter into the NRC model is 0.89, resulting in an adjusted NEm of 0.61 Mcal/lb and an adjusted NEg of 0.37 Mcal/lb. These adjusted NE values are then used in the prediction of gain, and should result in a more accurate prediction of gain.

While the strongest relationship to the required NE adjuster was found with TDN concentration, use of TDN intake equations may still be advisable, particularly in situations where observed gains are likely to be confounded by DMI that is considerably higher or lower than what would normally be expected. Regardless of the basis selected, caution is recommended when using the equations as they reflect any limitations in the data from which they were derived, and are appropriate only over the range of values from which they were defined. Whereas there are numerous observations at high rates of gain, high TDN intakes, and high TDN concentrations, we have confidence in the NE adjuster predictions at that end of the scale. However, due to fewer observations at low rates of gain, low TDN intakes, and low TDN concentrations, less confidence is held with NE adjuster predictions at this end of the scale.

Table 5. NE adjuster values based on ADG, TDN intake, or TDN concentration[a].

ADG[b]	NE adjuster[c]	TDN intake[d]	NE adjuster[c]	TDN concentration[e]	NE adjuster[c]
0.27	1.38	6.00	1.32	0.500	1.51
0.74	1.22	8.17	1.05	0.538	1.25
1.21	1.10	10.34	0.91	0.577	1.08
1.67	1.01	12.51	0.84	0.615	0.97
2.14	0.93	14.68	0.81	0.653	0.90
2.61	0.87	16.84	0.79	0.692	0.85
3.08	0.82	19.01	0.78	0.730	0.82
3.54	0.78	21.18	0.78	0.768	0.80
4.01	0.75	23.35	0.77	0.807	0.79
4.48	0.73	25.52	0.77	0.845	0.78

[a]ADG, TDN intake, or TDN concentration predictions of NE adjuster are not intended to match across rows.
[b]ADG, lb/day.
[c]Predicted NE adjuster, decimal form.
[d]TDN intake, lb/day.
[e]TDN concentration, lb/lb of DM.

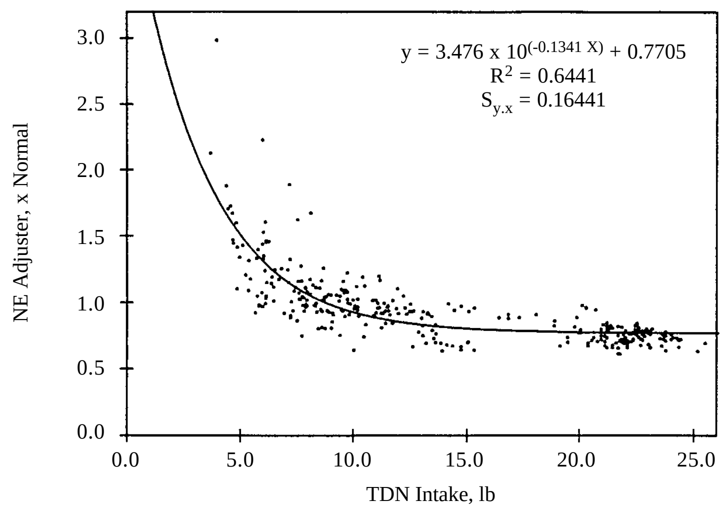

Figure 3. Prediction of NE adjuster from TDN intake. Each point represents a treatment mean (n=325).

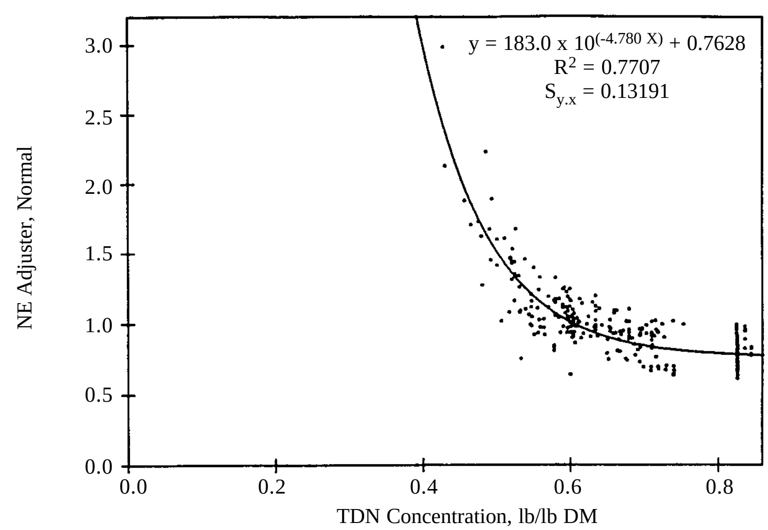

Figure 4. Prediction of NE adjuster from TDN concentration. Each point represents a treatment mean (n=325).

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