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Nebraska 2007 Beef Cattle Report

NEBRASKA

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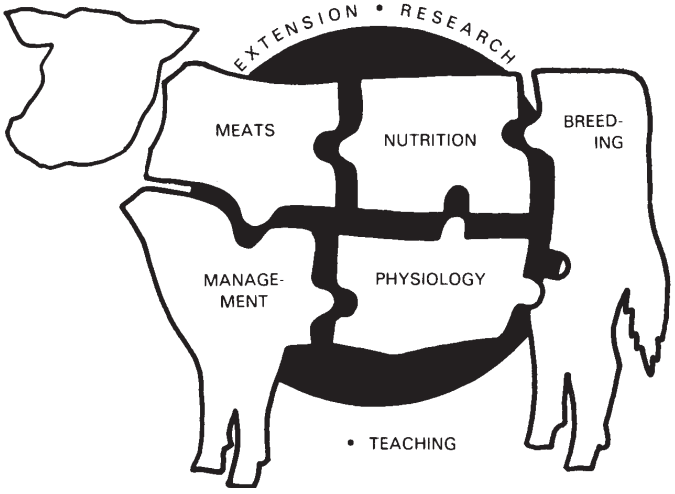

Agricultural Research Division
University of Nebraska Extension
Institute of Agriculture and Natural Resources
University of Nebraska–Lincoln

2007 Beef Cattle Report

IANR

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The 2007 Nebraska Beef Report Dedicated in Memory of Dr. Paul Q. Guyer, Professor Emeritus of Animal Science

Paul's contributions as a leader, an innovator, an organizer, a resource person and an educator were very significant in the development of Nebraska's beef cattle industry and that of surrounding states.

As the first beef specialist on the University of Nebraska faculty, he led and worked in all areas of beef extension, including performance testing, beef nutrition, feedlot nutrition and management, and cow-calf production. His unique blend of communicative ability, scientific excellence and practical know-how produced an outstanding extension education program for Nebraska cattlemen.

Paul will be remembered for his dedicated career to beef cattle extension education for producers, feeders, and youth. He also served as a mentor to many young faculty and gave much of himself to others through his dedication, professional honesty, and personal sincerity. It is with highest esteem for his contributions that this report is dedicated to Paul Q. Guyer.

Dr. Jim Gosey Retires

After 34 years as extension beef specialist at the University of Nebraska, Dr. Jim Gosey retired at the end of 2005. Over those 34 years of service, Jim's principal responsibilities have been providing leadership and programming in beef cattle genetics and management, and teaching Beef Cow-Calf Management and Beef Cattle Merchandising to undergraduate students. Over the years, Jim's style and approach have continued to evolve, offering ever-changing educational programs to meet the needs of the cattle producers of Nebraska and the nation and to meet the needs of undergraduates preparing themselves for a dynamic world. Whether talking to beef producers or students, Jim strives to simplify often complex concepts into practical, applied recommendations.

Jim has been a featured speaker at four Beef Improvement Federation (BIF) national meetings, nine Range Beef Cow Symposia (combined efforts of Nebraska, Colorado, South Dakota and Wyoming), four Four-State Beef Conferences (Nebraska, Iowa, Kansas and Missouri) and numerous Beef Breed Association Programs, including the 2005 National Angus Conference. He has received numerous recognitions, including: Distinguished Service (Beef Improvement Federation), Livestock Service (Walnut Grove Co.), Excellence in Programming (Nebraska Cooperative Extension), Hall of Merit (American Polled Hereford Association), and Holling Family Award for Teaching Excellence (UNL Institute of Agriculture and Natural Resources).

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Utilization of Dried Distillers Grains for Developing Beef Heifers

Jeremy L. Martin
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Summary

A two-year study evaluated feeding dried distillers grains (DDG) during heifer development on growth and reproductive performance. Supplements provided similar CP, energy, lipid, and fatty acids. Protein degradability of the supplements differed such that undegradable intake protein exceeded requirements of DDG heifers. Heifer pubertal development, artificial insemination (AI) pregnancy rate, and overall pregnancy rate were not affected by supplement. However, AI conception rate and AI pregnancy rate were improved by feeding DDG in the heifer development diet.

Introduction

The majority of replacement heifers developed in Nebraska are supplemented with protein and energy. In forage-based diets, dried distillers grains (DDG) have greater energy value than corn and are nearly 30% CP, with greater than 50% of the CP in the form of undegradable intake protein (UIP). Therefore, DDG may be an economically feasible source of energy and protein for growing replacement heifers.

When DDG are fed as an energy source in growing heifer diets, UIP is supplied in excess of requirements. Supplementation of prepubertal heifers with 250 g/d excess UIP increased age at puberty compared to heifers fed monensin and increased weight at puberty compared to control heifers (Lalman et al., 1993 Journal of Animal Science 71:2843). In the same study, fewer UIP supplemented heifers were detected in estrus during the first 21 days of the breeding season, but pregnancy rates were similar. Additionally, supplementing postpubertal heifers with high UIP decreased serum concentrations of follicle stimulating hormone, a key hormone in reproduction (Kane et al., *2004 Journal of Animal Science* 82:283). Research is needed to determine if supplementing heifers with excess UIP from DDG affects development or reproduction.

Procedure

All procedures were approved by the University of Nebraska Institutional Animal Care and Use Committee. Weaned heifer calves (n = 316) were blocked by age at location one (University of Nebraska Dalbey-Halleck farm, Virginia, Neb.) and age by sire at location two (University of Nebraska Agricultural Research and Development Center, Ithaca, Neb.) and assigned randomly within block to receive DDG or control (CON) supplement during development. Heifers from location one were composite MARC II (¼ Hereford, ¼ Angus, ¼ Simmental, ¼ Gelbvieh), Angus*Simmental, and Angus*Gelbvieh genetics. At location two, composite MARC III (¼ Angus, ¼ Hereford, ¼ Red Poll, ¼ Pinzgauer), and MARC III*Red Angus heifers were utilized. Heifers were weaned at an average age of 205 days and supplementation began at an average age of 238 days. Initial and final weights and body condition scores (BCS) were taken on two consecutive days. Two blood samples were taken at 10-day intervals to determine pubertal status of heifers before the beginning of the trial. Interim weights and blood samples were collected every 14 days. Plasma progesterone was determined by radioimmunoassay. Progesterone concentration greater than 1 ng/mL in plasma was interpreted to indicate ovarian luteal activity, and thus attainment of puberty.

Supplement composition, daily intake, and protein balance are presented in Table 1. Supplementation rate was determined by body weight so that supplemental CP, energy, and lipid intake were similar between groups. An ADG of 1.5 lb/day was targeted to achieve approximately 60% of mature weight at the time of breeding. Protein degradability of the supplements differed such that UIP was fed in excess of requirements for DDG heifers. Additionally, lipid in both supplements was derived from corn oil so fatty acid intake was similar between treatments. To ensure consistent nutrient delivery, supplements were bagged in approximately 50 lb bags. Supplements were fed daily in bunks with abundant bunk space. Supplement intake was adjusted to 0.73% of body weight for CON and 0.57% of body weight for DDG heifers following each weigh date. Each group was fed their respective supplement through the last day of AI, at which time heifers were placed in a single group on pasture.

Estrus was synchronized using two injections of prostaglandin $F_{2\alpha}$ (PGF) administered 14 days apart with an 18 gauge, 1.5 inch needle. No progestin was used for estrus synchronization to avoid hastening pubertal development. Estrus detection was performed for 5 days following the second PGF injection, and heifers observed in estrus were artificially inseminated approximately 12 hours later. Heifers were exposed to fertile bulls for approximately 45 days, beginning 10 days after the final artificial insemination (AI). Conception rate to AI was determined via transrectal ultrasonography approximately 45 days after AI. An additional ultrasound pregnancy diagnosis was performed 45 days following removal of bulls to determine final pregnancy rate.

Data included in the current report include growth performance, estrous synchronization, puberty data, and AI conception and pregnancy rates for heifers from both locations over two years. Overall pregnancy rate and final pregnancy diagnosis weight and BCS are from year one only.

Performance data were analyzed using PROC MIXED of SAS. Percentage of heifers reaching puberty, estrous synchronization response, conception rate, and pregnancy rate were analyzed using Chi-square procedures in PROC GENMOD of SAS. The model included treatment and location. The interaction between treatment and location was included for data sets when significant. In multiyear analyses, year was included as a random variable.

(Continued on next page)

Table 1. Supplement composition (DM basis) and daily intake.

Item	CON[a]	DDG[b]
Ingredient %, DM basis		
Dried distillers grains		99.76
Dried corn gluten feed	73.00	
Whole corn germ	24.48	
Urea	2.33	
Trace mineral premix	0.16	0.20
Vitamin ADE premix	0.03	0.04
Daily supplement rate, % of body wt	0.73	0.57
Average daily UIP intake, g/day[d]	92	253
Maximum daily UIP intake, g/day[e]	111	351
Metabolizable protein balance, g/day	34	163
Degradable intake protein balance, g/day	140	-50

[a]Supplemented daily with control supplement 0.73% of body weight.
[b]Supplemented daily with dried distillers grains supplement 0.57% of body weight.
[c]Predicted metabolizable protein and degradable intake protein balances calculated using 1996 NRC Level 1, predictions based on actual ADG, mid-test weight and forage value from yr 1.
[d]Daily UIP intake averaged across the length of the experiment.
[e]Maximum UIP intake achieved at the conclusion of the experiment.

Table 2. Effects of dried distillers grains supplementation during development on growth performance of composite beef heifers[ab].

	Location One		Location Two	
Item	CON[c]	DDG[d]	CON[c]	DDG[d]
Beginning age, day	242	242	229	230
Initial wt, lb	559	558	552	551
Initial BCS	5.33	5.34	5.38	5.37
Final wt, lb	826[ef]	820[e]	804[e]	845[f]
Final BCS	5.65	5.70	5.60	5.68
ADG	1.45[e]	1.42[ef]	1.35[f]	1.58[g]
Final pregnancy determination wt, lb	901	890	975	988
Final pregnancy determination BCS	5.53	5.47	5.84	5.85

[a]Treatment means are presented by location due to a treatment by location interaction for final weight and ADG.
[b]Includes data from year one and two, except pregnancy determination weight and BCS are from year one only.
[c]Supplemented daily with control supplement 0.73% of body weight.
[d]Supplemented daily with dried distillers grains supplement 0.57% of body weight.
[efg]Within a row, means without common superscripts differ at $P < 0.05$.

Table 3. Effects of dried distillers grains supplementation during development on pubertal development, estrous synchronization response, and reproductive performance of composite beef heifers[ab].

Item	CON[c]	DDG[d]	SEM	*P*-value
Pubertal prior to PGF, %[e]	77.7	86.1	1.3	0.44
Age at puberty, day	332	340	6	0.23
Weight at puberty, lb	677	704	11	0.03
Estrus response, %[f]	75.8	75.9	4.1	0.98
Time of estrus, hours[g]	68.0	64.8	2.1	0.19
AI conception rate[h], %	52.9	75.0	6.3	0.0004
AI pregnancy rate[i], %	40.1	57.0	4.0	0.003
Overall pregnancy rate, %	89.3	89.4	3.2	0.97

[a]No treatment by location interactions were detected, treatment main effects are reported.
[b]Includes estrous synchronization data, puberty, AI conception rate, and AI pregnancy rates from both years and overall pregnancy rate from year one only.
[c]Supplemented daily with control supplement 0.73% of body weight.
[d]Supplemented daily with dried distillers grains supplement 0.57% of body weight.
[e]Percentage of heifers that had attained puberty prior to initial PGF injection.
[f]Percentage of heifers detected in estrus within 5 d following second PGF injection.
[g]Time elapsed between second PGF injection and observed standing estrus.
[h]Proportion of heifers detected in estrus that conceived to AI service.
[i]Percentage of total group of heifers that conceived to AI service.

Results

Heifer performance and body condition data are presented in Table 2. There was no difference between groups ($P > 0.05$) in age, initial weight, initial BCS, or final BCS. Furthermore, weight and BCS at final pregnancy determination were not influenced ($P > 0.05$) by supplementation. There was a treatment by location interaction for final weight and ADG. Final weights and ADG were similar between groups at location one ($P > 0.05$) but were greater ($P < 0.05$) for DDG heifers than CON heifers at location two.

Supplement type did not influence ($P > 0.05$) the proportion of heifers that had achieved puberty prior to synchronization, or the average age at puberty (Table 3). Weight at puberty was greater ($P = 0.03$) for DDG heifers than CON heifers, primarily due to the higher ADG and final weight of DDG heifers at location two. A similar percentage ($P > 0.05$) of heifers from CON and DDG were detected in estrus within 5 days following the final PGF injection, and the timing of observed estrus was similar ($P > 0.05$) between groups. Conception rate to AI was greater ($P = 0.0004$) for DDG than CON heifers (52.9% vs. 75.0%). Furthermore, AI pregnancy rates were greater ($P = 0.003$) for DDG heifers than control heifers (40.1% vs. 57.0%). Overall pregnancy rates following exposure to bulls were similar ($P > 0.05$) between DDG and CON heifers in year one.

Conclusions

As ethanol production in Nebraska and the Great Plains expands, greater opportunity will exist to incorporate DDG in replacement heifer diets. These data indicate that utilizing DDG as a source of protein and energy in heifer development diets to promote moderate gains enhances AI conception and pregnancy rates.

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Progestin Concentrations Alter Follicle Characteristics and May Affect Quality of Oocytes (Eggs)

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Summary

Cows were treated with two progestin concentrations to develop ovulatory follicles exposed to different hormone environments. Cows were assigned to Control Group receiving a CIDR for 7 days (4-6 ng/ml of progestin), or to MGA-14 Group receiving 5mg/head/day of MGA for 14 days (< 1 ng of progestin). Our hypothesis was that the MGA-14 treatment would develop larger, persistent follicles with less granulosa cells per follicle volume and may have altered gene expression profiles in oocytes and granulosa cells. Cows in the MGA-14 treatment had larger follicles and less granulosa cells per volume than controls, suggesting that their development mimicked persistent follicles and may be of poorer quality.

Introduction

Melengesterol acetate (MGA) is commonly used in the beef industry to suppress estrus in feedlot heifers or to synchronize estrus to increase reproductive efficiency. The estrus directly after MGA treatment withdrawal has been demonstrated to have reduced conception rates, potentially, through the development of a persistent follicle. A persistent follicle is a follicle that remains dominant on the ovary for an extended time period but will regress on its own. If the MGA treatment produces a persistent follicle, the oocyte within that follicle may be compromised, incapable of fertilization, or unable to develop a viable embryo.

Currently, we do not have any genetic markers of oocyte quality nor do we understand what makes a "good" oocyte versus a "compromised" oocyte. We also do not understand how the granulosa cells surrounding the oocyte may aid in oocyte development. Therefore, the objective of the current study was to produce ovulatory follicles exposed to different hormonal environments to determine differences in gene expression profiles of oocytes and granulosa cells developed under different levels of progesterone. We plan to examine the gene expression profiles in oocytes and granulosa cells from both treatments to develop markers of follicle and oocyte "quality."

Procedure

Cows used for this trial were from the physiology herd located at the Agricultural Research and Development Center at Ithaca, Neb. The physiology cow herd is composed of ¾ MARC III (¼ Pinzgaurer, ¼ Red polled, ¼ Hereford, ¼ Angus) and ¼ Red Angus-European Cross cows. Approximately 194 were used in the experiment with 95 in the control group and 99 in the MGA-14 group.

Control treatment

The 95 control cows were administered an injection of GnRH to ovulate any dominant follicles and a CIDR was inserted for 7 days. At the end of the seven days the CIDR was removed and the cows were administered $PGF_{2\alpha}$ (5 mg/head; PG.) Follicles were then aspirated at 18 hour (n=19), 36 hour (n=18), and 60 hour (n=48) time points after the PG injection. The level of progestin in this treatment group was at least 4-6 ng/ml. With this higher level of progesterone normal follicular waves would occur without the development of persistent follicles.

MGA-14 treatment

In the MGA-14 treatment, approximately 99 cows were injected with PG and fed MGA-14 at a rate of 5mg/head/day for 14 days. At the end of the treatment, MGA-14 was removed from the cows' diets and they were given an injection of PG. The expected level of progestin administered to the cows was to be <1 ng/ml. Follicles were aspirated similar to the control group at 18 hour (n=24), 36 hour (n=25), and 60 hour (n=48) time points after the PG injection. The lower level of progestin in these cows would allow for increased LH which would develop a larger, persistent follicle.

Of the 194 cows, approximately 12 did not have samples due to lack of a dominant follicle or the follicle being lost prior to collection. Therefore, these were removed from the study.

Once all the collections were complete the samples were returned to the lab. The oocytes and granulosa cells were separated from the follicular fluid and either collected for RNA or protein. The follicular fluid was frozen for analysis of progesterone and estradiol. Follicles with a greater E_2 to P_4 ratio (i.e. >1) are considered to be estrogenic dominant follicles. RNA extraction is currently being conducted on the granulosa cell pellets and RIA analysis is being conducted on the follicular fluid.

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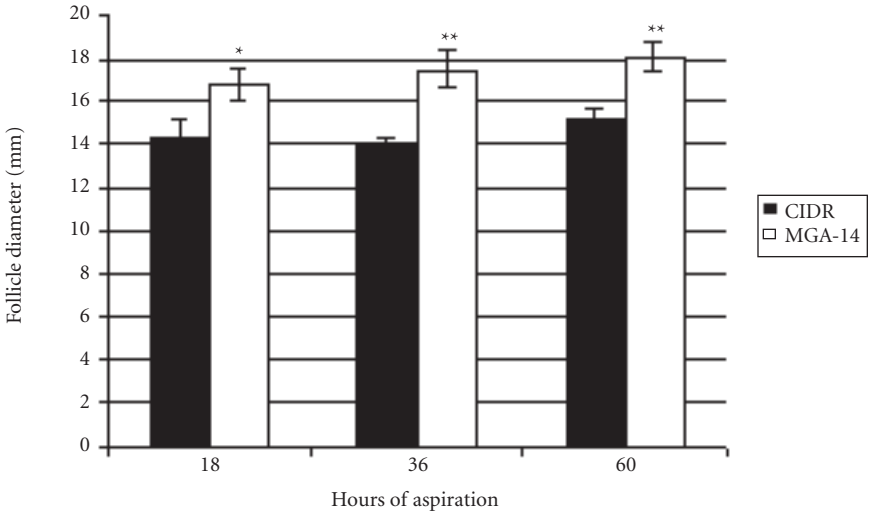

Figure 1. Follicle diameter in dominant follicles aspirated from cows from Control and MGA-14 treatments at 18, 36, and 60 h after PG. The * represents a difference of *(P*<0.03). The ** represents a difference of *(P*<**0.001).**

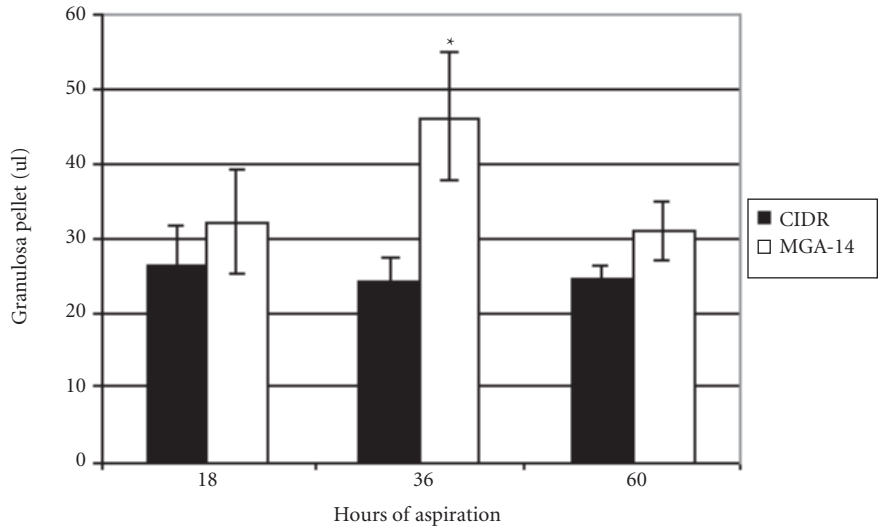

Figure 2. The size of granulosa cell pellets from dominant follicles aspirated from Control and MGA-14 treated cows 18, 36, and 60 hours after PG. The * represents a difference of *(P*<0.05).**

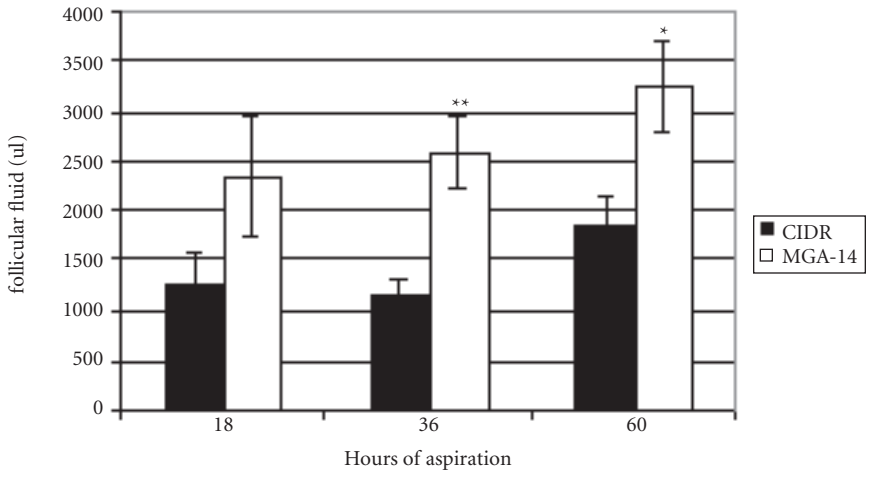

Figure 3. The follicular fluid from dominant follicles aspirated at 18, 36, and 60 hours after PG of the Control and MGA-14 treated cows. The * represents a difference of *(P*<0.02). The ** represents a difference of *(P*<**0.01).**

Results

Follicle diameter

The MGA-14 treatment group had follicle diameters that were statistically larger than the control group at each aspiration time point ($P<0.05$; Figure 1). As the follicles were aspirated at later time points, the differences between the two treatment groups became larger (Figure 1). The increase in follicle diameter in the MGA-14 treatment group is consistent with the formation of a persistent follicle. Persistent follicles have been demonstrated to develop when cows are exposed to levels of progesterone that are less than 1 ng/ml. Greater concentrations of progesterone (4-6 ng/ml) allow for follicle turnover and follicular waves to occur similar to our control treatment.

Granulosa pellet size

There was an effect on the size of the granulosa cell pellet due to the treatment at the 36 hour aspiration time point ($P<0.05$; Figure 2) with the MGA-14 treatment being larger (Control: 24.0 µl vs. MGA: 46.2 µl). However, there was no different in size of the granulosa pellet at the 18 and 60 hour aspiration time points.

Follicular fluid contained in dominant follicle

There was an effect on the amount of follicular fluid contained in the dominant follicle due to treatment with the greatest amounts collected from the MGA-14 group at the 36 ($P<0.01$; Figure 3) and 60 hours ($P<0.05$; Figure 3) aspirations. Again, the MGA-14 treatment group exhibited larger volumes of follicular fluid at all time points. Further analysis will be conducted on the follicular fluid to determine steroid profiles in follicles from each treatment group.

Granulosa cell pellet size to follicular fluid ratio

There was an effect on the granulosa cell pellet size to follicular fluid

ratio (which is indicative of total number of granulosa cells per follicle volume) at the 60 hour aspiration point with the control group having a higher ratio ($P<0.05$; Figure 4). Numerically, the Control group had a higher pellet to follicular fluid ratio at all aspiration points than the MGA-14 treatment group. These data support our hypothesis that there would be less granulosa cells per follicle volume in the MGA-14 treatment versus the Control. In persistent follicles the granulosa cell layer diminishes and may be the reason that the oocyte is less viable. Thus, by 60 h there was less granulosa cells in the MGA-14 follicles per volume than the control.

From this experiment thus far, we can conclude that feeding (5mg/head/day) for 14 days of MGA caused a larger diameter follicle to develop which resembles a persistent follicle. We are now evaluating the mRNA of granulosa cells and oocyte RNA to determine differences in gene expression between the two treatment groups. We speculate that the differential gene expression in these two treatments may help us identify markers of potential "oocyte and follicle quality." These markers would allow us to develop more objective assays to determine oocyte quality prior to fertilization and embryo transfer in beef females.

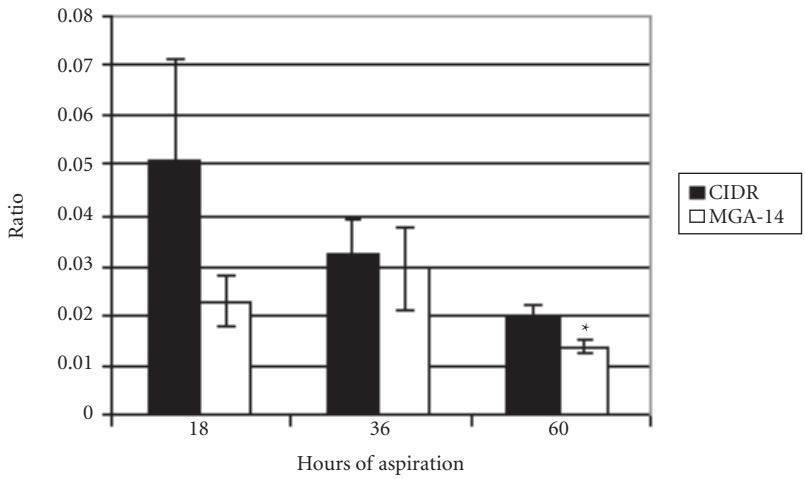

Figure 4. The ratio of granulosa cell size to the amount of follicular fluid aspirated (Ratio) from cows from Control and MGA-14 treatments at 18, 36, and 60 hours after PG. The * represents a difference of *($P<0.05$)*.

[1]Bayli J. Slepicka, undergraduate summer research student from University of Wisconsin-Platteville; Jeremy L. Martin, graduate student ; Robin Ten Broeck, graduate student; Michelle M. Baltes, graduate student; Debra T. Clopton, research technician; Zachary C. Hall, graduate student; Natalie C. Hart, undergraduate student; Shantille G. Kruse, undergraduate student; Robyn A. Longfellow, undergraduate student; Jocelyn R. Wiarda, graduate student; Karl V. Moline, cow/calf manager; Jeff W. Bergman, agriculture technician; Robert Cushman, staff scientist, USMARC; Brett R. White, associate professor; Andrea S. Cupp, associate professor, Animal Science, Lincoln.

Summary Analysis of Grazing Yearling Response to Distillers Grains

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Summary

Eight grazing experiments were summarized reflecting yearling performance when supplemented with 4.0 or 7.5 lb distillers grains. Daily gains were increased 0.53 and 0.89 lb/day. Subsequent feedlot performance was not influenced by distillers grains supplementation on grass. In a six-trial summary, each 1.0 lb of distillers grains decreased forage intake by 0.5 lb. Economic return for each $1.00 spent on distillers grains yielded returns from $1.41 to $1.94.

Introduction

The supply of distillers grains (DG) will triple or quadruple in the next few years as the Nebraska ethanol industry grows. The price of DG at the plant has ranged from $70 to 85/ton this past year. The price of grazing land (or rental cost) has increased steadily over the past several years. The average price for summer pasture in 2006 is about $27.31 per AUM (680 lb dry matter) or about $80/ton. We estimate that DG can be delivered to yearlings on pasture for about $138/ton dry matter ($120 as is). Therefore, DG would be about 166% the price of grass. However, DG has about 200% the energy value of grass. Therefore, we have hypothesized that it would be economical to supplement DG to yearlings on grass.

Procedure

Data were summarized from eight grazing experiments where distillers grains (DG) were supplemented to grazing yearlings on summer pasture. One experiment was conducted in southeast Kansas on smooth brome grass pasture, one in the Kansas Flint Hills, three on smooth brome grass at the Agricultural Research Development Center near Mead, Neb., two were conducted on Sandhills upland range near Stapleton, Neb., and one conducted on upland range at the Gudmundsen Sandhills Lab near Whitman, Neb. Three of the experiments were conducted with yearling heifers and five were with yearling steers. Lengths of trials ranged from 54 to 196 days. The DG supplementation levels were approximately 0.5 and 1.0% of BW.

Finishing performance of the yearlings was determined with cattle from six of the eight experiments. Feed intakes were available from 4 of the 6 experiments which enabled calculation of feed efficiency.

Six additional experiments were summarized where growing calves were fed harvested forage and supplemented with DG. Forage included alfalfa hay and silage, grass hay and grain-free sorghum silage. The DG was supplemented at a minimum of two levels. The lower level served to meet or exceed protein requirements. Higher levels of DG served primarily as an energy source. The objective was to determine the effect of DG supplementation on forage intake.

Results

Mean BW of the yearlings at the start of the grazing season was 638 lb and ranged from 437 to 811 lb (Table 1). Daily gains of nonsupplemented cattle averaged 1.60 lb/day and ranged from 1.08 to 2.31 lb/day. By feeding DG at 0.48% of BW, ADG increased to 2.13 lb/day and feeding at 0.92% of BW increased ADG to 2.49 lb/day. The response in ADG for each 1% BW supplementation was 0.95 and 0.99 lb. This suggests the response was similar with supplementation up to 0.92% BW.

The 0.48% BW level of feeding was about 4.0 lb DG/day (at 90% dry matter). The 0.92% BW level was about 7.5 lb/day. We estimate DG can be delivered to the cattle for about $120/ton ($0.06/lb). The daily costs were

(Continued on next page)

Table 1. Response to distillers grains supplement by grazing cattle.

Experiment	BW[e]	Control[f]	% BW[g]	ADG	↑[h]	% BW[g]	ADG	↑[h]
KS[a]	437	1.55	.50	2.12	1.14	1.00	2.39	.84
KS[b]	575	2.31	.41	2.81	1.22	.83	3.17	1.04
NEBR '06[c]	811	1.48	.50	2.18	1.40	.75	2.53	1.40
NEBR '04[c]	650	1.50	.50	1.70	.4	.60	1.75	.4
NEBR '07[c]	768	1.36	.55	1.96	1.08	—	—	—
NEBR '06[c]	686	1.63	.50	1.98	.7	1.00	2.42	.79
Unpub[d]	535	1.08	—	—	—	.90	2.38	1.54
Unpub[d]	645	1.94	—	—	—	1.30	2.79	.65
Mean	638	1.60	.48	2.13	.99	.92	2.49	.95

[a]Kansas State Southeast Ag. Research Center, 2006 Report.
[b]Unpublished, Kansas State University.
[c]Nebraska Beef Cattle Reports.
[d]Unpublished. University of Nebraska-Lincoln.
[e]Body Weight.
[f]Control ADG.
[g]Distillers Grains Supplementation level, dry matter as percent of body weight.
[h]Increase in ADG for each 1% body weight supplemental DG.

$0.24 and $0.45/day at 4 lb DG/day and 7.5 lb DG/day, respectively. The average grazing period was about 100 days so 50 and 89 lb of gain was achieved with the 4.0 and 7.5 lb feeding levels.

Research has clearly demonstrated a response in ADG of grazing cattle supplemented with ruminally undegradable protein. That response is about 0.3 lb/day and is greater with younger, lighter BW cattle. Some of the response to DG in the summary presented here is likely due to the response to the protein in the DG. The overall response is due to a combination of protein and the concentrated energy in DG.

In three experiments, ADG and feed efficiency in the feedlot, following grazing were not affected by DG supplementation on grass (Table 2). In the fourth experiment, feed efficiency was reduced due to supplementation of DG on grass. In this experiment the yearlings grazed for 196 days before entering the feedlot. Those supplemented at 1% BW of DG were 168 lb heavier entering the feedlot and 150 lb heavier at slaughter. They were also fatter which may account for some of the reduced feed efficiency. In two other experiments where feed intake was not measured, ADG in the feedlot was not influenced by DG supplementation on grass. We therefore conclude that extra gain produced by supplementing DG on grass does not have a negative effect on subsequent feedlot performance, if the grazing period is not more than 150 days and cattle are slaughtered at equal fatness.

Calves fed harvested forages supplemented with low levels (about 1.5 lb/d) of DG (controls) gained 1.62 lb/day (Table 3) which is comparable to gains of the yearlings on grass. The mean substitution rate was 0.48 lb of forage per lb of DG supplemented. The range was relatively large (0.268 to 0.622) but the calculation is by difference which exaggerates the variation (includes variation from both the control and supplemented cattle). We conclude that in a grazing situation at a moderate stocking rate one can expect to have a reduction in grazed forage intake of 0.5 lb for each lb of DG (dry matter) supplemented. Calves fed harvested forage increased gain by 0.18 lb/day for each 1.0 lb of DG dry matter supplemented. The grazing yearlings increased gain somewhat less (0.13 lb/day) in response to supplementation of 1.0 lb of DG. This might suggest a slightly larger reduction in grazed forage intake — perhaps 0.6 to 0.7 lb rather than 0.5 lb as stated above. Measuring intake on pasture is very difficult and has not been demonstrated with DG supplementation on pasture. The 0.5 lb substitution rate may be conservative. Yearlings supplemented with 4.0 lb DG gained 53.0 additional lb in 100 days at a cost of $24. Using five-year average prices, the value of the additional gain was $31.10. Approximately 189 lb of forage would be saved at a value of $7.60 for a total return of $38.70. At the 7.5 level of supplemented DG, the cost would be $45 for DG. An additional 89 lb of gain worth $49.96 would be obtained plus $13.66 for reduced forage use for a total of $63.62. Alternatively, the breakeven price one could pay for the DG would be $185 and $133/ton for the 4.0 and 7.5 lb supplementation levels respectively.

Because the yearlings that were finished after supplementation on grass gained at similar rates and efficiencies, we can assume the extra weight gain on grass is maintained to market with no additional costs. The five-year average price for that gain is $78/cwt. With the value of the extra gain and forage savings, the yearlings supplemented with 4.0 lb/day DG would return $48.94 for $24.00 invested in DG. Those supplemented with 7.5 DG/day would return $83.08 for $45.00 invested in DG. It would be necessary to retain ownership through the feedlot to realize these returns.

Table 2. Feedlot performance after distillers grains supplementation on grass.

Experiment	%BW[d]	G/F[e]	BW[f]	%BW[d]	G/F[e]	BW[f]
KS[a]	.50	-6.2%	+92	1.00	-9.6%	+150
NEBR '06[b]	.50	+3.7%	+40	1.00	+4.3%	+41
Unpub[c]	—	—	—	.90	+2.4%	+65
Unpub[c]	.58	+2.0%	+22	—	—	—

[a]Kansas State Southeast Ag. Research Center, 2006 Report.
[b]Nebraska Beef Cattle Reports.
[c]Unpublished.
[d]Distillers grains supplementation level while grazing.
[e]Percentage change in G/F for supplemented vs controls.
[f]Body weight difference at slaughter compared to controls.

Table 3. Substitution rate of distillers grains for forage.

Experiment	Control ADG	lb forage/lb DG[b]
NEBR '03[a]	.99	.268
NEBR '05[a]	1.79	.531
NEBR '05[a]	1.08	.492
NEBR '06[a]	1.83	.600
NEBR '07[a]	2.03	.364
NEBR '07[a]	1.99	.622
Mean	1.62	.480

[a]Nebraska Beef Cattle Reports.
[b]lb forage replaced by supplementing 1 lb dry matter from distillers grains.

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Dried Distillers Grains Substitute for Forage and Nitrogen on Pasture: N Dynamics and Use Efficiency

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Summary

Animal performance and N dynamics of different grazing management and supplementation strategies in cattle production systems were evaluated on smooth bromegrass pastures in eastern Nebraska. Steers supplemented with dried distillers grains with solubles (DDGS) on nonfertilized smooth bromegrass pastures gained more (0.58 lb/d) than steers on fertilized and nonfertilized smooth bromegrass. Nitrogen retention per steer supplemented with DDGS was 38.5% greater than non supplemented steers on fertilized smooth bromegrass and non-supplemented steers on nonfertilized smooth bromegrass stocked at 69% of the rate on fertilized pastures. Fertilized and supplemented pastures were stocked at equal densities. Nitrogen use efficiency based on the amount of N applied as either fertilizer or in DDGS was 3.2 times greater for supplemented steers than non-supplemented steers grazing fertilized pasture (26.38 % vs. 8.23%). Dried distillers grains can be used as a substitute for forage and N fertilizer by improving performance, reducing cost of gains, and increasing N retention in yearling steers.

Introduction

Usually, the amount of N applied as fertilizer to cool-season grasses is in excess of plant uptake. Historically, fertilization has increased forage production relative to the cost of application, but increases in energy and N costs may have negative implications. Previous research using pastures used for this experiment have shown fertilized (80 lb N/ac) pastures stocked at approximately 69% of nonfertilized pastures to be similar in animal and pasture performance. Apparent N recovery rates of fertilized grasses can be as low as 17 to 50%. The losses can create undesirable N sinks such as volatilization, losses to surface water runoff, and/or leaching into the ground water supplies.

Although difficult to accomplish with pasture cattle, N excretion can be minimized when both undegradable intake protein (UIP) and degradable intake protein (DIP) are fed to meet but not exceed requirements. Actively growing forages contain protein that is highly degradable in the rumen. Supplementing energy to ruminants on high quality forages can improve both N and energy efficiency by incorporating greater amounts of N in ruminal bacteria.

Dried distillers grains are a good source of both energy and UIP. Daily gain improvements are not exclusively related to UIP or fat, but both appear to contribute to the improved gain when supplemented to cattle grazing smooth bromegrass pastures. Accompanying improvements in cattle performance, DDGS supplementation has been shown to replace forage intake from 0.27 to 0.79 lb per lb of DDGS. The objective of this experiment was to measure animal performance and N dynamics (use efficiency) in cattle as affected by grazing management and supplementation strategies.

Procedure

Forty-five yearling steers (767 ± 22 lb) were used in a randomized complete block to evaluate performance, N use, and economic impact of supplementation and management strategies on smooth bromegrass pastures. Yearling steers were stocked at 4 AUM/acre for smooth bromegrass pastures fertilized with 72.78 lb N/acre (FERT), nonfertilized smooth bromegrass pastures stocked 69% of the FERT (CONT), or nonfertilized smooth bromegrass pastures stocked at the same rate as the FERT with 5 lb (DM) of DDGS supplemented daily (SUPP). Pastures were grazed from April 22 to Sept. 19, 2005, and blocked by location. Pasture represented the experimental unit and was replicated three times. Pastures were strip-grazed at the assigned stocking rate for 4 days/strip (6 strips/cycle) in cycles 1 and 5 and for 6 days/strip in cycles 2, 3, and 4. Midpoint diet samples were collected in one of the 6 strips for each cycle utilizing 6 ruminally fistulated steers. Diet DM, CP, and IVDMD were subsequently determined. In each strip selected for diet collection, standing crop was estimated immediately before and after each grazing period by a combination of hand clipping quadrants (0.38 m^2) and a calibrated drop disc method.

Nitrogen retention was estimated from weight gains using NRC (1996) equations which were a function of BW gain during the experimental period and final carcass composition.. Economic assumptions for evaluation of grazing management and supplementation strategies were: land costs $32/acre, yardage costs $0.10/head daily, fertilizer cost $0.3525/lb N ($324.30/ton 46-0-0), fertilizer application $4/acre, DDGS $110/T delivered to the bunk. Following the experimental period, steers were finished on a high concentrate diet containing high-moisture corn at 66% of DM, DRC at 16.5% of DM, alfalfa hay at 7.5% of DM, and a meal supplement at 5% of DM. Metabolizable protein, Ca, P, and K requirements were formulated to meet or exceed NRC (1996) requirements.

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Results

Steers on FERT gained the same as CONT (P=1.0, 1.37 lb/d and 1.37 lb/d for FERT and CONT, respectively; Table 1) but had greater costs of gain ($0.35/lb gain vs $0.28/lb gain; Table 3) due to additional costs of N being greater than the additional cost of land use. Previous studies at this site suggested equal animal and pasture performance can be obtained by reducing the stocking rate of the nonfertilized pastures to 69% of the fertilized pastures. In this experiment, the additional land use at $32/acre produced lower cost of gain than the addition of fertilizer at $0.3525/lb of N (application rate 72.78 lb/acre). Steers supplemented with DDGS gained more (P<0.01) than FERT or CONT (1.95 lb/day vs 1.37 lb/day; Table 1). Supplemented steers maintained their BW advantage during the feedlot phase with significantly (P<0.05) greater final weights than the FERT and CONT steers (Table 1). Individual intakes and F:G were not available for these steers in the feedlot.

The cost of gain for SUPP steers was $0.31/lb gain (DDGS was $0.055/lb, delivered). Nitrogen retention for SUPP steers was approximately 38.4% greater than FERT and CONT (P<0.01, 8.21 lb/head vs 5.94 lb/head; Table 2). These values estimated from the NRC (1996) equations show that the increase in N retention is a function of BW gain and final carcass composition. Increases in BW can be attributed to both the energy from fat and UIP when cattle are supplemented with DDGS. A portion of this response may be due to correcting a metabolizable protein deficiency.

Nitrogen inputs were highest for the FERT system, but N retention was greatest for the SUPP steers. This is mainly due to the inefficiencies between fertilization and plant uptake. Nitrogen use efficiency, based on the amount of N applied as either fertilizer or in DDGS, was 3.2 times greater for SUPP steers than FERT steers (26.38 % vs 8.23%; Table 2) which makes the total amount of potential

Table 1. Pasture and feedlot performance for grazing management and supplementation strategies of steers grazing smooth bromegrass.

	Treatment			
Item	CONT	FERT	SUPP	SEM
Pasture performance				
Days	153	153	153	
Initial BW, lb [a]	766	767	767	2
End BW, lb[a]	977[c]	977[c]	1065[d]	9
ADG, lb	1.37[b]	1.37[b]	1.95[c]	0.06
Forage disappearance, lb[d]	15.63	14.47	13.5	2.78
Forage disappearance, % of BW	1.79	1.66	1.47	0.83
Feedlot performance				
Days	115	115	115	
Final wt, lb[e]	1368[b]	1367[b]	1491[c]	20
ADG, lb	3.4	3.4	3.71	0.17

[a]Shrunk weight.
[bc]Means without a common superscript differ (P<0.01).
[d]Estimated from pre and post grazing biomass measurements for forage utilization within a grazing strip for each cycle.
[e]Calculated from hot carcass weight, adjusted to a 63% common dressing percentage.

Table 2. Nitrogen balance for grazing management and supplementation strategies of steers grazing smooth bromegrass [a].

	Treatment			
Item	CONT	FERT	SUPP	SEM
N inputs, lb[b]		69.71	31.17	
N intake from forage, lb	52.17	57.79	51.19	6.23
N intake total, lb	52.17[c]	57.79[c]	82.36[d]	8.14
N retention, lb[e]	5.95[c]	5.93[c]	8.21[d]	0.24
N excretion, lb[f]	46.22[c]	51.86[c]	74.15[d]	8.9
N use efficiency, %[g]		8.51	26.33	

[a]Items are based on the total lb of N/hd for the entire grazing period.
[b]N inputs include fertilizer and DDGS. Pastures were fertilized with urea at 72.78 lb/acre of N. Steers were supplemented with 5 lb (DM) of DDGS (24.6% CP) daily for the entire gazing period.
[cd]Means without a common superscript differ (P<0.05).
[e]N retention calculated from NRC (1996) equations.
[f]Difference between N intake total and N retention.
[g]System use efficiency, calculated by dividing N retention by N system inputs*100.

Table 3. Economic evaluation of grazing management and supplementation strategies for steers grazing smooth bromegrass.

	Treatment		
Item	CONT	FERT	SUPP
Number of steers	15	15	15
Total gain, lb/head[a]	218	217	309
Acres	21.49	14.88	14.88
Fertilizer lb/acre		72.78	
Supplement (as-is) lb/head daily			5.55
Costs, $/head[b]			
Land	45.84	31.73	31.73
Yardage	15.84	15.84	15.84
Fertilizer		25.44	
Fertilizer application		3.97	
DDGS			48.35
Total	61.68	76.98	95.92
Cost of gain, $/lb[c]	0.28	0.35	0.31
Cost of gain above CONT, %	—	25	10.71

[a]Total weight gain includes additional cattle used to graze during peak forage production times (27 days total). Cattle were of the same weight and type.
[b]Economic assumptions for evaluation of grazing management and supplementation strategies, land costs $32/acre, yardage costs $0.1/head daily, fertilizer cost $0.3525/lb N, fertilizer application $4/acre, DDGS $110/T delivered to the bunk.
[c]Calculated by dividing total cost by total gain.

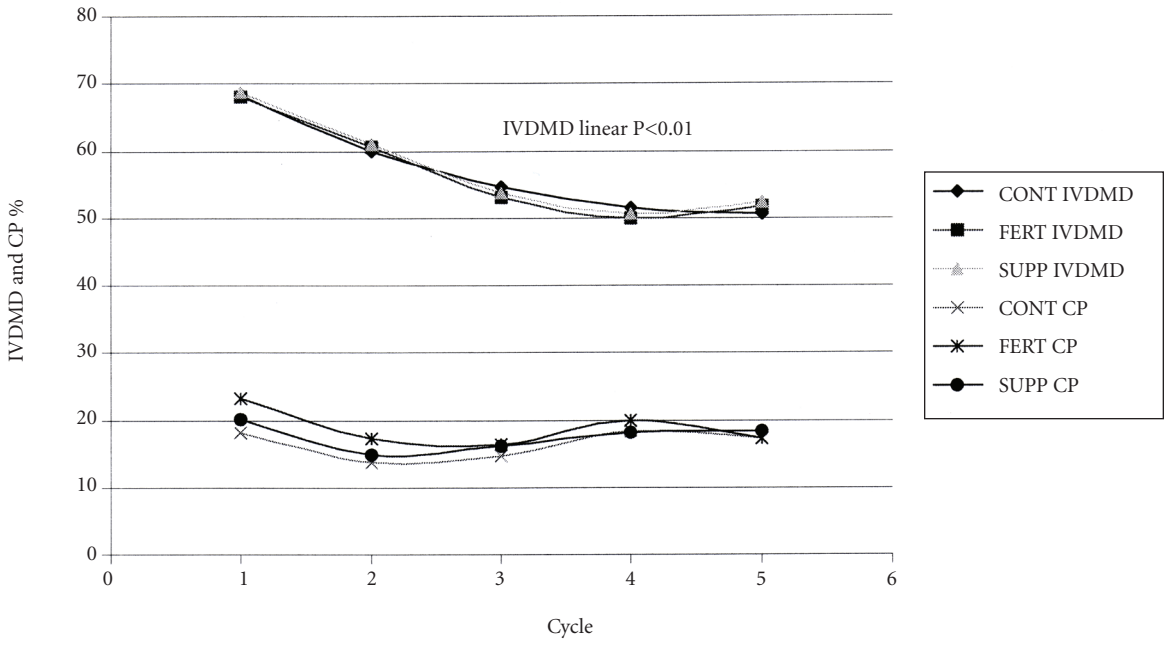

Figure 1. *In vitro* **dry matter digestibility and CP content of smooth bromegrass over time for grazing management and supplementation strategies of steers.**

N for volatilization or surface water runoff greater in the FERT livestock system.

The effects of DDGS supplementation and fertilization on forage disappearance are shown in Table 1. Steers supplemented with DDGS had numerically less forage disappearance with a replacement rate of 0.43 lb of forage per lb of DDGS. *In vitro* dry matter digestibility of diets (Figure 1) of the smooth bromegrass was not different ($P>0.05$) among treatments. However, there was a significant linear ($P<0.01$) decrease in IVDMD over time.

Dried distillers grains significantly increased steer performance when grazing smooth bromegrass pastures. Additionally, N retention and N use efficiency were greater for SUPP steers compared to FERT. Dried distillers grains can be used as a substitute for forage and N fertilizer by improving performance, reducing cost of gains, and increasing N retention in yearling steers.

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Comparing a Modified Dry By-product to Dry Distillers Grains with Solubles in Growing Calf Diets

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Summary

A growing trial was conducted to contrast a new by-product, Dakota Bran Cake (DBRAN), against dry distillers grains with solubles (DDGS) and evaluate the two by-products at two dietary inclusion levels on steer calf performance measurements. Diet treatments included 15% DBRAN, 30% DBRAN, 15% DDGS, and 30% DDGS, replacing a blend (70:30 ratio) of brome grass hay and alfalfa haylage (DM basis). Final BW, ADG, and DMI increased, while F:G decreased as the inclusion level for both of these by-products increased from 15 to 30% DM. DDGS significantly improved ADG and F:G compared to feeding DBRAN at both inclusion levels. Feeding DBRAN and DDGS in growing diets to steer calves improved performance at higher dietary inclusion levels, while DDGS tended to improve performance over DBRAN.

Introduction

Generally, by-products have lower starch levels compared to corn, but with equal or improved energetic gain responses in cattle. One modified dry by-product being produced now is Dakota Bran Cake (DBRAN). This product has comparable energy and lower protein content than dry distillers grains with solubles (DDGS). A previous feedlot study was conducted and found DBRAN fed wet had similar feeding performance to DDGS and 100-108% the energy value of corn (*2006 Nebraska Beef Report*, pp. 57-58). The objectives of this trial were to contrast the feeding value of DBRAN against DDGS and evaluate these by-products at two dietary inclusion levels in high roughage, growing diets for steer calves.

Procedure

An 82-day growing trial used 256 crossbred backgrounded steer calves (620 ± 51.1 lb) in a randomized complete block design experiment. Steers were weighed on two consecutive days (day 0 and day 1) to obtain an initial BW after a five-day limit feeding period of a 50% ground alfalfa hay and 50% wet corn gluten feed diet at 2.0% of BW. The weights obtained from day 0 were used to block the steers into 3 weight blocks, stratify by weight within block, and assign randomly to pens. Pens were then assigned randomly within block to one of four dietary treatments with four pens per treatment and 16 steers per pen.

Dietary treatments (Table 1) consisted of 15% DBRAN (15DBRAN), 30% DBRAN (30DBRAN), 15% DDGS (15DDGS), and 30% DDGS (30DDGS) on DM basis. Inclusion of by-products in the diets replaced 70:30 (DM basis) ground brome grass hay to alfalfa haylage. All diets contained 2% dry supplement (DM basis) and were formulated to contain 200 mg/ steer daily Rumensin® (*Elanco Animal Health, Greenfield, Ind.*). Diets were formulated to meet or

Table 1. Composition of dietary treatments for cattle fed 2 levels of 2 by-product types (%DM)[a].

Ingredient	15DBRAN	30DBRAN	15DDGS	30DDGS
Brome Grass Hay	58.1	47.6	58.1	47.6
Alfalfa Haylage	24.9	20.4	24.9	20.4
Dakota Bran Cake, pelleted	15	30	—	—
Dry Distillers Grains	—	—	15	30
Dry Supplement[b]	2	2	2	2
Ingredient Analysis	DBRAN	DDGS	BH	AH
DM	92.0	90.5	90.0	35.0
Starch	23.2	7.7		
NDF	30.3	29.2	72.5	39.7
CP	15.5	30.4	10.9	23.4
Ether Extract	10.8	11.2		
IVDMD	81.1	80.5	50.6	68.4

[a]15DBRAN = 15% DBRAN, 30DBRAN = 30% DBRAN, 15DDGS = 15%DDGS, 30DDGS = 30% DDGS, DBRAN = Dakota Bran Cake, DDGS = dry distillers grains with solubles, BH = brome grass hay, AH = alfalfa haylage.
[b]Formulated to provide 200 mg/ steer daily Rumensin-80®.

Table 2. Performance measurements for cattle fed 2 levels of 2 by-product types [ab].

	Level			Type			
Parameter	15	30	*P*-value	DBRAN	DDGS	*P*-value	Inter
Initial BW, lb	621	619	0.23	621	619	0.30	0.80
Final BW, lb	797	825	<0.01	806	816	0.06	0.33
DMI, lb	18.9	19.6	0.01	19.3	19.2	0.77	0.63
ADG, lb	2.15	2.51	<0.01	2.26	2.40	0.05	0.35
F:G	8.82	7.81	<0.01	8.54	8.04	0.01	0.19

[a]15DBRAN = 15% DBRAN, 30DBRAN = 30% DBRAN, 15DDGS = 15% DDGS, 30DDGS = 30% DDGS.
[b]Level = Main effects of by-product inclusion level; Type = main effects of by-product type; Inter = interaction of by-product level and type.

exceed NRC (1996) requirements for metabolizable protein, degradable intake protein, Ca, and P. DBRAN (Tall Corn Ethanol, Coon Rapids, Iowa) was dried from its modified wet form and then pelleted for feeding purposes in this trial.

Steers were fed their respective treatment diets ad libitum twice daily at 0700 and 1200 hours. They were then limit fed the same common diet as was fed at the beginning of the trial for 6 days at 2.0% of BW then weighed on two consecutive days to obtain a similar fill weight at the end of the 82 d treatment feeding period compared to that at the beginning of the trial.

Feed samples were collected weekly, analyzed for DM at 60°C for 48 hours. Data were analyzed using the mixed procedures of SAS as a randomized complete block design, with pen as the experimental unit.

Results

Feeding DBRAN and DDGS at 15 and 30% DM did not result in any significant interactions between by-product type or inclusion level (Table 2). Higher inclusion levels of both by-products resulted in greater ($P<0.01$) final BW and ADG. DBRAN and DDGS at 30% of diet DM also increased ($P= 0.01$) DMI and improved ($P<0.01$) F:G compared to feeding these by-products at 15% DM. Furthermore, feeding DDGS tended ($P= 0.06$) to increase final BW and significantly ($P<0.05$) increased ADG compared to feeding DBRAN. Although DMI was not affected ($P= 0.77$) by by-product type, F:G was significantly ($P<0.01$) improved for feeding DDGS compared to DBRAN.

Feeding DBRAN and DDGS in high roughage, growing steer diets improved weight gains and feed conversions at higher inclusion levels. DDGS tended to be a slightly superior by-product for feeding values compared to DBRAN with growing steers. As these diets were formulated to meet protein requirements, we estimate DBRAN had 84% the energy value of DDGS likely due to higher fat content in DDGS. Previous research has shown that DDGS has about 125% the energy value of corn in forage based diets. Therefore, DBRAN appears to have an energy value equal to or 3% higher than corn.

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Effect of Distillers Grains Composition and Level on Steers Consuming High-Quality Forage

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Summary

An experiment was conducted to determine the effects of dried distillers grains (DDG) supplementation level and composition on growing steer performance and forage intake. Factors included DDG supplementation level (0.25, 0.50, 0.75 or 1.00% of BW), and DDG solubles level (0, 5.4, 14.5, 19.1, or 22.1% DM). Final BW improved, and forage intake decreased with increasing levels of DDG. An interaction between DDG supplementation level and solubles level was observed on ADG and F:G and was likely related to supplemental fat levels. Supplementation of forages with DDG improves performance while decreasing forage intake when fat levels are not too great.

Introduction

Supplementing forage with dried distillers grains (DDG) decreases forage DMI and increases ADG (Morris et al., *2005 Nebraska Beef Report*, pp. 18-20; Morris et al., *2006 Nebraska Beef Report*, pp. 30-32). This allows producers to increase the carrying capacity of pastures, and expand current production without increasing the amount of land devoted to grazing. Although the forage replacement value of DDG has been researched, the importance of supplemental DDG composition has not. Of concern is the variability of DDG produced both between and within ethanol plants and its impact on animal production measures. The goal of the current study was to examine the effects of DDG composition at increasing levels of DDG supplementation in steers fed high quality forage.

Procedure

One-hundred twenty crossbred steer calves (549 ± 27 lb) were used in a randomized complete block design. Upon arrival at the feedlot, steers were individually identified and vaccinated. Five days prior to initiation of the experiment, steers were limit fed (2% BW) a diet containing 40% wet corn gluten feed, 27.5% grass hay, 27.5% alfalfa hay, and 5% supplement. Steers were weighed on three consecutive days, immediately prior to initiation of the experiment, and the average of the three weights was used as the initial BW. A 4 x 5 factorial treatment structure was used with the factors being DDG supplementation level (0.25, 0.50, 0.75 or 1.00% of BW), and DDG solubles level (0, 5.4, 14.5, 19.1, and 22.1% DM; calculated using NDF content of solubles and 0% solubles DDG). Varying solubles levels were added to the distillers grains before drying at the Otter Creek Ethanol, Ashton, Iowa. The amount ranged from 0 to 110% of the amount of solubles produced in the plant relative to the amount of dried grains (DM basis). Steers were stratified by weight before being assigned randomly to treatments, and the experiment was conducted in two blocks (60 steers/block) representing two different time periods.

All steers were fed once daily and allowed ad libitum access to the basal diet that consisted of 58.8% alfalfa hay, 39.2% sorghum silage, and 2% vitamin and mineral supplement. Steers were fed individually using Calan electronic gates and the DDG was placed on top of the forage to encourage complete consumption. Amount of DDG supplemented was determined using the initial BW for the first 28 days. Body weights were also taken days 27 and 28, as well as days 55 and 56. Average BW from those two-day periods was used to adjust supplemental DDG amounts appropriately. Prior to initiation of the trial, DDG was transferred from a feed bin to 50 lb bags. Samples were taken periodically during the bagging process to ensure a representative sample was obtained. Refused feed samples were taken weekly and analyzed for DM and CP content to determine the amount of DDG and forage refused. DDG samples were also taken and analyzed for DM, CP, fat, and NDF content (Table 1).

Results

Data for the effects of DDG supplementation level on intake and BW are presented in Table 2. There was a linear ($P<0.01$) effect of supplementation level on final BW, forage intake, and DDG intake. Distillers grains supplementation level also tended to affect final BW quadratically ($P= 0.08$). Final BW improved with increasing levels of DDG supplementation, but only a 1 lb increase was seen when increasing the DDG level from 0.75 to 1.00% of BW. Forage intake decreased, while DDG intake increased with increasing levels of supplementation. These observations are consistent with previous studies examining the effects of DDG supplementation level on intake and performance (Morris et al., *2005 Nebraska Beef Report*, pp. 18-20; MacDonald et al., *2006 Nebraska Beef Report*, pp. 27-29; Morris et al., *2006 Nebraska Beef Report*, pp. 30-32). Supplementing forage-based diets with DDG is advantageous in terms of maximizing forage use compared to corn. The high starch content of corn causes an increase in the number of ruminal amylolytic bacteria that compete with cellulolytic bacteria. Competition between these two bacterial populations leads to an overall reduction in fiber digestion. In the case of DDG, starch content is relatively low and bacterial competition is not a major factor.

Table 1. Composition of dried distillers grains with solubles.

	Solubles Level, %[a]				
	0	5.4	14.5	19.1	22.1
DM, %	95.5	92.1	90.8	89.3	89.6
CP, %	32.1	31.9	31.5	30.7	30.9
Fat, %	6.9	8.9	10.4	12.7	13.3
NDF, %	36.8	34.9	31.9	30.3	29.3

[a]Solubles level calculated using % NDF of solubles (2.3%) and 0% solubles DDG.

Table 2. Effect of dried distillers grains supplementation level on intake and BW of growing steers.

	DDG Supplementation Level, % BW					*P*-value		
	0.25	0.50	0.75	1.00	SEM	Linear	Quadratic	Cubic
Initial BW, lb	609	611	605	607	21.5	0.72	0.98	0.62
Final BW, lb	806	835	849	850	23.9	< 0.01	0.08	0.94
Forage intake, lb/day	15.2	14.6	13.8	12.4	0.8	< 0.01	0.18	0.50
DDG intake, lb/day	1.7	3.5	5.2	6.7	0.19	< 0.01	0.97	0.99

Table 3. Effect of dried distillers grains composition on intake and BW of growing steers.

	DDG Solubles Level, %						*P*-value		
	0.01	5.4	14.5	19.1	22.1	SEM	Linear	Quadratic	Cubic
Initial BW, lb	609	606	609	605	612	21.5	0.89	0.68	0.98
Final BW, lb	832	831	838	826	848	23.9	0.36	0.52	0.47
Forage intake, lb/day	13.9	14.1	13.9	13.6	14.5	0.8	0.69	0.28	0.06
DDG intake, lb/day	4.3	4.3	4.2	4.2	4.3	0.19	0.99	0.65	0.60

Table 4. Effect of dried distillers grains supplementation level and composition on ADG and F:G of growing steers.

	DDG Solubles Level, %					
DDG Level, % BW	0.0[a]	5.4[b]	14.5[b]	19.1[b]	22.1[c]	SEM
ADG						0.19
0.25[d]	2.57	2.33	2.13	2.22	2.50	
0.50[e]	2.38	2.52	2.85	2.49	3.08	
0.75	2.87	2.83	2.81	3.02	2.94	
1.0[f]	2.78	3.06	3.11	2.80	2.74	
F:G						—
0.25[d]	6.36	7.22	8.00	7.14	7.18	
0.50[e]	7.45	7.01	6.29	7.05	6.16	
0.75	6.58	6.64	6.42	6.28	6.74	
1.00	6.99	6.50	6.13	6.59	6.74	

[a]Cubic effect of DDG supplementation level on ADG within solubles level (*P*<0.05).
[b]Linear effect of DDG supplementation level on ADG within solubles level (*P*<0.01).
[c]Quadratic effect of DDG supplementation level on ADG within solubles level (*P*<0.05).
[d]Quadratic effect of solubles level within distillers grains supplementation level (*P*<0.01).
[e]Linear effect of solubles level within distillers grains supplementation level (*P*<0.01).
[f]Quadratic effect of solubles level within distillers grains supplementation level (*P*<0.05).

Data for the effects of DDG composition on intake and BW are presented in Table 3. There tended to be a cubic (*P*= 0.06) effect of solubles level on forage intake. The numerically lowest intake observed was with the 19.1% level and the numerically highest intake observed was with the 22.1% level. No other effects of solubles level on intake or BW were observed.

A DDG supplementation level x solubles level interaction (*P*<0.01) was observed for ADG and F:G (Table 4). The effects of DDG supplementation level on ADG within each solubles level may help explain this interaction. Within the intermediate solubles levels (5.4 - 19.1%) a linear (*P*<0.01) increase in ADG was observed in response to increasing DDG supplementation levels, but at the 22.1% level a quadratic (*P*<0.05) response was observed. Within the 22.1% solubles treatment group, the highest ADG were seen with the 0.50 and 0.75% DDG supplementation treatments. Within the 1.00% DDG supplementation group, a quadratic (*P*<0.05) response in ADG to solubles level was also observed. Within that group, a numeric increase in ADG was observed up to the 14.5% solubles level, but ADG numerically decreased when the solubles level was increased to 19.1 and 22.1%. Interestingly, steers within the 1.00% DDG supplementation group who were fed the 19.1 and 22.1% solubles consumed the highest amount of supplemental fat (4.5 and 4.8% of total diet DM respectively). Although fat content of the diet would be expected to increase the energy value of the diet, fat can also have a depressing effect on fiber digestion. At higher fat levels, the depression in fiber digestion may have overcome the increased energy supplied by the supplemental fat, possibly explaining the interaction. Results from this trial indicate that the highest supplemental fat level for maximizing ADG in steers consuming a high quality forage diet is between 3.6 and 4.5% of total diet DM.

In summary, with increasing levels of DDG, final BW was increased, whereas forage intake was decreased. The interaction between DDG supplementation level and solubles level on ADG and F:G is likely a reflection of factors associated with supplemental fat level. Although results from this trial indicate that feeding high levels of a high fat content DDG may depress ADG in steers fed a high quality roughage diet, over most treatments the response to solubles level appeared small. Within the DDG types fed in this trial that are most comparable to those fed by producers (5.4 - 19.1% solubles), ADG increased linearly with increasing DDG supplementation levels.

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Replacement of Forage with Dried Distillers Grains Reduces Ruminal Methane Production

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Summary

Our objective was to determine how replacing forage with dried distillers grains plus solubles (DDGS) affects ruminal methane production. Methane produced by lambs and ruminal cultures was quantified following the substitution of brome hay with DDGS. In vitro and in vivo methane production is reduced when brome hay is replaced with DDGS. A reduction in methane production in vitro is not associated with a reduction in energy produced in the form of volatile fatty acids or dry matter disappearance. Decreased ruminal methane production would increase the retention of gross feed energy and may explain the increase in ADG realized when DDGS are used to supplement cattle receiving a forage-based diet.

Introduction

Ruminal methane production accounts for a 3 to 12% loss of feed gross energy. This loss is greatest for cattle consuming forage-based diets and decreases with increasing amounts of concentrate included in the diet. Readily fermentable carbohydrates result in less methane produced per unit of digested DM. Methane also is a potent greenhouse gas. Decreasing ruminal methane emissions would decrease the amount of atmospheric methane contributed by agricultural activities and help mitigate global warming.

Supplementation of cattle consuming a forage-based diet with dried distillers grains increases ADG, DMI, and DM digestibility. However, the effect of such supplementation on ruminal methane production has not been investigated. The objectives of this work were to: 1) determine if replacing dietary forage with dried distillers grains plus solubles (DDGS) decreases ruminal methane production and 2) determine if any such effect can be attributed to the corn bran versus the non-fiber (protein + fat) component of the DDGS.

Procedure

In vitro methane production

Ruminal fluid extracted from a fistulated heifer receiving a mixed forage and concentrate diet was used to inoculate cultures (n = 4/treatment) provided with approximately 10 mg DM/mL of substrate that consisted of 100% brome hay (0%), 25% DDGS and 75% brome hay (25%), 50% DDGS and 50% brome hay (50%), 75% DDGS and 25% brome hay (75%), or 100% DDGS (100%). Nutrient content of the substrates is outlined in Table 1. In addition to the substrate and ruminal fluid inoculum cultures contained a modified McDougall's buffer, distilled H_2O, trypticase, resazurin, a micro mineral solution, and Na_2S. Following the addition of media to 40 mL glass vials, an oxygen-free environment was created by purging each of the cultures with CO_2. The vials were then sealed, pressurized to 100 kPa above atmospheric pressure, and allowed to incubate in a shaker (102°F) for 22 hours. Following incubation, headspace pressure was measured and methane concentration was analyzed using a gas chromatograph. Media were then centrifuged and supernatant drawn off for volatile fatty acid (VFA) concentration analysis, which was performed with a gas chromatograph. IVDMD was determined by filtration and subsequent drying of the filter (140°F) for 48 hours. Data were analyzed using the MIXED procedure of SAS and the model included the fixed effect of treatment.

Table 1. Nutrient content of substrates (% DM; *in vitro* experiment).

	Substrate	
Nutrient content	DDGS	Brome hay
Crude protein	29.5	14.7
Ether extract	9.9	2.4

In vivo methane production

Nine crossbred lambs were assigned randomly to receive a sequence of diets in a replicated 3 X 3 Latin square design. Lambs were offered a control diet (60% brome hay and 30% corn bran; CON), a diet in which the corn bran was replaced with DDGS (60% brome hay and 30% DDGS; DDGS), or a diet in which brome hay was replaced with DDGS (30% brome hay, 30% corn bran, and 30% DDGS; DDGS+BRAN) at 1% of BW as measured at the commencement of the trial. Diet composition and nutrient content is outlined in Table 2. Periods were 14 days with 9 days of adaptation followed by 5 days of collecting orts and feces for determination of DM digestibility. Methane production was determined on days 13 and 14 of each period using the sulfur hexafluoride (SF_6) tracer technique. Prior to the completion of the first period a brass bolus was placed in the rumen of the lambs (via the esophagus). Boluses had been previously filled with SF_6, fit with a Teflon disk to allow for permeation, and monitored for determination of SF_6 release rate (QSF_6). Prior to feeding, each animal was fit with a PVC collection canister that had been preevacuated. Exhaled gas was drawn into the collection canister from 8:00 a.m. to 2:00 p.m. through a capillary tubing and in-line filter that had been attached to a halter. The gas in the canister was analyzed for concentrations of methane ($[CH_4]$) and SF_6 ($[SF_6]$) with separate gas chromatographs equipped with a flame ionization

Table 2. Diet composition and nutrient content (%DM; in vivo experiment).

	Diet		
	CON	DDGS	DDGS+BRAN
Ingredient			
Brome hay	56.0	60.0	30.0
Dried distillers grains	—	30.0	30.0
Corn bran	30.0	—	30.0
Molasses	10.0	10.0	10.0
Soybean meal	4.0	—	—
Mineral	2.0	2.0	2.0
Ammonium chloride	2.0	2.0	2.0
Salt	1.0	1.0	1.0
Nutrient Content			
Crude protein	15.3	18.6	18.8
Ether extract	2.4	5.1	5.2

Table 3. Effects of different DDGS levels on *in vitro* fermentation products.

	DDGS Inclusion (% DM)					
Variable	0	25	50	75	100	SE
CH_4 (µmol)[a]	294[e]	315[e]	287[e]	250[f]	203[g]	10
IVDMD (%)	37.3[e]	39.8[ef]	42.0[f]	46.8[g]	49.2[g]	1.3
CH_4 (µmol/g)[b]	2.68[e]	2.65[e]	2.26[f]	1.82[g]	1.36[h]	0.10
ACT (mmol/g)[c]	6.92[e]	6.97[e]	6.08[e]	4.99[f]	3.91[g]	0.31
PRO (mmol/g)[c]	2.20[e]	2.66[f]	2.85[gf]	2.97[gf]	3.06[g]	0.11
BUT (mmol/g)[c]	0.08[e]	1.06[f]	1.19[f]	1.22[f]	1.11[f]	0.05
VFA (kcal)[d]	2.71	2.99	2.95	2.77	2.52	0.13

[a]Total amount of methane produced by ruminal cultures (µmol).
[b]Amount of methane produced per unit of digested DM (µmol/g).
[c]Amount of individual VFA produced per unit of digested DM (mmol/g).
[d]Energy (kcal) from VFA produced per unit of digested DM calculated as (0.209*ACT)+(0.367*PRO)+(0.524*BUT).
[e,f,g,h]Means within row lacking a common superscript differ (*P*<0.05).

Table 4. Effects of replacing brome hay or bran with DDGS.

	Diet			
Variable	CON	DDGS	DDGS+BRAN	SE
CH_4 (mL/min)	8.24[b]	7.14[b]	5.57[c]	0.76
DM Digestibility (%)	62.7[b]	62.7[b]	68.2[c]	0.8
CH_4 (mL/min • lb)[a]	26.4[b]	21.7[c]	16.4[d]	1.6

[a]CH_4 production rate per lb of digested DM.
[b,c,d]Means within row lacking a common superscript differ (*P*<.05).

detector and electron capture detector, respectively. Methane production rate (QCH_4) was then calculated as follows: $QCH_4 = (QSF_6 * [CH_4]) / [SF_6]$. Data were analyzed using the MIXED procedure of SAS. The model included the fixed effects of square, period, diet, and day of sampling and the random effect of animal. Because the same animal was sampled twice each period a repeated measures covariance structure was used.

Results

In vitro methane production

Inclusion rate of DDGS affected the total amount of methane produced by ruminal cultures resulting in a quadratic (*P*<0.05) response (Table 3). Cultures containing 0% DDGS produced more (*P*<0.05) methane than those containing 100% DDGS. IVDMD increased linearly (*P*<0.05) and methane production per milligram of digested DM decreased linearly (P<0.05) as the inclusion rate of DDGS was increased.

Acetate production per unit of digested matter decreased in a quadratic (P< 0.05) fashion as DDGS replaced brome hay. Cultures containing 0% DDGS (100% brome hay) produced 176% more (*P*<0.05) acetate per unit of digested DM than did cultures containing 100% DDGS. Propionate production per unit of digested DM increased linearly (*P*<0.05) as DDGS inclusion was increased. Cultures containing 0% DDGS produced 28% less (*P*<0.05) propionate per unit of digested DM than did cultures containing 100% DDGS. Butyrate concentrations increased in a quadratic (*P*< 0.05) fashion as DDGS inclusion rate was increased. Cultures containing 0% DDGS produced 23% less (*P*<0.05) butyrate per g of digested DM as compared to cultures containing 100% DDGS. The kcal of energy available from the VFAs produced per unit of digested DM ranged from 2.52 to 2.99 kcal but this response variable was not affected by DDGS inclusion rate. Therefore, the reduction in methane observed in vitro when brome hay is replaced with DDGS does not affect the amount of energy produced in the form of VFAs.

In vivo methane production

When lambs received the DDGS+BRAN methane production rates were reduced by 30% compared to the CON diet, and reduced by 20% compared to the DDGS diet (Table 4). No difference was detected in methane production rates when comparing the CON diet to the DDGS diet. Therefore, replacement of brome with DDGS reduced methane production but replacement of corn bran with DDGS did not affect methane production. These data indicate the addition of only the bran component of dried distillers grains (DDGS vs. DDGS+BRAN) may be partially responsible for this reduction in methane production, while addition

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of the nonfiber component (CON vs. DDGS) had less effect on methane production. Addition of the whole product (CON vs. DDGS+BRAN) resulted in the greatest reduction. We conclude that the effect DDGS has on methane production is not limited to solely the corn bran component or the non-fiber component but is a combination of the two.

Dry matter digestibility was greater ($P<0.05$) for the DDGS+BRAN diet than for either the CON or DDGS diet, which were not different. Methane production rate per unit of digested DM was different for all dietary treatments. DDGS+BRAN decreased methane production by 38% compared to the CON diet and by 24% compared to the DDGS diet. DDGS decreased methane production per unit of digested DM by 18% compared to the CON diet. The effect of DDGS on methane production rate per unit of digested DM indicates that independent of the amount of dry matter fermented, DDGS decreases ruminal methane production.

Both *in vitro* and *in vivo*, replacement of brome hay with DDGS decreased methane production. The amount of energy produced in the form of VFAs was not affected by increasing concentrations of DDGS in vitro. The enhanced ADG despite decreased DMI that is realized when forage in cattle diets is replaced with DDGS may be partially attributed to less feed energy being lost as methane.

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Dried Distillers Grains as Creep Feed for Yearling Beef Cattle Grazing Sandhill Range

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Summary

Seventy-nine crossbred summer and fall-born steers and heifers were stratified by weight, calving group, and sex and assigned to treatment or control. Yearlings in the treatment group (TRT; n = 40) grazed native summer Sandhill range and had access to ad libitum dried distillers grains (DDG) pellet in a creep feeder for 54 days of a 63-day grazing period. Control (CON; n = 39) yearlings grazed in an adjacent pasture without DDG. Immediately after the grazing period, yearlings were placed in a feedlot and fed to a similar backfat endpoint. Individual forage and DDG intake estimates and animal ADG and carcass characteristics were used to determine the value of DDG to TRT yearlings at the end of the grazing period and at harvest. Intake of DDG averaged 11 lb/d DM. Summer ADG was greater (P<0.01) for TRT (2.8 lb/day) than CON (1.9 lb/day). Yearlings previously allowed access to DDG gained more (P<0.01) during the first 30 days in the feedlot (2.9 vs. 2.4 lb/d for TRT and CON, respectively). Yearlings allowed access to DDG were harvested 14 days before CON (138 DOF). Final weight, ADG, and carcass characteristics were similar between TRT and CON. There was a tendency (P=0.15) for TRT cattle to have a higher percentage grading choice, (67 vs. 51% for TRT and CON, respectively). The value of DDG to yearlings grazing Sandhill range was greater than the estimated cost at both the grazing and harvest endpoints.

Introduction

Prices of grazed forage continue to rise in many areas throughout the United States, including Nebraska. Dried distillers grains (DDG) is typically priced relative to the price of corn. Because of its unique feed characteristics, this co-product of the ethanol industry may prove to be an economical replacement for a portion of the grazed forage in cow-calf or backgrounding operations. Economic trends and environmental incentives favoring the production of ethanol are likely to continue. Previous research has demonstrated improved performance of yearling heifers grazing smooth bromegrass pastures and yearling steers grazing Sandhill range when individually supplemented differing levels of distillers grains. Objectives of this study were to determine intake and ADG of yearling cattle offered DDG ad libitum while grazing Sandhill range. Subsequent feedlot and carcass characteristics were used to make an economic evaluation of utilizing DDG as a free choice supplement in yearling cattle.

Procedure

Experimental Procedure

Fifty-three crossbred (5/8 Red Angus, 3/8 Continental) June-born steers and 26 August-born steers and heifers were stratified by weight, calving group, and sex and assigned to one of two treatments. Yearlings in the treatment group (TRT; n = 40) grazed native summer Sandhill range and had access to ad libitum DDG pellet in a creep feeder for 54 days of a 63-day grazing period. The analysis for the pellet was 88% DM, 28% CP and 11.2% ether extract (DM). Control (CON; n = 39) yearlings grazed in an adjacent pasture without DDG. Two consecutive weights were taken before and at the end of the grazing period prior to starting on a finishing diet. Yearlings were placed in a feedlot at the University of Nebraska West Central Research and Extension Center in North Platte, where they were fed in two pens. Cattle were fed step-up diets for 21 days, then switched to the final finishing diet (Table 1). Steers were given a single implant (Revalor S®;Intervet, Millsboro, Del.) 30 days after arrival in the feedlot; heifers were given a Revalor H® (Intervet, Millsboro, Del.) at the same time. Weights were collected at implant time, approximately 50 days later, and at harvest. Harvest date was determined by weight upon entry into feedlot, past cattle performance of similar genetics, and intermediate weight gain to optimize marketing grid value. Final weights

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Table 1. Finishing diet, ingredient composition, and total amount fed (DM) per animal previously allowed access to ad libitum dried distillers grains (TRT) or not (CON)

Item	DM (%)	TRT (lb)	CON (lb)
Corn	48	2987	3331
Corn Gluten Feed	40	2606	2881
Alfalfa	7	626	650
Supplement	5	326	359
Supplement Ingredients			
Corn	58.25		
Limestone	29.60		
Salt	5.60		
Ammonium Chloride	4.65		
Trace Mineral	0.930		
Rumensin-80	0.349		
Tylan-40	0.250		
Thiamine	0.238		
Vitamin Premix	0.214		

were calculated using hot carcass weight adjusted to a common dressing percentage (63). This adjusted final weight was also used to calculate ADG. Cattle were harvested at a commercial packing plant and carcass characteristics were determined following a 24-hour chill. Carcass measurements included hot carcass weight, marbling score, KPH fat, 12th rib fat thickness, and ribeye area.

Economic Analysis

The value of DDG was calculated when the cattle were taken off grass in early August and at harvest in December.

For the August analysis, cattle were valued using Cattle-Fax (2005) prices which ranged from $108.97/cwt for 750 lb steers, to $135.70/cwt for 450 lb steers. Price differences for heifers ranged from -$9.00/cwt for a 750 lb heifer, to -$12.50/cwt for a 450 lb heifer.

Actual carcass prices received for the TRT group were used in the harvest analysis (Table 2). Weighted averages were used to calculate the group revenues used in the analysis.

Grazing costs were calculated using a rate of $28.30 per animal unit month (AUM) An AUM was defined as 680 lb of dry matter. Forage intake for non-creep fed animals was estimated using the calf equation from the National Research Council's Nutrient Requirements of Beef Cattle.

Individual DDG intakes for creep fed animals were estimated using the following formula, which was derived using the National Research Council's Nutrient Requirements of Beef Cattle (1996).

Table 2. Carcass grid price, using $153.08[a] per cwt as base price.

Item	Adjustment
Prime-Choice Price Spread	+17.50
Choice-Select Price Spread	-9.95
Yield Grade 1	+6.50
Yield Grade 2	+2.50
Heavy Carcasses (>1000 lb)	all yield grades priced at 137.65
Heifer	-0.07

[a]Adjustments from Choice Yield Grade 3 Steer.

Table 3. Effect of ad libitum access to dried distillers grains while grazing pasture (TRT) and season of birth on grazing BW change and subsequent feedlot gain and carcass characteristics.

	TRT	Control	*P* - value	June steer	August steer	August heifer	*P* - value
n	40	39		53	15	11	
Initial Wt. (lb)	648	644	.71	683[a]	642[b]	613[b]	<0.01
Final Wt. (lb)	825[a]	765[b]	<0.01	849[a]	798[b]	739[c]	<0.01
Grazing ADG (lb)	2.80[a]	1.94[b]	<0.01	2.62[a]	2.49[a]	2.01[b]	<0.01
1st 30 d ADG (lb)	2.91[a]	2.43[b]	<0.01	2.95	2.47	2.58	.07
Final Weight (lb)	1246	1243	.97	1354[a]	1257[b]	1124[c]	<0.01
ADG (Feedlot) (lb)	3.40	3.44	.67	3.86[a]	3.48[b]	2.82[c]	<0.01
Hot Carcass Wt. (lb)	785	783	.97	851[a]	791[b]	708[c]	<0.01
Marbling Score[d]	518	503	.43	506	476	551	.07
Choice (%)	67	51	.15	57	39	81	.10
Back Fat (in)	.35	.34	.73	.34	.31	.38	.21
Ribeye Area (in^2)	14.49	14.87	.30	15.14	14.74	14.15	.16
Yield Grade	2.21	2.07	.29	2.24	2.07	2.11	.54

[abc]Means without a common superscript differ ($P<0.01$).
[d]500=small 0

$$\text{Individual DDG} = \left(\frac{\text{Individual Calf Weight}}{\text{Average Calf Weight}}\right)^{.75} * \text{Average DDG}$$

Estimates of forage savings by TRT animals were calculated by reducing the amount of forage dry matter intake by one half pound for every pound of DDG consumed based on previous estimates of forage replacement by DDG (*2005 Nebraska Beef Report,* p. 18). It should be noted that the maximum amount of DDG supplementation was 6 lbs per head per day approximately one half the DDG consumed in the current study.

Individual feed costs during the finishing period were also estimated using the following formula, derived from NRC (1996).

$$\text{Individual Feed Cost} = \left(\frac{\text{Individual Calf Weight}}{\text{Average Calf Weight}}\right)^{.75} * \text{Average Feed Cost}$$

The value of DDG for the feeder cattle was determined by adding the value of the replaced forage and the difference between average revenues of TRT and CON groups. The value of DDG for feedlot cattle also accounted for differences in finishing costs between the two groups to a similar BF endpoint.

Results

Average beginning weight was 646 lb and did not differ between treatments. Intake of DDG averaged 11 lb/d DM. Summer ADG was greater ($P<0.01$) for TRT (2.8 lb/d) than CON (1.9 lb/d) as was BW at the end of the grazing period, 825 and 765 lb for TRT and CON, respectively. June-born steers were heavier ($P<0.01$) at the beginning and end of the grazing period than either August-born steers or heifers (Table 3). June-born steers also had greater ADG during the grazing period than August-born heifers. August-born steers gained more than August-born heifers and weighed more at the end of the grazing period. Yearlings previously allowed access to DDG gained more ($P<0.01$) during the first 30 days in the feedlot (2.9 vs. 2.4 lb/day for TRT and CON, respectively). Yearlings with previous access to DDG were harvested 14 days before the CON group, 124 and 138 DOF, respectively. Total feedstuff amounts for TRT and CON are presented in Table 1. Final weight, ADG, and carcass characteristics were similar between TRT and CON (Table 3). There was a tendency ($P=0.15$) for TRT cattle to have a higher percentage grading Choice, (67 vs. 51 for TRT and CON, respectively) even though TRT cattle were on a finishing diet for a shorter period. Final weight, feedlot ADG, and hot carcass weight was greatest ($P<0.01$) for June steers followed by August steers and August heifers (Table 3). August-born heifers tended ($P=0.10$) to have a higher percentage Choice than steers born

in June or August (Table 3). It was a challenge to feed cattle differing in age and sex together to an optimum end point for the entire group. In evaluating backfat and yield grade data it appears both groups could have been fed longer. However, carcass weights were reaching upper limits in June steer calves, as there was a June steer in each group with a carcass weight in excess of 1,000 lb. Total feed and yardage costs were $16.76/head greater for CON to reach a similar carcass weight and backfat endpoint.

Economic Analysis. The overall value of DDG for the TRT cattle through the grazing period was $146.86, and $154.37/ton for animals retained to harvest. This indicates DDG had a value in excess of its estimated cost. Using these forage costs and cattle prices it appears DDG is an economically viable feed source for yearling cattle grazing Sandhill range.

It was estimated the TRT yearlings consumed 30% less forage than the CON yearlings. Assuming this reduced forage consumption, the area of pasture required to support a single CON yearling would support approximately 1.4 TRT yearlings. If pasture is limiting, the carrying capacity of a given area may be extended with ad libitum use of DDG. In this study, the value of DDG as a pasture supplement for yearling cattle was dependent on length of ownership, initial BW on pasture, and sale price.

Implications

As ethanol production expands in the Midwest, additional distillers grains will be available to beef cattle producers. Feedlots are using much of this product at the present time; however, feeding DDG to yearling cattle grazing summer Sandhill range may be profitable depending on pasture and DDG prices and feeder and fed cattle market prices.

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Effect of Feeding a By-product Combination at Two Levels or By-product Alone in Feedlot Diets

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Summary

A finishing cattle study was conducted to evaluate feeding a by-product combination at two inclusion levels, compared with these by-products fed alone, or a corn-based diet without by-products. Treatments consisted of 0% by-products, 30% WCGF (wet corn gluten feed), 15% WCGF with 15% WDGS (wet distillers grains with solubles), 30% WDGS, and 30% WCGF with 30% WDGS (DM basis). Final BW, ADG, and F:G were improved for cattle fed by-products, including the 60% Blend. No associative effects resulted from feeding WCGF and WDGS in a blend compared to these by-products fed alone. Feed conversion was similar for feeding a by-product blend at 30 and 60% of dietary DM. A by-product blend at 30% did not have any additive effects, while a blend at 60% had comparable F:G to a blend at 30% with higher gains than the corn diet.

Introduction

Wet corn gluten feed (WCGF) has been shown to have 100-110% the energy content of dry rolled corn that it replaces in feedlot diets (2000 Proceedings American Society of Animal Science) and decreased acidosis challenges. Wet distillers grains with solubles (WDGS) has been shown to have a higher energy content compared to corn ranging from 110-160% *(2006 Nebraska Beef Report,* pp. 51-53). However, the energy content of WDGS declines at dietary inclusion levels greater than 40% DM, possibly due to high dietary fat levels. We hypothesized that combining WCGF and WDGS would result in an associative effect and higher dietary inclusion levels may be fed to utilize more by-products.

Therefore, the objective of this trial was to determine if feeding a WDGS: WCGF combination would be beneficial compared to each by-product alone and if a high by-product blend inclusion would result in better performance than corn-based diets.

Procedure

A 124-day finishing study used 250 crossbred backgrounded steer calves (755 ± 33.3 lb) in a randomized complete block design experiment. Steers were weighed on two consecutive days (day 0 and day 1) to obtain an initial BW after a five-day limit feeding period at 2.0% of BW. The weights obtained from day 0 were used to block the steers into three weight blocks, stratify steers by weight within block, and assign steers randomly to pens. Pens were then assigned randomly within block to one of five dietary treatments with five pens per treatment and 10 steers per pen.

Dietary treatments (Table 1) consisted of control (CON) with no by-products, 30% WCGF (30WCGF, Sweet Bran, Cargill, Blair, Neb.), 15% WCGF with 15% WDGS (30Blend), 30% WDGS (30WDGS, Abengoa Bioenergy, York, Neb.), and 30% WCGF with 30% WDGS (60Blend) on DM basis. The by-product blends were formulated on a 1:1 ratio of WCGF and WDGS (DM basis). Inclusion of by-products in the diets replaced a 1:1 ratio (DM basis) of dry-rolled and high-moisture corn. All diets contained 7% ground alfalfa hay and 5% dry supplement. Adaptation to these finishing diets included a 21-day adaptation period in which corn replaced alfalfa hay at decreasing levels of 44, 34, 24, 14% alfalfa hay for four ration steps and these were fed for 3, 4, 7, and 7 days, respectively. By-product inclusion levels remained the same throughout the adaptation period to the finishing diets except for 60Blend which had 51% by-product, 44% alfalfa hay, and no corn in step 1, then continued with 60% by-product inclusion throughout the remainder of the adaptation diets.

Steers were implanted on day 28 with Revalor-S® (*Intervet, Millsboro, Del.*) Feed samples were collected weekly and analyzed for DM at 60°C for 48 hours.

Steers were slaughtered on day 125 at Greater Omaha Pack, Omaha, Neb., where liver scores and hot carcass weights were recorded. Fat thickness and LM area were measured, while %kidney, pelvic, and heart fat (%KPH) and USDA marbling scores were recorded after a 48-hour chill. Hot carcass weight, fat thickness, LM area, and %KPH were used to calculate yield grade. Final BW, ADG, and F:G were calculated based on

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Table 1. Composition of dietary treatments for cattle fed different by-products alone or blends[a] (%DM).

Ingredient	CON	30WCGF	30Blend	30WDGS	60Blend
Dry rolled corn	44	29	29	29	14
High moisture corn	44	29	29	29	14
Wet corn gluten feed	0	30	15	0	30
Wet distillers grains	0	0	15	30	30
Alfalfa hay	7	7	7	7	7
Dry supplement[b]	5	5	5	5	5

[a]CON = 0% By-product, 30WCGF = 30% WCGF, 30Blend = 15% WCGF + 15% WDGS, 30WDGS = 30% WDGS, 60Blend = 30% WCGF + 30% WDGS.
[b]Formulated to provide 320, 150, and 90 mg/ steer daily Rumensin-80®, Thiamine-40, and Tylan-40®, respectively.

hot carcass weights and adjusted to a common dressing percentage (63) in order to obtain an accurate estimate of final weight and to minimize error associated with gut fill.

Data were analyzed using the mixed procedures of SAS as a randomized complete block design, with pen as the experimental unit.

Results

Cattle fed the by-product diets gained faster and more efficiently than the cattle fed the control diet (Table 2, P < 0.01). ADG was the highest and F:G was the lowest *(P*<0.01) for cattle on the 30WDGS treatment. Steers on the 30Blend treatment had intermediate ADG, DMI, and F:G between 30WCGF and 30WDGS, indicating this treatment did not result in any associative effects. Cattle fed the 60Blend treatment consumed feed similarly, gained numerically faster, and were more efficient *(P*<0.01) than cattle fed CON. Cattle fed 60Blend had lower ADG and DMI *(P*<0.01) than cattle fed 30Blend, but F:G was similar.

With the exception of hot carcass weight, calculated yield grade was the only carcass variable found to be different due to dietary treatment. Steers receiving the CON treatment had the lowest yield grade, while cattle on the 30WDGS treatment had the highest yield grade *(P*<0.01), with the other treatments being intermediate.

In summary, feeding WCGF and WDGS either alone at 30% of diet DM or as a combination at 30 or 60% of diet DM improved cattle performance over feeding the control, corn-based treatment. The 30Blend treatment had intermediate performance to that of 30WCGF and 30WDGS, representing no associative effect. Although 60Blend resulted in lower ADG and DMI than 30Blend, F:G remained similar. The improved feeding performance for 60Blend over CON indicates higher by-product inclusion levels can be fed to feedlot cattle in a combination blend to achieve greater by-product use.

Table 2. Performance measurements and carcass characteristics for cattle fed different by-products alone or blends [a].

Parameter	CON	30WCGF	30Blend	30WDGS	60Blend	*P*-value
Performance						
Initial BW, lb	755	754	756	755	755	0.70
Final BW [b], lb	1262[e]	1312[g]	1325[fg]	1338[f]	1287[e]	<0.01
DMI, lb	23.7[e]	26.2[g]	25.4[fg]	25.0[f]	23.8[e]	<0.01
ADG, lb	4.06[e]	4.47[g]	4.56[fg]	4.67[f]	4.26[e]	<0.01
F:G	5.82[g]	5.86[g]	5.58[f]	5.34[e]	5.60[f]	<0.01
Carcass Characteristics						
Hot Carcass Weight, lb	795[e]	827[fg]	835[fg]	843[g]	811[ef]	<0.01
Marbling Score [c]	481	507	496	487	478	0.14
Ribeye Area, in^2	13.2	13.0	13.2	12.9	13.1	0.39
12^{th} Rib Fat Thickness, in	0.47	0.51	0.52	0.56	0.52	0.78
Calculated Yield Grade [d]	2.84[e]	3.12[fg]	3.12[fg]	3.35[g]	3.07[ef]	<0.01

[a]CON = 0% By-product, 30WCGF = 30% WCGF, 30Blend = 15% WCGF + 15% WDGS, 30WDGS = 30% WDGS, 60Blend = 30% WCGF + 30% WDGS.
[b]Calculated from carcass weight, adjusted to a 63% common dressing percentage.
[c]400 = Slight [0], 500 = Small [0].
[d]Calculated as 2.5 + (2.5*Fat Depth) + (0.2* % KPH) + (0.0038* Hot Carcass Wt.) – (0.32*Ribeye Area) from Meat Evaluation Handbook, 2001.
[efg] Different superscripts within a row are different *(P*<0.05).

[1]Crystal D. Buckner, research technician; Galen E. Erickson, associate professor; Terry J. Klopfenstein, professor; Rick A. Stock, adjunct professor; and Kyle J. Vander Pol, former research technician, Animal Science, Lincoln.

Effects of Different Inclusion Levels of Wet Distiller Grains in Feedlot Diets Containing Wet Corn Gluten Feed

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Summary

A finishing trial was conducted to determine the optimum level of inclusion of distillers grains plus solubles (WDGS; Abengoa, York, Neb.) in diets containing 30% wet corn gluten feed (WCGF, Sweet Bran®, Cargill, Blair Neb.) Six WDGS inclusion levels (0, 10, 15, 20, 25, 30%DM) were compared with a dry rolled corn (DRC)/high moisture corn (HMC)-based diet. The inclusion of 30% Sweet Bran® in the diets improved DMI, ADG and feed conversion when compared to a corn-based diet. DMI tended to respond quadratically to WDGS inclusion level, ADG responded quadratically, while F/G was not affected by WDGS level. Diets containing 30% of both WCGF and WDGS improved performance compared with cattle fed no by-products. These results indicate optimumADG and F:G were achieved with inclusions levels of WDGS ranging from 15 to 20% in diets containing 30% WCGF.

Introduction

The Nebraska ethanol and the sweeteners industries provide an abundant and reliable supply of wet distillers grains (WDGS) and wet corn gluten feed (WCGF) respectively. Inclusion of WDGS in finishing diets has consistently resulted in improved cattle performance when compared to corn based finishing diets. The inclusion of WCGF in finishing diets has improved cattle performance by increasing DMI and ADG *(2004 Nebraska Beef Report,* pp 61-63). Optimum inclusion level of WDGS has been defined at 40% DM Basis (*2006 Nebraska Beef Report,* pp 51-53). Higher inclusions of WDGS tended to reduce DMI when compared to a corn based diets likely due to its high fat content. A 50:50 combination of WCGF and WDGS improved performance compared to a corn-based control diet when the blend inclusion level was fed at 25 and 50% (DM basis). In the same trial, cattle fed a 75% DM inclusion level of the blend performed similarly as cattle fed a corn-based finishing diet (*2004 Nebraska Beef Report,* pp.45-46). In a subsequent trial, feeding a 15%:15% blend of WCGF and WDGS did not improve cattle performance when compared with steers fed 30% DM WCGF or WDGS alone (*2007 Nebraska Beef Report,* pp 25-26). The inclusion of 30%DM of WCGF in finishing diets seems to be necessary to minimize acidosis in finishing diets while the optimal inclusion level of WDGS in blends should be determined. The objective of this trial was to determine the effect of increasing WDGS (Abengoa, York, Neb.) inclusion levels in finishing diets containing 30% WCGF (Cargill, Blair Neb.) on animal performance and carcass characteristics.

Procedure

Five hundred and four yearlings steers were blocked by BW (828 ± 36 lb), stratified within block and assigned to 63 pens (8 steers/pen), and pens were assigned randomly to one of seven treatments (nine pens/treatment). Treatments consisted of a corn-based control diet, a diet containing 30% WCGF (Sweet Bran®, Cargill, Blair Neb.), and finishing diets containing increasing (10, 15, 20, 25 and 30%DM) WDGS inclusion levels and 30% WCGF (Table 1). Steers were limit-fed a diet consisting of 50:50 alfalfa:WCGF (DM basis) fed at 2% of BW for 5 days before day 1 of the experiment, and then weighed for two consecutive days to determine initial BW. Steers were adapted to treatment diets in 21 days using five step up diets, where alfalfa hay was replaced by a 50:50 blend of DRC: HMC. Diet supplements were formulated to provide 320mg/head/day of monensin (Rumensin, Elanco Animal Health), 90 mg of tylosin (Tylan, Elanco Animal Health) and 140 mg of thiamine per steer daily. Steers were implanted on day 21 with Revalor-S® (Intervet, Millsboro, Del.) On day 116, steers were harvested and carcass weights and characteristics (dressing percentage, USDA quality and calculated yield grade, kidney heart and pelvic fat, 12th rib fat and LM area) were determined. Final weights were calculated using carcass weights and a common 63% dressing percentage. Data were analyzed using Proc Mixed of SAS, linear and quadratic effects

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Table 1. Composition of dietary treatments[a].

	Treatments[b]						
Ingredients	Control	30/0	30/10	30/15	30/20	30/25	30/30
High moisture corn	44	29	24	21.5	19	16.5	14
Dry-rolled corn	44	29	24	21.5	19	16.5	14
WDGS	—	30	30	30	30	30	30
WCGF	—	—	10	15	20	25	30
Dry supplement	5	5	5	5	5	5	5
Alfalfa hay	7	7	7	7	7	7	7

[a]Values expressed on a DM basis.
[b]Treatments that included wet corn gluten feed (WCGF, Sweet Bran ® Cargill, Blair, Neb.) and wet distillers grains (WDGS, Avengoa, York, Neb.) are expressed as %DM of WCGF / %DM of WDGS.
[c]Supplements provided 320mg/head/day of monensin, 90 mg of tylosin and 140 mg of thiamine per steer daily.

Table 2. Effect of different inclusion levels of WDGS in finishing diets containing 30% WCGF fed to yearling steers for 116 days.

	Treatments[a]										
	DRC/HMC	30/0	30/10	30/15	30/20	30/25	30/30	SEM	Lin	Quad	Con vs. 30% WCGF
DMI lb/d	25.3	26.4	26.4	26.7	26.4	26.2	25.8	1.4	0.22	0.12	0.01
ADG lb	3.59	3.91	3.87	3.98	3.96	3.89	3.77	0.13	0.01	0.05	<0.05
F:G	7.11	6.79	6.86	6.75	6.68	6.79	6.9	0.54	0.8	0.35	0.02
Calculated YG[b]	2.62	2.8	2.93	2.93	2.91	2.7	2.77	0.11	0.42	0.1	0.16
Marbling Score[c]	497	506	517	513	497	506	502	11	0.44	0.49	0.48
12th rib fat, in	0.45	0.46	0.5	0.51	0.51	0.47	0.46	0.02	0.97	0.03	0.82
LM area, in ^{2}	13.91	13.91	13.87	13.99	13.9	14.07	13.71	0.16	0.84	0.42	1

[a]Treatments that included wet corn gluten feed (WCGF, Sweet Bran®,Cargill, Blair, Neb.) and wet distillers grains (WDGS, Avengoa, York Neb.) are expressed as %DM of WCGF / %DM of WDGS.
[b]USDA Yield Grade calculated as 2.5 + (2.5*Fat Depth) + (0.2*2% KPH) + (0.0038*HCW) - (0.32*REA).
[c]USDA called marbling score where 450=Slight^{50}, 500=Small^{0}, 550=Small^{50}, etc.

were determined using orthogonal polynomials. Orthogonal polynomial coefficients were obtained using Proc ILM of SAS.

Results

Steers fed the 30% WCGF, 0%WDGS diet had increased DMI and ADG, and improved F/G compared with steers fed the control diet. There was a significant difference ($P<0.05$) for F/G between the control diet and the diet including 30% WCGF, with the inclusion of WCGF improving F/G by 4.7%. The positive response to the inclusion of 30% WCGF is in agreement with previous research *(2004 Nebraska Beef Report,* pp. 61-63), and this effect could be due to acidosis control as a consequence of replacing starch from corn (DRC and HMC) with fermentable fiber from WCGF.

The inclusion of WDGS in diets with 30% WCGF tended to produce a quadratic ($P=0.12$) effect on DMI. There was a quadratic ($P=0.05$) response in ADG to increasing levels of WDGS, in agreement with previous research (*2006 Beef Report,* pp. 51-53) Higher values for ADG were observed in treatments containing 15 and 20% WDGS (DM basis).

When compared to the 30% WCGF treatment, the inclusion of WDGS did not result in a significantly better F/G. The lack of response to inclusion of 10% WDGS could be due to lack of acidosis control that was already achieved by the inclusion of 30% WCGF. The response observed in the 25 and 30% WDGS diets might be explained as an energy dilution effect as a result of replacing starch from the corn with by-product fiber.

Feed conversion was numerically lowest for the steers fed diets with WDGS inclusion levels of 15 and 20%. The highest inclusion levels of WDGS (30% DM) in feedlot diets containing 30% of WCGF resulted in ADG and F/G that did not differ from the control corn-based diet.

There was a tendency ($P=0.10$) for higher calculated YG in the treatments that included 10, 15 and 20% WDGS (DM basis), as a consequence of the differences ($P=0.03$) observed in 12th rib fat thickness. No significant differences due to treatment were observed in marbling or LM area. These results indicate that optimal cattle performance would be achieved with inclusions levels of WDGS ranging from 15 to 20% in diets containing 30% WCGF.

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Effects of Roughage Source and Level with the Inclusion of Wet Distillers Grains on Finishing Cattle Performance and Economics

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Summary

A finishing trial was conducted to evaluate roughage source and level compared to no roughage inclusion in finishing diets containing 30% (DM basis) wet distillers grains plus solubles (WDGS). Roughage sources included alfalfa hay, corn silage, or corn stalks fed at either a low (4% alfalfa hay) or high (8% alfalfa hay) level and sources were included on an equal NDF basis. In general, higher roughage levels increased DMI, ADG, and profit. However, steers fed 3% corn stalks performed similarly to steers fed high levels of roughage. When roughage was eliminated from the diet, DMI, ADG, and profit were decreased compared with diets containing corn stalks or high levels of alfalfa or corn silage. Results indicate at high roughage levels, sources can be exchanged on an equal NDF basis in finishing diets containing 30% WDGS (DM basis).

Introduction

Roughages such as alfalfa hay or corn silage have traditionally been used to control acidosis in finishing diets. More recently, corn milling by-products have been shown to help manage acidosis and it may be beneficial to change traditional roughage sources and levels in finishing diets when by-products are included. Research at Nebraska has shown when 35% wet corn gluten feed (WCGF; DM basis) was included in finishing diets, it was beneficial to reduce alfalfa hay from traditional levels (Farran et al., 2003 *Nebraska Beef Report*, pp. 61-63). The cost of roughages can vary, and at times, can be quite expensive sources of energy and nutrients. Reducing the inclusion level will lower roughage costs in a finishing diet. Another option may be to replace more expensive roughages with a lower cost roughage such as corn stalks.

The objectives of this study were to: 1) determine if roughage sources can be exchanged on an equal NDF basis in diets containing 30% WDGS (DM basis), and 2) determine the effects of roughage inclusion levels compared with no roughage inclusion in finishing diets containing 30% WDGS (DM basis).

Procedure

Three hundred eighty-five crossbred steer calves (BW = 763 ±63 lb) were used in a randomized complete block design. Upon arrival, steers were vaccinated and weaned on smooth bromegrass for approximately four weeks. Steers were then implanted with Synovex-C *(Fort Dodge Animal Health,* Fort Dodge, Iowa*)* and allowed to graze corn stalks for 45 days. While on stalks, steers were supplemented with 6 lb/head/day of a blend of WCGF and alfalfa (DM basis). Steers were brought back to the feedlot five days before initiation of the trial and limit-fed a diet consisting of 50% wet corn gluten feed and 50% alfalfa hay (DM basis) at 2% of body weight. On day 0 and day 1, steers were individually weighed in order to get an accurate initial weight and all steers were implanted with Revalor-S® (*Intervet, Millsboro, Deleware*). The weights from day 0 were used to assign steers to treatment. Steers were blocked by weight into three blocks, stratified by weight within block and assigned randomly to pen (11 steers/pen). There were two light, two medium, and one heavy weight blocks. Pens were assigned randomly to one of seven finishing diets within block (five pens/diet). During the trial, there were seven steers treated for polioencephalomalacia (PEM, polio, "brainer") and two of these steers were removed. Two other steers were removed due to death and 14 other steers were treated for other health reasons.

The seven dietary treatments (Table 1) consisted of a control (CON) with no roughage inclusion and two levels of roughage inclusion for alfalfa hay (LALF and HALF), corn silage (LCSIL and HCSIL), and corn stalks (LCSTK and HCSTK). Inclusion of alfalfa hay at 4 and 8% was used for the low and high inclusion level, respectively. Diets containing corn silage or corn stalks were then balanced to provide equal percentages of NDF from the roughage. This resulted in feeding approximately 6 or 12% corn silage or 3 or 6% corn stalks. All diets contained a mixture of dry-rolled and high-moisture corn fed at a 1:1 ratio and 30% WDGS (DM Basis). Diets were initially formulated to contain 3% dry supplement but on day 42, it was increased to 5%, replacing the corn mixture. The increase in dry supplement was done because of concerns that the supplement was not getting mixed sufficiently into the diets. All diets were formulated to contain a minimum of 0.65 % calcium, 0.60% potassium, and supply 360 mg/steer Rumensin® (*Elanco Animal Health, Greenfield, Ind.*), 90mg/steer Tylan® (*Elanco Anima Health*), and 130mg/steer thiamine daily. Feed ingredients were sampled weekly and dry matter was conducted by drying samples in a 60°C forced air oven for 48-hours. After the trial, all diet samples were

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composited by month and analyzed for CP and NDF.

The dry-rolled corn, high-moisture corn, and corn silage were grown at the Agriculture Research and Development Center near Mead, Neb. The corn silage was nonirrigated and yielded 16.7 ton/acre at 35% DM. The alfalfa hay was purchased at one time from one supplier, as were the baled corn stalks, in an attempt to reduce variation of roughage sources during the feeding period. The corn silage was coarsely chopped at harvest and ensiled in a plastic silo bag. Both the alfalfa hay and corn stalks were ground through a tub grinder using a 5-inch screen. Roughage particle size was determined using dry sieving and alfalfa, corn silage, and corn stalks had an average geometric mean diameter of 1,498, 2,927, and 4,323 μm, respectively. As mentioned, alfalfa hay and corn stalks were both ground through a tub grinder with the same screen from a practical standpoint, however, they did not grind to the same particle size. Wet distillers grains plus solubles were obtained from a commercial ethanol plant (*Abengoa Bioenergy,* York, Neb.) and delivered on an as needed basis (approximately 1 load /week).

Cattle were adapted to grain by feeding a roughage mixture composed of alfalfa hay, corn silage, and corn stalks on an equal NDF basis which replaced the corn mixture in the final diets. There were five steps formulated to supply NDF equal to 45% , 35%, 25%, 15%, and 8% alfalfa hay (DM basis). The five steps were fed for 3, 4, 6, 6, and 5 days, respectively, where the corn replaced the roughage mixture. Steers fed diets containing higher roughage levels, 6-12%, were fed their respective forage at step 5 (NDF supply equal to 8% alfalfa hay). Steers fed diets containing low levels or no roughage were fed their respective diet on day 25. Steers were fed once daily and allowed ad libitum access to feed and water. All cattle were supplemented with Optaflexx™ (*Elanco Animal Health*) the last 28 days of the feeding period at a rate of 200 mg/ steer daily. Cattle were fed for 139 days (January 25, 2006 to June 12, 2006) and harvested at a commercial packing plant (*Greater Omaha Pack,* Omaha, Neb.) Hot carcass weight and liver score were collected the day of harvest and 12th rib fat, LM area, and USDA called marbling score were collected following a 24-hour chill. Yield grade was calculated using the following equation (YG = (2.50 + (0.0038*HCW, lb) + (0.2*2.0% KPH) + (2.5*12th rib fat, in) - (0.32*LM area, in^2)) published in the Meat Industry Handbook, 2001. Final BW, ADG, and feed:gain were calculated using hot carcass weight divided by an average dressing percentage of 63%.

Economic analysis was performed for all diets and seven-year average pricing (1998-2004) was used. Initial steer price was calculated as average initial BW of a pen multiplied by the USDA Nebraska auction markets 1998 to 2004 average January calf price ($84.67/cwt) for a 600 to 700 lb calf. Final selling price was calculated as average live final BW of a pen multiplied by the USDA Nebraska markets 1998 to 2004 average June fed steer price ($71.74/cwt). Seven year average prices during the months of January to June were used for corn ($4.49/cwt) and alfalfa hay ($69.67/ton DM, baled). The price used for corn stalks was $55.87/ton DM, baled. Adjustments used for corn processing were from previous research at Nebraska (Cooper et al., *2001 Nebraska Beef Report,* pp. 51-54) and a cost of $8.00/ton DM was used for grinding alfalfa hay and corn stalks. The price for corn silage was calculated according to Guyer and Duey (NebGuide G99) using the average corn price. The price for WDGS was priced at 95% the price of corn. Cattle were charged a cost of $0.26/steer daily for the last 28 days of the finishing period for the cost of Optaflexx™. Feed ingredient costs (DM basis) were ground alfalfa hay ($81.76/ton), corn silage ($72.48/ton), corn stalks ($67.23), dry-rolled corn ($91.40/ton), high-moisture corn ($92.14/ton), WDGS ($85.20/cwt), and dry supplement ($100/ton). Ration prices of the finishing diet for each treatment are listed in Table 1.

Total finishing cost includes health cost, feed cost, yardage, death loss, and interest charges. Steers were charged $16.66 for health and processing costs. Feed costs were calculated by multiplying the cost of each diet by the average DMI for that diet. Yardage was charged at a rate of $0.33/steer daily. A 1.5% death loss was used for all treatments. Interest was charged using prime interest rate plus 1% (7.6%) for all costs. Simple interest was charged on initial steer cost and health over the entire ownership. Interest was charged on feed and yardage costs for half the finishing period. Total cost of production includes total finishing costs and initial steer cost.

Table 1. Composition of finishing diets and formulated nutrient analysis[a].

Treatments[b]:	CON	LALF	LCSIL	LCSTK	HALF	HCSIL	HCSTK
DRC	32.50	30.50	29.44	30.98	28.50	26.37	29.46
HMC	32.50	30.50	29.44	30.98	28.50	26.37	29.46
WDGS	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Alfalfa Hay	—	4.00	—	—	8.00	—	—
Corn Silage	—	—	6.13	—	—	12.26	—
Corn Stalks	—	—	—	3.04	—	—	6.08
Dry Supplement[c]	5.0	5.0	5.0	5.0	5.0	5.0	5.0
CP, %	16.4	16.7	16.3	16.3	17.0	16.3	16.1
Roughage NDF, %[d]	0.00	2.44	2.65	2.30	4.89	5.31	4.60
Ration Cost, $/ton	90.21	89.81	89.03	89.46	89.41	87.84	88.72

[a]Values presented on a DM basis.
[b]CON = Control, LALF = low alfalfa hay, LCSIL = low corn silage, LCSTK = low corn stalks, HALF = high alfalfa hay, HCSIL = high corn silage, and HCSTK = high corn stalks.
[c]All diets were formulated to contain a minimum of 0.65 % calcium, 0.60% potassium, 360 mg/ steer daily Rumensin®, 90mg/steer daily Tylan®, and 130mg/steer daily thiamine. 200mg/steer daily Optaflexx™ was fed for the least 28 days.
[d]Roughage NDF: NDF supplied from roughage source included in the diet.

Table 2. Effects of roughage source and level compared to no roughage inclusion on performance, carcass characteristics, and economics of steers fed finishing diets containing 30% WDGS .

Treatments[a]:	CON	LALF	LCSIL	LCSTK	HALF	HCSIL	HCSTK	SEM	P-value
Roughage Inclusion[b]:	0.00	4.00	6.13	3.04	8.00	12.26	6.08		
Performance									
Final BW, lb[c]	1365^{w}	1396^{wxy}	1392^{wx}	1432^{z}	1425^{yz}	1422^{xyz}	1430^{z}	11	<0.01
DMI, lb/day	22.3^{w}	24.4^{x}	24.3^{x}	25.0^{xy}	25.7^{y}	25.3^{y}	25.6^{y}	0.3	<0.01
ADG, lb	4.33^{w}	4.54^{wx}	4.52^{w}	4.79^{y}	4.76^{xy}	4.75^{xy}	4.80^{y}	0.08	<0.01
Feed:gain[d]	5.14	5.37	5.36	5.20	5.41	5.33	5.32	0.04	0.09
Carcass Characteristics									
HCW, lb	860^{w}	879^{wxy}	877^{wx}	902^{z}	898^{yz}	896^{xyz}	901^{z}	7	<0.01
12th rib fat, in	0.57^{w}	0.65^{y}	0.58^{wx}	0.66^{y}	0.64^{y}	0.63^{xy}	0.66^{y}	0.02	<0.01
LM area, in^2	13.7	13.6	14.1	13.9	13.7	13.9	13.7	0.2	0.81
Marbling score[e]	489	497	494	489	503	501	510	11	0.37
Choice or above, %	39.8	47.4	46.0	45.6	59.4	44.0	52.2	5.9	0.80
Yield grade[f]	3.20^{wx}	3.52^{y}	3.16^{w}	3.54^{y}	3.52^{y}	3.44^{xy}	3.56^{y}	0.09	0.01
Liver Abscesses[g]	3	3	3	6	0	2	4		
Economics									
Cost of gain, $[h]	40.58	40.83	40.60	38.93	40.03	39.00	39.42	0.56	0.10
Breakeven, $[I]	65.16^{w}	64.70^{wx}	64.43^{wx}	63.31^{y}	63.83^{xy}	63.43^{y}	63.42^{y}	0.41	0.02
P/L, $[j]	91.73^{w}	100.74^{wx}	100.85^{wx}	122.63^{y}	114.57^{xy}	118.98^{xy}	121.31^{y}	6.73	0.02

[a]CON = Control, LALF = low alfalfa hay, LCSIL = low corn silage, LCSTK = low corn stalks, HALF = high alfalfa hay, HCSIL = high corn silage, and HCSTK = high corn stalks.
[b]Inclusion level of each roughage source in the finishing diet (DM basis).
[c]Final BW calculated as hot carcass weight divided by a common dressing percentage of 63%.
[d]Analyzed as gain:feed, reciprocal of feed conversion.
[e]Marbling score: 400 = Slight 0, 450 = Slight 50, 500 = Small 0, etc.
[f]Yield grade: 2.50 + (0.0038*HCW, lb) + (0.2*2.0% KPH) + (2.5*12th rib fat, in) - (0.32*LM area, in^2).
[g]Liver Abscesses: Number of A- liver abscesses observed, only A- liver scores were observed in this study.
[h]Cost of gain: (feed cost + health cost + yardage + interest + death loss) / (Final BW - Initial BW).
[i]Breakeven: (Initial steer cost ($84.67/cwt) + feed cost + health cost + yardage + interest + death loss) / Final BW.
[j]Profit or loss: Final steer value ($71.74/cwt) - (Initial steer cost ($84.67/cwt) + feed cost + health cost + yardage + interest + death loss) .
[w,x,y,z]Means in a row with unlike superscripts differ (*P*<0.05).

Cost of gain was calculated by dividing total finishing cost by the average gain for each pen. Slaughter breakeven was calculated by dividing the total cost of production by the carcass-adjusted final BW. Profit or loss (P/L) was calculated by subtracting the total cost of production from the final steer value.

Data were analyzed using the Mixed procedure of SAS (*Version 9.1,* SAS Inc., Cary, N.C.) as a randomized complete block design, with pen serving as the experimental unit. All treatments were analyzed using the Least Significance Difference method to separate least square means.

Results

Across treatments, final BW, DMI, and ADG were different (*P*<0.01; Table 2). Steers fed CON without any roughage inclusion had lower (*P*<0.01) DMI compared with steers fed roughages. There were no differences (*P*>0.05) in DMI observed between steers fed low roughage levels or between steers fed corn stalks or high levels alfalfa hay or corn silage. Steers fed CON had lower (*P*<0.05) final BW and ADG compared with steers fed corn stalks or high levels of alfalfa hay or corn silage. Final BW and ADG of steers fed CON and low levels of alfalfa or corn silage were not different (*P*> 0.05). For steers fed corn stalks, final BW and ADG were higher (*P*<0.05) compared with steers fed CON or low levels of alfalfa or corn silage but similar (*P*> 0.05) to steers fed high levels of alfalfa or corn silage. Additionally, no differences (*P*> 0.05) were observed between final BW of steers fed corn silage and LALF or between final BW and ADG of steers fed alfalfa hay and HCSIL. Feed:gain tended to be different (*P*=0.09) across treatments where feed conversion was lowest for steers fed CON and LCSTK and highest for steers fed HALF.

The only observed carcass characteristics differences were for fat thickness (*P*<0.01) and yield grade (*P*=0.01). Fat thickness of cattle fed CON was lower (*P*<0.05) compared with steers fed alfalfa, corn stalks, or HCSIL and was similar (*P*> 0.05) to cattle fed LCSIL. Yield grade of steers fed CON was lower (*P*<0.05) compared with steers fed alfalfa or corn stalks and was similar (*P*>0.05) to steers fed corn silage. There were no differences (*P*>0.05) in fat thickness between steers fed corn silage. Additionally, there were no differences observed for fat thickness or yield grade between steers fed alfalfa hay, corn stalks or HCSIL. There was a trend for cost of gain to be different (*P*=0.10) across treatments where cost of gain was lowest for steers fed corn stalks or HCSIL and highest for steers fed CON, LALF, or LCSIL. Breakeven and P/L was different (*P*=0.02) among treatments. There were no differences in breakeven or P/L (*P*>0.05) observed between steers fed CON or low levels of alfalfa hay or corn silage. For steers fed CON, breakeven was increased (*P*<0.05) and profit was decreased (*P*<0.05) compared with steers fed corn stalks or high levels of alfalfa hay

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or corn silage. Breakeven for steers fed low levels of alfalfa hay or corn silage were similar ($P > 0.05$) to cattle fed HALF and increased ($P < 0.05$) compared with steers fed HCSIL. Profit was similar ($P > 0.05$) between steers fed alfalfa hay and corn silage. There were no differences ($P > 0.05$) in breakeven and P/L between steers fed corn stalks and high levels of alfalfa or corn silage. However, for steers fed corn stalks, breakeven was decreased ($P < 0.05$) and profit was increased ($P < 0.05$) compared to steers fed CON or low levels of alfalfa or corn silage.

In general, higher roughage levels resulted in increased DMI, ADG, and live profit. The increase in DMI may be due to an energy dilution effect from increased roughage levels where cattle are attempting to eat to a constant energy level. It cannot be concluded that roughage sources can be exchanged on an equal NDF basis at all levels, because DMI, ADG, and profit of steers fed low levels of corn stalks was similar to steers fed high levels of roughage. However, at high roughage levels (6-12%), results from this study indicate roughage sources can be successfully exchanged on an equal NDF basis in finishing diets containing 30% WDGS (DM basis) without any effects on steer performance or economics. Furthermore, results indicate that in finishing diets containing 30% WDGS (DM basis) and low levels of roughage, it is beneficial to use corn stalks compared to alfalfa hay or corn silage. When roughage was eliminated from the diet, DMI, ADG, and profit was decreased compared to diets containing corn stalks or high levels of alfalfa hay or corn silage. Due to the differences in particle size of alfalfa hay and corn stalks, even though, from a practical standpoint, they were ground through a tub grinder using the same screen, it may be necessary to account for NDF digestibility or the physical effectiveness of NDF from roughage sources. The physical effectiveness of NDF is described as the percent of NDF from particles remaining on a 1.18 mm screen after dry sieving.

In conclusion, results from this study indicate it is not beneficial to completely eliminate roughage sources from a finishing diet containing 30% WDGS (DM basis). Overall, with the increase in supply and use of WDGS in the feedlot industry, along with the large supply and reasonable price of corn stalks in Nebraska, it appears that the use of corn stalks as a roughage source in diets containing WDGS is a viable option.

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Effect of Corn Processing and Wet Distillers Grains Inclusion Level in Finishing Diets

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Summary

Dry-rolled corn (DRC), high-moisture corn (HMC), or steam-flaked corn (SFC) was replaced with increasing levels of wet distillers grains with solubles (WDGS; 0, 15, 27.5, 40% DM) to determine if an interaction exists between corn processing method and WDGS level in finishing steer diets. Optimal feedlot performance was observed with 40%, 27.5%, and 15% WDGS in DRC, HMC, and SFC based diets, respectively. Fat thickness, DMI, and marbling score responded quadratically to WDGS level and incidence of liver abscess decreased linearly with increasing WDGS levels. In conclusion, a greater response to WDGS level was observed with less intensely processed corn.

Introduction

Wet distillers grains with solubles (WDGS), has been shown to have an energy value that is superior to a 1:1 ratio of high-moisture and dry-rolled corn when included in finishing cattle diets (Vander Pol et al., *2006 Nebraska Beef Report*, pp. 51-53). There is some evidence however of an interaction between corn processing method and optimum WDGS inclusion level. Results from literature indicate high-moisture ensiled corn and steam-flaked corn have 104 and 113% the energy value of dry-rolled corn, respectively. Vander Pol et al. *(2006 Nebraska Beef Report*, pp. 48-50) fed diets based on corn processed by various methods that contained 30% WDGS (DM basis) and found F:G was superior in steers fed high-moisture corn and similar in steers fed dry-rolled corn compared to steers fed steam-flaked corn. Generally the cost of corn processing increases with the intensity of the processing method, so a greater response to WDGS inclusion in diets based on less intensely processed grain may render them an economically attractive alternative to diets based on more intensely processed grain. Therefore, the objective of this trial was to determine if an interaction exists between the effects of corn processing method and WDGS inclusion level on finishing steer performance measurements.

Procedure

In this trial, 480 crossbred steer calves (BW = 692 ± 39 lb) were used. Upon arrival at the feedlot, steers were individually identified, vaccinated with Bovi-Shield Gold 5 and Somubac (Pfizer Animal Health), and injected with Dectomax Injectable (Pfizer Animal Health). Steers were revaccinated approximately 16 days following initial processing with Bovi-Shield Gold 5, Somubac, and Ultrachoice 7 (Pfizer Animal Health). Seven days prior to initiation of the experiment, steers were limit fed (2% BW) a diet containing 33% dry-rolled corn, 33% wet corn gluten feed, 33% alfalfa hay, and 1% supplement (DM basis). Steers were weighed on day 0 and 1 of the experiment and the average was used as initial BW. Steers were blocked by weight and randomly assigned to one of 48 feedlot pens (10 steers/pen). Pens were then assigned randomly to one of 12 treatments. A randomized complete block design was used with a 3 x 4 factorial treatment structure. The first factor was corn processing method (dry-rolled - DRC, high-moisture ensiled - HMC, or steam-flaked - SFC) and the second factor was WDGS dietary inclusion level (0, 15, 27.5, and 40% DM).

Experimental diets (Table 1) contained 7.5% alfalfa hay, 5% dry meal

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Table 1. Experimental diets (DM basis).

	0%WDGS	15%WDGS	27.5%WDGS	40%WDGS
DRC, HMC, or SFC[a]	82.5	72.5	60.0	47.5
WDGS[b]	—	15.0	27.5	40.0
Alfalfa hay	7.5	7.5	7.5	7.5
Molasses	5.0	—	—	—
Dry supplement[c]				
Fine ground corn	1.570	2.460	2.988	2.988
Urea	1.36	0.5	-	-
Limestone	1.29	1.50	1.47	1.47
Salt	0.30	0.30	0.30	0.30
Potassium chloride	0.08	—	—	—
Calcium sulfate	0.16	—	—	—
Tallow	0.13	0.13	0.13	0.13
Trace mineral premix[d]	0.05	0.05	0.05	0.05
Rumensin-80 premix[e]	0.021	0.021	0.023	0.023
Thiamine premix[f]	0.015	0.015	0.015	0.015
Vitamin premix[g]	0.015	0.015	0.015	0.015
Tylan-40 premix[h]	0.009	0.009	0.009	0.009
Formulated Nutrient Composition				
CP	13.0 %	14.2 %	15.7 %	18.6 %
Ca	0.70 %	0.70 %	0.70 %	0.71 %
P	0.33 %	0.36 %	0.41 %	0.46 %
K	0.65 %	0.66 %	0.85 %	1.03 %
S	0.20 %	0.25 %	0.33 %	0.41 %

[a]DRC = dry-rolled corn, HMC = high-moisture corn, and SFC = steam-flaked corn.
[b]WDGS = wet distillers grains with solubles.
[c]Formulated to be fed at 5% of diet DM.
[d]Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co.
[e]Premix contained 80 g/lb monensin, fed at 0.018% of diet DM for the first 92 days of experiment and then adjusted to due to differences in intakes between treatments.
[f]Premix contained 40 g/lb thiamine.
[g]Premix contained 1500 IU vitamin A, 3000 IU vitamin D, 3.7 IU vitamin E per g.
[h]Premix contained 80 g/lb tylosin.

Table 2. Effect of corn processing method (CPM) and wet distillers gains with solubles (WDGS) inclusion level on performance and carcass characteristics in finishing steer diets.

	Dry-Rolled Corn				High-Moisture Corn				Steam-Flaked Corn				*P*-value		
WDGS level:	0	15	27.5	40	0	15	27.5	40	0	15	27.5	40	CPM	WDGS	CxW[1]
Performance															
Initial BW, lb	702	702	700	702	700	701	703	705	703	701	702	704	0.32	0.01	0.02
Final BW, lb[2ab]	1311	1333	1347	1359	1316	1365	1367	1351	1318	1328	1305	1280	< 0.01	0.02	< 0.01
DMI, lb/day[c]	22.3	22.2	21.4	21.3	20.1	21.0	20.2	20.0	20.2	20.2	19.8	18.8	< 0.01	< 0.01	0.10
ADG, lb/day[abd]	3.64	3.77	3.87	3.92	3.68	3.96	3.97	3.86	3.67	3.74	3.60	3.44	< 0.01	0.01	< 0.01
Feed:gain[ae]	6.12	5.89	5.52	5.42	5.46	5.29	5.08	5.16	5.50	5.39	5.49	5.46	< 0.01	<0.01	<0.01
Carcass Characteristics															
HCW, lb[ab]	826	840	849	856	829	860	861	851	830	836	822	806	< 0.01	0.02	< 0.01
12th rib fat, in.[f]	0.53	0.55	0.62	0.58	0.53	0.62	0.54	0.61	0.47	0.57	0.51	0.47	< 0.01	0.05	0.08
LM area, in. sq.	12.5	13.0	12.6	13.1	12.9	13.0	12.8	12.8	13.2	12.8	12.8	12.9	0.66	0.59	0.36
Marbling score[3c]	521	557	551	528	529	542	524	516	500	531	539	482	0.04	< 0.01	0.59
KPH fat, %	1.96	2.01	2.10	2.01	2.00	2.00	1.96	2.04	1.96	2.06	1.95	1.93	0.31	0.44	0.05
Yield grade[4c]	3.33	3.28	3.67	3.42	3.20	3.54	3.43	3.55	3.01	3.39	3.19	2.98	< 0.01	< 0.05	0.07
Liver abscess, %[g]	2.5	5.0	2.5	2.5	11.0	10.0	0	13.1	21.1	5.0	2.5	2.5	0.14	0.04	0.07

[1]*P*-value for the effect of corn processing method x WDGS.
[2]Calculated from hot carcass weight, adjusted to a common dressing percentage of 63.
[3]400 = Slight 0, 500= Small 0.
[4]Where yield grade = 2.5 + 2.5(Fat thickness, in) - 0.32(LM area, in^2) + 0.2(KPH fat, %) + 0.0038(hot carcass weight, lb).
[a]Linear effect of WDGS within DRC *(P*<0.01).
[b]Quadratic effect of WDGS within SFC *(P*<0.05).
[c]Quadratic effect of WDGS across all treatments *(P*<0.01).
[d]Quadratic effect of WDGS within HMC *(P*<0.05).
[e]Linear effect of WDGS within HMC *(P*<0.05).
[f]Quadratic effect of WDGS across all treatments *(P*<0.05).
[g]Linear effect of WDGS across all treatments *(P*<0.05).

supplement, and varying proportions of corn and WDGS. Molasses was included in diets containing 0% WDGS to prevent any problems associated with the low moisture content of those diets. Gluten meal was also included in the 0% WDGS diets until d 120 of the experiment. From day 1 to 42 of the experiment, gluten meal replaced 4.3% (DM) of corn to meet the metabolizable protein (MP) requirement of those calves. The level of gluten meal was decreased every 3 weeks after that, until the MP requirement was met with the basal diet. Rumensin-80 premix inclusion levels were increased to reflect differences in expected and actual DMI as well as differences in DMI between diets. The amount fed per head was also increased from 345 mg of rumensin per head daily to 360 mg/head daily.

On day 1 of the experiment, steers were implanted with Synovex-S (Fort Dodge Animal Health). On day 50 of the experiment, steers were re-implanted with Synovex-Choice (Fort Dodge Animal Health) and poured with Durasect II (Pfizer Animal Health).

Steers in the heavy (120 head) and medium (120 head) weight blocks were slaughtered on day 167 and steers in the light (240 head) weight block were slaughtered on day 168 at Greater Omaha Packing Co, Inc., Omaha, Neb. Hot carcass weights and liver abscess data were recorded on the day of slaughter. Marbling score, 12th rib fat thickness, LM area, and kidney, pelvic and heart fat percentage were recorded after a 48-hour chill. Final BW, ADG, and feed efficiency were calculated based on hot carcass weights adjusted to common yield of 63%. Yield grade was calculated using the USDA yield grade equation (yield grade = 2.5 + 2.5(Fat thickness, in.) - 0.32(LM area, in^2) + 0.2(KPH fat, %) + 0.0038(hot carcass weight, lb).

Performance and carcass data were analyzed using the mixed procedure of SAS. Factors included in the model were processing method, WDGS inclusion level, and processing method x WDGS inclusion level. The random variable was weight block and pen was the experimental unit. Orthogonal contrasts were used to detect linear and quadratic effects of WDGS inclusion level across all corn processing treatments when no significant interaction existed and within corn processing treatment when a significant interaction was present *(P*<0.05).

Results

Performance and carcass characteristics are presented in Table 2. There were processing method x WDGS level interactions for carcass adjusted final BW, ADG, and F:G (*P*<0.01). Steers fed DRC experienced linear improvements in final BW, ADG, and F:G (*P*<0.01), as dietary WDGS level increased. Conversely, final BW and ADG of steers fed SFC responded quadratically (*P*<0.05) to WDGS level, with steers fed the 15% WDGS having the highest value for both. There was a quadratic (*P*<0.05) response of ADG and a linear (*P*=0.04) response of F:G to dietary WDGS level in HMC fed steers. Both corn processing method and WDGS inclusion level affected DMI (*P*<0.01). Steers fed DRC had higher (*P*<0.01) DMI than steers fed either HMC or SFC and steers fed HMC had higher (*P*<0.01) DMI than steers fed SFC. Level of WDGS had a quadratic effect on DMI across

all treatments with steers fed the 40% level having the lowest DMI. In this study, the numerically optimal ADG and F:G were observed with 40% WDGS for DRC, 27.5% WDGS for HMC, and 15% WDGS for SFC thus, there was a greater performance response to WDGS level in diets containing less intensely processed grains.

The only processing method x WDGS level interaction ($P<0.01$) observed for carcass characteristics was for HCW. There tended to be a processing method x WDGS level interaction for 12th rib fat thickness ($P= 0.08$), KHP fat percentage ($P= 0.05$), yield grade ($P= 0.07$) and incidence of liver abscess ($P= 0.07$). There was an effect of processing method on 12th rib fat thickness ($P<0.01$), yield grade ($P<0.01$) and marbling score ($P= 0.04$). Fat thickness and yield grade were greater ($P<0.01$) for both DRC and HMC fed steers compared with SFC fed steers, while marbling score was greater ($P<0.01$) only for steers fed DRC compared with steers fed SFC. Dietary level of WDGS had a quadratic effect on marbling score ($P<0.01$), yield grade ($P<0.01$), and 12th rib fat thickness ($P<0.05$). Steers fed 40% WDGS had the lowest numeric marbling score, while steers fed 0% WDGS had the lowest numeric yield grade and 12th rib fat thickness. A linear ($P<0.05$) decrease in the percentage of steers with liver abscesses with increasing levels of WDGS was also observed. A linear decrease in the incidence of liver abscesses with increasing WDGS levels indicates an effect on acidosis. This linear trend appears to be strongest in cattle fed SFC with the largest numeric decrease in abscess incidence observed when increasing the WDGS level from 0 to 15%. We have previously observed no effect of WDGS on rumen pH in DRC based diets. However, a severe acidotic insult may help explain why ADG was not higher in steers fed 0% WDGS and SFC compared with steers fed 0% WDGS and either DRC or HMC. The high incidence of liver abscess in the SFC 0% WDGS treatment group (21%) indicates the starch of the SFC used in this trial was highly degraded in the rumen. Assuming this was the case, replacing 15% of this highly degradable SFC with WDGS, which has very little starch and higher fiber content, may have had an impact on rumen pH. Furthermore, it may help explain the relatively poor performance of the SFC 0% WDGS treatment group because one benefit of SFC is thought to be the high digestion of starch reaching the small intestine. This advantage may have been compromised by high ruminal starch digestion, thereby decreasing the amount of starch reaching the intestine. An interesting observation was that steers fed HMC, which has relatively high ruminal starch digestion, performed very well compared with steers fed SFC or DRC.

In summary, an interaction between corn processing method and WDGS inclusion level occurred. Optimal HCW, final BW, ADG, and F:G were seen with 40% WDGS in DRC based diets, 27.5% WDGS in HMC based diets, and 15% WDGS in SFC based diets. Dry matter intake, fat thickness, and marbling score responded quadratically to WDGS inclusion level. In contrast, incidence of liver abscess responded linearly to WDGS level. It appears that the greatest response of WDGS level on percentage of steers with liver abscesses was seen in the SFC based diet, indicating a high rumen degradability of starch from SFC. In conclusion, a greater performance response to WDGS inclusion in diets based on less intensely processed grain may render them an economically attractive alternative to diets based on more intensely processed grain.

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Optimum Levels of Dry Distillers Grains with Solubles for Finishing Beef Steers

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Summary

A feedlot study was conducted to evaluate increasing levels of dry distillers grains with solubles (DDGS) in corn-based diets on steer performance. Treatments consisted of 0, 10, 20, 30, 40, and 50% (DM basis) DDGS dietary inclusion. Quadratic trends were observed for final BW and ADG with increasing levels of DDGS and 20% inclusion being the most improved. DMI was not changed with DDGS treatment level, while F:G was numerically optimum for 20% inclusion, although all DDGS levels had improved F:G compared to the 0% treatment. No differences in carcass characteristics were observed. Energy value of DDGS at 10 to 40% dietary inclusion remained above 100% in a quadratic trend, with the most improved values at 10 and 20% inclusion. Results showed DDGS can be fed in finishing diets to improve ADG and F:G with optimum level at 20% dietary inclusion.

Introduction

Past research has indicated mixed results from feeding varying dietary inclusion levels of DDGS. Most of these results indicate improved or similar energy values for feeding distillers by-products compared to the corn that is replaced in feedlot diets. However, a response curve resulting from feeding DDGS is needed to generate accurate energy response levels.

The objectives of this trial were to determine the optimum level of DDGS based on steer performance and carcass characteristics and determine the energy value of DDGS at 0 to 40% dietary DM, with 10% increments, relative to a dry-rolled corn diet.

Procedure

A 167-day finishing study used 250 crossbred backgrounded steer calves (676 $\pm$ 54.1 lb) in a randomized complete block design experiment. Steers were weighed on two consecutive days (day 0 and day 1) to obtain an initial BW after a five-day limit feeding period at 2.0% of BW. The BW obtained from day 0 were used to block the steers into four weight blocks, stratify the animals by weight within block, and assign steers randomly to pens. Pens were then assigned randomly within block to one of six dietary treatments with five pens per treatment and eight steers per pen.

Dietary treatments (Table 1) consisted of control (CON) with no DDGS, 10% DDGS (10DDGS), 20% DDGS (20DDGS), 30% DDGS (30DDGS), 40% DDGS (40DDGS), and 50% DDGS (50DDGS) replacing dry rolled corn in the diets on a DM basis. All diets contained 10% corn silage and 2.5% ground alfalfa hay to generate a 7.5% roughage level and 6% liquid supplement. The diets were formulated to contain 13% dietary CP, in which urea was provided in a dry supplement and fed in CON and 10DDGS diets at 2 and 1%, respectively. Metabolic adaptation to these finishing diets included a 22-day step-up period in which dry rolled corn replaced alfalfa hay at decreasing levels of 30, 20, and 10% alfalfa hay for 3 ration steps and these were fed for 7, 7, and 8 days, respectively. Inclusion level of DDGS (Dakota Gold Research, Sioux Falls, S.D.) remained the same throughout the step-up period to the finishing diets.

At the end of the 22-day step-up period, sulfur content of DDGS resulted in toxic dietary sulfur levels for the 50DDGS treatment (0.6%) which is higher than threshold sulfur level (0.4%). Some steers experienced polioencephalomalacia (PEM, polio, "brainers") incidences. There were a total of nine steers that either died or were removed from the trial, with two of these due to PEM and four others treated for PEM during the first 22 days; the other trial removals were not due to dietary treatments. Therefore, the 50DDGS treatment was removed from this experiment and the pens of cattle were randomly assigned to one of the other five treatments and finished the trial on those other treatments. Live BW were taken on day 22 and pencil shrunk by 4%, which were used to calculate ADG, DMI, and F:G for all 30 pens on 0-50% DDGS treatments during those 22 days. For the remainder 145 days of the trial (days 22-167), performance was analyzed

Table 1. Composition of dietary treatments for cattle fed increasing levels of DDGS[a] (%DM).

Ingredient	CON	10DDGS	20DDGS	30DDGS	40DDGS
Dry rolled corn	79.5	70.5	61.5	51.5	41.5
Dry distillers grains	0	10	20	30	40
Corn silage	10	10	10	10	10
Alfalfa hay	2.5	2.5	2.5	2.5	2.5
Liquid supplement[b]	6	6	6	6	6
Dry supplement	2	1	0	0	0
Fine ground corn	0.85	0.425	—	—	—
Urea	1.15	0.575	—	—	—

[a]CON = 0% DDGS, 10DDGS = 10% DDGS, 20DDGS = 20% DDGS, 30DDGS = 30% DDGS, 40DDGS = 40% DDGS.
[b]Formulated to provide 320, 150, and 90 mg/ steer daily of Rumensin-80®, Thiamine-40, and Tylan-40®, respectively.

Table 2. Performance measurements and carcass characteristics for cattle fed increasing levels of DDGS[a].

Parameter	CON	10DDGS	20DDGS	30DDGS	40DDGS	50DDGS	*P*-value Lin[b]	*P*-value Quad[c]
Performance–22 day step-up period								
DMI, lb	19.3	19.5	19.1	19.6	19.1	20.3	0.84	0.75
ADG, lb	3.40	3.54	3.75	3.74	3.12	3.12	0.61	0.06
F:G	5.66	5.55	5.13	5.23	6.06	6.47	0.75	0.10
Performance–145 day finishing period								
Final BW[d], lb	1230	1266	1297	1273	1258	—	0.32	0.04
DMI, lb	20.8	21.8	20.8	21.2	20.7	—	0.69	0.52
ADG, lb	3.29	3.55	3.71	3.56	3.56	—	0.15	0.08
F:G	6.32	6.15	5.60	5.93	5.77	—	0.08	0.29
Diet NE_g[e], Mcal/cwt	61.23	63.66	66.28	63.35	64.02	—	0.37	0.20
DDGS NE_g, %	—	124	126	108	108	—	0.96	0.07
Carcass Characteristics								
Hot carcass weight, lb	782	799	816	804	797	—	0.32	0.07
Marbling score[f]	540	548	550	533	522	—	0.24	0.24
Ribeye area, in^2	12.3	12.5	12.7	12.6	12.6	—	0.68	0.58
12^{th} rib fat thickness, in	0.56	0.55	0.60	0.56	0.57	—	0.72	0.68
Calculated yield grade[g]	3.42	3.41	3.51	3.42	3.39	—	0.86	0.49

[a]CON = 0% DDGS, 10DDGS = 10% DDGS, 20DDGS = 20% DDGS, 30DDGS = 30% DDGS, 40DDGS = 40% DDGS.
[b]Contrast for the linear effect of treatment P-value.
[c]Contrast for the quadratic effect of treatment P-value.
[d]Calculated from carcass weight, adjusted to a 63% common dressing percentage.
[e]Calculated with iteration process for net energy calculation based on performance (Owens et al., 2002).
[f]400 = Slight ^{0}, 500 = Small ^{0}.
[g]Calculated as 2.5 + (2.5*Fat Depth) + (0.2* % KPH) + (0.0038* Hot Carcass Wt.) – (0.32*Ribeye Area) from Meat Evaluation Handbook, 2001.

by removing the pens starting on 50DDGS completely from the trial. However, the summary of carcass characteristics included all 30 pens and assumed the six pens on 50DDGS had been reassigned to each of the other treatments from 0 to 40DDGS throughout the 167 days.

Steers were implanted initially on day 0 with Ralgro and re-implanted on day 56 with Revalor-S® (*Intervet, Millsboro, Del.*) Feed samples were collected bi-weekly and analyzed for DM at 60°C for 48 hours.

Steers were slaughtered on day 168 at Greater Omaha Pack, Omaha, Neb., where liver scores and hot carcass weights were recorded. Fat thickness and LM area were measured, while %kidney, pelvic, and heart fat (%KPH) and USDA marbling scores were recorded after a 48-hour chill. Hot carcass weight, fat thickness, LM area, and %KPH were used to calculate USDA Yield Grade. Final BW, ADG, and F:G during the finishing period were calculated based on hot carcass weights and adjusted to a common dressing percentage (63) in order to obtain an accurate estimate of final BW and to minimize error associated with gut fill.

Performance and carcass data were analyzed using the mixed procedures of SAS as a randomized complete block design, with pen as the experimental unit. Orthogonal contrasts were used to test significance for the highest order polynomial. Feeding behavior data were analyzed with chi-square procedures of SAS.

Results

During the 22-day step-up period, which included 0-50DDGS treatments, ADG (*P*= 0.06) and F:G (*P*= 0.10) tended to be quadratic. Steers fed 20DDGS and 30DDGS had the highest ADG, while 20DDGS fed steers had the lowest F:G. DMI was not affected by level of DDGS during this period.

Furthermore, final BW (*P*= 0.04) and ADG (*P*= 0.08) followed a quadratic trend similar to the 22-day step-up period. Steers fed 20DDGS had the heaviest final BW and highest ADG, while 30 and 40DDGS fed steers had numerically heavier final BW and gained faster than CON fed steers. DMI was not affected by treatment, but F:G tended (*P*= 0.08) to linearly decrease as DDGS inclusion increased. Other than HCW, no other carcass characteristics were affected by DDGS inclusion level.

A visual scoring system was used on five selected days during the finishing period as we observed cattle were moving feed in the bunk and some was tossed over the bunk. Scores used were: 0 (no feed movement) to 3 (some feed moved within the bunk and some tossed over the bunk walls onto the feed alley). Feeding scores indicated that cattle fed 10, 20, and 30% DDGS tended to move the feed in the bunk. Interestingly, cattle fed 40% DDGS did not move their feed around as much as intermediate DDGS levels.

Calculated relative energy values for DDGS compared to CON, regardless of inclusion level, were improved above dry rolled corn. The NE_g values as a percentage of corn tended (*P*= 0.07) to be quadratic. DDGS at 10 and 20% were similar with average relative energy values of 125%, whereas DDGS at 30 and 40% declined to 108% of corn.

Quadratic trends were observed for final BW and ADG both prior to and after the step-up period when feeding

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increasing levels of DDGS. DMI was not affected at any time during the feeding period by DDGS level. However, F:G tended to be quadratic during the step-up period and changed to a linear effect during the finishing period. Relative energy values for DDGS inclusion compared to dry rolled corn were the highest at 10 and 20% inclusion, while 30 and 40% DDGS remained better than cattle fed corn alone.

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Digestibility, Rumen Metabolism, and Site of Digestion for Finishing Diets Containing Wet Distillers Grains or Corn Oil

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Summary

Five ruminally and duodenally fistulated, Holstein steers were used in a 5X5 Latin square metabolism experiment to evaluate digestibility of wet distillers grains plus solubles (WDGS) compared with corn fiber and corn oil in finishing diets. Treatments were a 40% WDGS diet, a composite of corn fiber and corn protein (COMP), COMP plus corn oil to equal the distillers diet (COMP+OIL), and dry-rolled corn control diets without (CON) or with corn oil (CON+OIL). Cattle fed WDGS had numerically lower rumen pH compared with cattle fed other treatments. Cattle fed the WDGS had greater propionate, lower acetate:propionate ratios, greater total tract fat digestion, and a greater proportion of unsaturated fatty acids reaching the duodenum than cattle fed other treatments. These data indicate the higher energy value of WDGS compared with corn is not due to acidosis control, but to more propionate production, higher fat digestibility, and more unsaturated fatty acids reaching the duodenum.

Introduction

The increasing supply and availability of wet distillers grain plus solubles (WDGS) has made it a popular feed resource for finishing cattle. One of the primary drivers of its use in finishing diets is the higher energy value of WDGS compared with corn (*2006 Nebraska Beef Report,* pp. 51-53). However, it is unclear whether the higher energy value of WDGS is attributed to fat (greater energy) or acidosis control. The fat content of WDGS is roughly three times that of corn. It is also unclear if fat from distillers grains is protected from rumen biohydrogenation compared to corn oil.

The objectives of this research were to determine the effect of feeding WDGS or supplemental fat on performance and rumen metabolism and digestibility, with an aim of determining what is responsible for the higher energy value of WDGS compared with corn in finishing diets.

Procedure

A metabolism trial was conducted to evaluate effects of feeding WDGS, a composite of corn fiber (corn bran) and corn protein (corn gluten meal), or supplemental corn oil on various aspects of feeding behavior, digestion, duodenal fatty acid profile, and metabolism in finishing diets. The trial utilized a 5x5 Latin square experiment design with five Holstein steers previously equipped with cannulas in the rumen and proximal duodenum. Dietary treatments (Table 1) were 40% WDGS (WDGS), a composite consisting of corn bran and corn gluten meal (COMP), a composite consisting of corn bran, corn gluten meal, and corn oil (COMP + OIL), and 2 DRC-based high concentrate controls without (CON) and with corn oil (CON + OIL). The COMP diet was formulated to be equal in NDF and CP to the WDGS diet. The COMP + OIL diet was formulated to be equal in NDF, CP, and EE to the WDGS diet. The CON + OIL diet was formulated to be equal in EE to the WDGS diet. All diets contained Rumensin and Tylan

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Table 1. Composition of diets fed to Holstein steers in metabolism experiment evaluating wet distillers grains plus solubles or corn oil with or without added corn bran.

	Treatment [a], % of diet DM				
Item	WDGS	COMP	COMP + OIL	CON	CON + OIL
Dry-rolled corn	51.0	46.8	42.7	88.0	84.6
WDGS	40.0	—	—	—	—
Corn bran	—	29.6	29.6	—	—
Corn gluten meal	—	11.6	11.6	—	—
Alfalfa hay	5.0	5.0	5.0	5.0	5.0
Corn oil	—	—	4.1	—	3.4
Molasses	—	3.0	3.0	3.0	3.0
Dry supplement [b]	4.0	4.0	4.0	4.0	4.0
Limestone	1.60	1.30	1.30	1.60	1.60
Fine ground corn	1.38	2.10	2.08	0.46	0.34
Urea	—	—	—	1.15	1.27
Salt	0.30	0.30	0.30	0.30	0.30
Potassium chloride	0.53	0.11	0.13	0.30	0.30
Molasses	0.10	0.10	0.10	0.10	0.10
Beef trace mineral [c]	0.05	0.05	0.05	0.05	0.05
Rumensin-80 [d]	0.02	0.02	0.02	0.02	0.02
Tylan-40 [e]	0.01	0.01	0.01	0.01	0.01
Vitamin A-D-E [f]	0.01	0.01	0.01	0.01	0.01
Nutrient Analysis, %					
CP	17.9	17.9	17.9	12.5	12.5
NDF from by-product	22.6	22.6	22.6	0.0	0.0
Ether Extract	7.2	3.2	7.2	3.9	7.2
Sulfur	0.36	0.20	0.19	0.16	0.15

[a] WDGS = wet distillers grains plus solubles (WDGS) diet, COMP = composite diet, COMP + OIL = composite + corn oil diet, CON = control diet, CON + OIL = control + corn oil diet.
[b] Supplement formulated to be fed at 4% of diet DM.
[c] Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, 0.05% Co.
[d] Premix provided 300 mg/day monensin.
[e] Premix provided 90 mg/day tylosin.
[f] Premix contained 1500 IU vitamin A, 3000 IU vitamin D, 3.7 IU vitamin E per g.

(Elanco Animal Health, Indianapolis, Ind.). Periods were three weeks in length with 16 days for adapting steers to experimental diets and 5 days for data collection. For days 1 through 16, steers were housed in individual, slotted-floor pens with rubber mats in a temperature controlled room and ad libitum access to water. On day 17, steers were moved within the same room to tie stalls and tethered.

Steers were fed once daily at 0700 hour and were allowed ad libitum intake. Continual monitoring of DMI by steers was accomplished through use of feed bunks suspended on load cells (Omega, Stamford, Conn.) and connected to a computer with data acquisition software (Labtech, Wilmington, Mass.) that recorded bunk weight every minute over the entire feeding period. Data were obtained for continuously monitored DMI on days 17 through 21 of the collection period, and included daily DMI, time spent eating, number of meals consumed, and average meal size. Feed ingredients were sampled weekly and composited by period, while feed refusals were sampled on days 17 through 21 and composited by period and stored frozen. At the conclusion of each period, feed ingredients and feed refusal composites were freeze-dried and ground to pass through a 1 mm screen of a Wiley mill (Thomas Scientific, Swedesboro, N.J.).

Chromic oxide (Landers-Segal Color Co., Montvale, N.J.) was dosed intraruminally 2X daily to provide 15 g/steer daily on days 14 through 20, to provide an estimate of duodenal flow and fecal output.

Ruminal fluid samples were collected every two hours on day 17 between 0700 and 1900 hours. Approximately 50 ml were collected, which was immediately frozen for later analysis. Ruminal volatile fatty acids (acetate, propionate, butyrate, isobutyrate, valerate, and isovalerate) were measured using gas chromatography.

Ruminal pH was measured continuously on days 18 to 21 with submersible pH probes (Sensorex, Stanton, CA) fitted through the rumen cannula and suspended in rumen fluid. Rumen pH measurements were collected with software (Labtech, Wilmington, Mass.) with a reading taken every six seconds and averaging data across every 1 minute (1,440 measurements/day). Ruminal metabolism measurements included average ruminal pH, maximum and minimum ruminal pH, ruminal pH change (maximum minus minimum), ruminal pH variance, and ruminal pH area below 5.6. Average ruminal pH was calculated as the average of 1,440 measurements recorded daily. Ruminal pH variance and area below 5.6 were calculated as described by Cooper et al. (*1997 Nebraska Beef Report,* pp. 49-52).

Fecal samples (approximately 50 g) were collected at 0700, 1300, and 1900 on days 17 through 20. Fecal samples were composited by day and stored frozen. Duodenal samples (approximately 250 ml) were collected at 1000, 1600, and 2200 hours on day 20, and 0700, 1300, and 1900 hours on day 21. At the conclusion of each period, fecal and duodenal composites were freeze-dried and ground to pass through a 1mm screen of a Wiley mill. After grinding, samples were composited by period.

Feed ingredient, feed refusal, duodenal, and fecal sample analysis included DM, ash, CP, NDF, total starch, and ether extract. Duodenal and fecal samples were ashed, digested with a phosphoric acid-manganese sulfate solution, and analyzed for chromium using atomic absorption spectrophotometer. Duodenal samples were analyzed for fatty acids according to the born trifluoride-methanol procedure utilizing gas chromatography.

All data were analyzed as a 5 x 5 Latin square design using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) with steer (random effect) x period (fixed effect) as the experimental unit. Repeated samples were made on experimental units for volatile fatty acids. These data were also analyzed as a repeated measurement, with hour repeated. Autoregressive (AR-1) covariance structures were utilized with final covariance structure based on the lowest AIC for covariance structures with successful convergence. There were no significant period effects ($P > 0.10$) observed for any variable measured; therefore, results are reported by dietary treatment.

Results

Average ruminal pH was greatest ($P<0.10$) for the COMP + OIL treatment and numerically lowest for the WDGS treatment, however, maximum pH, minimum pH, and pH change were not different among treatments (Table 2). Time below pH 5.6 was the least ($P<0.10$) for the COMP + OIL treatment. This is partially due to the lower digestibility of the COMP + OIL diet due to NDF (corn bran) and oil. These results are consistent with previous data with corn bran (Sayer et al., *2005 Nebraska Beef Report,* pp. 39-41). Interestingly, time below pH 5.6 was numerically greatest for the WDGS. No differences were observed between treatments for time below pH 5.3 or 5.0, respectively. Molar proportions of acetate were lower ($P<0.10$) and propionate were higher ($P<0.10$) for the WDGS treatment. Molar proportion of butyrate was not affected by treatment. Lower acetate and greater propionate molar proportions for the WDGS treatment resulted in lower ($P<0.10$) acetate:propionate ratio for the WDGS compared with the other treatments. The greater acetate:propionate ratios for the diets containing corn bran indicate fiber digestion was being promoted, similar to previous results (Sayer et al., *2005 Nebraska Beef Report,* pp. 39-41).

Dry matter intake and OM intake were lowest ($P<0.10$) for cattle fed the CON + OIL diet (Table 3). Neutral detergent fiber intake was greatest ($P<0.10$) for cattle fed the COMP and COMP + OIL diets and least ($P<0.10$) for cattle fed the CON and CON + OIL diets. Starch intake was greatest ($P<0.10$) for cattle fed the CON diet. Dietary fat intake was greatest ($P<0.10$) for cattle fed the WDGS and CON + OIL diets and least ($P<0.10$) for cattle fed the COMP and CON

Table 2. Ruminal pH variables and volatile fatty acids profiles of steers fed wet distillers grains plus solubles (WDGS), a composite, or supplemental corn oil.

	Treatment [a]						
Item	WDGS	COMP	COMP + OIL	CON	CON + OIL	SEM	F-test[b]
Ruminal pH Variables							
Average pH	5.24[f]	5.40[f]	5.66[e]	5.37[f]	5.38[f]	0.10	0.08
Maximum pH	5.77	6.06	6.30	5.91	5.92	0.15	0.16
Minimum pH	4.95	4.90	5.09	4.88	5.00	0.08	0.42
pH change	0.82	1.16	1.21	1.02	0.91	0.11	0.13
Time < 5.6, min	1251[e]	1047[e]	652[f]	1136[e]	1050[e]	123	0.03
Time < 5.3, min	916	515	166	630	634	184	0.12
Time < 5.0, min	242	186	17	81	157	105	0.59
Volatile Fatty Acid Profile and Acetate:Propionate Ratio[c]							
Acetate	41.9[f]	48.8[e]	49.3 [e]	48.2 [e]	49.1 [e]	3.0	0.04
Propionate	40.0 [e]	36.6 [f]	34.8 [f]	36.7 [f]	34.7 [f]	3.0	0.06
Butyrate	12.7	8.5	9.7	10.7	12.8	1.5	0.20
A:P [d]	1.05 [f]	1.33 [e]	1.42 [e]	1.31 [e]	1.41 [e]	0.3	0.04

[a]WDGS = wet distillers grains plus solubles (WDGS) diet, COMP = composite diet, COMP + OIL = composite + corn oil diet, CON = control diet, CON + OIL = control + corn oil diet.
[b]Data were analyzed using a protected F-test where numbers represent *P* – value for variation due to treatment.
[c]Molar proportion, mol/100 mol.
[d]A:P = acetate:propionate ratio.
[e,f]Means within a row with unlike superscripts differ (*P*<0.10).

Table 3. Influence of wet distillers grains plus solubles (WDGS), a composite, or supplemental corn oil on characteristics of ruminal and total-tract digestion.

	Treatment [a]						
Item	WDGS	COMP	COMP + OIL	CON	CON + OIL	SEM	F-test [b]
Intake, lb/d							
DM	17.2[e]	18.3[e]	19.4[e]	17.4[e]	13.4[f]	1.5	0.06
OM	16.3[e]	17.6[e]	18.7[e]	16.5[e]	12.6[f]	1.3	0.05
NDF	5.1[f]	6.6[e]	7.0[e]	3.1[g]	2.2[g]	0.4	< 0.01
Starch	7.3[f]	7.5[f]	7.5[f]	11.5[e]	8.4[f]	0.4	< 0.01
Fat	1.50[e]	0.84[g]	1.67[e]	0.90[fg]	1.17[f]	0.13	< 0.01
Ruminal digestibility, %							
Apparent OM	43.6	42.3	39.0	47.0	41.3	5.7	0.89
True OM[c]	64.1	60.1	58.4	63.4	58.2	4.8	0.84
NDF	71.0	52.0	55.6	56.2	60.1	6.0	0.25
Apparent starch	79.5[e]	84.7[e]	76.6[e]	76.6[e]	62.1[f]	5.5	0.03
True starch[d]	83.8[e]	87.9[e]	85.9[e]	81.5[e]	70.0[f]	4.3	0.03
Postruminal digestibility, % entering							
OM	48.0	38.1	33.5	51.1	52.2	6.9	0.24
NDF	34.5[ef]	48.5[e]	19.1[f]	47.4[e]	44.1[ef]	9.1	0.08
Starch	70.8[e]	52.6[fg]	39.7[g]	56.7[ef]	72.2[e]	7.4	0.04
Total-tract digestibility, %							
DM	81.0[e]	74.5[f]	71.1[f]	81.6[e]	80.3[e]	1.7	< 0.01
OM	82.5[e]	75.8[f]	72.2[f]	82.2[e]	82.4[e]	1.8	< 0.01
NDF	78.9[e]	65.9[f]	64.5[f]	78.2[e]	78.8[e]	3.2	< 0.01
Starch	94.6[e]	91.7[ef]	90.6[f]	92.2[ef]	89.0[f]	1.7	0.10
Fat	81.0[e]	64.1[g]	67.6[fg]	72.5[f]	72.8[f]	3.7	< 0.01

[a]WDGS = wet distillers grains plus solubles (WDGS) diet, COMP = composite diet, COMP + OIL = composite + corn oil diet, CON = control diet, CON + OIL = control + corn oil diet.
[b]Data were analyzed using a protected F-test where numbers represent *P* – value for variation due to treatment.
[c]Corrected for microbial OM reaching the duodenum.
[d]Corrected for microbial starch.
[e,f,g]Means within a row with unlike superscripts differ (*P*<0.10).

diets. The primary factor responsible for the lower starch and fat intake for cattle fed the CON + OIL diet is the low overall DMI compared with cattle fed the other diets. However, corn oil did not affect DMI of steers fed the COMP + OIL diet.

Ruminal apparent OM, true OM, and NDF digestibility were not different among treatments (Table 3). Ruminal apparent starch and true starch digestibility were less (*P*<0.10) for cattle fed the CON + OIL diet than for cattle fed the other diets; however, postruminal starch digestion was greatest for the CON + OIL diet. Total tract DM, OM, and NDF digestibility were less (*P*<0.10) for cattle fed the COMP and COMP + OIL diets compared with cattle fed the WDGS, CON, and CON + OIL diets. Total-tract starch digestibility was greater (*P*<0.10) for cattle fed the WDGS diet, relative to cattle fed the COMP + OIL and CON + OIL diets. Therefore, it appears that supplemental corn oil may impede total tract starch digestion relative to fat supplied by WDGS. Therefore, the WDGS appears to have no effect or a positive effect on total-tract starch digestion, with the fat content of WDGS not negatively affecting starch digestion whereas corn oil supplementation does negatively affect starch digestion. Total tract fat digestibility was greatest (*P*<0.10) for cattle fed the WDGS diet and lowest (*P*<0.10) for cattle fed the COMP diet. Interestingly, fat digestibility was greater for WDGS than CON+OIL or COMP+OIL suggesting that some "protection" of fat occurred.

Cattle receiving the WDGS and CON diets had greater (*P*<0.10) proportions of 16:0 reaching the duodenum than cattle receiving the COMP, COMP + OIL, and CON + OIL diets (Table 4). In terms of the long chain fatty acids, cattle receiving diets supplemented with corn oil had greater (*P*<0.10) proportions of 18:0 reaching the duodenum, while cattle receiving the WDGS diet had the least (*P*<0.10) amount of 18:0 reaching the duodenum. In contrast,

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cattle receiving WDGS had greater proportions of 18:1 *trans*, 18:1, and 18:2 reaching the duodenum relative to cattle fed the other diets, while cattle receiving diets supplemented with corn oil had the least amount of 18:1 *trans*, 18:1, and 18:2 reaching the duodenum, respectively. These data indicate that the fatty acids in WDGS are not hydrogenated to the same extent in the rumen as fatty acids in supplemental corn oil. This research and other research (*Journal of Animal Science* 78:1738) suggests that unsaturated fatty acids have greater intestinal digestibility than saturated fatty acids.

[1]Kyle Vander Pol, former research technician; Matt Luebbe, research technician; Grant Crawford, graduate student; Galen Erickson, associate professor; and Terry Klopfenstein, professor; Animal Science, Lincoln.

Table 4. Fatty acid profiles of duodenal fat content expressed as a % of fat entering the duodenum of steers fed wet distillers grains plus solubles (WDGS), a composite, or supplemental corn oil.

	Treatment						
Item	WDGS	COMP	COMP +OIL	CON	CON +OIL	SEM	F-test
Medium Chain Fatty Acids							
14:0	0.92^{bc}	1.14^{b}	0.76^{c}	2.07^{a}	0.89^{bc}	0.22	< 0.01
15:0	0.46^{c}	0.69^{b}	0.46^{c}	1.15^{a}	0.46^{bc}	0.08	< 0.01
16:0	13.80^{a}	12.55^{bc}	12.28^{b}	13.41^{ac}	12.52^{bc}	0.37	0.04
16:1 *trans*	0.12^{b}	0.28^{a}	0.15^{b}	0.15^{b}	0.15^{b}	0.03	0.04
17:0	0.34^{b}	0.62^{a}	0.37^{b}	0.56^{a}	0.33^{b}	0.05	< 0.01
Long Chain Fatty Acids							
18:0	48.5^{c}	55.0^{b}	62.1^{a}	56.1^{b}	60.5^{a}	1.4	< 0.01
18:1 *trans*	12.6^{a}	9.0^{b}	7.4^{c}	5.9^{c}	7.1^{c}	0.7	< 0.01
18:1	9.4^{a}	6.6^{bc}	5.8^{b}	7.0^{c}	6.5^{bc}	0.4	< 0.01
18:2	8.5^{a}	5.9^{b}	4.9^{bc}	4.9^{bc}	4.4^{c}	0.5	< 0.01
18:3	0.29^{a}	0.28^{a}	0.19^{b}	0.23^{ab}	0.20^{b}	0.05	0.04
Other	5.3^{b}	7.0^{a}	5.2^{b}	8.0^{a}	6.0^{b}	0.5	< 0.01

^{a,b,c}Means within a row with unlike superscripts differ (P<0.10).

Pen Density and Straw Bedding During Feedlot Finishing

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Summary

Two experiments evaluated effects of straw bedding (in sheltered and unsheltered facilities) and pen density (in unsheltered facilities) on cattle performance during winter/spring (mid-December to late March) seasons. Bedding had no effect on overall performance in the sheltered facilities, but performance improvements were noted from December through February in unsheltered facilities. Lowering pen density (increasing pen space per animal) improved performance and lowered mud condition scores on the animal and in the feedlot.

Introduction

Managing cattle in periods of adverse weather can be challenging. Winter cold and wind, combined with precipitation, can increase the maintenance requirement of feedlot cattle and decrease performance. While cold stress alone can reduce profits, it is most detrimental when combined with mud. Cattle in mud have a tendency to eat less frequently and the muddy hair coat reduces insulation. Shelter belts and windbreaks have been shown to be effective at reducing cold stress, however, more knowledge regarding how to reduce mud and mud effects in feedlots is needed.

While feedlot surface maintenance, such as removing manure and rebuilding mounds, can help reduce mud in the winter and spring time, more can be done to further minimize the problems associated with mud. The objectives of our trials were to evaluate the effects of adding straw bedding and reducing pen density to reduce mud and cold stress in feedlot cattle.

Procedure

One-hundred eighty (Trial 1) and two-hundred thirty-four (Trial 2) crossbred steers were received at Haskell Agricultural Laboratory, Concord, Neb. Following receiving, all cattle were vaccinated (Vision 7 and Titanium 5 PHM Bac 1; Intervet, Millsboro, Del.). Additionally, in Trial 1, cattle were implanted (Ralgro; Schering-Plough Animal Health, Kenilworth N.J.) following receiving. At trial initiation (d-1), steers in both trials were revaccinated (Vision 7 and Titanium 5; Intervet, Millsboro, Del.), treated for external parasites (Saber; Schering-Plough Animal Health, Kenilworth, N.J.), and weighed. In Trial 2, cattle were implanted with Ralgro at trial initiation. On day 0 (Dec. 18, 2003, and Dec. 16, 2004, respectively) of each trial, steers were weighed and randomly assigned to 20 pens (Trial 1) or 24 pens (Trial 2) based on the weight from the previous day (day-1). Average body weight for the two consecutive days was used as the initial weight (Trial 1 mean BW=824 lb; Trial 2 mean BW=885 lb). In both trials, cattle were treated for external parasites (Saber) and reimplanted (Revalor-S; Intervet, Millsboro, Del.) on day 35 (Trial 1) or d 34 (Trial 2). Throughout both trials, all cattle were fed a 65.2 NEg mcal/cwt finishing diet which contained (DM Basis) 83.1% dry rolled corn, 6.0% corn silage, 5.0% alfalfa, 3.7% liquid protein supplement, and 2.2% dry Rumensin-Tylan (Elanco; Indianapolis, Ind.) supplement.

In Trial 1, pens were randomly assigned to the following treatments: 1) Low pen density, oat straw bedding, sheltered (overhead shelter, enclosed on north side, and open to dirt lot on south side) feeding area; 2) Low pen density, no bedding, sheltered feeding area; 3) Low pen density, no bedding, unsheltered feeding area; or 4) high pen density, no bedding, unsheltered feeding area. The treatments (Trt) were chosen to exemplify a range of environmental conditions from most comfortable (Trt 1) to least comfortable (Trt 4). For Trial 2, treatments were assigned to pens using a 2 x 2 factorial design, which consisted of pen density (High vs Low) and oat straw bedding (provided vs not provided).

In both trials, pen density was obtained by adjusting the number of head per pen in two different pen sizes. The low pen density treatment consisted of 6 or 7 head/pen for a stocking rate of approximately 500 ft^2/head. The high pen density treatment had 12 or 14 head/pen for a stocking rate of approximately 250 ft^2/head. All cattle had a minimum of 18 inches of bunk space/head.

In both trials, pens receiving the bedding treatment were bedded at the rate of 5 lb/head/day the first day of the trial. Thereafter, bedding was applied at the rate of approximately 2 lb/head/day based on the following two primary thresholds: 1) air temperature was below 14°F; and/or 2) precipitation of at least 0.10 inch rain or 1 inch snow was received. When more than 0.10 inch rain or 1 inch snow was received, cattle were bedded on subsequent days for each 0.10 inch rain or 1 inch snow. Additionally, when there was melting snow or mud in the pen, even if thresholds were not met, cattle received 2 lb/head/day of bedding every day or every other day, respectively, until the snow and mud were gone. Slight alternations in the bedding schedules were made to maintain a minimal amount of bedding in the pens at all times, however, in Trial 2, no bedding was added from day 98 to the end of the trial due to warmer temperatures and greater windspeeds, which allowed for improved conditions in the pens. Bedding was added to pens a total of 65 and 59 days in Trial 1 and 2, respectively.

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Feed intakes were recorded daily. Body weights were obtained on days 0, 35, and 110 in Trial 1 and on days 0, 34, 71, and 98 in Trial 2. Cattle were fed 110 and 124 d in Trials 1 and 2, respectively. In Trial 1 (after thawing) and Trial 2 (trial duration), animal and lot mud condition scores were recorded twice per week. Animal mud condition scores were defined as: 0) clean, no mud; 1) small lumps of mud on the hide in limited areas of the leg and underbelly; 2) small and large lumps of mud covering larger areas of the legs, side, and underbelly; 3) small and large lumps of mud covering the hide in even areas that included the hind quarter, stomach, and front shoulder; or 4) lumps of mud continuously covering the underbelly and side of the animal from brisket to rear quarter. Lot mud condition scores were defined as: 0) no mud or mud less than 3 inches deep; 1) mild mud, 3 to 7 inches deep; or 2) severe mud, more than 7 inches deep. Additionally, in Trial 2, lot condition was denoted as frozen ground or thawed. At slaughter (day 110, Trial 1; and day 124, Trial 2) final weight, hot carcass weight, liver score, USDA marbling score, and USDA yield grades were obtained.

Statistical analysis of performance data, marbling scores, and yield grade was done using General Linear Models procedures of SAS. In Trial 1, the model included Trt. Contrasts were used to compare density in the unsheltered feed area treatments and bedding in the sheltered feed area treatments. In Trial 2, the model included density, bedding, and the density by bedding interaction. Liver and mud condition scores (animal and lot) were analyzed using frequency procedures of SAS. The P-value reported is the Mantel-Haenszel Chi-Square.

Table 1. Weather conditions for trials.[a]

	Mean Ta, °F	Max Ta, °F	Min Ta, °F	RH, %	WSPD, mph	Precip, in
Trial 1						
day 0 to 35	25.44	36.43	13.97	75.30	5.29	0.16
day 36 to 110	35.78	47.26	24.39	73.96	6.46	3.75
day 0 to 110	32.58	43.90	21.16	74.38	6.10	3.91
Trial 2						
day 0 to 33	16.55	25.83	5.82	75.30	5.83	0.13
day 34 to 70	30.85	40.46	20.47	82.35	5.99	1.21
day 71 to 98	33.28	46.11	20.06	67.53	6.79	0.03
day 99 to 124	49.77	60.57	38.25	68.03	8.34	1.98
day 0 to 124	31.56	42.06	20.21	74.13	6.62	3.35

[a]Ta = Ambient temperature; RH = relative humidity; WSPD = wind speed; Precip = precipitation, as rain or melted snow.

Table 2. Performance and carcass data (Trial 1).

	Facilities								
	Sheltered		Unsheltered						
Pen Density:	Low	Low	Low	High					
Bedding:	Yes	No	No	No			Contrasts		
Treatment No:	1	2	3	4	SEM	P-Value	1 v 2	3 v 4	1 v 4
Weight, lb									
day 0	823	822	824	827	2.0	0.48	0.89	0.46	0.21
day 35	968	967	969	967	8.2	1.00	0.99	0.89	0.99
day 110	1281	1272	1277	1245	14.3	0.31	0.68	0.13	0.10
day 110 (adjusted)[a]	1239	1238	1247	1216	13.2	0.42	0.93	0.12	0.24
ADG, lb									
day 0 to 35	4.14	4.15	4.14	4.02	0.23	0.98	0.98	0.72	0.73
day 36 to 110	4.12	4.01	4.05	3.65	0.16	0.18	0.60	0.09	0.05
day 0 to 110	4.13	4.05	4.08	3.77	0.12	0.20	0.66	0.09	0.06
day 0 to 110 (adjusted)[a]	3.75	3.74	3.81	3.51	0.11	0.30	0.94	0.08	0.15
DMI, lb									
day 0 to 35	20.57	21.13	20.80	20.64	0.47	0.84	0.41	0.82	0.92
day 36 to 110	22.94	22.99	23.22	22.80	0.60	0.97	0.95	0.62	0.88
day 0 to 110	22.19	22.40	22.46	22.12	0.53	0.96	0.78	0.66	0.93
Feed/gain									
day 0 to 35	5.01	5.12	5.11	5.21	0.26	0.97	0.79	0.80	0.61
day 36 to 110	5.58	5.80	5.75	6.26	0.23	0.22	0.50	0.13	0.05
day 0 to 110	5.39	5.57	5.50	5.88	0.18	0.27	0.49	0.15	0.07
day 0 to 110 (adjusted)[a]	5.94	6.03	5.90	6.32	0.22	0.54	0.78	0.19	0.24
Carcass data									
HCW, lb	769	767	773	754	8.2	0.43	0.92	0.13	0.24
Marbling score[b]	483	460	495	481	11.3	0.22	0.18	0.39	0.91
Yield grade	2.45	2.26	2.39	2.34	0.11	0.65	0.23	0.73	0.47
Dressing %	60.0	60.3	60.6	60.6	3.30	0.57	0.45	0.96	0.22
Liver score[c]	0	3.33	2.86	5.71	—	—	0.31	0.52	—

[a]Based on hot carcass weight adjusted to a 62% dressing percentage.
[b]Marbling score: 400 = slight[0] (select), 500 = small[0] (low choice).
[c]Percentage condemned, due to abscesses based on Chi-Square analysis.

Table 3. Performance and carcass data (Trial 2).

	Pen density (Den)[a]		Bedding (Bed)			P-values		
	Low	High	No	Yes	SEM	Den	Bed	Den*Bed
No. pens	12	12	12	12				
Weight, lb								
Initial	879	882	878	884	2.5	0.33	0.11	0.19
day 34	1048	1054	1043	1059	4.3	0.34	0.01	0.09
day 71	1163	1160	1150	1172	5.8	0.76	0.02	0.25
day 98	1252	1248	1243	1257	7.2	0.64	0.20	0.37
Final[b]	1328	1327	1320	1336	8.5	0.95	0.41	0.45
ADG, lb								
day 0 to 34	4.84	4.91	4.73	5.02	0.09	0.61	0.04	0.23
day 0 to 71	4.00	3.91	3.85	4.07	0.06	0.33	0.02	0.46
day 0 to 98	3.82	3.74	3.74	3.82	0.06	0.33	0.41	0.70
day 0 to 124[b]	3.63	3.59	3.57	3.65	0.04	0.57	0.36	0.50
DMI, lb								
day 0 to 34	22.87	24.96	23.81	24.01	0.39	<0.01	0.73	0.57
day 0 to 71	22.42	24.02	23.25	23.18	0.38	0.01	0.90	0.38
day 0 to 98	21.83	23.41	22.64	22.60	0.35	0.00	0.93	0.27
day 0 to 124	22.11	23.87	23.04	22.94	0.39	0.19	0.89	0.20
F/G								
day 0 to 34	4.74	5.10	5.05	4.80	0.11	0.03	0.12	0.63
day 0 to 71	5.62	6.15	6.05	5.72	0.10	<0.01	0.03	0.75
day 0 to 98	5.72	6.28	6.05	5.94	0.11	<0.01	0.46	0.45
day 0 to 124[b]	6.11	6.66	6.46	6.31	0.05	0.07	0.25	0.45
Carcass data[c]								
Dressing %	63.9	64.0	63.5	64.3	0.19	0.65	0.21	0.40
HCW	823	823	818	828	6.8	0.94	0.32	0.46
Marbling[d]	563	527	537	552	7.6	0.00	0.16	0.59
Yield Grade	2.38	2.37	2.40	2.34	0.07	0.92	0.56	0.34
Liver Score[e]	10.56	5.63	2.35	6.57	—	0.23	0.02	—

[a]Low = 500 ft^2/animal; High = 250 ft^2/animal.
[b]Final weight (d 124) calculated as hot carcass weight (HCW) divided by a 62% dressing percentage.
[c]Carcass data was analyzed using the individual animal as experimental unit.
[d]Marbling score: 500 = Small^0 (Low Choice), 600 = Modest^0 (Average Choice)
[e]Percentage condemned, due to abscesses; based on Chi-Square analysis.

Table 4. Animal and lot mud condition scores (Trial 1).

Feeding area:	Sheltered			Unsheltered		
Pen density:	Low	Low		Low	High	
Bedding:	Yes	No		No	No	
Treatment no.:	1	2	P-value	3	4	*P*-value
Animal condition[b]			0.020			0.003
Score 0, %[a]	20.00	46.67		50.00	16.67	
Score 1, %[a]	43.33	36.67		26.67	43.33	
Score 2, %[a]	36.67	16.67		20.00	33.33	
Score 3, %[a]	0.00	0.00		3.33	13.67	
Lot condition[c]			0.001			0.002
Score 0, %[a]	50.00	0.00		26.67	0.00	
Score 1, %[a]	50.00	100.00		73.33	96.67	
Score 2, %[a]	0.00	0.00		0.00	3.33	

[a]Percentage of pens observed at given score.
[b]Animal condition: 0 = clean, no mud; 1 = small lumps of mud on the hide in limited areas of the leg and underbelly; 2 = small and large lumps of mud covering larger areas of the legs, side, and underbelly; 3 = small and large lumps of mud covering the hide in areas along the hind quarter, stomach, and front shoulder.
[c]Lot condition: 0 = no mud or mud less than 3 inches deep; 1 = mild mud, 3 to 7 inches deep; 2 = severe mud, more than 7 inches deep.

Results

In Trial 1 (Table 2), there were no differences for bedding versus no bedding (Trt 1 vs Trt 2) in the sheltered cattle. In the unsheltered groups, low pen density tended to increase ($P<0.10$) ADG from days 35 to 110, and day 0 to 110, when based on unadjusted full weights. Cattle with bedding and the most pen space (Trt 1) had improved ADG and lower F/G from days 36 to 110 ($P\leq0.05$) when compared with nonbedded cattle with the least pen space (Trt 4). Overall performance was similar among groups when comparisons were based on a common dressing percentage, however, in the unsheltered group, increased cattle density tended ($P\leq0.10$) to reduce overall gain. In Trial 2 (Table 3), the addition of bedding increased ($P<0.05$) day 34 weight, day 71 weight, ADG from days 0 to 34 and ADG from days 0 to 71, and improved feed efficiency from days 0 to 71. The low density group had lower ($P<0.05$) DMI and F/G from day 0 through day 98 when compared with the high density group. The low density group tended ($P=0.07$) to have lower overall F/G and a greater ($P=0.001$) marbling score when compared with the high density group. Bedding improved ($P=0.03$) F/G through day 71 only, however, it did result in a greater ($P=0.02$) percentage of condemned livers. There were no pen density by bedding interactions for performance or carcass data.

In Trial 1, bedding did not ($P=0.02$) result in lowering animal mud condition scores, but did lower ($P<0.001$) lot mud condition scores. However, animal and lot mud condition scores were lower ($P<0.005$) in the low density treatment when compared with the high density treatment. Data suggest cattle with bedding were dirtier ($P<0.05$) than cattle without bedding, even though pens with bedding were less muddy ($P<0.05$). In Trial 2 (Table 5), no differences ($P>0.05$) in animal or lot mud condition were observed for bedded versus

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nonbedded treatments. Lower cattle density resulted in lower ($P<0.05$) mud condition scores on cattle day 36 to day 71, and lower ($P<0.05$) mud condition scores in the lot for days 36 to 71, and days 72 to 98. These results indicate a lower stocking density can potentially improve comfort and performance during winter (cold) and spring (rainy) weather patterns.

In both trials, positive responses to providing more pen space per animal and to providing bedding were observed. However, responses were not always maintained for the duration of the trials. Lowering pen density tended ($P=0.08$) to enhance ADG over the entire trial in Trial 1, while F/G tended ($P=0.07$) to improve and marbling score increased ($P=0.001$) in Trial 2. Benefits of bedding were not sustained. Bedding did increase the percentage of condemned livers in Trial 2, however trends in the percentage of condemned livers as a result of providing bedding or changing pen density were opposite for the two trials. For both trials, decreasing pen density lowered lot mud condition scores; however, the use of bedding did not consistently improve animal or lot mud condition scores.

The use of straw bedding may improve cattle performance during periods of cold stress in feedlots that are not sheltered. However, in sheltered feedlots or times of no cold stress, bedding has little effect on ADG or F/G. It was more effective to reduce mud in feedlots by reducing the pen density versus using bedding during typical winter/spring weather patterns.

Table 5. Animal and lot mud condition scores (Trial 2).

	Bedding			Density		
	None	Bedded	*P*-Value	Low	High	P-Value
Animal condition[b]						
Score, day 0 to 35			1.00			0.31
0, %[a]	57.41	58.33		60.19	55.56	
1, %[a]	24.07	26.85		26.85	24.07	
2, %[a]	12.96	4.63		12.04	5.56	
3, %[a]	5.56	10.19		8.33	7.41	
Score, day 36 to 71			0.92			0.001
0, %[a]	0	0		0	0	
1, %[a]	31.82	30.30		52.27	9.85	
2, %[a]	56.06	58.33		37.88	76.52	
3, %[a]	12.12	11.36		9.85	13.64	
Score, day 72 to 98			1.00			1.000
0, %[a]	0	0		0	0	
1, %[a]	100.00	100.00		100.00	100.00	
2, %[a]	0	0		0	0	
3, %[a]	0	0		0	0	
Lot condition[c]						
Score, day 0 to 35[d]			1.00			1.000
0, %[a] 1	33.33	33.33		33.33	33.33	
1, %[a] 1	66.67	66.67		66.67	66.67	
2, %[a] 1	0	0		0	0	
Score, day 36 to 71[e]			0.557			0.001
0, %[a]	10.61	11.36		15.15	6.82	
1, %[a]	75.00	69.70		77.27	67.42	
2, %[a]	14.39	18.94		7.58	25.76	
Score, day 72 to 98[f]			0.641			0.001
0, %[a]	75.00	71.88		84.40	62.50	
1, %[a]	17.71	19.79		12.50	25.00	
2, %[a]	7.29	8.33		3.10	12.50	

[a]Percentage of animals or pens observed at given score over all days in given period.
[b]Animal Condition: 0 = clean, no mud; 1 = small lumps of mud o the hide in limited area of the leg and underbelly; 2 = small and large lumps of mud covering larger areas of the legs, side, and underbelly; 3 = small and large lumps of mud covering the hide in areas along the hind quarter, stomach, and front shoulder; 4 = lumps of mud continuously covering the underbelly and side of the animal from brisket to rear quarter.
[c]Lot condition: 0 = no mud or mud less than 3" deep; 1 = mild mud 3 to 7" deep; 2 = severe mud, more than 7" deep.
[d]n = 216; 144 frozen, 72 thawed.
[e]n = 264; 168 frozen, 96 thawed.
[f]n = 192; 24 frozen, 168 thawed.
n = number of pen observations.

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Environmental Factors Affecting Water Intake in Steers Finishing in Feedlots

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Summary

Simple and multiple regression analyses were executed using records of six experiments conducted from 1999 to 2006 at the University of Nebraska Northeast Research and Extension Center. The objective of the study was to obtain the best equation to predict water intake of feedlot steers under summer and winter weather conditions. The analysis permitted regression equations to be obtained for summer, winter and both seasons (overall model). From simple regression analysis, the best predictor of water intake was minimum temperature with r^2= 0.61 in the overall model. Whereas, from multiple regression analysis the overall model with the best fit had R^2 = 0.70. This model included 4 factors; daily mean minimum temperature, solar radiation, dry matter intake and wind speed.

Introduction

Adequate water is essential for maintaining optimum physiological and metabolic function. In some locations and at certain times of the year water availability or access by cattle may be limited. It is important for commercial feedlot operators to know and be able to predict daily water intake of cattle and allow for additional water allotments to implement cooling strategies during summer heat waves. However, there is limited information available on water intake by beef cattle managed in modern commercial feedlots. Water intake recommendations of NRC beef cattle (2000) are based on research summarized by Winchester and Morris during the 1950s. The Winchester and Morris system was developed from a database derived primarily from dairy cattle that were managed under constant temperature chambers, beef cows managed under various regimens in the Imperial Valley, Calif., and a small data set from Beltsville, Md., (six heifers). Climatic conditions, system of production, and management of animals used in the Winchester and Morris database are very different from those found in commercial feedlots, especially in the Midwest. This study was undertaken to derive models to predict daily water intake in feedlot steers.

Procedure

The dataset used for this analysis was derived from six experiments that were conducted at the University of Nebraska Northeast Research and Extension Center and used predominantly Angus or Angus crossbreds. Experiment 1 was conducted in 1999 and used 144 steers to determine effects of different feeding regimens on performance, behavior and tympanic temperatures of steers exposed to environmental heat stress (*2001 Nebraska Beef Report*, pp. 69-73). Experiment 2 was conducted in 1999 (*2001 Nebraska Beef Report,* pp. 77-81) and used 96 steers to determine the effect of water application to feedlot mounds on performance, behavior and tympanic temperatures of steers. Only data from the first 23 days of this study were used, since this was a period in which no water was applied. Experiment 3 used 168 crossbred steers and was conducted during the winter of 2002-03 to assess the effects of salt and fat supplementation on DMI, daily water intake (WI), behavior, and tympanic temperature in finished cattle (*2006 Nebraska Beef Report,* pp. 62-65). Steers in this experiment were fed for a period of 128 days. Experiment 4 used 48 steers over a period of 92 days and was conducted during the summer of 2002 with the same objectives as Experiment 3 (*2006 Nebraska Beef Report,* pp. 62-65). Experiment 5 was conducted in the winter of 2004-05, used 250 crossbred steers and was conducted to evaluate bedding and pen density on feedlot surface conditions and cold stress in feedlot cattle. Experiment 6 was conducted during the winter of 2005-06 with 96 Angus steers over a period of 168 days to evaluate levels of inclusion of dried distillers grains with solubles (DDGS) on performance and water intake of cattle.

The database included daily measures of temperatures (mean, maximum and minimum), precipitation, relative humidity, wind speed, solar radiation and temperature-humidity index (THI); as well as DMI and WI. The THI was calculated as: THI= Ta (0.55- (0.55*(RH/100))*(Ta-58); where Ta = ambient temperature and RH =% relative humidity. The climatic variables were compiled using a weather station located at the feedlot facility. Solar radiation was obtained from the High Plains Climate Center automated weather station located 0.37 miles west and 0.93 miles north of the feedlot facilities. The total combination of these observations resulted in a total of 2,612 data points. Due to water meter malfunction or possible recording error, approximately 2% of the total data points were removed from the final dataset. The criterion of elimination was data with less than $\pm$ 2.65 studentized residuals.

For each season, simple regression analysis for linear, quadratic, cubic and quartic polynomial degrees were determined between WI and each environmental variable using JMP 5.0.1.2 © (SAS Institute Inc). Subsequent analysis used stepwise regression procedures of SAS © (SAS Ins. Inc., Cary, N.C.) with water intake (gal/day) used as response variable, and the following independent variables: DMI (lb/day), maximum temperature (°F), minimum tempera-

(Continued on next page)

Table 1 Means for season on daily water intake and other climatic factors for overall data-base (±SD)[a].

Season	Water Intake (gal/d)	DMI (lb/d)	Temperature (°F) Max	Min	Mean	RH (%)	Wind speed (mph)	Solar radiation (kcal/d)	Precipitation (in/d)	THI
Summer	8.97 ±2.37	22.4 ±3.88	80.8 ± 9.5	59.6 ± 8.9	70.2 ± 8.2	77.4[a] ±10.1	6.7[b] ±2.66	4575 ± 1452	0.070 ±0.28	68.6 ± 7.07
Winter	4.46 ±1.50	23.6 ±2.72	39.8 ±16.5	17.1 ± 14.1	28.8 ±14.0	74.8[b] ±12.5	8.2[a] ±5.13	2249 ± 1204	0.013 ±0.07	32.5 ±12.2
Overall	5.94 ±2.80	23.2 ±3.20	53.3 ±24.2	31.1 ± 23.6	42.4 ±23.1	76.3 ±11.8	7.7[a] ±4.51	3013 ± 1692	0.032 ±0.17	44.4 ±20.1

[a] Means with unlike superscript within column differ ($P < 0.001$)

ture (°F, mean temperature (°F), wind speed (mph), precipitation (in/d), RH (%), solar radiation (kcal/m^2/d), THI (temperature-humidity index), and experimental error. Multiple regression analysis were conducted using the entire database (both seasons = overall model) and for each season (the summer and the winter). The number of final parameters included in each model was determined when the change in the magnitude of R^2 was greater than 0.01 units with the addition of an additional parameter. An inflection point was determined from the 2nd derivatives of the simple linear polynomial equations. The present study did not consider in the final models THI or daily mean temperature due to the existence of collinearity of these variables with other variables in the multiple regression analysis.

Results

Water intake for steers during the summer was 2x greater than during the winter (9.0 ± 2.4 vs. 4.5 ± 1.5 gal/day). There was also greater variability during the summer seasons than during the winter seasons (Table 1). Similar responses were reported by Hoffman et al. (1972; JAS 35(4):871-876) with greater water intake for the summer than the winter (63.2%); and by Kreikemeier et al. (2004; JAS 82:2481-2488), whom also reported greater water intake for the summer than the winter (73.9%). Dry matter intake was 5.5 % lower in the summer than in the winter (22.4 ± 3.9 vs. 23.6 ± 2.7 lb/day). There were no ($P>0.05$) differences in RH between the summer and the winter season, while wind speed was greater ($P<0.001$) in the winter than in the summer season (Table 1).

Table 2 Coefficients of determination (r^2) of simple linear regression for environmental variables to predict WI.

Environmental variables	r^2 Summer model	Winter model	Overall model
Minimum temperature	0.1495	0.0357	0.5191
Maximum temperature	0.0708	0.0574	0.4778
Solar radiation	0.1158	0.1615	0.4530
Wind speed	0.0010	0.0170	0.0295
Dry matter intake	0.0170	0.0050	0.0051
Relative humidity	0.0016	0.0492	0.0007
Precipitation	0.0016	0.0479	0.0045

Table 2 displays the values of coefficient of determination for simple linear regression by season and environmental variable. Daily minimum temperature (r^2=0.15) and solar radiation (r^2 = 0.12) obtained the highest r^2 values among the variables evaluated for the summer model. For the winter model solar radiation (r^2 = 0.16) and daily maximum temperature (r^2 = 0.06) were the best variables explaining water intake. In the overall season simple linear regression the best predictors were daily minimum temperature, daily maximum temperature and solar radiation with r^2 of 0.52, 0.48 and 0.45, respectively. Simple linear, quadratic, cubic and quartic regression analyses were performed to determine best fit. The selection of the polynomial equation that fits best was based in the improvement in r^2 value over simple linear regression. These analyses demonstrate the minimum temperature fit better in a simple linear regression (r^2= 0.15) for summer, and a simple quartic regression for the overall model (r^2= 0.61, values not showed in the tables); whereas for the winter, solar radiation (r^2 = 0.22) and daily maximum temperature (r^2 = 0.09) were the best variables explaining water intake in simple cubic regression.

The results of multiple regression analysis performed to predict WI

Table 3 Partial regression coefficients ±SE for models assessing environmental and performance factors affecting water intake in feedlot steers[a].

Parameter	Summer Estimate	SE	Partial R^2	Winter Estimate	SE	Partial R^2	Overall Estimate	SE	Partial R^2
Intercept	-3.13781	0.666	—	2.96506	0.374	—	-1.04313	0.250	—
Dry matter intake	0.20047	0.017	0.0763	0.07382	0.010	0.0200	0.14994	0.010	0.0285
Solar radiation	0.00046	0.000	0.0840	0.00039	0.000	0.1847	0.00064	0.000	0.1255
Max temperature	—	—	—	0.00636	0.004	0.0506	—	—	—
Min temperature	0.10865	0.008	0.1552	0.02187	0.004	0.0109	0.06470	0.002	0.5391
Wind speed	-0.13291	0.025	0.0224	-0.03819	0.005	0.0176	-0.05801	0.007	0.0092
Relatively humidity	—	—	—	-0.01825	0.003	0.0108	—	—	—
Precipitation	—	—	—	-4.20499	0.386	0.0385	—	—	—
Total R^2			0.3380			0.3333			0.7023

[a] P values for all statistics < 0.0001.

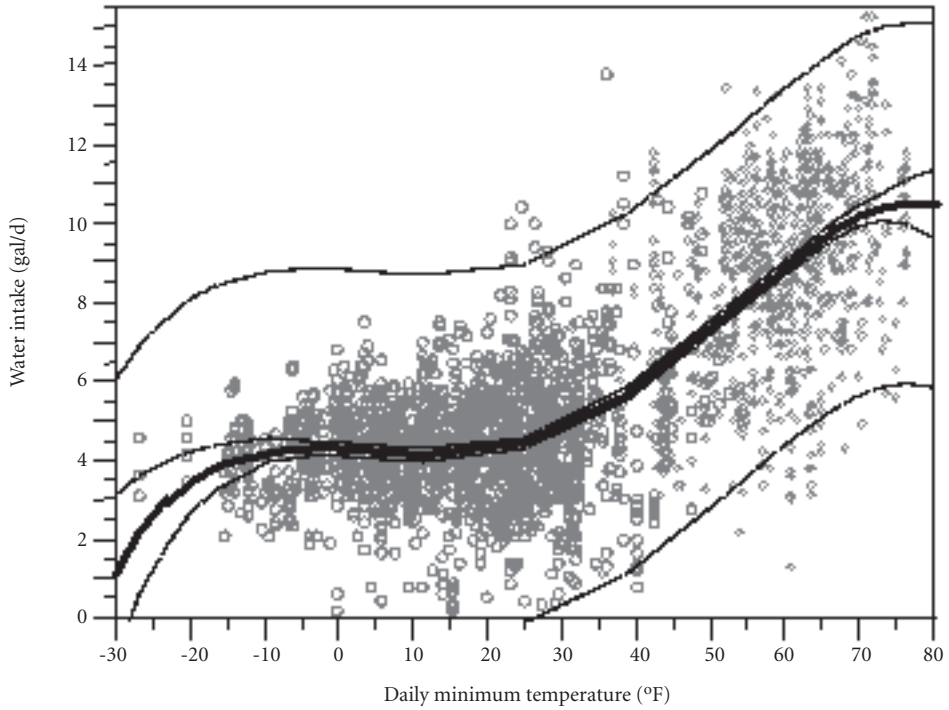

Figure 1 Water intake in function of daily minimum temperature (mt) for overall season in feedlot steers. Water intake = 4.3250 - 0.0120mt - 8.412e-4 mt^2 +8.17e-5mt^3 - 7.144e-mt^4 (r^2 =0.61, inflection point = 53.5). Inflection point would represent a threshold or shift in the rate of change of daily water intake.

using environmental variables, as well as DMI are shown in Table 3. The summer season and the overall model included the same four factors; minimum temperature, DMI, solar radiation and wind speed. In the summer and the winter models environmental variables do not account for much of the total variation in water intake achieving $R^2 < 0.5$. The summer model had R^2 of 0.34 with three factors; whereas the winter model had R^2 of 0.33 including all the factors. Solar radiation was the most important factor in the winter model followed by maximum temperature and wind speed. Minimum temperature was the more important factor in the summer and overall model.

Overall models explained nearly 70% of the variation in WI in steers, and included four factors, with minimum temperature accounting for 54% of the total variability, followed by solar radiation accounting for 13% of the variation in water intake. These data demonstrate that minimum temperature has a very important role in the regulation of water intake, and is associated with the loss of heat by animals. In the summer cool nights allow animals to efficiently reduce heat load through conductive and convective processes, while warm nights require animals to drink more water in an effort to reduce heat load. These results agree with NRC equation for dairy cattle, where minimum temperature was also found to play an important role in WI (Dairy cattle NRC, 2001). The lower R^2 values obtained in the present study for the summer and the winter compared with previous reports could be possibly explained by the fact that the weather variables were entered as daily values in the present study and as weekly means in some of the previous research thereby reducing the natural variation in the data and improving the prediction. Figure 1 displays the relationship of water intake with daily minimum temperature (over both seasons) and associated confidence interval (alpha level of 0.01). The quartic degree polynomial equation was selected based on its highest r^2 value. The inflection point for minimum temperature in the overall model was close to 54 °F. This value represents a transition or threshold between warm and cold conditions in each season, and may represent a shift in the animals' heat stress coping ability due to a change in the rate of WI.

All the variables used to determine water intake with simple regression procedure had lower r^2 than the final R^2 from multiple regression procedure. Multiple regression analysis improved predictions across the seasons and resulted in better models to predict water intake than with simple regression models. These results also confirm water intake increases significantly during the summer season. Mean minimum temperature plays an importance role for the summer, whereas solar radiation seems to be the most important factor during the winter season. Putting both summer plus winter seasons together in one model improved the prediction of WI. This model included four factors mean minimum temperature, solar radiation, DMI and wind speed.

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Feedlot Surface Conditions and Ammonia Emissions

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Summary

*Moisture and urine were applied to a feedlot surface in a 2x2 factorial design. Forced-air wind tunnels were used to determine differences in the net flux of ammonia (NH_3) being volatilized. Surface DM, pH and surface temperature were all analyzed within each treatment to determine effect on NH_3 net flux. No effects of urine were detected. There were differences detected due to moisture and moisture*time with the dry plots releasing significantly more NH3.*

Introduction

Feedlot surface conditions continually change due to variations in temperature, moisture, manure, urine and microbial population. NH_3 emissions continually change due to the time of year, time of day, environmental conditions and feedlot surface conditions. Past reports indicated an increase in NH_3 flux during the summer due to an increase in soil temperature and N level (*2006 Nebraska Beef Report,* pp. 92-93).

NH_3 flux usually follows a diurnal pattern with the NH_3 concentration increasing from early morning, peaking at midday and then decreasing into early evening. Our first hypothesis is the application of urine will increase NH_3 emissions from the feedlot pen surface. Additionally, as plots with moisture added begin to dry an increase in NH_3 flux will be observed. According to diurnal patterns and temperatures, our second hypothesis is NH_3 loss will be highest during the afternoon.

Procedure

The experiment was conducted the first 3 weeks of August 2005. Each week, cattle were removed from the pens the afternoon of day 0 and returned to the pens to re-equilibrate the surface the morning of day 3. Treatments were applied to 5.76 ft^2 plots on a feedlot surface as a 2x2 factorial. Factors included water addition at 0 or 4 gallons, to simulate a 1-inch rainfall and/or urine addition of 0 or 0.26 gallons (0.762 % N). Therefore, the four treatments were DRY (nothing added), DRY+URINE (urine added), WET (only water added), and WET+URINE (water and urine added). Water was applied to assigned plots at 6 a.m. on day 1. Urine was applied immediately prior to collection one on day 1 of designated plots. Plot location and treatment remained the same throughout 3 weeks. NH_3 samples were collected using two forced-air wind tunnels every 3 hours on day 1 from 6 a.m. to 9 p.m. On day 2, samples were collected every 6 hours from 8 a.m. to 8 p.m. Wind tunnels directed air over the surface at 0.3 m/s for 30 minutes per plot. A fraction of the airflow (0.024 m^3/s) was diverted for analysis and NH_3 was collected using a 0.2 *M* sulfuric acid trap. The trapped NH_3 was measured in the lab using a spectrophotometer. One-inch cores of the feedlot surface were collected, two at the beginning of day 1, and two at

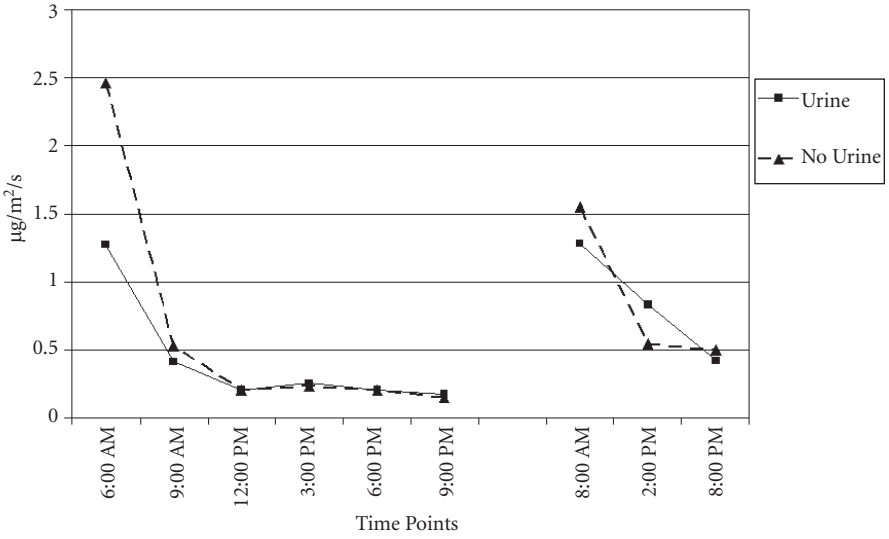

Figure 1. NH_3 emissions due to urine and time (interaction: $P = 0.78$; urine effect: $P = 0.46$).

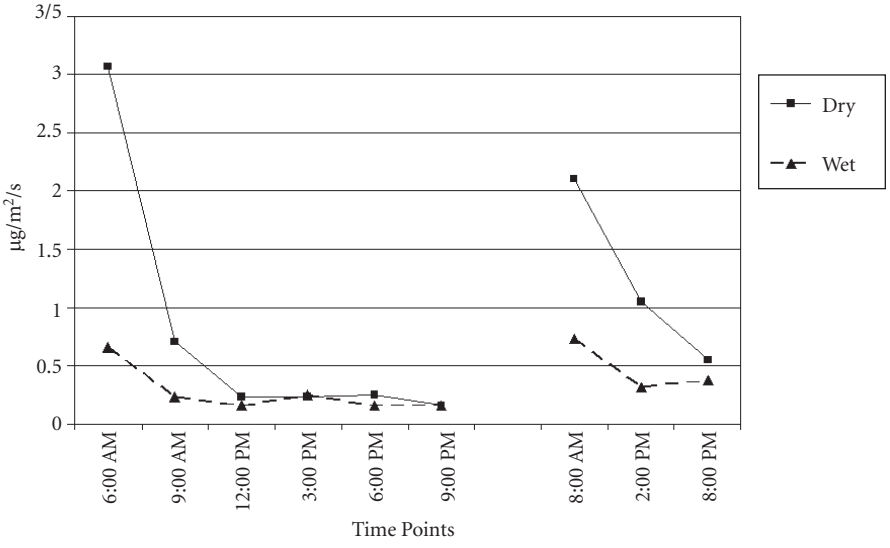

Figure 2. NH_3 emissions due to moisture and time of day (interaction: $P = 0.03$; moisture effect: $P < 0.01$).

Table 1. Core characteristics influenced by moisture and urine.

					P-value		
	DRY+ DRY	URINE	WET+ WET	URINE	Moisture *urine	Moisture	Urine
Core N	1.18[ab]	1.12[ab]	1.11[b]	1.22[a]	0.02	0.74	0.49
Core pH	8.01	7.96	8.21	8.32	0.19	<0.01	0.72
Core Moisture	11.3	12.0	27.6	28.7	0.89	<0.01	0.53

[a,b]Means with different superscripts differ significantly (P<0.05).

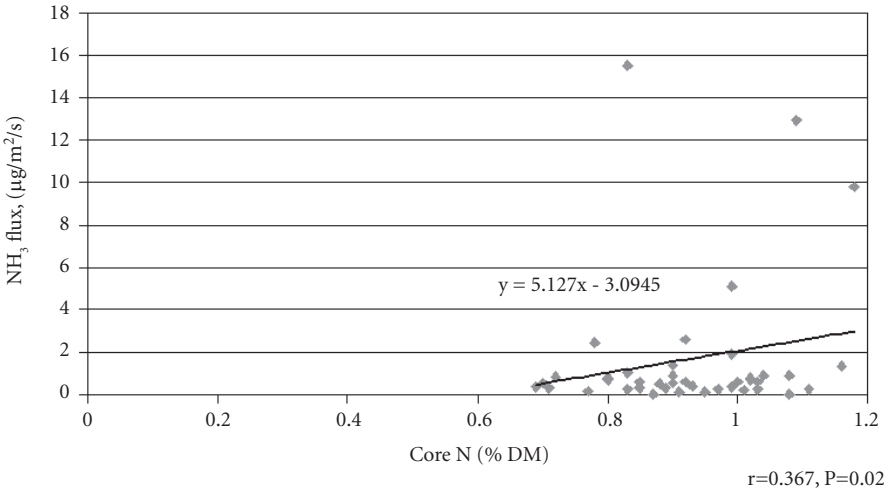

Figure 3. Correlation between N loss and core N.

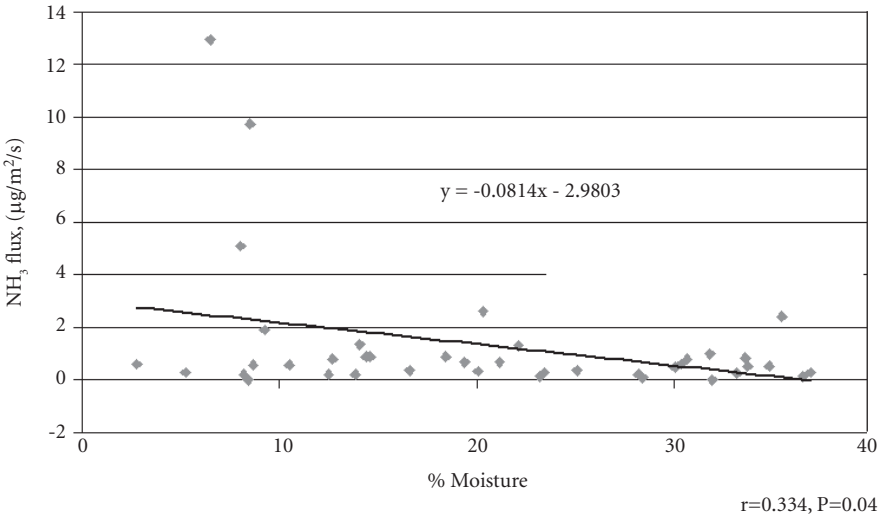

Figure 4. Correlation between N loss and core moisture.

the end of day 2. They were analyzed for DM, pH and N. Soil and surface temperatures were recorded at the beginning of each 30-minute period.

Results

There was no moisture*urine*time interaction (P= 0.57), no urine*time interaction (P= 0.78) and no main effect of urine (P= 0.46; Figure 1) . A moisture*time interaction (P= 0.03) was observed across all 3 weeks, the highest NH_3 loss was observed prior to 9 a.m. on both day 1 and day 2, with NH_3 losses decreasing to very low levels after 12 p.m. The net flux was affected by moisture (P<0.01) with the DRY and DRY+URINE plots emitting higher levels of NH_3 on both day 1 and day 2 (3.07 and 2.09 µg/m^2/s) versus the WET and WET+URINE plots emitting only 0.65 and 0.72 µg/m^2/s of NH_3 (Figure 2).

There was a significant moisture*urine effect (P= 0.02) on core N with the WET+URINE having a higher N level when compared to the other three treatments. Soil pH was effected by moisture (P<0.01) with WET and WET+URINE treatments having higher pH values. The WET and WET+URINE core moisture was twice the amount of that observed in the DRY cores (27.6 and 28.7 WET, 11.3 and 12.0 DRY; Table 1).

NH_3 flux weakly correlated to core N (r = 0.367, P = 0.02). As core N increased, the NH_3 emitted also increased (Figure 3). A low correlation (r = 0.334, P = 0.04) was observed between moisture and NH_3 flux. Emissions were high on DRY and DRY+URINE plots and as the WET and WET+URINE plots dried the emissions increased (Figure 4). At the high moisture of the WET and WET+URINE plots, the surface is moist and holds the NH_3 in solution. As the surface dries it allows the NH_3 to volatilize and be released.

In this trial, NH_3 loss appears to be related to soil moisture, with the greater loss from dry surfaces. The NH_3 flux followed a diurnal pattern with the greatest loss prior to 9 a.m. and decreasing into the evening. The diurnal trend of the lowest emissions during the midday, rather than the midday emissions being the highest, could be due to the repeated measurement of the plots throughout the day. This could have modified the microenvironment. The change in the microenvironment could have reduced the amount of NH_3 produced, and thus emitted, resulting in the low NH_3 flux midday. Low air exchange rates within the chamber can also modify the microenvironment reducing NH_3 loss.

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Effect of Phase Feeding Protein on Cattle Performance and Nitrogen Mass Balance in Open Feedlots

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Rick R. Stowell
Dawn M. Sherwood[1]

Summary

Two experiments using calves fed 176 days from November to May (WINTER) and yearlings fed 117 days from May to September (SUMMER) were conducted to compare conventional CP levels to phase-fed diets balanced for degradable intake protein and undegradable intake protein on performance and N volatilization. Phase fed diets were formulated to balance degradable intake protein and metabolizable protein. Phase feeding resulted in greater ADG and better F:G in WINTER and similar performance in SUMMER than traditional feeding methods. Nitrogen excretion was significantly reduced in both WINTER and SUMMER which translated into significantly less N volatilization without impacting N removed in manure.

Introduction

Overfeeding nutrients increases the excretion and subsequent loss of those nutrients *(1998 Nebraska Beef Report,* pp. 78-80; 2000 Nebraska Beef Report, pp. 65-67). Nutrition and management practices can influence the quantity, form, and route (feces, urine) of nutrient excretion by the animal (*2002 Nebraska Beef Report,* pp.54-57; *2003 Nebraska Beef Report,* pp. 54-58). As nutrient requirements change with the physiological state of an animal, it may be possible to decrease NH_3 emissions and nutrient excretion by decreasing CP concentrations of beef cattle finishing diets as time on feed increases without adversely affecting performance. The objective of these experiments was to compare the effects of a phase feeding system balanced for degradable intake protein (DIP) and undegradable intake protein (UIP) to a constant, conventional CP level on animal performance and nitrogen mass balance in feedlot cattle.

Procedure

Two experiments were conducted using 96 steer calves (647 ± 0.59 lb BW) fed 176 days from November to May (WINTER) and 96 yearling steers (823 ± 0.26 lb BW) fed 117 days from May to September (SUMMER). Steers were weighed initially on two consecutive days after being limit fed (2% BW) for 5 days to minimize gut fill differences. Steers were stratified by BW and assigned randomly to treatment (eight steers/pen, six pens/treatment)

Two diets were fed (Table 1). One was a "typical" feedlot diet with dry-rolled corn and contained 12.7% and 14.2% CP for WINTER and SUMMER, respectively. Cattle assigned to the PHASE treatment were intensively managed for protein requirements across the feeding period. A basal diet identical to CONTROL was fed. The dry supplement was incorporated at 5% of the diet (DM basis) and altered every 14 days. PHASE was formulated with the 1996 NRC computer model to balance DIP and MP. Formulations were conducted to meet changing animal requirements across the feeding period for every 50 lb of gain. Adjustments were made to the 1996 NRC calculations to balance DIP and MP with the following hypothesis: excess MP, from excess UIP from DRC corn, will encourage blood urea N recycling to a DIP deficient rumen.

For formulations, the DIP and MP supply and requirements from 1996 NRC computer model were used to predict DIP and MP balances. For example, 341 kg initial BW and 591 kg final BW were entered into the computer model along with historical gain and DMI. The first step was to formulate the diet without urea. The resulting MP and DIP requirements, supplies and balances were used for the second step of formulation. The 1996 NRC predictions for MP supply assume that DIP requirements are met. However, this is not always true. Therefore, if DIP was in negative balance but MP was in positive balance, we modified MP supply to determine the amount of MP that would be necessary to bring DIP to a positive balance. For example, if the MP balance

Table 1. Composition of diet (% DM) fed to steers during WINTER[a] and SUMMER[b] trials

	Treatment					
	Winter			Summer		
Item[c]	Control	Phase 1[d]	Phase 11[d]	Control	Phase 1[d]	Phase 9[d]
DRC[e]	74	74	74	83	83	83
WCGF[f]	8	8	8	—	—	—
Alfalfa Hay	7	7	7	7	7	7
Molasses	5	5	5	5	5	5
Supplement	6	6	6	5	5	5
Urea	0	0.25	0	1.17	0.78	0.33
Soypass	4	2.47	0	0	0	0
Composition						
CP	12.3	13.5	11.5	14.2	12.8	11.3
DIP[g]	-45	2	-96	77	80	253
MP[h]	32	0	101	42	-27	-125

[a]WINTER calves fed from November to May.
[b]SUMMER yearlings fed from May to September.
[c]% of DM.
[d] Each diet phase is 14 days; Phase 1 is first finisher diet, Phase 11 is last diet fed for WINTER, Phase 9 is last diet fed for SUMMER.
[e]Dry-rolled corn.
[f]Wet corn gluten feed.
[g,h]Values from 1996 Beef NRC Level 1 model; inputs were expected feedlot performance of 3.50 ADG and 21 lb/day DMI.

Table 2. Performance of steer calves fed during WINTER.

Item	CONTROL	PHASE	SEM	P-value
Initial BW, lb	647	648	0.5	0.38
Final BW, lb	1273	1298	7	0.09
DMI, lb/d	22.0	21.5	0.17	0.20
ADG, lb	3.56	3.62	0.05	0.11
Feed:gain	6.17	5.95	—	—
Hot carcass weight, lb	802	809	5	0.52
Marbling score[a]	566	531	15	0.52
12th rib fat, inches	0.43	0.41	0.01	0.69

[a]Marbling score: 450 = slight^{50}, 500 = small^{00}, and 550 = small^{50}.

Table 3. Performance of steer calves fed during SUMMER.

Item	CONTROL	PHASE	SEM	P-value
Initial BW, lb	823	824	2	0.88
Final BW, lb	1254	1235	11	0.22
DMI, lb/d	22.0	21.5	0.4	0.08
ADG, lb	3.68	3.51	0.09	0.23
Feed:gain	6.28	6.30	—	—
Hot carcass weight, lb	750	743	5	0.40
Marbling score[a]	464	462	9	0.86
12th rib fat, inches	0.43	0.35	0.04	0.08

[a]Marbling score: 450 = slight^{50}, 500 = small^{00}, and 550 = small^{50}.

was +30 but the DIP balance was - 26, then we assumed that 26*(80% true protein)*(80% digestibility) = 16.64g of MP would not be produced. The actual MP supply was then reduced by this amount to result in a MP balance of +13.4. The final step was to add urea to the diet to bring the DIP balance from - 26 up to - 13.4 and thus be in zero balance. In this diet, a dry supplement containing urea was changed every 14 days to match the 1996 NRC computer model predictions for the MP balance of the animals. Therefore, CP levels for PHASE decreased across the feeding period as the animal's requirement for protein concurrently decreased (13.5 to 11.5% CP in WINTER; 12.8 to 11.3% CP in SUMMER).

On day 1, WINTER steers were initially implanted with Synovex-C® (Fort Dodge Animal Health, Overland Park, Kan.) followed by Revalor-S® (Intervet, Inc., Somerville, N.J.) on day 63. SUMMER yearling steers were implanted on day 1 with Synovex-C® (Fort Dodge Animal Health, Overland Park, KS) and reimplanted on day 35 with Revalor-S® (Intervet, Inc., Somerville, N.J.). Carcass data were collected upon completion of experiments at a commercial abattoir. At harvest, HCW were recorded. Final BW was calculated using a common dressing percentage (63%). Following a 24-hour chill, fat thickness at the 12th rib and LM area were collected. Marbling scores were determined by a USDA grader. USDA (1989) Yield Grade was calculated with the following equation: YG = 2.50 + (2.50 × fat thickness, inches) + (0.20 × Kidney, Pelvic and Heart Fat %) + (0.0038 × HCW, lb)- (0.32 × REA, in^2).

Nutrient balance

Nitrogen mass balance was conducted to assess the impact of dietary treatment on N flow in 12 open feedlot pens with a stocking density of 332 ft^2. Animals were fed in the morning. Seven earthen retention ponds collected runoff from the 12 pens. In the case of a runoff event, effluent was collected in the retention ponds, drained through a PVC pipe, sampled, and quantified using an ISCO model 4230 air-bubble flow meter (ISCO, Lincoln, Neb.)

Throughout the feeding period, feed refusals were collected. After cattle were removed from the pens for slaughter, manure was piled on the pen surface. Twenty four subsamples were taken as the wet manure was being loaded out of the pens. Manure was weighed on an as-is basis and hauled to the University of Nebraska compost yard.

Before initiation of the WINTER trial, 16 soil core samples (5.9 inch depth, 1.0 inch diameter soil probe) were taken from each pen and six samples from each retention pond. Core locations were evenly spaced throughout the pen on a grid pattern. Each core represented 165 ft^2. Soil samples were used to correct for manure/soil mixing by cattle activity throughout the experiment and pen cleaning variation. Time between the WINTER and SUMMER trials was 9 days; therefore, cores taken following the WINTER trial were used for the initiation of the SUMMER trial. During this 9-day period following core sampling, runoff was collected and attributed to the SUMMER trial.

Nitrogen intake was calculated using analyzed individual dietary ingredient N content multiplied by DMI, corrected for amount and N content of feed refusals. Net protein and net energy equations established by the NRC (1996) were used to calculate N retention. Nitrogen excreted (urine plus feces) was determined by subtracting N retention from N intake. Manure N was determined by multiplying manure N concentration by manure amount removed from the pen surface on a DM basis. Manure N values were corrected for soil contamination by subtracting the quantity of N in the soil from quantity of manure N. Runoff N was the N concentration from the runoff multiplied by the gallons of water collected. Total N lost (lb/steer) was calculated by subtracting manure N (corrected for soil N content) and runoff N from excreted N. Percentage of N lost was calculated as N lost divided by N excretion. In addition to the mass balance technique, ammonia emissions were measured weekly during the last five (WINTER) or six (SUMMER) weeks of the feeding period using forced air wind tunnels and a sulfuric acid trap for 30 minutes in each pen.

Statistical analysis was conducted using the PROC MIXED procedure of SAS to compare the two treatments.

Results

Feedlot Performance

Performance measurements for PHASE were equal to or better than CONTROL in both WINTER

(Continued on next page)

and SUMMER (Tables 2 and 3). In WINTER calves, PHASE tended to have greater (P= 0.11) ADG than CONTROL and similar (P= 0.20) DMI. However, PHASE calves had significantly lower (P= 0.02) F:G. Carcass characteristics were similar (P> 0.10) for all measured traits. In SUMMER yearlings, ADG was similar but PHASE had lower (P= 0.08) DMI than CONTROL. Even though DMI was lower for PHASE, ADG was not significantly improved compared to CONTROL treatment, therefore, F:G was similar between treatments. CONTROL had greater (P= 0.08) fat thickness than PHASE, but all other carcass characteristics were not different from CONTROL. These data demonstrate PHASE cattle were able to perform similar to CONTROL at low levels of CP (< 12%) compared to the industry average of 13.5% CP.

Nutrient Balance

Nitrogen mass balance results are presented in Tables 4 and 5. As designed, PHASE had lower (P<0.01) N intakes than CONTROL for both SUMMER and WINTER trials. N retained was similar between CONTROL and PHASE treatments (P> 0.10; 12.8 lb/steer WINTER and 6.9 lb/steer SUMMER). Therefore, N excretion was greater (P<0.01) for CONTROL cattle than PHASE in both SUMMER and WINTER trials. WINTER PHASE excreted 59.8 lb/steer compared to 66.3 lb/steer for CONTROL treatment. Manure N, soil N, and runoff N were similar (P> 0.05) between treatments. However, there was a tendency for WINTER PHASE to have lower N loss than CONTROL (35.6 vs. 29.2 lb/steer, respectively).

SUMMER PHASE excreted 42.4 lb/steer compared to 54.8 lb/steer for the CONTROL treatment. Manure N, soil N, and runoff were similar (P> 0.05) between treatments. However, there was a significant (P= 0.02) decrease in N lost for PHASE cattle compared to CONTROL (38.6 lb/steer and 28.2 lb/steer, respectively).

WINTER ammonia emissions were not different between the CON and PHASE pens (29.51 and 32.46 g/head/day) as measured by forced air wind tunnel (*2006 Nebraska Beef Report,* pp. 91-93). There was a significant effect of time across wk (P<0.01) for ammonia measured with the wind tunnel, but no treatment by time interaction (P= 0.24). SUMMER ammonia emissions were also not different between the CON and PHASE pens (19.41 and 19.84 g/head/day) as measured by forced air wind tunnel.

Seasonal ambient temperature differences are positively correlated to volatile N losses. Manure, corrected for soil contamination, contained 19.5% more N in WINTER than SUMMER. Therefore the SUMMER trial experienced more N losses (68%) as a percentage of N excreted than WINTER (51%). Compared to previous research *(2003 Nebraska Beef Cattle Report,* pp. 54-58) PHASE volatile N losses were greater during winter months (29.1 vs 48.8%, respectively) and summer months (56.4 vs 66.5%, respectively). These differences may be attributed to yearly climatic variation. The average temperature during WINTER of this study was 39°F with 14.3 inches of precipitation while the average temperature during the winter *(2003 Nebraska Beef Cattle Report,* pp. 54-58) study was 33°F with 12.8 inches of precipitation. Therefore the moist and warmer winter conditions of this trial can explain the greater volatilization of N than previous research. SUMMER temperatures were similar in this study (71°F) when compared to previously published data (*2003 Nebraska Beef Cattle Report,* pp. 54-58; 71°F) but precipitation was greater in the present study (12.0 inches vs 10.5 inches, respectively).

Phase feeding significantly improved performance in the WINTER and was similar to CONTROL in SUMMER. In both trials N volatilization was reduced without impacting N removed in manure. These data demonstrate that phase feeding may be a viable option to decrease N excretion and volatilization from feedlot pens while maintaining or improving animal performance.

Table 4. Nitrogen mass balance during WINTER expressed as lb/steer.

Item	CONTROL	PHASE	SEM	P-value
N intake	79.0	72.8	0.9	<0.01
N retention[a]	12.8	13.0	0.2	0.51
N excretion[b]	66.3	59.8	0.7	<0.01
Manure N[c]	23.8	25.3	2.7	0.71
Soil core N	4.3	3.0	1.5	0.54
Runoff N	2.7	2.4	0.4	0.55
N lost[d]	35.6	29.2	2.6	0.11
N loss, %[e]	53.7	48.8	2.4	0.44

[a]Calculated using NRC 1996 net protein and net energy equations.
[b]Calculated as N intake minus N retention.
[c]Calculated for pen soil N balance.
[d]Calculated as N excretion minus manure N (corrected for soil) and runoff N.
[e]Calculated as N lost divided by N excreted

Table 5. Nitrogen mass balance during SUMMER expressed as lb/steer.

Item	CONTROL	PHASE	SEM	P-value
N intake	61.8	49.2	1.0	<0.01
N retention[a]	6.9	6.8	0.2	0.74
N excretion[b]	54.8	42.4	0.9	<0.01
Manure N[c]	10.8	8.1	2.0	0.35
Soil core N	4.1	4.7	1.5	0.79
Runoff N	1.3	1.4	0.2	0.81
N lost[d]	38.6	28.2	2.5	0.02
N loss, %[e]	70.4	66.5	2.0	0.58

[a]Calculated using NRC 1996 net protein and net energy equations.
[b]Calculated as N intake minus N retention.
[c]Calculated for pen soil N balance.
[d]Calculated as N excretion minus manure N (corrected for soil) and runoff N.
[e]Calculated as N lost divided by N excreted.

[1]Stephanie Quinn, graduate student; Galen Erickson, assistant professor; Terry Klopfenstein, professor; Rick Stowell, professor; and Dawn Sherwood, graduate student, Animal Science, Lincoln.

Changes in Gain Through the Feeding Period

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Kyle J. Vander Pol[1]

Summary

Three years of research trials were compiled to determine how weight gain changes throughout the feeding period. Results suggest that body weight and carcass weight increase linearly through the feeding period. While daily gain decreases on a body weight basis, it remains constant on a carcass basis suggesting that nearly all of the weight gain is transferred to the carcass at the end of the feeding period.

Introduction

Beef producers now have a variety of marketing options when selling fed cattle. Most options result in prices paid per pound of live animal weight or carcass weight. It is important to know an optimum marketing date to maximize profitability; however, optimum marketing date encompasses a variety of factors and may depend on marketing strategy used. Profitability can generally be increased until a point at which the cost of producing an additional unit of weight (live or carcass) becomes greater than the price received for the additional unit of weight. In order for producers to make appropriate decisions about optimal marketing date for each marketing option, it is important to know what happens to animal gain and feed conversion on a live weight and carcass weight basis throughout the feeding period. Information related to the end of the feeding period when marketing decisions are made is especially important. The purpose of this report is to document changes in animal gain and feed conversion on a live weight and carcass weight basis by compiling data from previous research trials conducted at the University of Nebraska.

Procedure

Three years of data were compiled to determine how weight, gain, dry matter intake, and feed conversions change throughout the feeding period on a shrunk body weight basis and carcass weight basis. The data set included 115 pens of steers from three research trials consisting of 920 head. The trials were selected because all steers within a trial were on similar diets, treatments had no effect on animal performance, and interim weights were collected on individual animals throughout the feeding period. Average initial body weight was 750 lb (SD=43 lb) and steers were on feed for 120 to 150 days from May to September or October. Individual animal weights were collected at approximately 30-day intervals which resulted in four or five interim weights collected for each steer. Initial body weights were collected for at least two consecutive days following three days of limited intake to equilibrate gut fill. However, interim weights were single day full fed weights which were shrunk 4%.

Interim carcass weights were calculated using a dressing percentage based on the amount of time steers had been on feed. Changes in dressing percentage with time on feed were determined by reviewing published research trials in which cattle were serially slaughtered and dressing percentages reported. Two studies meeting these criteria were identified. One was a calf-fed study (187 days on feed to achieve 0.55 inch 12th rib fat thickness) and the other used yearlings (112 days on feed to achieve 0.57 inch 12th rib fat thickness). Since studies had groups of cattle that were serially slaughtered until 12th rib fat thickness was greater than industry averages, cattle groups that were slaughtered with an average 12th rib fat thickness that was nearest to 0.50 inch were used for final dressing percentages. The data were extrapolated to the intercept to determine dressing percentage at day 0. Dressing percentage was regressed on days on feed expressed as a percentage of total days on feed. Expressing days on feed as a percentage of total days on feed was necessary since the two trials varied by 75 days in the amount of time necessary to reach 0.50 inch 12th rib fat thickness.

Changes in weight, weight gain, dry matter intake, and feed conversion were calculated for each interim period and expressed on a shrunk body weight and carcass weight basis. Regression analysis was conducted using the mixed

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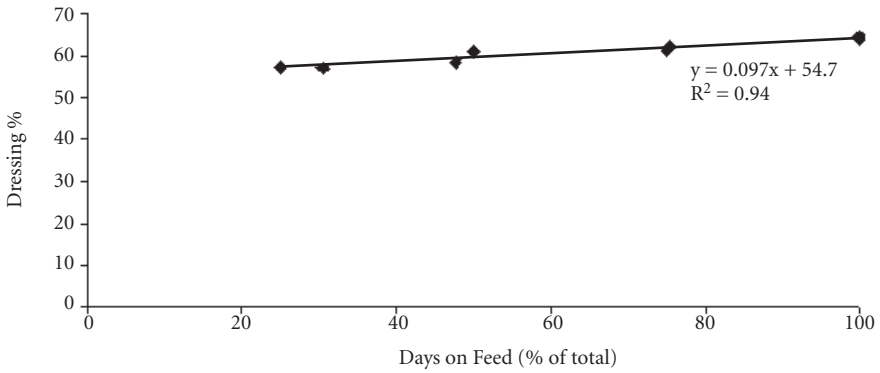

Figure 1. Change in dressing percent as a function of time on feed. Data were combined from two published trials in which cattle were serially slaughtered and dressing percentages reported. Groups of cattle slaughtered with an average 12th rib fat thickness of 0.55 inch or 0.57 inch were used for final dressing percentages. The intercept is an extrapolation of the data sets. Data are expressed as a percent of total days on feed because one trial used calf-feds (187 days on feed at 0.55 inch 12th rib fat thickness) and the other used yearlings (112 days on feed at 0.57 inch 12th rib fat thickness).

procedures of SAS with repeated measures of all response variables. Some trials contained different weight blocks. Therefore, trial and block within trial were included as random variables.

Results

Analysis of the two published trials suggests that dressing percent increased in a linear rate with time on feed (Figure 1). Remarkably, the calf-fed and yearling studies closely agreed in how dressing percentage changes when days on feed are expressed as a percent of total days on feed. This linear equation may be used to calculate expected carcass weight from shrunk body weight (full body weight * 0.96) at any time during the feeding period.

Analysis of the three years of research trials suggests that shrunk body weight and carcass weight both increased in a linear manner ($P<0.01$; Figure 2). However, while shrunk body weight gain decreased through the feeding period ($P<0.01$; Figure 3), carcass weight gain remained constant as suggested by a slope that is not different from 0 ($P=0.33$; Figure 3). When carcass weight gain is expressed as a percentage of body weight gain, the transfer of weight to the carcass can be estimated. These data are provided in Figure 4. The percentage of body weight gain that is transferred to the carcass increased linearly ($P<0.01$) as the feeding period progressed and approached 100% at the end of the feeding period. This suggests that every pound of additional body weight gain at the end of the feeding period was transferred directly to the carcass and resulted in an additional pound of carcass weight. Dry matter intake also increased linearly through the feeding period ($P<0.01$; Figure 5). Feed conversions (Figure 6) increased through the feeding period on both a carcass weight basis ($P<0.01$) and a shrunk weight basis ($P<0.01$). While slopes were not compared, the change in feed conversion on a body weight basis was more than double the change in

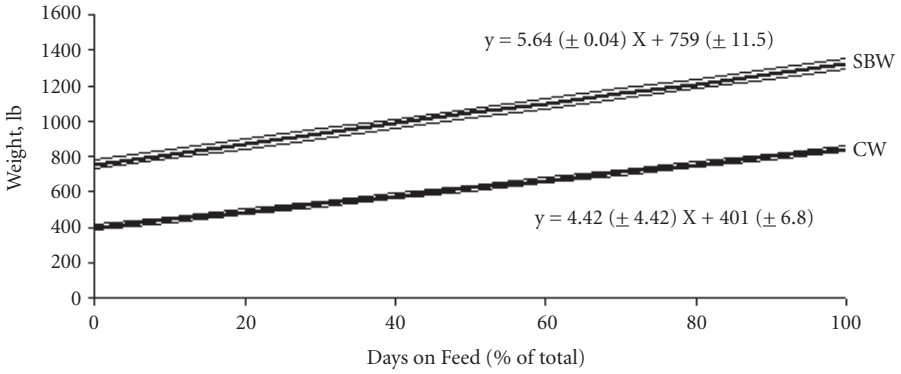

Figure 2. Changes in shrunk body weight (SBW) and carcass weight (CW) as a function of time on feed. SBW slope > 0 ($P<0.01$). CW slope > 0 ($P<0.01$). Heavy lines are means and light lines are 95% confidence intervals.

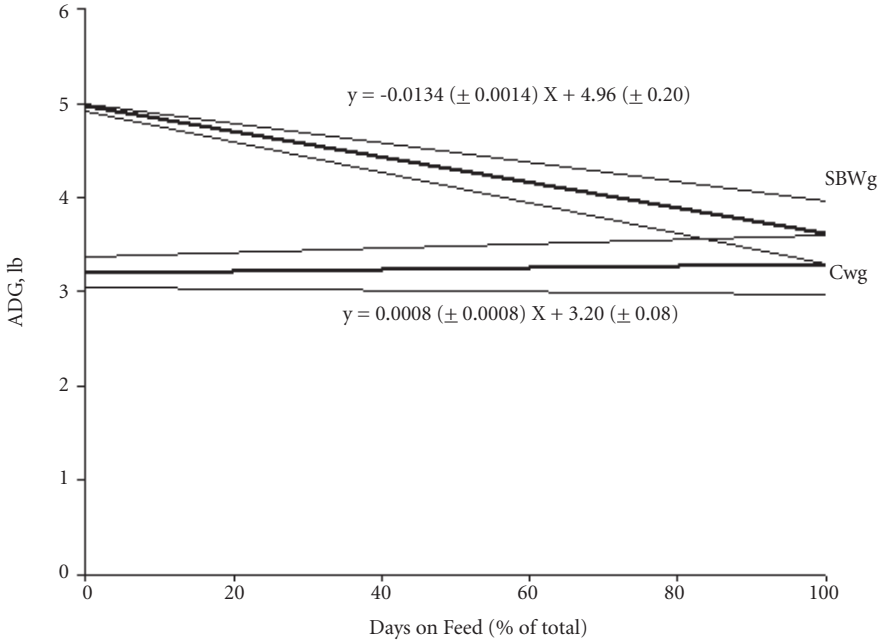

Figure 3. Changes in shrunk body weight gain (SBWg) and carcass weight gain (CWg) as a function of time on feed. SBWg slope > 0 ($P<0.01$). CWg slope > 0 ($P=0.33$). Heavy lines are means and light lines are 95% confidence intervals.

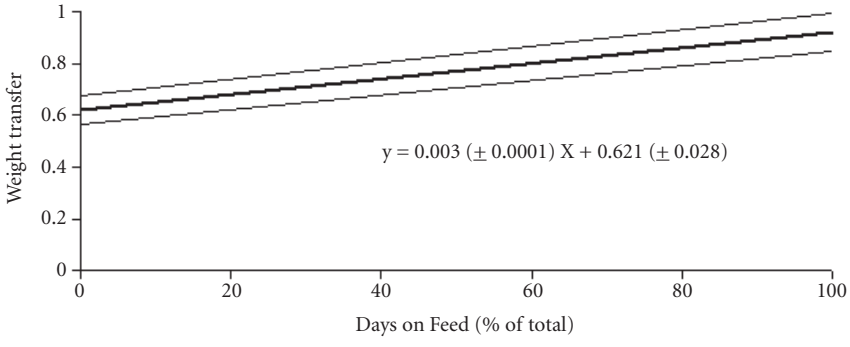

Figure 4. Transfer of weight from shrunk body weight to carcass weight as a function of time on feed. Slope > 0 ($P<0.01$). Heavy line is the mean and light lines are 95% confidence intervals.

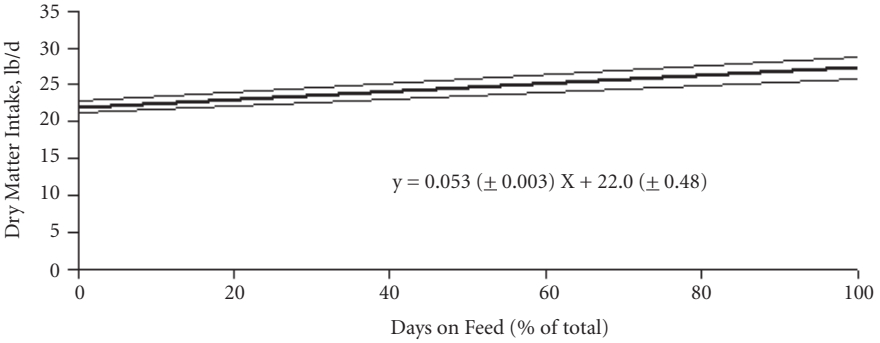

Figure 5. Changes in dry matter intake as a function of time on feed. Slope > 0 (*P*<0.01). Heavy line is the mean and light lines are 95% confidence intervals.

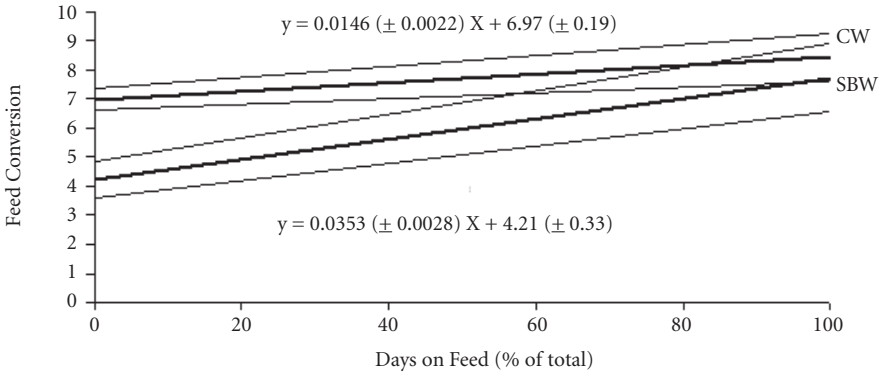

Figure 6. Changes in feed conversion on a shrunk body weight (SBW) and carcass weight (CW) basis as a function of time on feed. CW slope > 0 (*P*<0.01). . SBW slope > 0 (*P*<0.01). Heavy lines are means and light lines are 95% confidence intervals.

feed conversion on a carcass weight basis such that feed conversions were similar on a body weight and carcass weight basis at the end of the feeding period.

This information is important to producers as they determine marketing strategies. Producers marketing cattle on a live weight basis may choose to market cattle earlier because shrunk body weight gain and feed efficiency are decreasing. Producers marketing cattle on a carcass weight basis or on a grid formula may feed cattle longer because carcass weight gain is not reduced. These data are concurrent with previous research that suggests that producers marketing on a grid formula may benefit by continuing to feed cattle until 10-15% are discounted because carcass weights are increasing (*2002 Nebraska Beef Report*, pp. 39-41).

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Comparison of a Long Yearling System and Calf-fed Performance and Economics

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Summary

A study was conducted to determine differences in performance, carcass characteristics, and profitability of a calf-feeding and a yearling production system. Yearlings had higher daily gains compared to calf-feds; however, calf-feds were more efficient than yearlings. Yearlings produced more weight than calf-feds leading to an improvement in profitability for yearlings compared to calf-feds. There were no differences in yield grade or percentage grading Choice for yearlings compared to calf-feds, even though calf-feds had higher fat thickness compared to yearlings.

Introduction

There are two major types of cattle production systems. One is an extensive system where cattle are placed in a backgrounding program after weaning and before finishing. The other is an intensive system where cattle are weaned and fed a high concentrate diet until slaughter.

Heavier calves are suited for intensive finishing systems which results in acceptable carcass weights at a quality grade of Choice. If larger framed animals are placed in an extensive production system, animals may become too heavy and produce overweight discounts. In contrast, lighter, smaller framed animals can be grown for a period of time in an extensive system and still be slaughtered at acceptable weights. Smaller framed animals can enter intensive production systems; however, this leads to lighter carcasses and decreased profitability because of the amount of weight sold.

Therefore, the objectives of this study were to compare a calf- and a yearling-finishing system by analyzing performance, carcass characteristics, and profitability.

Procedure

Experiments

The calf vs. yearling system comparison used data from the University of Nebraska from 1996-2004. Data used in this project are from a calf-feeding or a yearling grow/finish experiments conducted each year except for 1997, where a different yearling production system was used. Calf-finishing trials beginning in the fall each year were selected for comparisons Calves were sorted from a large pool of animals received during the fall of each year and sorted by weight. Heavier, larger framed steers from this sort were placed into a calf-feeding system. Lighter, smaller framed steers were purchased each year and placed into a yearling finishing system. The calf system represents 804 head of steers fed in 80 pens and the yearling system represents 302 head of steers fed in 18 pens.

Calf Trials

Calf trials used in this study were selected based on the composition of the finishing diet. Finishing diets had to contain 25 - 40% wet corn gluten feed (WCGF) and either dry rolled of high moisture corn. Inclusion of WCGF at levels of 25 - 40% have not shown any differences in finishing performance of steers. Calves where weaned in the fall, acclimated to the feedlot for 20 to 40 days and placed directly on feed until slaughter in late April to early May, depending on the year.

Yearling Trials

Steers were purchased in the fall and placed on to cornstalks from December 1st until April 20th of each year. During the wintering period steers were supplemented 5 lb/head daily of WCGF to achieve a gain of 1.5 lb/day. After the wintering period steers were placed on brome grass pasture until the middle of May and then moved to Sandhills range until September. After completion of the summer grazing period steers were placed into the feedlot and fed until slaughter. The finishing diet contained 40% WCGF and 45% of either dry rolled or high moisture corn, depending on the year. As with the calf-feds the control cattle from the yearling studies were used to make comparisons between yearlings and calf-feds

Economic Analysis

Initial animal price in both systems was determined using a slide of $3.20/cwt and the USDA 1998-2004 average December feeder cattle price of $ 98.98/cwt for a 600 lb steer. The average December price was determined by averaging the price of a 550 lb steer ($ 102.97/cwt) and a 650 lb steer ($ 94.98/cwt). The price slide was determined from the actual purchase prices for cattle purchased by the University of Nebraska from 2000-2005. After determining the average December price for a 600 lb steer, the slide was used to adjust the price paid for the steers, using the weight of the steers at initiation of experiments.

The interest rate used was determined using the seven-year average prime interest rate. The interest rate used is equal to prime plus 1% for the months that cattle were owned (6.6%). The interest rate was the same for both calf-feeding and yearling cost. Therefore, all costs are assessed as interest rate of 6.6%.

Calf Finishing Economics

Calf-finishing slaughter breakevens were calculated on pens of animals from each of the respective trials. Initial animal cost was determined using the average price ($97.37/cwt)

times the BW. Interest was applied to initial cost of the animal over the entire ownership. Health, processing, and implanting were assessed a flat rate of $ 16.66/head. Feed costs for calf-feds were based on the seven-year average price of ingredients for the months that ingredients were used. Depending on type of corn processing used in the calf feeding trials a processing charge was applied to the cost of corn. Wet corn gluten feed was priced as 95% the price of corn using the seven-year average price for corn. The average ration cost for calf-fed diets was $ 104.28/ton (DM-basis). Yardage was charged at a rate of $0.33/head daily. Interest was charged on finishing diet and yardage for half of the feeding period. A 2% death loss was applied to the calf-feds. To calculate slaughter breakeven, total cost was divided by slaughter weight.

Yearling Grow/Finishing Economics

Initial steer cost was determined using the average price ($101.44/cwt) times the BW. Health and processing were charged at $8.33/head for the winter period and a 1.5% death loss was assumed. Simple interest was charged on initial animal cost and health for the entire period of ownership.

The cost of corn residue was charged at a rate of $0.32/head daily. This cost includes $0.12/head for the rent of cornstalk residue and $0.20/head daily charged as yardage while steers grazed cornstalk residue. This yardage cost includes the cost of fencing stalk fields and cost of labor to deliver WCGF and water to the cattle. Steers were supplemented with 5 lb/head daily of WCGF for the winter period at a cost of $84.20/ton (DM basis). Interest was charged on the WCGF for half of the winter period and the remainder of ownership.

Summer grazing cost was charged using the seven-year average animal unit month (AUM) value of $23.29 for native range. To determine the animal unit equivalent of the steers used in this study the initial weight and weight of cattle when they were removed from grass was averaged and divided by 1,000 lbs.

Cattle were charged $8.33 for summer health cost and a death loss of 0.5% was assessed during the summer grazing period. Interest was charged for the cost of the AUM and health cost.

Finishing costs for yearlings were similar to calf-feds using the same yardage rate of $0.33/head daily. Feed ingredients were priced using the seven-year average for ingredients the month they were used. The average cost of the yearling diet was $96.08/ton. There was no death loss or medical charges assessed during the finishing period for the yearling cattle. Average DMI for each pen was used to determine total feed consumption during the finishing period. Interest was charged on finishing diet and yardage for half of the feeding period. To calculate slaughter breakeven, total cost was divided by slaughter weight.

Profit was calculated two ways. Profit was calculated using seven-year average live price for the month of May (calf-fed; $72.68/cwt) and December (yearling; $74.23/cwt) and subtracting the total cost of production from the value of the animal. Second, profit was calculated by selling cattle on the rail in a value based market that rewards for quality. The grid used was calculated using two-years of grid prices from the plant where these cattle were sold and averaging the premiums and discounts received for the carcasses. The grid used is presented in Table 1. The base carcass for this grid was a carcass with a minimum quality grade of Choice^0 and an Yield Grade 3 carcass. The base price used for the animal was the average Nebraska dressed fed cattle price of a Yield Grade 3, Choice^0 for calf-feds in May ($120.69/cwt) and yearlings in December ($121.52/cwt) from 1998 to 2004. This price was calculated using the Nebraska Dressed Price (1998 to 2004) adjusted by adding the sum of 1 minus the average Choice grading percentage for the month of May for calf-feds and December for yearlings multiplied by the Choice/Select spread for the month of May and December.

Table 1. Premiums and discounts for grid marketing analysis.

Item, $/cwt	Calf-fed	Yearling
Prime	8.00	8.00
Upper Choice	3.00	6.00
Choice	0.00	0.00
Select	-9.01	-8.10
Standard	-10.50	-15.00
Yield Grade 1	8.00	3.00
Yield Grade 2	4.00	3.00
Yield Grade 3	0.00	0.00
Yield Grade 4	-10.00	-10.00
Yield Grade 5	-15.00	-17.49
Carcass weight > 950 lbs	-10.00	-10.00
Carcass weight > 1000 lbs	-20.00	-20.00

Results

Animal Performance and Carcass Characteristics

Animal performance data are presented in Table 2. At receiving calf-feds were 116 lb heavier ($P<0.01$) than steers entering the yearling/grow finish system. However, when comparing calf-feds to yearlings at feedlot entry the yearling cattle were 315 lb heavier ($P<0.01$) than calf-feds. The increase in initial feedlot BW led to a 83 lb heavier ($P<0.01$) final BW for yearling cattle compared to calf-feds. Yearlings consumed more DM/d ($P<0.01$) compared to calf-feds. Calf-feds consumed 838 lb more total DM ($P<0.01$) during the finishing period compared to yearlings. The increase in total DM is because calf-feds were fed 78 days longer ($P<0.01$) than yearlings. Yearlings had 0.72 lb greater ($P<0.01$) daily gain compared to calf-feds; however, calf-feds were 16.7% more efficient ($P<0.01$) than yearlings. Carcass characteristics of yearlings and calf-feds are presented in Table 3. When comparing hot carcass weight, yearlings were 52 lb heavier than calf-feds ($P<0.01$).

Calf-feds had greater fat thickness ($P<0.01$) compared to yearlings, however, marbling was not different ($P= 0.21$) when comparing production systems. There was no difference in the percentage of animals grading Choice or higher ($P=0.13$) or USDA yield grade ($P=0.46$) when comparing production systems.

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Economic Results

Results from the economic analyses are presented in Table 4. Initial animal cost was $93.96 ($P<0.01$) higher for calf-feds compared to yearlings, because the calf-feds were 116 lb heavier at receiving than yearlings. During the yearling growing phase, winter cost of grazing corn stalks and supplementing WCGF totaled $78.72 and Sandhills Range rental was $90.10 for the summer grazing period. When comparing the cost of the finishing periods the calf-feds had $25.80 ($P<0.01$) higher yardage cost due to increased days on feed, and $54.63 ($P<0.01$) more feed cost due to increased total feed consumption. However, yearlings accrued $25.60 ($P<0.01$) more interest during ownership due to the increase in the length of ownership compared to calf-feds. Death loss was not different, when considering the percentage of animals that died before harvest; however, the cost of yearling death loss was $0.31 more per head ($P=0.02$) than calf-feds, because some yearlings died in the summer grazing period after wintering cost of production had occurred and the animal was heavier when it died compared to calf-feds.

When comparing total cost of production, breakevens, and cost of gain across production systems, yearlings had a slight advantage due to increased total weight gain in the production system and low input cost in the winter and summer growing periods of production. Total cost of production was $20.80/head higher for yearling cattle ($P=0.02$) compared to calf-feds; however breakevens ($/cwt) were $2.88 lower for yearling cattle ($P=0.04$) compared to calf-feds. The advantage in breakevens for yearling cattle is due to the increase in weight gain during the production system and yearling cost of gain during production was not different compared to calf-feds. When comparing live and grid values of yearlings and calf-feds; yearlings were $80.63 ($P<0.01$) and $62.53 ($P<0.01$) more valuable than calf-feds, respectively. The increase in yearling value led to a $60.04 ($P<0.01$) and $41.91 ($P<0.01$) higher profitability for yearlings compared to calf-feds, respectively.

Table 2. Animal performance as a main effect of treatment

Item	Calf-fed	Yearling	SEM
Initial BW, lb	642[a]	526[b]	5
FINT[c], lb	642[a]	957[b]	7
Final BW, lb	1282[a]	1365[b]	8
Feedlot ADG	3.81[a]	4.53[b]	0.04
DOF[d]	168[a]	90[b]	1
DMI, lb/d	21.36[a]	30.56[b]	0.15
F/G	5.63[a]	6.76[b]	0.02
Total Feed[e], lbs	3591.9[a]	2754.0[b]	32.1

[ab]Means within a row with different superscripts differ ($P<0.01$).
[c]FINT = initial BW at the beginning of the finishing period.
[d]DOF = days on feed.
[e]Total Feed = amount of feed consumed during the finishing period.

Table 3. Carcass characteristics as a main effect of treatment.

Item	Calf-fed	Yearling	SEM
Carcass weight, lb	808[a]	860[b]	5
Fat thickness, in	0.53[a]	0.47[b]	0.01
Yield grade	2.71	2.60	0.14
Marbling Score[c]	510	525	9.9
% Choice	58.4	65.0	3.8

[ab]Means within a row with different superscripts differ ($P<0.01$)
[c]Marbling score = 400=slight[0], 500=small[0], etc.

Table 4. Economic analysis as a main effect of treatment

Item	Calf-fed	Yearling	SEM
Steer cost, $	627.50[a]	533.54[b]	5.11
Wintering cost, $		78.72	
Summer cost, $		90.10	
Interest[c], $	24.95[a]	50.55[b]	1.19
Feed cost, $	188.34[a]	133.71[b]	6.54
Yardage, $	55.58[a]	29.78[b]	1.90
Death loss, $	13.43[a]	13.74[b]	0.10
Total Cost, $	925.09[a]	945.89[b]	7.07
COG[cd], $	42.97	43.32	1.24
Breakeven[d], $	72.26[a]	69.38[b]	1.12
Live Value[e], $	932.28[a]	1012.91[b]	19.26
Grid Value[f], $	955.19[a]	1017.72[b]	15.95
Live p/l[g], $	6.83[a]	66.87[b]	15.40
Grid p/l[g], $	29.68[a]	71.59[b]	10.53

[ab]Means within a row with different superscripts differ ($P<0.05$)
[b]Interest is the total amount of interest accrued from the animal and all cost of production.
[c]All prices on a cwt carcass basis.
[d]COG is the cost of gain for the entire production system.
[e]Live sale price of $74.23/cwt for yearlings and $72.68/cwt for calf-feds.
[f]Carcass base price of $121.52/cwt for yearlings and $120.69/cwt for calf-feds.
[g]p/l is profit or loss.

Yearlings have an advantage in performance in the feedlot due to the increased gain and less feed consumed during the finishing period. However, yearlings require more days of ownership in order to reach harvest. Even though calf-feds may be more efficient in gain, yearlings are more profitable than calf-feds, having lower breakevens than calf-feds, because yearlings produce more weight and exhibit no difference in marbling scores and yield grades.

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Effect of Sorting and Feeding Optaflexx on Performance and Economics of Long Yearling Steers

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Summary

A two-year experiment evaluated the effects of sorting long yearling steers by initial feedlot BW and supplementing 200 mg/steer of Optaflexx daily the last 28 days of the feeding period on ADG, F/G, carcass characteristics and profitability. Feedlot ADG, F/G, and profitability were not effected by sorting. However, sorted cattle exhibited increased fat thickness, increased ribeye area, and increased percentage of carcasses with a yield grade of four or higher. Supplementing Optaflexx the last 28 days of the feeding period had no effect on feedlot performance, carcass characteristics, or profitability.

Introduction

Sorting may be used in production systems to reduce variability or reduce overweight carcasses and BW of yearlings entering the feedlot is a good predictor of final BW (*2003 Nebraska Beef Report*, pp. 61-65).

Optaflexx, the trade name for ractopamine hydrochloride, is a βeta-1 adrenergic agonist that increases weight gain the last 28 to 42 days of the finishing period. However, data on the use of Optaflexx in long yearling production are limited.

Therefore, the objectives of this study were to 1) to determine the effects on performance and economics of sorting yearling steers by initial BW, and to 2) determine the effects of feeding 200 mg/steer daily of Optaflexx the last 28 days to yearling steers.

Procedure

Yearling Steer Development

Two hundred medium-framed English-cross steers (517 ± 46 lb) were used in each year of a two-year study conducted from December 2003 to January 2006. Steers were purchased in the fall and were allowed a 28-day adaptation period prior to the beginning of the trial. Steers were managed as one group in the winter and allowed to graze cornstalk residue from December 2nd until April 20th in year 1 and November 11th until April 20th in year 2. Steers were supplemented 5 lb/steer daily of wet corn gluten feed (WCGF) for the entire wintering period to achieve a gain of at least 1.5 lbs/day.

On April 20th of each year cattle were implanted with Revelor-G and placed on smooth brome grass pastures near Mead, Neb., until May 20th. On May 20th steers were transported to native warm-season grass pastures near Rose, Neb. Cattle were removed from pasture on September 8th in year 1 and September 13th in year 2. While on grass steers were managed as one group.

Finishing Period

Steers were adapted to the final finishing diet in 21 days using four step-up diets containing 45, 35, 25, and 15% roughage, fed for 3, 5, 6, and 7 days, respectively. The final finishing diet contained 48% high moisture corn, 40% WCGF, 7% alfalfa, 5% supplement, and contained a minimum of 12% CP, 0.7% Ca, 0.35% P, 0.6% K, 30g/ton Rumensin, and 10g/ton Tylan. Half the cattle in this experiment were supplemented Optaflexx the last 28 days of the feeding period at a rate of 200 mg/steer daily.

Initial and final weights for all periods of the system were based on 2 day consecutive weights following 5 days of limit feeding 50% alfalfa and 50% WCGF fed at 2% of BW. All steers were implanted with Synovex-Choice, weighed, and sorted into pens at feedlot initiation. Final BW was calculated assuming a constant dressing percent of 63%. Steers were harvested at the same commercial abattoir. On the day of slaughter hot carcass weight (HCW) and liver scores were collected. Following a 48-hour chill 12th rib fat thickness (FT), ribeye area (REA), USDA Yield Grade (YG), and USDA quality grade were collected.

Sorting

In both years after the summer grazing period, steers were weighed and stratified into groups of 25 by BW, with each group having equal average BW. Steers were then allotted to one of four treatment groups. The treatments were 1) sorted without Optaflexx supplementation, 2) sorted with Optaflexx supplementation, 3) Unsorted without Optaflexx supplementation, and 4) Unsorted with Optaflexx supplementation. Steers that were sorted were placed into one of three sort groups, the heavy sort (32%, BW = 1030 lb) contained eight steers per replication, the medium sort (44%, BW = 950 lb) contained 11 steers per replication, and the light sort (24%, BW = 878 lb) contained six steers per replication. Steers in the unsorted control (BW = 959 lbs) were fed for an average of 111 days. Steers in the heavy group were fed for an average of 96 days and were marketed two weeks earlier than the unsorted controls. Because of the removal of the heavy steers, the middle sort was fed for an average of 118 days, and marketed one week later than the unsorted controls. Steers in the light sort were fed an average of 132 days, and marketed three weeks later than the unsorted controls.

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Cattle in the unsorted treatments were fed in the same pen (25 steers/pen). Cattle in the sorted treatments were assigned to pens based on sort groups leading to heavy cattle having eight steers/pen, medium cattle having 11 steers/pen, and light cattle having six steers/pen. Pen space and available bunk space per animal was kept constant at 226 ft^2 and 18 inches, respectively.

Economic Analysis

Cost of animal and feed ingredients were calculated using seven-year average pricing for the month that cattle were bought and the months that feed ingredients were used. For steer initial cost, average BW of a replicate was multiplied by the USDA Nebraska auction markets 1998 to 2004 average December calf price ($102.97/cwt) for a 500 to 600 lb calf. Steers were charged $8.33/head for health and processing cost during the winter period. Simple interest was charged on initial steer cost and health over the entire ownership. Interest was charged using prime interest rate plus 1% (7.6%) for all costs.

The cost of corn residue was charged at a rate of $0.32/steer daily while steers grazed cornstalk residue. This cost includes $0.12/steer for the rent of cornstalk residue and $0.20/steer daily charged as yardage while steers grazed cornstalk residue. This yardage cost includes the cost of fencing stalk fields and cost of labor to deliver WCGF and water to the cattle while grazing cornstalk residue.

Steers were supplemented with 5 lb/steer daily (DM basis) of WCGF for the entire winter period at a cost of $84.20/ton (DM basis). Interest was charged on the WCGF for half of the winter period and the remainder of ownership. Total winter cost was calculated using a 1.5% death loss, steer purchase price, health, feed, yardage, and interest charges.

Summer grazing cost was charged using the seven-year average animal unit month (AUM) value of $23.29 for native range. To determine the animal unit equivalent of the steers used in this study the initial BW and BW of cattle when they were removed from grass was averaged and divided by 1,000 lbs.

Cattle were charged $8.33 for summer health cost and a death loss of 0.5% was assessed during the summer grazing period. Interest was charged for the cost of grazing using prime plus 1% for the cost of the AUM and health cost.

Finishing cost includes feed and yardage. Feed costs were determined by multiplying the cost of the finishing ration ($99.53/ton) by the average DMI for each replicate. Cattle fed Optaflexx were charged a cost of $0.26/steer daily the last 28 days of the finishing period to account for the cost of Optaflexx. Feedlot yardage was charged at a rate of $0.35/steer daily. Interest was charged on feed and yardage costs for half the finishing period. Slaughter breakeven was calculated by dividing total cost by carcass-adjusted final BW.

Profit was calculated two ways. First, profit was calculated using seven year average live price for the month of December ($74.23/cwt) and subtracting the total cost of production from the value of the animal. Second, profit was calculated by selling cattle on the rail in a value based market that rewards quality. The grid used was calculated using two years of grid prices from the plant where cattle were sold and averaging the premiums and discounts received for the carcasses. The grid used is presented in Table 1. The base carcass for this grid was a carcass with a minimum quality grade of Choice^0 and YG 3. The base price used for the animal was the average Nebraska dressed fed cattle price of a Yield Grade 3, Choice^0 for December ($121.59/cwt) from 1998 to 2004. This price was calculated using the Nebraska Dressed Price (1998 to 2004) adjusted by adding the sum of 1 minus the average Choice grading percentage for the month of December multiplied by the Choice/Select spread for the month of December.

Table 1. Premiums and discounts for grid marketing analysis.

Item, $/cwt	Premium/Discount
Prime	8.00
Upper Choice	6.00
Choice	0.00
Select	-8.10
Standard	-15.00
Yield Grade 1	3.00
Yield Grade 2	3.00
Yield Grade 3	0.00
Yield Grade 4	-10.00
Yield Grade 5	-17.49
Carcass weight > 950 lbs	-10.00
Carcass weight > 1,000 lbs	-20.00

Results

Sorting Performance

Feedlot performance as a main effect of sorting is presented in Table 2. Initial BW for the finishing period was not different (P=0.82), however, sorted cattle exhibited a numerical increase in final BW of 9.6 lbs (P=0.15) compared to unsorted cattle. This is

Table 2. Feedlot performance as a main effect of sorting yearling steers by initial feedlot weight.

Item	Sorted	Unsorted	SEM	P-value
Initial BW, lb	515	520	10	0.14
GINT [a] , lb	758	760	11	0.73
FINT [b] , lb	959	959	21	0.82
Final BW, lb	1419	1410	4	0.15
Winter ADG, lb/day	1.63	1.61	0.1	0.32
Summer ADG, lb/day	1.40	1.39	0.04	0.65
Feedlot ADG, lb/day	4.05	4.05	0.20	0.88
DOF [c]	114	111	0	< 0.01
DMI, lbs/day	28.86	28.69	0.17	0.35
G/F	0.140	0.141	0.006	0.50

[a]GINT = initial BW at the beginning of summer grazing.
[b]FINT = initial BW at the beginning of the finishing period.
[c]DOF = days on feed.

Table 3. Carcass characteristics as a main effect of sorting yearling steers by initial feedlot weight.

Item	Sorted	Unsorted	SEM	P-value
Carcass weight, lbs	894	888	3	0.14
Fat thickness, in	0.50	0.44	0.04	0.02
Ribeye area, in [2]	14.51	13.70	0.12	< 0.01
Yield grade	2.90	2.80	0.11	0.27
Marbling Score [a]	576.6	571.6	32.2	0.35
% Choice	80.3	78.8	9.1	0.72
% Carcasses > 950 lb	14.1	15.1	2.1	0.75
% Carcasses > 1000 lb	1.5	3.0	0.9	0.25
% Yield grade 4+	16.7	7.5	2.3	0.02

[a]marbling score = 400=slight[0], 500=small[0], etc.

Table 4. Feedlot performance as a main effect of supplementing 200mg/steer of Optaflexx daily to yearling steers the last 28 days of the feeding period.

Item	Optaflexx	Control	SEM	P-value
Initial BW, lb	519	516	10	0.29
GINT [a] , lb	759	759	11	0.89
FINT [b] , lb	959	959	21	0.82
Final BW, lb	1415	1414	4	0.86
Winter ADG, lb/day	1.61	1.63	0.10	0.32
Summer ADG, lb/day	1.40	1.39	0.04	0.72
Feedlot ADG, lb/day	4.06	4.04	0.20	0.85
DOF [c]	113	113	0	1.00
DMI, lb/day	28.80	28.75	0.17	0.75
G:F	0.141	0.140	0.006	0.82

[a]GINT = initial BW at the beginning of summer grazing.
[b]FINT = initial BW at the beginning of the finishing period.
[c]DOF = days on feed.

Table 5. Economic analysis as a main effect of sorting yearling steers by initial feedlot weight.

Item	Sorted	Unsorted	SEM	P-value
Steer cost, $	530.66	538.70	8.25	0.08
Interest [a] , $	79.91	79.30	3.90	0.03
Feed cost, $	162.73	158.47	1.25	< 0.01
Yardage, $	39.88	38.85	0.09	< 0.01
Total Cost, $	1021.72	1020.30	21.65	0.68
Feedlot COG [b c] , $	46.04	45.80	2.34	0.71
System COG [b d] , $	45.84	46.02	1.50	0.64
Breakeven [b] , $	72.17	72.58	1.62	0.34
Live Value [e] , $	1053.57	1046.45	3.25	0.15
Grid Value [f] , $	1061.54	1057.32	10.67	0.55
Live p/l [g] , $	31.86	26.15	22.43	0.33
Grid p/l [g] , $	39.82	37.02	31.91	0.73

[a]Interest is the total amount of interest accrued from the animal and all cost of production.
[b]All prices on a cwt carcass basis.
[c]Feedlot COG is the cost of gain during the finishing period.
[d]System COG is the cost of gain for the entire production system.
[e]Live sale price of $74.23/cwt.
[f]Carcass base price of $121.59/cwt.
[g] p/l is profit or loss.

because sorted cattle were fed an average of three days longer than unsorted cattle ($P<0.01$). However, DMI ($P=0.35$), ADG ($P=0.88$), and G:F ($P=0.50$) were not different when comparing sorted cattle to unsorted cattle. Carcass characteristics as a main effect of sort are presented in Table 3. Sorted cattle exhibited a numerical increase in HCW ($P= 0.14$) of 6.1 lb compared to unsorted cattle. However, there was not a difference in the percentage of carcasses that were over 950 lb ($P= 0.75$). Sorted cattle had increased FT ($P= 0.02$) and increased REA ($P<0.01$). Yield grade ($P= 0.27$) and marbling score ($P= 0.35$) were not different when compared to unsorted cattle. However, sorted cattle had 9.2% more carcasses with a YG 4 or higher ($P= 0.02$) compared to unsorted cattle due to the increase in the number of days fed.

Optaflexx Performance

Feedlot performance as a main effect of Optaflexx supplementation is presented in Table 4. There was no difference in feedlot initial BW of Optaflexx supplemented cattle compared to cattle not supplemented Optaflexx. Supplementing Optaflexx the last 28 days of the feeding period did not lead to an increase in final BW, ADG, improvement in G/F or difference in DMI. Feeding Optaflexx had no impact on HCW, fat thickness, LMA, YG, or marbling score compared to control cattle.

Sorting Economics

The economics of sorting steers at the initiation of the finishing period are presented in Table 5. Sorting cattle increased yardage cost $1.03/steer ($P<0.01$) due to the increased days fed (114 vs. 111 days) compared to unsorted cattle. This increase in days fed led to an increased feed cost of $4.26/steer ($P<0.01$) for sorted cattle. The increase in yardage cost, feed cost, and days fed led to an increased interest cost of $0.61/head ($P=0.03$) for sorted cattle. However, the differences in the production cost for the sorted cattle did not lead to an increase in the total cost of the animal and production, this is because there were no differences in cost of gain for the system or the cost of gain in the feedlot. This led to no difference in the breakeven for sorted cattle compared to unsorted cattle.

When comparing final animal value of sorted and unsorted cattle, sorted cattle were $7.12 more valuable on a live basis ($P= 0.15$) due to a 6.2 lb increase in HCW; however, the increase in final animal value did not lead to increased profitability of sorted cattle. When comparing

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sorted to unsorted cattle using grid pricing, animal value was not different due to the increase in the number of discounts sorted cattle received for carcasses with YG 4 and because sorting did not reduce the number of carcasses receiving overweight discounts. Since animal value was not increased for sorted cattle, profitability of sorted cattle was not different than unsorted cattle.

Optaflexx Economics

Interest cost ($P<0.01$) and total cost of production ($P<0.01$) were increased $0.87 and $11.10, respectively, for cattle supplemented Optaflexx. The increase in interest and total cost is due to the slight increase in initial animal cost and the price of supplementing Optaflexx ($0.26/steer daily).

The cost of supplementing Optaflexx led to a slight increase in the breakeven cost of $0.78/cwt ($P=0.09$), increased system cost of gain of $1.03 ($P=0.02$), and increased feedlot cost of gain of $1.90 ($P=0.01$) compared to control cattle. Final animal value on a live ($P=0.85$) and grid marketing ($P=0.52$) basis were not different for Optaflexx supplemented cattle compared to control cattle. When comparing live profitability and grid profitability, Optaflexx supplemented cattle tended to be $10.23 ($P=0.09$) and $15.66 ($P=0.07$) less profitable, respectively, than control cattle.

In this study sorting cattle was not successful because the percentage of overweight carcasses was not reduced and the incidence of YG 4 carcasses increased leading to increased discounts for sorted cattle. Sorting did increase REA. However, these increases did not lead to an economic advantage for sorted cattle. Feeding Optaflexx to long yearlings had no impact on performance.

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Performance Profile and Carcass Characteristics of Steers Fed Optaflexx

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Summary

An experiment evaluated the live BW response of steers being fed Optaflexx for various durations. The design consisted of two Optaflexx levels (0 vs. 200 mg per steer daily) and two Optaflexx feeding durations (28 or 42 days immediately prior to slaughter). However, Optaflexx was started on the same day (day 151 of the feeding period). Feeding 200 mg/steer daily of Optaflexx significantly (P<0.01) improved final BW, ADG, and F:G compared to controls. Feeding 200 mg /steer daily of Optaflexx provided 16.4 and 18.8 lb of added BW above controls for the 28 and 42 feeding duration, respectively, but most (approximately 87%) of this weight gain was within the first 28 days of the time that Optaflexx was fed.

Introduction

Optaflexx (ractopamine hydrochloride) is a growth promoting feed additive approved for use with feedlot cattle the last 28 to 42 days immediately prior to slaughter. The expected increase in final BW of feeding 200 mg/steer daily of Optaflexx from Elanco's post approval studies is 14.8 to 17.6 lb. Market shifts and environmental factors such as weather make optimal slaughter dates challenging to predict prior to the start of feeding Optaflexx. The ability to predict performance changes during the late part of finishing period is important to justify making feeding and management changes to improve performance and carcass characteristics. Currently, there are limited data to evaluate the effects of feeding Optaflexx over time, or to evaluate the effects of Optaflexx when cattle are fed past their projected slaughter date.

The objectives of our study were to evaluate 0 and 200 mg/steer daily of Optaflexx fed to steers for the last 28 or 42 days immediately prior to slaughter, and to evaluate how feeding Optaflexx can affect feedlot performance past projected finishing dates.

Procedure

Crossbred steer calves (BW = 1189 lb) were used in a 2 by 2 factorial design (n=331; 28 pens). The treatments consisted of two Optaflexx levels (0 vs. 200 mg/steer daily) fed for two durations (28 or 42 days immediately prior to slaughter). However, Optaflexx feeding was started on the same day (day 151 of the feeding period). Steers were managed for a pre-trial phase (83 days) in pens of 20 head. At reimplant time cattle were weighed for two consecutive days. First day weights were used for stratification and steers were assigned to weight block (three blocks) and randomly allocated to treatment. Pens were assigned randomly to the four treatments. During weights on day 2, cattle were sorted into their respective pens with similar numbers of animals in each pen (12 steers/pen) and comparable bunk (>18 inches/head) space for each animal.

All steers were fed twice daily (0730 and 1230) with Optaflexx treatments being applied in a meal supplement fed at 4% of the diet DM. Metabolizable protein, Ca, P, and K requirements were formulated to meet or exceed NRC (1996) requirements. High-moisture corn was fed at 58.5% of DM, wet corn gluten feed at 30% of DM, and alfalfa hay at 7.5% of DM (Table 1). Diets were prepared by loading the HMC first and then by adding the supplement while the mixer/delivery box (Roto-Mix® model 420, *Roto-Mix®, Dodge City, Kan.*) was running at idle. Gluten feed and alfalfa hay were subsequently added and diets were mixed continuously for 12 revolutions (approximately three minutes) at 1,500 rpm. Feeds and feeding procedures remained the same throughout the pre-trial and trial phase, except for the use of the new supplements formulated to provide 0 and 200 mg/head of Optaflexx daily in the 28 or 42 days prior to slaughter.

Table 1. Diet composition and analyzed nutrient analysis.

Ingredient, % of DM	
High-moisture corn	58.5
Wet Corn Gluten Feed	30.0
Alfalfa hay	7.5
Dry supplement [a]	4.0
Analyzed Nutrient Analysis	
Moisture	67.89
CP, %	14.05
TDN, %	77.90
ADF, %	7.84
Calcium, %	0.66
Phosphorus, %	0.50
Ether Extract, %	4.30

[a]Dry supplement supplied 24.8 g/ton (DM basis) of Rumensin®, 90 mg/hd of Tylan®, and either 0 g/ton or 17.4 g/ton 100% DM of ractopamine to the experimental diets.

Two feed samples (approximately .5 lb) were retrieved from each batch of feed prepared for the morning feed deliveries (0730) in the first and last week of the experiment. Samples were collected at the mixer discharge from the beginning, middle, and end of each treatment load. Samples were processed and analyzed for CP, ether extract, TDN, ADF, Ca, P, and moisture.

Individual BW were collected on days -14, 0, and 28 or 42 of the experiment. Pen weights were taken on days -14, -7, 0, 7, 14, 21, 28, 35, and 42. A list of study events is presented in Table 2. All residual feed remaining at the time the steers were removed from their pen was weighed.

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On day 28, steers being fed Optaflexx for 28 days were transported to Excel, Schuyler, Neb., and randomly presented for slaughter. Steers being fed Optaflexx for 42 days were fed for an additional 14 days (past day 28) to determine the effects of Optaflexx on performance and carcass characteristics when steers are fed past their projected finishing date (179 DOF).

At slaughter, hot carcass weights were collected and carcasses were chilled for approximately 36 hours, after which LM area and fat thickness were measured and marbling score called by a trained USDA grader. Yield grade was calculated using the equation (YG = 2.50 + (2.5*FT, in) - (0.32*LM area, in^2) + (0.2*KPH, %) + (0.0038*HCW, lb)).

Data were analyzed using a mixed model analysis (Proc Mixed, SAS) with treatment (dose and duration) included in the model as fixed variables and block as a random effect. Day 0 weight was used as a covariate in the analysis. Pen constituted the experimental unit with probabilities less than or equal to α (0.05) being considered significant.

Results

Growth was evaluated on a 4% shrunk basis, across and within Optaflexx feeding durations. There were no Optaflexx dose (0 or 200 mg/steer daily) by Optaflexx feeding duration (28 or 42 days) interactions observed for growth performance traits in this study.

The main effects of feeding 200 mg/steer daily of Optaflexx to steers for either 28 or 42 days immediately prior to slaughter increased ($P<0.01$) final live BW and ADG by 0.53 lb/day (14.4%) compared to controls (Table 3). Using regression analysis (Figure 1) to calculate point-in-time estimates for Optaflexx response, the quadratic equation ($R^2 = 0.97$; P = .02; ($y = -0.0095x^2 + 0.83x + 0.53$)) would predict that feeding 200 mg/steer daily of Optaflexx would provide 16.4, 18.1, and 18.8 lb of added live BW above controls for a 28, 35 and 42 feeding duration, respectively.

Table 2. List of study events.

		Individual Weights		Pens Weights		Slaughter	
		Optaflexx Feeding Duration[a]		Optaflexx Feeding Duration[a]		Optaflexx Feeding Duration[a]	
Study Day	Date	28 days	42 days	28 days	42 days	28 days	42 days
-14	3/29/05	X	X	X	X		
-7	4/05/05			X	X		
0	4/12/05	X	X	X	X		
7	4/19/05			X	X		
14	4/26/05			X	X		
21	5/03/05			X	X		
28	5/10/05	X		X	X	X	
35	5/17/05				X		
42	5/24/05		X		X		X

[a] Optaflexx was fed the final 28 or 42 days immediately prior to slaughter.

Table 3. Main effects of growth and carcass characteristics of steers fed Optaflexx for an average of 35d[a].

Optaflexx mg/head/day	0	200		
Pens, n	14	14		
Steers, n	168	163	INT [b]	DOSE [c]
Performance, individual weights				
Initial BW, lb [d]	1189	1189	—	—
Final BW , lb	1318	1336	0.69	<0.01
DMI, lb/d	23.59	23.72	0.66	0.66
ADG, lb	3.68	4.21	0.44	<0.01
F:G	6.46	5.68	0.85	<0.01
Carcass Characteristics				
HCW, lb	844	854	0.74	<0.01
Dress, % [e]	64.08	64.01	0.37	0.60
12^{th} rib fat, in	0.66	0.64	0.99	0.28
LM area, in^2	14.07	14.21	0.42	0.34
Marbling score [f]	517	517	0.50	0.99
Yield grade, calculated [g]	3.30	3.24	0.63	0.52

[a]Steers were fed Optaflexx for 28 and 42 days and presented in the table as an average of 35 days. Growth performance calculated on a shrunk basis (4%), LS means.
[b]INT = Observed significance level for Optaflexx Dose by Duration treatment interaction.
[c]DOSE = Observed significance level for main effect of Optaflexx Dose.
[d]Initial weights were used as a covariate.
[e]Dressing percentage = carcass weight / average live weight (4% shrink).
[f]USDA marbling score where 450=slight50, 500=small0, and 550=small50.
[g]Where yield grade = 2.50 + (2.5*FT, in) - (0.32*LM area, in^2) + (0.2*KPH, %) + (0.0038*HCW, lb).

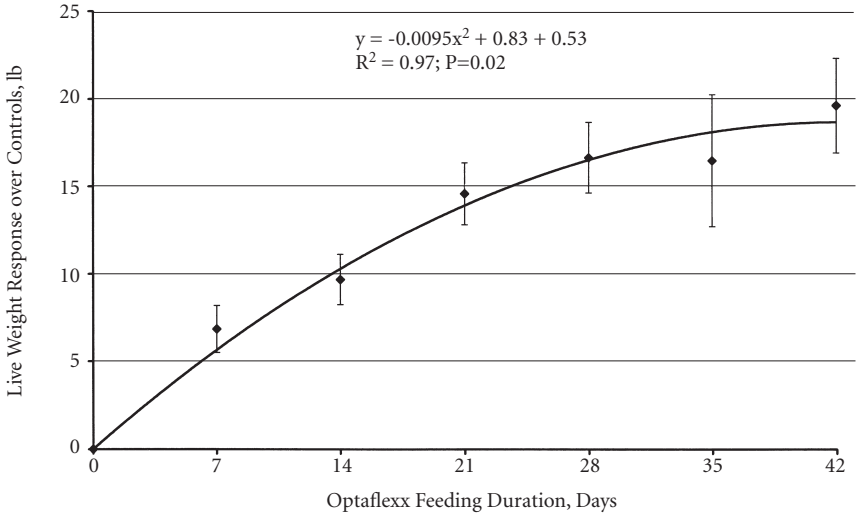

Figure 1. Growth performance profile for steers fed Optaflexx for 28 or 42[ab].
[a]Growth performance is calculated on a shrunk basis (4%), LS means.
[b]Day 7 – 28 has 28 Optaflexx pens averaged together (28 days and 42 days Optaflexx treatments), days 35-42 have only 14 pens (42 days Optaflexx treatments).

Table 4. Growth and carcass characteristics of steers fed Optaflexx for 28 or 42[a]

Oaflexx Feeding Duration	28		42			
Optaflexx mg/head/day	0	200	0	200		
Pens, n	7	7	7	7		
Steers, n	84	84	82	81	DOSE [b]	DURA [c]
Performance						
Initial BW, lb [d]	1189	1189	1189	1189	—	—
Final BW , lb	1294	1310	1342	1361	<0.01	<0.01
DMI, lb/d	23.16	23.42	24.01	24.01	0.63	0.02
ADG, lb	3.73	4.32	3.64	4.09	<0.01	0.07
Feed:gain	6.26	5.46	6.66	5.90	<0.01	<0.01
Carcass Characteristics						
HCW, lb	826	837	862	872	<0.01	<0.01
Dress, % [e]	63.88	63.93	64.29	64.10	0.64	0.06
12th rib fat, in	0.62	0.60	0.71	0.68	0.25	<0.01
LM area, in^2	13.59	13.86	14.55	14.57	0.37	<0.01
Marbling score [f]	517	512	517	522	0.96	0.42
Yield grade, calculated [g]	3.26	3.16	3.34	3.33	0.47	0.11

[a]Growth characteristics calculated on a shrunk basis (4%), LS means.
[b]DOSE = Observed significance level for main effect of Optaflexx Dose.
[c]DURA = Observed significance level for main effect of Optaflexx Duration.
[d]Initial weights were used as a covariate and are also represented as arithmetic means.
[e]Dressing percentage = carcass weight / average live weight (4% shrink).
[f]USDA marbling score where 450=slight50, 500=small0, and 550=small50.
[g]Where yield grade = 2.50 + (2.5*FT, in) - (0.32*LM area, in^2) + (0.2*KPH, %) + (0.0038*HCW, lb).

Feeding 200 mg/steer daily of Optaflexx to steers had no effect on DMI, thus, the added BW from feeding Optaflexx resulted in an improvement ($P<0.01$) in feed conversion (12.1%) over controls. Body weight, DMI and ADG were increased ($P<0.04$) with duration of feeding (Table 4). Pen weights were taken on a weekly basis to monitor the growth of steers (Table 2). Steers fed 200 mg/steer daily of Optaflexx had significant ($P<0.01$) increases in BW and ADG during all weekly weight intervals (7, 14, 21, 28, 35 and 42 days). There were no differences in DMI during any of the weekly measurements, resulting in significant ($P<0.03$) improvements in F:G during all weekly intervals.

There were no Optaflexx dose (0 or 200 mg/steer daily) by Optaflexx feeding duration (28 or 42 days) interactions observed for carcass characteristics in this study. The main effects of feeding 200 mg/steer daily of Optaflexx to steers for either 28 or 42 days immediately prior to slaughter, increased ($P<0.01$) hot carcass weights by 10.5 lb. Feeding 200 mg/steer daily of Optaflexx to steers had no effect on dressing percentage, 12th rib fat thickness, LM area, marbling scores, or calculated yield grade (Table 3).

Results from this experiment indicate feeding 200 mg/steer daily of Optaflexx for the last 28 or 42 days prior to slaughter increases BW, but most of this BW advantage (87%) is within the first 28 days of the feeding period. Steers fed Optaflexx past their projected slaughter date maintained their performance advantage over the controls.

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Evaluation of Excede® Given at Either Initial Processing or Revaccination on Bovine Respiratory Disease and Pasture vs. Feedlot Receiving Systems

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Summary

An experiment (Exp. 1) was conducted to determine the effect of Excede® at arrival or at revaccination on morbidity, mortality, and gain in both feedlot and pasture receiving systems. A second experiment (Exp. 2) was conducted to determine the effect of feedlot and pasture receiving systems on animal health. In Exp. 1, no treatment differences were observed for initial or final BW, or ADG. In Exp. 1, initial BW, treatment, receiving system (pasture or feedlot); and buyer of cattle explained the cumulative incidence of bovine respiratory disease (BRD). The incidence of BRD in this study was 4.7%, 11.0%, and 13.8% for arrival, control, and revaccination treatments respectively. The arrival medication effectively reduced BRD incidence. BRD was less (P= 0.02) for pasture receiving than feedlot receiving, averaging 7.4% and 11.0% respectively. In Exp. 2 BRD was less for pasture receiving than feedlot receiving with 23% and 53% treated for BRD respectively.

Introduction

As a general trend, the percentage of feedlot cattle fed as "calf-feds" relative to yearlings has increased in recent years. The increased trend of calf feeding can be a health management challenge for many feedlots. Administration of appropriate antibiotics to control BRD in cattle that are at high risk of developing BRD may be an important management option for producers. Often feedlots observe their greatest health challenges 10 to 14 days after receiving.

In addition, calves transitioning from a pasture based ranch system to a feedlot can experience multiple stressors that weaken immune function. Receiving calves with a system like their previous ranch environment should reduce calf receiving stress. Therefore, receiving calves with a pasture based system has the potential to be a less stressful system than feedlot pen receiving.

The objective of Exp. 1 was to determine the effect of Excede® at arrival or at revaccination (16-27 days post arrival) on morbidity, mortality, and gain of calves in both feedlot and pasture receiving systems. The objective of Exp. 2 was to determine the effect of pasture vs. feedlot receiving on morbidity and growth performance of freshly weaned calves.

Procedure

Exp. 1 - Three treatments were evaluated within a pasture receiving system and feedlot receiving system: 1) control (no medication; CON), 2) Excede® (Pfizer Animal Health, New York, NY) on arrival (ARR), or 3) Excede at revaccination (median 18 days post arrival; range 16-27 days; REVAC). A total of 2,264 freshly weaned steer calves received at the University of Nebraska Agricultural Research and Development Center (Mead, Neb.) between Oct. 13 and Oct. 22 were used in this experiment. Steers were procured from three buyers representing northern Nebraska, central Nebraska, and western Nebraska from a mixture of "ranch-direct" and "sale barn" sources. Steers were penned by treatment group to minimize environmental or "herd-immunity" effects. The trial had a total of 12 replications for each treatment. Twenty-one feedlot pens housed 20 head/pen (388 ft2/head; 420 head total) to supply seven replications per treatment in a feedlot receiving system. The treatment groups were assigned randomly to one of 21 pens. Fifteen pastures housed 123 head/ 14-acre pasture (1,844 head total) for five reps per treatment. The treatment groups were assigned randomly to one of 15 pastures. Steers housed in the feedlot received ad libitum intake of a typical feedlot receiving ration containing (DM basis) 33% dry rolled corn, 33% wet corn gluten feed, 33% alfalfa, and 1% mineral supplement containing 135 mg/steer daily Deccox® (Alpharma Inc., Fort Lee, NJ) and 200 mg/ steer daily Rumensin® (Elanco, Greenfield, IN). Steers on one pasture replication received only limited hay supplementation and 16 oz Corid® (Merial, Atlanta, Ga.) per 100 gallons twice for coccidiosis prevention. Pasture location, adequate pasture forage, and management did not require this replication to receive concentrate supplementation. Steers on all other pastures were provided 3 lb/head steer daily of wet corn gluten feed plus mineral supplement containing 135 mg/steer Decox and 200 mg/steer Rumensin daily and cool-season grass. In addition, cattle on these pastures received ad libitum hay supplementation.

Steers were assigned to treatments based on processing order within buyer at arrival, with every third animal assigned to each treatment. Steers' panel ID tags were notched to identify treatment assignment. Calves were processed at arrival by receiving three separate tags for individual identification including

an electronic ID, panel tag, and metal clip tag. Calves were weighed and vaccinated with Bovi-Shield Gold 5®, and Somubac® (Pfizer Animal Health). Calves also received a weight dependant dose of Dectomax Injectable® (Pfizer Animal Health) anthelmintic. Any calves having horns were dehorned and cauterized. Bull calves (51 head) were identified for banding upon completion of the study. Calves were revaccinated at 18 days (range 16-27 days) post arrival. They received vaccinations of Bovi-Shield Gold 5, Somubac and Ultrachoice 7® (Pfizer Animal Health). Individual animal BWs were collected. All pasture calves also received a dose of pinkeye vaccine (Schering-Plough, Kenilworth, N.J. Calves were individually weighed off trial after 31 days (range 26-39 days).

All pens and pastures were evaluated by the same pen riders within day to provide equal pull evaluation across antibiotic treatments. A post treatment interval (PTI) was not in effect for the calves after receiving Excede as pen riders were blind as to which cattle had received Excede to prevent preferential pulling of untreated calves. Calves that were categorized as respiratory pulls by the cattle crew, based on individual animal observation each day, were pulled, symptoms assessed, and treated with Draxxin® (Pfizer Animal Health, New York, N.Y.). When a sick calf was treated, panel ID tag was notched to prevent receiving Excede at revaccination (REVAC treatment only). Animals were returned to home housing units as soon as possible after treatment. Any animals receiving Draxxin were subject to a seven-day PTI before any secondary medication was administered.

Initial, revaccination, and final BW were recorded for each animal. Average daily gain and respiratory disease incidence data were recorded for each animal. In addition, morbidity outcomes and causes were recorded. Body weights, ADG, and mortality data using the individual animal as the observation were compared using the Proc MIXED procedure of SAS to analyze for treatment effects. The Proc GENMOD procedure of SAS was used to analyze respiratory disease morbidity outcomes. An animal was determined to be a confirmed respiratory disease observation for the trial if the animal was treated for respiratory disease by the animal health personnel or if the animal died and was confirmed a respiratory disease dead.

Exp. 2 – In the fall of 1997 1,172 head of freshly weaned ranch direct and sale barn sourced calves were received at the University of Nebraska Research Feedlot. The calves were randomly assigned to either feedlot pens or the same pastures used for Exp 1. Calves were managed similar to Exp. 1 except none of the calves were treated with preventative medication.

Results

Exp. 1 - No significant differences ($P>0.05$) of initial BW (575 ± 10 lb), revaccination BW (615 ± 12 lb), final BW (633 ± 14 lb), or ADG (1.85 ± 0.21 lb/day) were observed due to medication treatment. The number of respiratory disease caused mortalities did not differ ($P> 0.05$) among treatments, albeit low. The number of respiratory disease caused mortalities was 1, 1, and 2 for ARR, CON, and REVAC treatments respectively. The variables of the GENMOD model that explained the incidence of respiratory diseases were initial BW, preventative antibiotic treatment, receiving system and buyer of cattle. Interactions of these variables were not significant ($P> 0.05$).

Initial BW, accounting for medication treatment; affected ($P<0.01$) animal respiratory disease outcome with lighter calves being more likely to be treated for respiratory disease. Excede treatment at arrival affected ($P<0.01$) animal respiratory disease outcome. The respiratory disease cumulative incidence for this trial was 4.7%, 11.0%, and 13.8% for ARR, CON, and REVAC treatments, respectively. The ARR treatment reduced respiratory disease cumulative incidence of this trial ($P<0.01$) compared to CON. The REVAC treatment did not reduce respiratory disease cumulative incidence.

Table 1. Exp. 1 differences in BW of pasture and feedlot received calves. Revac BW = Revaccination BW.

Item	Pasture	Feedlot
Initial BW, lb	585	589
Revac BW, lb	621	635
Final BW, lb	627	661
Trial ADG, lb	1.26	2.36

The BW and ADG differences of pasture and feedlot received steers are presented in Table 1. Receiving steers in a pasture based system compared to a feedlot system significantly reduced ($P= 0.02$) cumulative BRD incidence from 11.0% to 7.4%.

No difference of BW change due to preventative medication treatment is presumably due to the short window of study length (26 – 39 days on trial). The ineffectiveness of the REVAC treatment relative to the ARR can be explained by animals experiencing respiratory disease challenge and individual animal treatment prior to revaccination on days 16 – 27 (Figure 1). The shorter bars of the ARR treatment indicate decreased incidence of BRD relative to the CON treatment. The ARR treatment significantly ($P<0.01$) improved animal health status by reducing BRD incidence from initial processing to revaccination. The decrease in CON and REVAC BRD incidence after day 15 is due to the natural incidence cycle of BRD and not revaccination which occurred on average at day 18.

Exp. 2 pasture and feedlot daily gain from arrival weight to 28 or 42 days post receiving was similar. The percentage of calves treated for BRD in the feedlot receiving system was significantly greater than for the pasture receiving system with 53% and 23% treated within feedlot and pasture receiving, respectively.

In conclusion, preventative medication administered at arrival effectively reduced the incidence of respiratory disease by reducing

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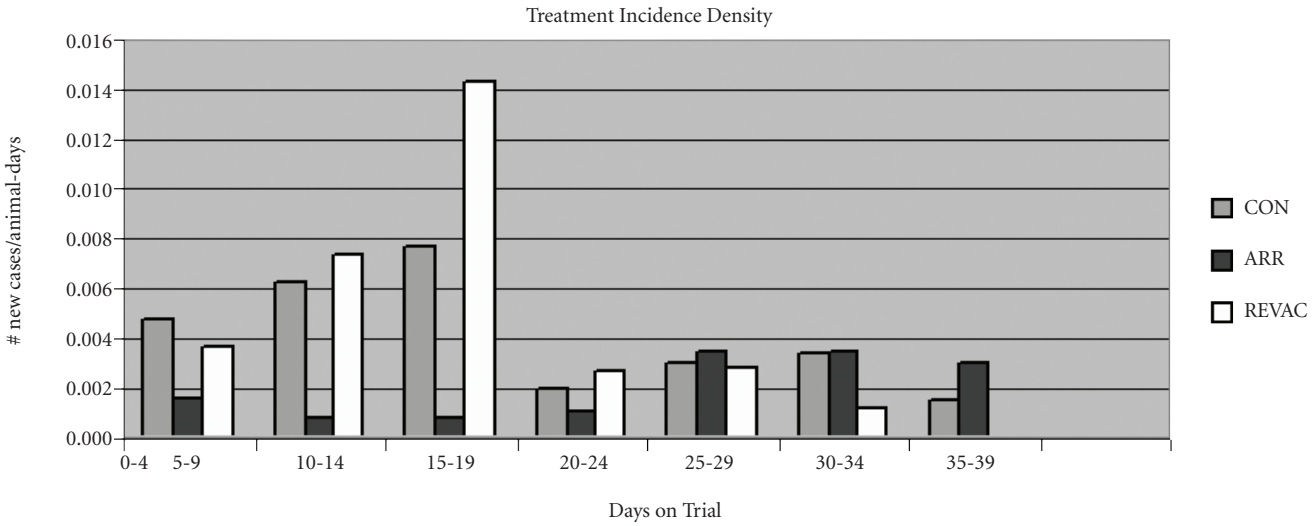

Figure 1. Treatment Incidence Density. CON = no preventative medication, ARR = preventative at initial processing, and REVAC = preventative at revaccination.

BRD during the first 15 days of arrival. Administering preventative medication at revaccination (median day 18) in Exp. 1 was not a feasible option for BRD control due to animals experiencing BRD prior to preventative medication administration. The low incidence of BRD (11% of controls) in Exp. 1 did not maximize the potential value of preventative medication that is possible with calves at higher risk of BRD. However, part of the low incidence of BRD was due to pasture receiving as feedlot received control steer actual incidence of BRD was 21.4%. The calves from this study will be followed to slaughter for lung tissue damage analysis, feedlot ADG calculation, and economic analysis. The data will be published in a future Nebraska Beef Cattle Report.

Pasture receiving effectively improved animal health status by reducing BRD incidence over feedlot receiving.

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Evaluation of Synovex Choice Versus Revalor Implant Strategies in Beef Finishing Steers

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Summary

A commercial feedlot experiment was performed with the objective to compare a Synovex-Choice/ Synovex-Choice (Choice) implant strategy to a Revalor-IS/Revalor-S (Revalor) strategy on finishing steer performance and carcass characteristics. DMI did not differ between treatments). When calculated from carcass adjusted FW, ADG was not significantly different between Choice and Revalor implant strategies. Consequently, F/G was not significantly different when the Choice strategy was compared with Revalor strategy. No differences were observed for marbling scores or calculated yield grade) due to treatment. Based on carcass-adjusted performance, significant differences do not exist in performance between the two implant strategies.

Introduction

Synovex-Choice is an implant that contains 100 mg of trenbolone acetate (TBA) and 14 mg of estradiol benzoate. Revalor-IS contains 16 mg of estradiol 17 β and 80 mg of TBA and Revalor-S contains 24 mg of estradiol 17 β and 120 mg of TBA. ADG, F/G and carcass characteristics were compared when using two implant combinations, Synovex Choice/Synovex Choice and Revalor-IS/Revalor-S.

Procedure

Eight hundred ninety two steer calves (initial BW = 641± 21 lb) from auction barns in Missouri, Montana and South Dakota and a ranch in Idaho, blocked by arrival date (six blocks), were assigned randomly to one of two pens per block in a feedlot trial conducted at Hi Gain feedlots (Farnam, Neb.) Pens were assigned randomly to one of two treatments (six pens/treatment). Treatments were two implant strategies consisting of an initial implant of Synovex-Choice followed by a second dose of Synovex-Choice at reimplant, or Revalor-IS followed by Revalor-S. Reimplant occurred at 89 days after first implant, steers were fed for an average of 169 days. Cattle were fed the same diet (Table 1) following a common step up period. The step-up period consisted of three step-up diets with incremental percentages of dry-rolled corn and steam flaked corn replacing alfalfa hay. The finishing diet included 33.5% dry-rolled corn, 30% steam flaked corn, 22% wet distillers grains, 5% alfalfa hay, 2% cane hay, 1.5% tallow, and 5% liquid supplement. The supplement included Rumensin (300 mg/hd/d) and Tylan (90mg/hd/d). Pen and individual BW were recorded on day 1 and on reimplant day and pen weights were recorded at harvesting date. Because no differences were observed between the individual and pen weight measurements, pen weights were used to determine ADG and F/G. Fort Dodge personnel checked for missing implants and abscesses at reimplant. At first implant time, cattle were vaccinated using Bovishield and Titanium 3, and administered Dectomax. Feedintakes and health records were recorded daily. Feed conversion was calculated from final BW adjusted from hot carcass weight (HCW) recorded at slaughter, assuming 64% dressing percentage. Cattle were harvested at IBP, Lexington Neb., at different dates according to arrival at the feedlot and degree of finish. Carcass 12th rib fat thickness, longissimus muscle area (LMA) and USDA yield and quality grades were recorded following a 24 hour chill. Statistical analysis was performed using PROC MIXED of SAS. Proc FREQ of SAS was used for the Chi Square distribution analysis for quality and yield grade.

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Table 1. Performance of steer calves implanted with either Synovex-Choice on day 1 followed by Synovex-Choice on day 89 (Choice) compared to steers implanted on the same days with Revalor-IS followed by Revalor-S (Revalor)

	Choice	Revalor	SEM	P-value
Overall carcass performance[a,b]				
Pens, n	6	6		
Steers, n	449	443		
DOF, days	169	169		
Initial BW	640.4	640.7	8.9	0.953
Final BW	1328	1328	19.6	0.994
DMI	21.70	21.67	0.52	0.804
ADG	4.08	4.08	0.08	0.964
G:F	0.188	0.188	0.002	0.783
F:G	5.32	5.31		0.783[d]
Overall live performance[c]				
Final BW	1316	1309	19.8	0.322
ADG	4.00	3.96	0.09	0.210
G:F	0.184	0.183	0.002	0.318
F:G	5.42	5.46		0.318[d]

[a]All BW are shrunk 4% except initial BW.
[b]Overall live performance calculated from live BW on a pen basis collected prior to study initiation and on day of slaughter.
[c]Overall carcass performance calculated using a 64% dressing percentage for both treatments.
[d]P Val calculated from G:F

Results

There was no difference in DMI due to treatments. Using final BW calculated from carcass weights, there were no differences in any feedlot performance measurements (Table 1). Carcass adjusted final BW did not differ between treatments. Consequently, ADG and F/G were not different between treatments. Using live performance, live final BW was not affected by treatment. Therefore, ADG based on live weights was not different for the Choice treated steers when compared to steers treated with the Revalor implant strategy. Similar results were observed in feed conversion on a live basis. Because no differences were observed in carcass weight or carcass-adjusted performance, we conclude performance is similar between implanting with a Synovex-Choice and Synovex-Choice compared to Revalor-IS and Revalor-S implant regimen.

There were no differences in hot carcass weight, dressing percentage, marbling and back fat depth between the steers implanted using the Choice strategy compared to the Revalor implants (Table 2). There was a tendency (*P*=0.09) for a higher number of carcasses grading average choice for the Choice implanted steers, and this difference was due to a numerically lower number of standard and upper choice carcasses for the Revalor treatment. No differences in calculated USDA Yield Grade were observed in the Choice implanted steers compared to the Revalor treated steers. Chi square analysis showed frequency distributions for USDA Quality and Yield Grades did not differ (P=0.82) by treatment.

Table 2. Carcass characteristics of steer calves implanted with either Synovex-Choice on day 1 followed by Synovex-Choice on day 89 (Choice) compared to steers implanted on the same days with Revalor-IS followed by Revalor-S (Revalor).

	Choice	Revalor	SEM	P-value
Carcass characteristics				
Pens	6	6		
Carcasses	424	416		
Hot carcass weight, lb	850.0	850.0	12.5	0.992
Dressing %	64.61	64.91	0.20	0.128
Fat depth, in	0.553	0.543	0.019	0.581
LM area, in^2	14.69	14.82	0.15	0.496
KPH, %	2.44	2.41	0.05	0.305
Marbling [a]	531	525	5.6	0.477
Calc. YG [b]	2.97	2.87	0.08	0.423
USDA Quality Grade, as percentage of total				
Prime	0.23	0	0.17	0.363
Upper Choice	3.61	4.68	1.28	0.443
Mid Choice	15.35	10.05	1.76	0.086
Low Choice	42.81	46.71	2.23	0.271
Select	36.45	35.21	2.77	0.765
Standard	1.55	3.36	0.88	0.205
Choice or >	61.92	61.43	2.55	0.899
Select or <	38.08	38.57	2.55	0.899
USDA Yield Grade, as percentage of total				
YG 1	13.42	15.91	3.09	0.470
YG 2	41.44	41.17	3.57	0.959
YG 3	36.91	34.52	3.84	0.679
YG 4	6.72	5.54	1.76	0.644
YG 5	1.51	2.87	0.91	0.341

[a] 450=Slight^{50}, 500=Small^{0}, 550=Small^{50}, etc.
[b] Calculated as 2.5 + (2.5*Fat Depth) + (0.2*2% KPH) + (0.0038*HCW) - (0.32*REA)

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Effect of CRINA RUMINANTS AF, a Mixture of Essential Oil Compounds, on Finishing Beef Steer Performance

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Summary

Three-hundred seventy six crossbred yearling steers were fed one of four treatments: 1) Control (CON) 2) CRINA RUMINANTS AF (CRINA) 3) CRINA RUMINANTS AF plus Tylan® (CRINA + T), and 4) Rumensin® plus Tylan® (RUM + T) to determine the potential of an essential oil additive to improve steer growth performance and carcass characteristics. There were no differences in Final BW or ADG between treatments. Steers fed RUM + T had lower DMI than other treatments and F:G was improved for the CRINA + T and RUM + T fed steers compared with CON steers. Treatments containing Tylan® had significantly fewer liver abscesses as compared to the other treatments. The addition of CRINA RUMINANTS AF plus Tylan® or Rumensin® plus Tylan® improved F:G and decreased liver abscesses compared to no additives.

Introduction

The response from increased production and improved F:G of many common feed additives results in a return on investment that is favorable for cattle producers. As new feed additives are introduced it becomes critical that biological responses and determinations are made in situations that closely simulate industry settings.

CRINA RUMINANTS AF is a flavor enhancer derived from essential oil compounds with various claims such as, appetite stimulant, digestion stimulant, and antioxidant.

This study was conducted to determine the effects of Rumensin®, Tylan®, and CRINA on performance measurements and carcass characteristics of finishing beef steers.

Procedure

Yearling steers (BW = 878 $\pm$ 74 lb; n = 376) were used in a completely randomized design. Steers were purchased in the fall as weaned calves, grown on cornstalks and summer range, and then finished from September to January. Five days prior to study initiation, steers were limit fed a diet that consisted of 50% alfalfa and 50% wet corn gluten feed (DM basis) at 2% of BW to minimize variation in gastrointestinal fill. On day 0 and 1, steers were individually weighed and the average weight was used to determine starting BW. Based on day 0 weight, steers were blocked by weight into one of three blocks: light, medium, and heavy, stratified by weight within block, assigned to pens, and pens were assigned randomly to treatment. Forty pens were used at the University of Nebraska ARDC feedlot with 9-10 steers/pen. There were a total of four treatments with 10 pens per treatment.

The four dietary treatments (Table 1) all had a similar basal composition of high moisture corn (HMC) fed at 66% of diet, dry rolled corn (DRC) at 16.5% of diet, alfalfa hay at 7.5%, liquid molasses at 5%, and supplement at 5% (DM basis). Supplements were formulated to contain the different feed additives with the control (CON) containing no feed additives, CRINA Ruminants AF (**CRINA**) formulated to provide 1 g/head/day, CRINA Ruminants AF (1 g/head/day) plus Tylan® formulated to provide 90 mg/head/day (CRINA + T), and Tylan® (90 mg/head/day) plus Rumensin® formulated to provide 300 mg/hd/d (**RUM + T**, *Elanco Animal Health, Greenfield, Ind.*). Diets were formulated to meet or exceed the NRC (1996) requirements for metabolizable protein, Ca, P, and K. Steers were adapted to the finishing diet with a step-up period that consisted of 3, 3, 4, 7, and 7 days. During the step-up period, HMC replaced alfalfa and was included at 0, 28.5, 38.5, 48.5, and 58.5% and alfalfa was included at 45, 45, 35, 25, and 15% (DM basis), for each of the respective steps. Steers were fed once daily with a Roto-Mix® (*Roto-Mix®, Dodge City, Kan.*) feed truck.

All steers were implanted with Revalor-S® (*Intervet, Millsboro, Del*) at study initiation and were fed for a total of 115 days. Cattle were slaughtered on day 116 at a commercial packing plant (*Greater Omaha Pack, Omaha, Neb.*) where hot carcass weight and liver scores were recorded. Following a 48-hour chill, carcass data were collected that included: 12-13th rib fat thickness, LM area, KPH percentage, and called USDA marbling scores were recorded. A calculated yield grade was determined from the equation (YG = 2.50 + (2.5*FT, in.) – (0.32*REA, in^2) + (0.2*KPH, %)

Table 1. Composition of dietary treatments and formulated nutrient analysis.

Ingredient	% of diet DM
Corn, HM[a]	66.0
Corn, DR[b]	16.5
Alfalfa hay	7.5
Molasses	5.0
Supplement[c]	5.0
Formulated Nutrient Analysis	
NEg, mcal/lb	0.64
Crude protein, %	13.0
Calcium, %	0.65
Phosphorus, %	0.33
Potassium, %	0.70
Sulfur, %	0.16
Ether extract, %	3.7

[a]HM denotes high-moisture.
[b]DR denotes dry-rolled.
[c]Supplements differ according to dietary treatment, supplements formulated to provide CRINA Ruminants AF at a rate of 1 g/hd/d, Tylan® at a rate of 90 mg/hd/d, Rumensin® at a rate of 300 mg/hd/d.

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+ (0.0038*HCW, lb.)). Values for final BW, ADG, and F:G were calculated using hot carcass weight divided by an average dressing percentage of 63 to minimize errors associated with gastrointestinal tract fill.

Dry-rolled corn was processed through a single-roll roller mill. High-moisture corn was harvested at 31% moisture, processed through a single-roll roller mill, stored in a horizontal bunker silo, covered, and used throughout the study.

Data were analyzed using the mixed procedures of SAS (*Version 9.1, SAS Inc., Cary, NC)* as a randomized complete block design, with pen as the experimental unit and three weight blocks. When treatment differences were significant based on a protected F-test, means were separated using the PDIFF option of SAS.

Results

Cattle fed the CON, CRINA, and CRINA + T dietary treatments had significantly higher ($P<0.01$) DMI then cattle receiving the RUM + T treatment (Table 2). Stock et al. (1995) also observed a decrease in DMI and in addition, reported an increase in ADG when Rumensin® and Tylan® were included in finishing steer diets.

ADG was not statistically different between treatment groups ($P=0.52$) but was numerically highest for the CRINA + T treatment group (4.03 lb) and lowest for the CON group (3.89 lb). Cattle receiving the CRINA + T and RUM + T treatments were more efficient than the CON group ($P<0.01$). The CRINA group was intermediate in F:G value compared to CON and the CRINA + T and RUM + T treatments. There was a trend for the CRINA group to have an improved F:G compared to the CON group (6.66 vs. 6.92).

When evaluating carcass differences, there was a significant yield grade difference for the CRINA + T treatment (Table 2). It is not clear why the CRINA + T treatment had a numerically higher 12th rib fat thickness measure and numerically smaller LM area. This observation is most likely an anomaly and therefore the yield grade difference may not be real.

Cattle fed Tylan® had fewer total liver abscesses compared to control cattle and there was a trend for severity of liver abscesses to be lessened as well (Table 3). The response of increased F:G seen in the CRINA + T and RUM + T treatments may be partially attributed to Tylan® inclusion and observed reduction in liver abscesses. Cattle in the CRINA treatment were intermediate in total liver abscesses with no statistical difference between the CRINA and the other treatments.

In summary, this study indicates that cattle fed CRINA Ruminants AF plus Tylan® (CRINA + T) or Rumensin® plus Tylan® (RUM + T) have improved feed efficiency and decreased liver abscesses compared to no additives. In addition, other carcass characteristics were not appreciably different when feed additives were included.

Table 2. Performance and carcass characteristics of steers fed differing feed additives for a 115 day finishing period.

	Treatment[c]				Statistics	
	CON	CRINA	CRINA+T	RUM+T	SEM	*P*-value
Pens, n	10	10	10	10		
Steers, n	94	94	94	94		
Days on feed	115	115	115	115		
Performance						
Initial BW, lb	900	896	897	897	2	0.29
Final BW[d], lb	1345	1356	1361	1348	9	0.55
DMI, lb	26.8[a]	26.5[a]	26.4[a]	25.3[b]	0.2	<0.01
ADG[e], lb	3.89	3.99	4.03	3.93	0.08	0.52
F:G[f]	6.92[a]	6.66[ab]	6.55[b]	6.44[b]	0.03	0.03
Carcass Characteristics						
HCW, lb	847	854	857	849	6	0.54
12th rib fat, in	0.44	0.45	0.48	0.42	0.02	0.06
KPH fat, %	2.08	2.01	2.01	2.02	0.03	0.20
LM area, in^2	14.1	14.1	13.9	14.0	0.1	0.47
Marbling score[g]	553	534	555	538	8	0.14
Yield grade	2.1[a]	2.3[a]	2.7[b]	2.3[a]	0.1	0.02

[ab]Within a row means without a common superscript letter differ ($P<0.05$).
[c]CON = Control, CRINA = CRINA RUMINANTS AF, CRINA+T = CRINA RUMINANTS AF + Tylan®, RUM+T = Rumensin® + Tylan®.
[d]Calculated from carcass weight adjusted to a 63% common dressing percentage.
[e]Calculated from carcass adjusted final body weight.
[f]Calculated as total feed intake (DM basis) divided by total gain.
[g]Where 400 = Slight 0, 500 = Small 0.

Table 3. Effects of treatment on liver abscesses.

	Treatment[c]				Statistics	
Liver Scores	CON	CRINA	CRINA+T	RUM+T	SEM	*P*-value
Steers, n	93	94	93	92		
A+, n	9	7	3	0		
A, n	2	0	0	0		
A-, n	15	9	5	6		
Total abscesses, %	26.25[a]	15.65[ab]	7.75[b]	5.55[b]	3.80	<0.01
A+, %	8.52	6.52	2.52	0.00	2.78	0.09

[ab]Within a row means without a common superscript letter differ ($P<0.05$).
[c]CON = Control, CRINA = CRINA RUMINANTS AF, CRINA+T = CRINA RUMINANTS AF + Tylan®, RUM+T = Rumensin® + Tylan®.

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Effect of CRINA RUMINANTS AF, a Mixture of Essential Oil Compounds, on Ruminal Fermentation and Digestibility

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Summary

Eight ruminally fistulated steers were used in a metabolism experiment to determine effects of an essential oil feed additive in altering steer ruminal fermentation characteristics and nutrient digestibilities. Yearling steers were fed three treatments: 1) Control (CON) 2) CRINA RUMINANTS AF (CRINA) and 3) Rumensin® (RUM). There were no differences in DMI, OM intake, total tract DM and OM digestibilities, or pH among treatments. Steers receiving the CRINA treatment consumed 24.5% fewer meals than CON. Ruminal acetate was greatest and total VFA concentrations tended to be greatest for CRINA treatment. Acetate:propionate was 1.68, 1.49, and 1.43 for CON, CRINA, and RUM, respectively, suggesting addition of CRINA RUMINANTS AF favorably alters rumen fermentation end products without negatively affecting intake or rumen pH.

Introduction

Intensive beef cattle finishing systems rely heavily on the use of cereal grains for increased efficiencies and improved net profit compared to forage- based systems. Use of large quantities of cereal grains may result in physiological disturbances such as ruminal acidosis, bloat, and digestive and metabolic upsets. Compounds that alter rumen fermentation may result in more efficient digestion and absorption of feed nutrients with the possibility of improved feed efficiency and increased gains. Rumensin® is a type of ionophore that minimizes subacute acidosis by altering ruminal fermentation and feeding behavior of cattle fed high-grain diets (Erickson et al., *2003, Journal of Animal Science).* Essential oils are another class of compounds that have exhibited the ability to alter rumen fermentation profiles. Decreased acetate:propionate ratio and increased total VFA concentrations have been observed with the addition of specific essential oil compounds (Cardoza et al., 2005, *Journal of Animal Science).* The objectives of our research were to determine effects of feed additives on ruminal fermentation characteristics, feed intake behavior, and nutrient digestibility in concentrate-fed steers.

Procedure

Eight ruminally fistulated steers (BW = 879 lb) were used in concurrent 3 x 4 Latin rectangles to determine digestibility and ruminal fermentation characteristics of diets fed without feed additives (CON), with CRINA RUMINANTS AF (**CRINA**), and with Rumensin® (**RUM**, Elanco Animal Health, Greenfield, Ind.). Basal diets (Table 1) consisted of 66% high-moisture corn, 16.5% dry-rolled corn, 7.5% alfalfa hay, 5% molasses, and 5% supplement (DM basis). The CRINA treatment was formulated for a target intake of 1 g/head/day. The RUM treatment was formulated for a target intake of 300 mg of Rumensin® per day.

Table 1. Composition of dietary treatments and formulated nutrient analysis.

Ingredient	% of diet DM
Corn, HM[a]	66.0
Corn, DR[b]	16.5
Alfalfa hay	7.5
Molasses	5.0
Supplement[c]	5.0
Nutrient Analysis	
NEg, mcal/lb	0.64
CP, %	13.0
Calcium, %	0.65
Phosphorus, %	0.33
Potassium, %	0.70

[a]HM denotes high-moisture.
[b]DR denotes dry-rolled.
[c]Supplements identical except, CRINA Ruminants AF formulated for a consumption of 1 g/head/day and Rumensin® at a rate of 300 mg/head/day.

Four, 28 day periods were used, with a 23-day adaptation period and a five-day collection period. From day 1 to day 23 steers were fed individually in pens and on the evening of day 23 moved into stanchions for the collection period. Steers remained in the stanchions during the collection period (days 24 to 28) while continuous feed intake patterns and ruminal pH measurements were collected as described in the *1998 Nebraska Beef Report,* pp. 71-75. Cattle were fed once daily at 07:30, feed refusals were collected if necessary and were composited by steer within period for analysis.

Chromic oxide was used as an indigestible marker for determination of fecal output during the collection period. Cattle were intraruminally dosed with 7.5 g of chromic oxide twice daily at 07:30 and 19:30 starting on day 20 of each period and continuing until day 28. Fecal grab samples were collected three times daily at 0, 6, and 12 hours post-feeding, composited by steer within period and analyzed to determine nutrient digestibilities. Feed samples and feed refusals were composited by period, forced-air oven dried, ground through a 2 mm screen, and subsequently analyzed.

On day 28, rumen samples were collected for determination of volatile fatty acid (VFA) concentrations. Rumen samples were collected at 0, 3, 6, 9, 12, 18, and 24 hours post-feeding. Specific VFA concentrations measured included acetate, propionate, butyrate, and total VFA.

Data were analyzed using the mixed procedures of SAS (*Version 9.1, SAS Inc., Cary, N.C.)* as a Latin square, with animal as the experimental unit. When treatment differences were sig-

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nificant, based on a protected F-test, means were separated using the PDIFF option of SAS.

Results

Results from this study show no significant differences in DMI among the different dietary treatments. Cattle averaged 18.5 lb of DMI with a range of 1.5 lb between the RUM and CON treatments. Organic matter intake followed similar trends to DMI with the CON having numerically higher intake and the RUM treatment consuming the least (Table 2). There were no apparent differences ($P>0.10$) in DM or OM digestibility due to inclusion of feed additive. Dry matter digestibilities of the diets ranged from 83.6% for the RUM treatment to 79.9% for the CON treatment. Average meals per day were 6.1, 5.5, and 5.5 for CON, CRINA, and RUM, respectively ($P=0.36$). Cattle receiving the RUM spent numerically more time eating compared to cattle fed the CRINA treatment (354.7 vs. 323.7 min).

Cattle fed the CON had an average pH of 5.71 with a range in pH from 6.55 to 5.08 (Table 3). Average ruminal pH was numerically lower for the RUM treatment with a value of 5.61 and a maximum observed pH of 6.47 and minimum pH of 4.98. Cattle receiving CRINA treatment had an average pH of 5.68 with a range of 6.75 to 5.01. There were no significant treatment differences between the CON, CRINA, and RUM treatments for pH change and pH variances ($P>0.10$).

There was a significant treatment difference for acetate concentration ($P=0.04$) and total VFA concentrations tended to be affected by treatment ($P=0.07$). Total VFA production was 108.8, 125.9, and 105.9 mM for CON, CRINA, and RUM treated groups respectively. Acetate concentrations were 54.4, 63.9, and 52.5 mM for CON, CRINA, and RUM group respectively. Cattle receiving the CRINA treatment had a 17.5% greater acetate concentration compared to CON treated cattle (63.9 vs. 54.4 mM). Propionate concentrations were 32.4, 42.9, and 36.6 mM for CON, CRINA, and RUM, respectively. Numerically, the CRINA treatment had a lower acetate:propionate ratio CON than the treatment.

In summary, the addition of CRINA and RUM to finishing steer diets did not have an affect on intake and digestibility of DM and OM. Ruminal pH variables were also unaffected by the addition of feed additives to the basal diet. Acetate concentrations were significantly greater and there was a trend for total VFA concentrations to be greater for the CRINA treated cattle. The greater total VFA concentrations and acetate concentrations in the CRINA treatment may be an indicator of increased ruminal fermentation of the treatment diet. The addition of CRINA RUMINANTS AF tended to result in a positive change in ruminal fermentation products and may lead to more efficient digestion of feed nutrients.

Table 2. Effects of feed additives on nutrient digestibility and feed intake.

	Treatment[a]			Statistics[b]
Item	CON	CRINA	RUM	P-value
Intake and Digestibility				
Dry Matter				
Intake, lb/day	18.5	21.2	17.0	0.28
Digestibility, %	79.9	83.1	83.6	0.44
Organic Matter				
Intake, lb/day	17.8	20.5	16.3	0.26
Digestibility, %	82.7	85.6	85.5	0.46
Intake Patterns				
Meals/day[c]	6.1	5.5	5.5	0.36
Total eating time, min	351.1	323.7	354.7	0.78

[a]CON = Control, CRINA = CRINA RUMINANTS AF, RUM = Rumensin®.
[b]No differences ($P>0.10$) due to treatment.
[c]Meal is defined as an eating bout where ≥ 1.0 lb of feed is consumed.

Table 3. Effects of feed additives on rumen fermentation characteristics.

	Treatment[a]			Statistics[b]
Item	CON	CRINA	RUM	P-value
Rumen pH				
Average pH	5.71	5.68	5.61	0.71
Maximum pH	6.55	6.75	6.47	0.45
Minimum pH	5.08	5.01	4.98	0.84
pH change	1.48	1.72	1.48	0.68
pH variance	0.113	0.123	0.110	0.85
VFA Production				
Total, mM	108.8	125.9	105.9	0.07
Acetate, mM	54.4[b]	63.9[c]	52.5[b]	0.04
Propionate, mM	32.4	42.9	36.6	0.18
Butyrate, mM	13.7	13.1	11.9	0.80
Acetate:Propionate	2.29	1.67	1.83	0.28

[a]CON = Control, CRINA = CRINA RUMINANTS AF, RUM = Rumensin®.
[b,c]Within a row means without a common superscript letter differ ($P<0.05$).

[1]Nathan F. Meyer, research technician; Galen E. Erickson, assistant professor; Terry J. Klopfenstein, professor; and Matt K. Luebbe, research technician, Animal Science, Lincoln. Peter Willams, DSM Nutritional Products, Inc., Parsippany, N.J.; Riccardo Losa, CRINA SA, Gland, Switzerland.

Feeding Potassium Bicarbonate and Sodium Chloride in Finishing Diets

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Summary

Angus crossbred yearling steers (n = 180) were used to evaluate effects of feeding additional potassium and sodium on performance and tympanic temperature of steers under heat stress and seasonal summer conditions. Steers were assigned one of four treatments: 1) control; 2) potassium (diet containing 2.10% $KHCO_3$); 3) sodium (diet containing 1.10% NaCl); or 4) potassium and sodium (diet containing 2.10% $KHCO_3$ and 1.10% NaCl). Daily water intake was increased and dry matter intake to daily water intake ratio was decreased for cattle fed potassium and potassium and sodium rations. Tympanic temperatures did not differ among dietary treatments under thermoneutral or hot environmental conditions.

Introduction

Potassium and sodium play important roles in maintaining osmotic pressure within cells, controlling the passage of nutrients into cells, and water metabolism. A deficiency of these ions may result in impaired cellular function and reduced coping ability to heat stress. As ambient temperatures approach body temperatures, the amount of heat dissipated through sweating and increased urinary output are key physiological processes for maintaining body temperature. Potassium and sodium are excreted from the body via urine and sweating. This study was designed to evaluate the effect of additional potassium and sodium in the diet on the ability of cattle to manage heat stress in the feedlot.

Procedure

Angus crossbred yearling steers (n = 180) were received at Haskell Ag Lab near Concord, Neb. Two days post-receiving, steers were weighed, implanted (Ralgro; Shering-Plough Animal Health, Kenilworth, N.J.), vaccinated (Vision 7 and Titanium 5 PHM Bac 1; Intervet, Millsboro, Del.), treated for external parasites (Saber; Schering-Plough Animal Health, Kenilworth, N.J.), and ear tagged for individual identification. Forty-three days after receiving, cattle were individually scored for body condition score (BCS) by two observers. Upon initiation of trial (50 days post-receiving), steers were implanted with Revalor-S (Intervet, Millsboro, Del.) and average body weight on two consecutive days used as the initial weight (mean BW = 1,069 lb). Steers were stratified by BCS and weight, and randomly assigned to one of 24 pens.

Pens were blocked by location and assigned to one of four diet treatments: 1) control; 2) potassium (diet containing 2.10% $KHCO_3$); 3) sodium (diet containing 1.10% NaCl); or 4) potassium and sodium (diet containing 2.10% $KHCO_3$ and 1.10% NaCl). In addition, slight adjustments in roughage type were made in an attempt to elevate dietary cation anion difference (DCAD) in the diets containing added potassium.

Feed and water intakes were recorded daily. Body weights were obtained on days 0, 35, and 67 (day before slaughter). Due to a scheduling problem at the packing plant, carcass data were unable to be obtained. Tympanic temperatures (TT) were recorded using Stowaway XTI® data loggers and thermistors (Onset Corporation, Pocasset, Mass.). The thermistor was inserted approximately 4 to 5 inches into the ear canal until the tip was near the tympanic membrane. The loggers recorded temperatures at 1-hour intervals in 24 animals from eight pens (two pens/treatment; three animals/pen) during days 18 to 22 and days 41 to 46. The same animals were used in both periods. Days 18 to 22 was designated as a thermoneutral (TNL) period, while days 41 to 46 were broken down into two periods; moderately hot (MHOT – days 41 to 43) and hot (HOT – days 44 to 46).

Performance data was analyzed using the mixed procedures of SAS. The model included potassium, sodium and the potassium by sodium interaction. Tympanic temperatures were analyzed using a

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Table 1. Diet composition, dry matter basis.

Treatment[a]:	Control	K	Na	KNa
Ingredient				
Alfalfa	8.00	5.00	7.00	2.50
Corn Silage	4.50	4.50	4.0	7.00
Dry Rolled Corn	80.50	80.40	80.55	78.30
Dry Supplement	2.00	2.00	2.00	2.00
Liquid Supplement	4.50	4.00	4.00	3.50
Soybean Meal	0.50	2.00	1.35	3.50
$KHCO_3$	--	2.10	--	2.10
NaCl	--	--	1.10	1.10
Estimated Nutrient Composition (NRC, 2000)				
Crude Protein, %	13.4	13.4	13.4	13.4
NEg, mcal/lb	0.638	0.638	0.638	0.638
Potassium, %	0.75	1.54	0.73	1.53
Sodium, %	0.12	0.10	0.54	0.52
DCAD, meq/100g[b]	9.13	29.38	8.59	28.8

[a]Control = control; K = potassium added to diet; Na = sodium chloride added to diet; KNa = potassium and sodium chloride added to diet.
[b]DCAD = meq (% in diet/equivalent weight) of [(Na + K) – (CL + S)].

repeated measures model that included sodium, potassium, time of day, period, and all possible interactions. The specified term for the repeated statement was animal within period.

Results

The addition of $KHCO_3$ had a tendency ($P<0.10$) to reduce DMI from days 0 to 34 (Table 3). However, daily water intake (DWI) was increased ($P<0.05$) and DMI/DWI ratio was decreased ($P<0.05$) when $KHCO_3$ was added to the diet. The addition of sodium decreased ($P<0.05$) ADG and increased ($P<0.05$) F/G for days 35 to 67. The combined feeding of potassium and sodium tended to reduce ($P=0.09$) overall ADG, when compared to the other three treatments.

Weather conditions that correspond with the weigh dates (days 0 to 34 and days 35 to 67) and TT observation periods (days 18 to 22 and days 41 to 46) are presented in Table 2. A heat wave occurred during days 44 to 46, so that period was divided into the two three-day periods (MHOT and HOT). Initial analyses revealed significant potassium by sodium by time of day ($P=0.01$) and potassium by sodium by period effects ($P=0.02$). However, when TT were compared within each hour (Figure 1), there were no significant differences ($P>0.10$) among treatments in any given hour. The interaction is significant because of the differing daily cycles in TT for the treatments. Namely, sodium may have a lower peak TT and the potassium and sodium combination treatment TT may drop off faster during the late evening hours. When TT were compared within each period (Table 4), no significant treatment effects ($P>0.10$) were found. The tendency for the potassium and sodium combination treatment group to have a lower TT may be due to the lower DMI and greater DWI that was found in that group. Also, the addition of $KHCO_3$ increased DCAD from below 10 meq to near 30 meq. Increased

Table 2. Weather conditions[a].

	Temperature						
	High	Low	Avg	RH, %	THI[b]	Windspeed, mph	Solar radiation, Ly
day 0 to 34	83.67	62.15	72.91	71.31	70.6	9.81	555.52
day 35 to 67	85.67	62.83	74.25	77.06	72.2	7.24	507.28
day 18 to 22[c]	84.58	63.72	74.15	72.59	71.7	10.46	617.44
day 41 to 43[c]	88.47	65.46	76.96	81.44	75.0	9.51	585.89
day 44 to 46[c]	93.24	71.83	82.53	75.10	79.2	8.14	579.56

[a]Solar radiation recorded from a weather station located 1 mile north and ½ mile west of feedlot. Other recordings taken from weather station located in feedlot.
[b]Temperature Humidity Index (THI), calculated as THI = AvgTemp – (0.55-(0.55*(RH/100)))*(AvgTemp-58)
[c]Weather for periods that correspond to tympanic temperature recording. Heat stress was denoted at thermoneutral for days 18 to 22 (TNL), moderately hot days 41 to 43 (MHOT), and hot for days 44 to 46 (HOT).

Table 3. Performance data.

	Treatment[a]					P-value		
	Control	K	Na	KNa	SEM	K	Na	K*Na
Weights, lb[b]								
day 0	1070	1067	1069	1070	4.2	0.81	0.78	0.61
day 34	1193	1188	1208	1189	9.2	0.25	0.43	0.49
day 67	1280	1275	1283	1260	9.1	0.15	0.53	0.35
ADG, lb								
day 0 to 34	3.61	3.58	4.04	3.50	0.19	0.15	0.38	0.20
day 35 to 6	2.64	2.62	2.32	2.15	0.14	0.51	0.01	0.60
day 0 to 67	3.09	3.11	3.20	2.82	0.11	0.12	0.46	0.09
DMI, lb								
day 0 to 34	23.21	22.95	23.06	21.42	0.55	0.09	0.13	0.21
day 35 to 67	22.53	22.32	22.05	21.97	0.46	0.75	0.38	0.89
day 0 to 67	22.88	22.64	22.57	21.69	0.48	0.26	0.20	0.51
Feed/Gain								
day 0 to 34	6.66	6.67	5.92	6.46	0.32	0.40	0.15	0.41
day 35 to 67	8.68	8.70	9.60	10.28	0.49	0.49	0.02	0.51
day 0 to 67	7.44	7.36	7.08	7.73	0.27	0.33	0.99	0.19
DWI, gal								
day 0 to 34	7.48	9.26	6.84	9.67	0.78	0.02	0.89	0.53
day 35 to 67	8.62	10.39	7.18	10.43	0.73	0.01	0.37	0.35
day 0 to 67	8.03	9.81	7.01	10.04	0.74	0.01	0.60	0.42
DMI/DWI[c]								
day 0 to 34	3.25	2.49	3.42	2.26	0.34	0.02	0.94	0.58
day 35 to 67	2.72	2.15	3.07	2.13	0.23	0.01	0.49	0.44
day 0 to 67	2.97	2.31	3.23	2.20	0.27	0.01	0.80	0.50

[a]Control = control; K = potassium added to diet; Na = sodium chloride added to diet; KNa = potassium and sodium chloride added to diet.
[b]All weights are full weight.
[c]Pair of pens served as experimental unit for daily water intake (DWI) and DMI/DWI.

Table 4. Tympanic temperatures within logger period.

	Treatment[a]					
Item[b]	Control	K	NA	KNa	SEM	P-value
TNL	102.3	102.2	102.1	102.1	0.15	0.56
MHOT	102.3	102.3	102.1	102.1	0.15	0.93
HOT	103.4	103.4	103.5	103.2	0.15	0.76

[a]Control = control; K = potassium added to diet; Na= sodium chloride added to diet; KNa = potassium and sodium chloride added to diet.
[b]TNL = thermoneutral; MHOT = moderately hot; HOT = hot.

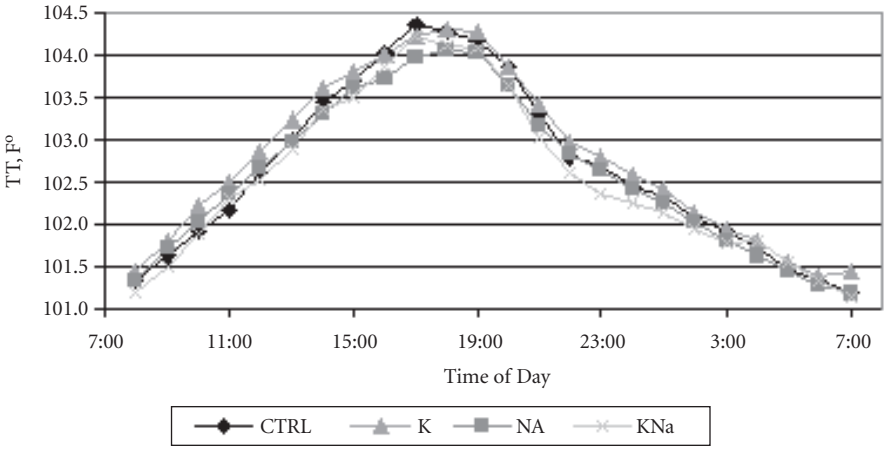

Figure 1. Tympanic Temperatures (TT) within Time of Day[a]. Differences within each hour are not significant ($P > 0.05$).
[a]CTRL = control; K = potassium added to diet; Na = sodium chloride added to diet; KNa= potassium and sodium chloride added to diet.

DCAD levels are generally thought to aide in maintaining body electrolyte balance during hot weather as well as aid in the reduction of acidosis. The increased water intake could possibly be attributed to the increased DCAD levels.

Overall, additional $KHCO_3$ at the 2% level or NaCl at the 1% level did not improve performance or heat stress tolerance with these diet formulations. However, the addition of $KHCO_3$ did enhance water intake.

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[1] Sheryl Colgan, research technician; and Terry Mader, professor, Animal Science, Haskell Agricultural Laboratory/Northeast Research and Extension Center, Concord.

Effect of Feeding DAS-59122-7 Corn Grain and Non-transgenic Corn Grain to Finishing Feedlot Steers

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Summary

Sixty crossbred steers were individually fed either corn genetically modified for corn rootworm protection (Das-59122-7), a conventional non-transgenic corn hybrid, or a near isoline control for 109 days to evaluate nutritional equivalency. The corn was coarsely rolled (geometric mean diameter = 4,200 microns) and treatments offered in the finishing diet at 82% of diet (DM basis). Dry matter intakes, ADG, and F:G were similar among all three corn hybrids. Carcass characteristics showed no significant differences among treatments. The genetically modified corn DAS-59122-7 was nutritionally equivalent to a conventional corn hybrid and a near isoline control when fed to finishing steers. Feeding this genetically modified hybrid did not impact steer performance or carcass quality.

Introduction

Western corn rootworms (CRW) are responsible for more annual crop damage in the United States than all other insects (Metcalf 1986). Although pesticide treatment and crop rotation strategies have historically been used to control the impact of CRW on crop yield, the potential economic and biological benefits of CRW resistant corn grain are substantial (Oehme and Pickrell, 2003; *Biomedical and Environmental Science*).

Fed at a high percentage of many finishing diets, corn provides a large portion of the dietary energy, and genetically modified corn grain and silage are fed widely for livestock consumption. The purpose of this study was to compare corn grain from DAS-59122-7 (*Herculex® RW) with grain from a non-transgenic corn, and a near isoline corn grain. Effects of diets containing these three grains on performance and carcass characteristics were compared to assess the difference in feeding value among these grains.

Procedure

Sixty crossbred steers (BW= 873 $\pm$ 33 lb) were individually fed using Calan gates for 109 days. Dietary treatments consisted of a non-transgenic, near isoline control (CONTROL), a reference, non-transgenic Pioneer Hybrid 35P12 corn hybrid (REFERENCE), and corn grain from DAS-59122-7 (Herculex® RW; Bt-CORN). The dietary ingredients consisted of 82% of the treatment corn, 8.5% alfalfa hay, 5% molasses, and 4.5% supplement. Rumensin® and Tylan® (Elanco Animal Health, Greenfield, Ind.) were fed at rates of 300 and 90 mg/steer daily, respectively. Cattle were fed once daily at 0700 hours and feed refusals were recorded and collected weekly. Samples were dried in a forced air oven at 60°C for 48 hours to calculate accurate DMI and feed efficiencies. Prior to trial initiation, steers were trained to the Calan gate system and adapted to the facilities for a 28-day period. Steers were also grown by limit feeding at 18 lb a diet consisting of 65% dry rolled, non-transgenic corn, 20% alfalfa haylage, 11% grass hay, and 4% supplement. Steers were individually weighed on two consecutive days (day 0 and day 1) to determine initial BW. The BW collected on day 0 was stratified and steer blocked into a light (15 steers), middle (27 steers) and heavy (18 steers) weight block. Within each weight block, steers were assigned randomly to dietary treatment (20 steers per treatment). One CONTROL steer was removed from the experiment due to shoulder problems. On trial initiation (day 1) cattle were implanted with Synovex-Choice® . After being fed for 109 days, steers were harvested at Greater Omaha Pack, Omaha, Neb. where hot carcass weights and liver scores were recorded. Following a 48-hourr chill, kidney-pelvic-heart-fat (KPH), fat depth, LM area, and USDA marbling score were collected. A calculated USDA Yield Grade was derived from hot carcass weight, fat depth, KPH, and LM area. Carcass adjusted performance was calculated assuming a dressing percentage of 63%, which was used to final BW from carcass weights.

Data were analyzed using mixed procedure of SAS for performance and carcass characteristics. Animal was the experimental unit and individual data were analyzed as a randomized complete block design. Differences due to treatment were considered significant when the F-test statistic had a probability level of less than 5% ($P < 0.05$).

Results

Initial BW was not different for steers fed different corn hybrids, as designed. Steers in this experiment were backgrounded and weighed approximately 871 lb. Daily gain was not impacted ($P = 0.32$) by corn hybrid. Numerically, steers fed 35P12 and Bt-CORN had 5% greater DMI, 7% greater ADG, and 2% greater final BW than steers fed CONTROL, but these differences were not statistically significant. As a result, F:G was not

Table 1. Performance and carcass characteristics of steers fed non-transgenic reference (Pioneer 35P12; REFERENCE) corn grain, a near isoline, non-transgenic control hybrid (CONTROL), or Herculex® RW (DAS-59122-7; Bt-CORN).

Item	CONTROL	REFERENCE	Bt-CORN	SEM	P-value
Performance					
Initial BW, lb	871	870	873	3	0.817
Final BW, lb[a]	1220	1250	1240	15	0.365
DMI, lb/day	21.0	21.8	22.3	0.5	0.213
ADG, lb	3.20	3.49	3.37	0.14	0.319
F:G[a]	6.54	6.21	6.62	0.451	
Carcass characteristics					
Carcass weight, lb	769	788	781	10	0.365
Marbling score[b]	463	508	475	18	0.210
LM area, inch^2	12.01	12.42	12.53	0.23	0.266
Fat depth, inch	0.41	0.38	0.37	0.02	0.556
% KPH	1.94	1.94	1.87	0.04	0.345
Calculated YG[c]	2.99	2.85	2.77	0.12	0.425

[a]Final BW calculated from HCW/0.63.
[b]400 = Slight^{0}, 450 = Slight^{50}, 500 = Small^{0}
[bc]YG = 2.5 + (2.5* Fat Depth) + (0.2 * 2% KPH) + (0.0038 * HCW) – (0.32 * LM area) from *Meat Evaluation Handbook*, 2001.

influenced by corn hybrid. Carcass characteristics also were not influenced by corn hybrid. The different corn hybrids fed in this study did not impact fat depth and marbling score suggesting cattle were finished to similar endpoints.

Although the genetically modified hybrid was not compared with other GMO hybrids in this study, previous experiments evaluating GMO hybrids have not detected differences in steer performance. In one other experiment with a different GMO hybrid with corn rootworm protection (event MON 863), performance was not different between that GMO hybrid and either conventional or parental hybrids (Vander Pol et al., 2005; *Journal of Animal Science*).

Our results indicate that Herculex® RW corn grain (DAS-59122-7) is nutritionally equivalent to a non-transgenic, near isoline and conventional corn hybrid. These data suggest that steer performance and carcass composition will be similar for steers fed Herculex® RW corn grain compared to non-transgenic hybrids.

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[1]Taia J. Huls, graduate student; Galen E. Erickson, associate professor; Terry J. Klopfenstein, professor; Matt K. Luebbe, research technician; Kyle J. Vander Pol, former research technician, Animal Science, Lincoln. David W. Rice, research scientist; Brenda Smith[1], research associate; Mark Hinds[1], biometrician; Fred Owens[1], senior research scientist; and Matthias Leibergesell[1], Pioneer Hi-Bred International Inc., Johnston, Iowa.

*Herculex Rootworm Insect Protection by Dow AgroSciences and Pioneer Hi-Bred. Herculex is a trademark of Dow AgroSciences LLC.

Identification of Off-Flavor Compounds in Beef Round and Chuck Muscles

Jennie M. Hodgen
Susan L. Cuppett
Chris R. Calkins[1]

Summary

Volatile off-flavor compounds are present in beef. Using purge and trap gas chromatography and mass spectrometry, some volatile compounds were shown to have different concentrations in normal-flavored beef, compared to samples with liver-like off-flavor. Most of the compounds, like pentanol, hexanal, hexanol, 1–octen–3–ol, and nonanol, are associated with lipid oxidation. The compounds, β-pinene and 1-octen-3-ol were in higher concentration in the liver-like samples in all muscles tested. Several, small, unidentified peaks also differed between samples. Determination of the possible origins of these compounds may improve the quality and consistency of beef products.

Introduction

Flavor is an important factor in beef palatability. With the increased use of individual muscles from the chuck and round, quality and consistency becomes essential to maintain consumer acceptability. Meat flavor is typically developed through reactions between amino acids and carbohydrates in addition to the flavor created by the fatty acid profile. Volatile compounds formed during heating also contribute to flavor and off–flavor in meat. To minimize undesirable volatile off-flavors, an understanding of the compounds being produced in off-flavored samples compared to normal samples is worthwhile. The objective of this research was to identify differences in volatile compounds between steaks with liver–like off–flavors and normal samples.

Procedure

Infraspinatus (Flat Iron; INF), Triceps brachii (Clod Heart; TRI), Rectus femoris (Knuckle Center; REC), Vastus lateralis (Knuckle Side; VAL), and Vastus intermedius (Knuckle Bottom; VAI) were evaluated. These muscles from USDA Select carcasses were identified as "liver–like" or "normal" by a trained taste panel with "normal" classification having an off–flavor rating of 5 or above on an 8–point scale. "Normal" INF were not available at the time of testing. Five grams of the raw, homogenized sample and 10 mL of distilled water analyzed with a O-I- Analytical Eclipse 4660 purge and trap gas chromatograph (GC) system (Hewlett Packard 6890) from 86°F to 176°F. An 11-minute purge was collected in the 86°F trap and allowed to desorb for four minutes. The volatile compounds were auto-injected into the GC and run through a Hewlett Packard 5MS column (98 ft, 0.25 mm ID, and 0.25 µm film thickness), starting at 104°F for four minutes, raised to 482°F at 46.4°F/minute, and held for 10 minutes. Compounds were identified with a mass spectrometer (Hewlett Packard 5973). Samples were kept at refrigerated temperatures (<12 hours) until analyzed.

Table 1. Compound concentration differences between the liver-like and normal beef muscles

	TRI[c]		REC[c]		VAL[c]		VAI[c]	
Compound[a, b]	Liver-like	Normal	Liver-like	Normal	Liver-like	Normal	Liver-like	Normal
2,3-Dimethyl Oxirane							↓	↑
Pentanal	↑	↓					↑	↓
Heptanol	↑	↓			↑	↓	↑	↓
Hexanal	↑	↓			↑	↓	↑	↓
Hexanol					↑	↓	↑	↓
2-Heptanone	↑	↓					↑	↓
Heptanal	↑	↓					↑	↓
Benzaldehyde	↑	↓					↑	↓
β-Pinene	↑	↓	↑	↓	↑	↓	↑	↓
1-Octen-3-ol	↑	↓	↑	↓	↑	↓	↑	↓
2-Methyl-3-Octanone or N-Caproic Acid Vinyl Ester	↑	↓			↑	↓	↑	↓
2-Pentyl Furan	↑	↓					↑	↓
Octanol	↑	↓					↑	↓
α-Pinene	↑	↓					↑	↓
2-Octenal	↑	↓					↑	↓
1-Octenal	↑	↓					↑	↓
Nonanal	↑	↓			↑	↓	↑	↓
Hydroxymandelic Acid							↑	↓
Cyclotetrasiloxane	↑	↓			↑	↓	↑	↓
1,3-bis (1,1-Dimethylethyl)-Benzene							↑	↓

[a]Compounds listed revealed concentration differences in chromatograms.
[b]↑ indicates that a higher concentration of the compound was found in that type of sample; ↓ indicates that a lower concentration of the compound was found in that type of sample.
[c]TRI = Triceps brachii, REC = Rectus femoris, VAL = Vastus lateralis, and VAI = Vastus intermedius.

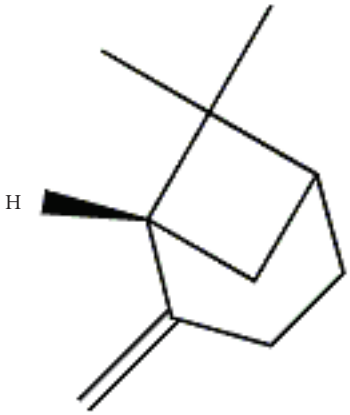

Figure 1. Structure of β-pinene.

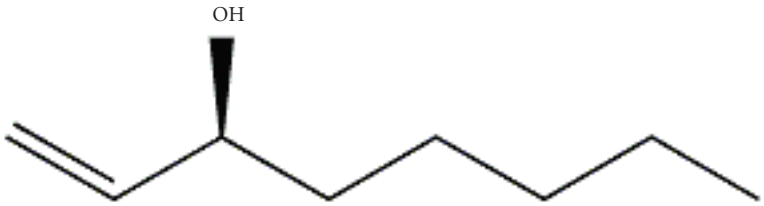

Figure 2. Structure of 1-Octen-3-ol.

Results

Thirty–eight to 74 volatile compounds were present in the samples with normal TRI having the least number of compounds and liver-like VAI having the most. Differences in the presence and concentration of compounds were noted between liver–like and normal samples, as well as among muscles. Several small, unidentified peaks were absent in liver–like samples, but present in the normal. Approximately four peaks were present in the liver-like samples, but absent in the normal samples. When the concentration of the compounds was different, the normal samples, in most cases, had lower concentration in the muscles (Table 1). Most of the compounds found in greater amounts in the liver–like samples are associated with lipid oxidation, such as pentanol, hexanal, hexanol, 1–octen–3–ol, and nonanol. The compounds, β-pinene and 1-octen-3-ol (Figure 1 and 2, respectively), were in higher concentration in the liver-like samples in all muscles tested. As mentioned previously, 1-octen-3-ol is related to lipid oxidation, while β-pinene is an oxidation product of limonene (a common citrus aromatic terpene) found in pine trees and their berries in addition to many plants and forages.

Differences were observed in volatile compounds between liver–like and normal beef muscles from the chuck and round. A combination of compounds, not a single compound, likely contributes to the undesirable flavor. Research to determine the possible origins of these compounds in the beef system is necessary to ensure that quality and consistency of meat from these muscles is acceptable to consumers.

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[1]Jennie M. Hodgen, graduate student; and Susan L. Cuppett, professor, Food Science and Technology, Lincoln; Chris R. Calkins, professor, Animal Science, Lincoln.

[2] This project was funded in part by beef and veal producers and importers through their $1-per-head checkoff and was produced for the Cattlemen's Beef Board and state beef councils by the National Cattlemen's Beef Association.

Fatty Acids and Minerals Affect the Liver-Like Off-Flavor in Cooked Beef

Blaine E. Jenschke
Jennie M. Hodgen
Chris R. Calkins[1]

Summary

Sixty knuckle centers were obtained from a local harvesting facility to determine factors causing the liver-like off-flavor in beef. Medium chain unsaturated fatty acids and sodium explain 46% of the variation of the liver-like off-flavor intensity ratings in cooked knuckle center steaks. Future studies to manipulate the fatty acid and mineral profiles of muscle might prove beneficial in lowering the incidence of the liver-like off-flavor in beef.

Introduction

Flavor is an important trait that consumers use to determine acceptability. Meat flavor is a result of reducing sugars and amino acids, differences in fatty acid composition that are responsible for species-specific flavor, off-flavor development due to lipid oxidation, microbial by-products, or other degradative mechanisms. Current research in our laboratory has specifically concentrated on the liver-like off-flavor.

Research has suggested that potential causes of the liver-like off-flavor in beef are lipid oxidation, heme iron content, and elevated degrees of doneness. Slow cooking (36-40 minutes) and subsequent holding for 1 hour of specific muscles from the chuck and round prior to serving reduces off-flavor intensity *(2006 Beef Report*, p. 112). These results suggest off-flavors may result from volatile compounds.

The objectives of this research were to explore more fully the relationships of minerals and fatty acids to liver-like off-flavors in beef.

Procedure

Samples were obtained using a screening procedure. Briefly, two trained sensory panelists tasted a 10 g piece of the knuckle center (*M. rectus femoris*). Knuckles identified as having an off-flavor (n=30) and knuckles not having an off-flavor were vacuum-packaged and shipped to the Loeffel Meat Laboratory at the University of Nebraska. Following a seven-day aging period at 34°F, the *M. rectus femoris* was isolated and cut into 2.54 cm thick steaks, freezer wrapped and frozen (3°F) until sensory analysis was conducted.

Steaks were cooked to an internal temperature of 158°F on an electric broiler. Internal temperature was monitored with a digital thermometer and a type T thermocouple. When the internal temperature reached 95°F, the steak was turned once until the final temperature was reached. The steak was then cut into 0.5 in x 0.5 in x 1.0 in cubes and served warm to the panelists, approximately five minutes post cooking. Six samples, identified using three-digit codes, were served on each day. Eight-point descriptive attribute scales (Muscle fiber tenderness: 1=extremely tough, 8=extremely tender; Connective tissue: 1=abundant,

Table 1. Distribution of fatty acids in "normal" and liver-like samples[a].

Fatty acid	Normal	Liver-Like	*P*>F
14:0	21.83	16.23	0.08
14:1	4.51	3.08	0.05
15:0	11.10	12.57	0.60
16:0	152.82	127.27	0.16
16:1	17.79	12.05	0.03
17:0	5.70	4.76	0.32
18:0	52.97	59.08	0.37
18:1	164.04	158.42	0.79
18:1 (n-7)	29.85	8.63	0.02
18:2	47.56	40.46	0.35
18:3	1.82	1.41	0.99
20:0	1.55	1.12	0.13
20:1	0.84	1.16	0.30
20:2	0.96	0.81	0.71
20:2 (n-6)	3.49	4.05	0.47
20:3	11.51	12.27	0.77
20:4	1.21	0.00	0.53
20.5	1.49	1.94	0.36
22:5	3.37	3.81	0.63
22:6	0.09	0.12	0.77

[a]All fatty acids are expressed as mg/g.

Table 2. Distribution of minerals in "normal" and liver-like samples[a].

Fatty acid	Normal	Liver-Like	*P*>F
Zn	44.73	49.74	0.36
Fe	20.56	22.15	0.26
P	2018.53	2030.04	0.73
Mn	0.05	0.05	0.99
Mg	247.97	254.59	0.27
Ca	49.87	46.48	0.18
Cu	0.83	0.86	0.67
Na	499.65	516.91	0.35

[a]All minerals are expressed as µg/g.

Table 3. Simple correlations of the liver-like off flavor intensity ratings with fatty acids.

	r (*P*>F)
15:0	0.27 (0.05)
18:1 (n-7)	-0.32 (0.02)
20:2 (n-6)	0.34 (0.02)
20:5	0.28 (0.05)

8=none; Juiciness: 1=extremely dry, 8=extremely juicy; Off-flavor intensity: 1=extreme off-flavor, 8=no off-flavor) were used. Off-flavors were rated using a 15-point intensity scale (0=extremely bland; 15=extremely intense).

Heme iron was determined using an acidified acetone extraction procedure while pH was determined using a penetrating pH probe. Moisture and ash (expressed as percentages) were quantified using a LECO Thermogravimetric Analyzer-601 while percent fat was determined using an ether extraction method. Mineral were isolated and quantified using an inductively-coupled argon plasma spectrometer. Fatty acids were extracted using a 2:1 chloroform:methanol solution and methylated using boron fluoride-methanol.

Data were analyzed using the REG procedure of SAS (Version 9.1.3), and the stepwise option was used to determine the final variables to be included in the model. The CORR procedure was used to generate correlation coefficients.

Results

Amount of fatty acids and minerals are presented in Table 1 and Table 2, respectively. Non-liver-like samples had 3.5 times more vaccenic acid (18:1 n-7) when compared to liver-like samples. Simple correlations from our data indicated vaccenic (r=-0.32; *P*=0.02) and cis-11,14-eicosadienoic (20:2 n-6) (r=0.34; *P*=0.02) and eicosapentaenoic acid (20:5) (r=0.28; *P*=0.05) significantly affected the liver-like off-flavor in this study (Table 3). Others have shown vaccenic acid (r= -0.32; *P*<0.05) and cis-11,14-eicosadienoic acid (r=0.38; *P*<0.05) individually account for a significant amount of variation in the livery off-flavor, which is in agreement with our data. Although not significant, our results suggest palmitoleic acid may also play a role in the development of the liver-like off-flavor (r=-0.25; *P*=0.08).

The final model for predicting liver-like off-flavor was: Liver-like off-flavor rating = -0.21+ 0.0008 (Na) + 0.13 ((20:2 (n-6))- 0.005 (16:1) – 0.002 ((18:1 (n-7)) – 0.033 (20:3) which explained 46% of the variation in the liver-like off-flavor. Previous research from our laboratory indicated heme iron might be a cause of the livery off-flavor in beef, but neither heme iron nor total iron played a role in the development of the liver-like off-flavor in this study.

Data from this study indicate individual fatty acids and minerals play a significant role in the development of the liver-like off-flavor. A better understanding of factors influencing fatty acid and mineral profiles might prove beneficial in lowering the incidence of the liver-like off-flavor in beef.

[1]Blaine E. Jenschke, graduate student; Jennie M. Hodgen, graduate student; and Chris R. Calkins, professor, Animal Science, Lincoln.

Off-Flavor Mitigation in Cow Steaks

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Summary

Strip loins from fed (high energy diet for at least 60 days) and nonfed cows were treated with 1% water a solution containing one of four commercial bitter blockers to determine if off-flavors could be blocked. Neither trained nor consumer taste panels detected differences among the bitter blockers. Trained panelists frequently found metallic, sour, rancid, bloody, salty, and bitter flavors, with nonfed cow beef having more bloody, bitter, and burnt off-flavors. Consumers most frequently identified bloody, metallic and liver-like off-flavors in cow beef, but found no differences in frequency of off-flavor notes between fed and nonfed cow beef. Commercial bitter blockers did not improve flavor. Feeding a high energy diet for at least 60 days prior to harvest changes the flavor of cow beef.

Introduction

More than one thousand volatile compounds have been identified from cooked meats. Perception of off-flavor likely relies on both the olfactory and taste systems. Sour and bitter receptors are likely candidates for detection of off-flavors.

Most off-flavor descriptors seem unrelated to sour, so bitter receptors were the focus of this research. Past approaches to off-flavor were either to remove the troublesome compound or counteract the response (i.e., drown it out by another taste). Our approach was to study compounds that interfere with the transduction mechanism of taste in a taste-receptor cell to prevent the taste cells from ever being activated. This technology has been associated with the pharmaceutical and beverage industries to manage inherently bitter compounds. We hypothesized that incorporation of commercially available bitter blockers would improve acceptability of off-flavored beef.

Procedure

Fed (n=10) and nonfed (n=10) cows were harvested and strip loins collected at Gibbon Packing Inc. (Gibbon, Neb.), obtained from Skylark Meats (Omaha, Neb.) and delivered to the Loeffel Meat Laboratory at the University of Nebraska–Lincoln. The "fed" strips were taken from Gibbon's Prairie Premium program, which is comprised of cows 30 months of age or older that have been fed a high energy diet for at least 60 days, posses white fat, grade commercial or higher, and posses a lean score of 1-4 on a 10-point scale with 1= cherry red and 10= extremely dark. The "nonfed" strips were taken from Gibbon's commodity program, which is comprised of cows that do not fall into the branded program. Half of the strip loins were assigned to either trained or consumer panels. A replication (n=5) consisted of steaks from one strip loin, to which were applied five treatments.

Sample Preparation

The experiment was a split-plot design, with the whole plot being feed level and the split plot being treatment. For the trained panel samples, five 1-inch steaks were removed from each strip loin in succession, from anterior to posterior. For the consumer panel, 10 steaks were removed in the same manner and grouped (1 with 2, 3 with 4, etc.). Either individual or paired steaks were removed from the anterior end of each strip loin, trimmed of any external fat, and randomly assigned to one of five treatments: a control or one of four commercial bitter blockers.

A preliminary screening of 12 bitter blockers took place to identify the most promising compounds for this application. Screening involved applying the 12 bitter blockers at industry-recommended levels to a sample of ground beef with liver-like off-flavor notes (Table 1). Three evaluators conducted an informal evaluation of each product to see if the liver-like off-flavor notes were masked; products showing masking potential were selected for the study. After the screening, four products were selected and used on whole, longissimus muscle steaks at industry-recommended levels: Wixon #12006611 at 0.25%, International Fragrance and Flavor (IFF) #13559607 at 0.20%, IFF #13673888 at 0.20%, and Givaudan #513409 at 0.05% (manufacturers' information in Table 1). Five treatments were represented in each strip loin. For distribution purposes, each treatment (including control) was mixed with water so that addition of 1% of steak weight would deliver the industry-recommended level in the final product. Steaks were combined with 1% water (control) or 1% solution including the appropriate bitter blocker, vacuum packed and tumbled by replication (loin) for 15 min. After equilibrating for 24 hours, samples were frozen and stored at -20°C.

Trained Taste Panel

One-inch thick steaks were broiled on a tabletop broiler to a final internal temperature of 160°F. Temperature was monitored at the geometric center of each steak using a thermocouple thermometer. Steaks were then placed into glass double broilers; samples were held no more than 10 minutes. Immediately before serving the steaks were cut into 0.5 in x 0.5 in portions. The panel was specifically trained for evaluating tenderness, connective tissue, juiciness and to identify off-flavors, if present. The panelists received five samples per session. In a given taste panel session all samples were from the same strip loin with all treatments being represented.

Table 1. Total ingredients screened at industry recommended levels.

Ingredient	Usage	Selected	Corporate Headquarters
Wixon 12006611	0.25%	X	St. Francis, Wis.
Wixon 61004132	0.10%		St. Francis, Wis
IFF 13559607	0.20%	X	New York, N.Y.
IFF 13632175	0.20%		New York, N.Y.
IFF 13673888	0.20%	X	New York, N.Y.
Givaudan 522466	1.50%		Zurich, Switzerland
Givaudan 524293	0.20%		Zurich, Switzerland
Givaudan 513409	0.10%	X	Zurich, Switzerland
Linguagen AMP	0.40%		Cranbury, N.J.
Mastertaste VN	0.10%		Teterboro, N.J.
Mastertaste VGN	0.10%		Teterboro, N.J.

Table 2. Least square means for main effects for trained panel evaluation for tenderness, connective tissue, juiciness, and off-flavor.

Main Effect	Tenderness[a]	Connective tissue[b]	Juiciness[c]	Off-flavor[d]
Treatment				
Control	4.26	3.84	5.47	2.03
Wixon 12006611	4.24	3.77	5.43	2.07
IFF 13559607	4.59	4.10	5.56	2.16
IFF 13673888	4.65	4.20	5.37	2.33
Givaudan 513409	3.91	3.66	5.21	2.60
SEM[e]	0.35	0.36	0.24	0.19
P-value[f]	0.08	0.43	0.54	0.10
Feeding				
Fed	4.09	3.72	5.16	2.10
Nonfed	4.57	4.11	5.66	2.37
SEM[e]	0.39	0.42	0.24	0.15
P-value[f]	0.38	0.54	0.12	0.15

[a]Tenderness: 1= extremely tough; 8= extremely tender.
[b]Connective tissue: 1= abundant amount; 8= no connective tissue.
[c]Juiciness: 1= extremely dry; 8= extremely juicy.
[d]Off-flavor intensity: 0= no off-flavor; 15= very extreme amount.
[e]Standard error of the mean.
[f]*P*-value for the main effects from analysis of variance tables.

Table 3. Percentage incidence of off-flavor notes by the trained panel.

Off-flavor note	Fed[a]	Nonfed[b]	SEM[c]	*P* –value
Metallic	38.9	40.0	0.02	0.69
Sour	34.3	33.7	0.04	0.91
Rancid	20.6	22.3	0.05	0.79
Bloody	10.3[x]	22.9[y]	0.04	0.03
Bitter	9.7[x]	14.9[y]	0.02	0.02
Livery	4.0	5.1	0.02	0.73
Fatty	1.1	5.1	0.01	0.08
Burnt	0.1[x]	1.1[y]	0.01	0.04
Salty	15.4	9.1	0.03	0.16
Sweet	4.0	2.2	0.01	0.21

[a]Fed cow beef.
[b]Nonfed cow beef.
[c]Standard error of the mean.
[x,y]Means with different superscripts within the same row differ significantly ($P<0.05$).

Consumer Taste Panel

Steaks were cooked and served as described above. The panel was asked to evaluating tenderness, connective tissue, juiciness, and overall like. The panel was also asked to note any off-flavors, if present. The panelists received five samples per session. In a given taste panel session all samples were from the same strip loin with all treatments being represented.

Statistical Analysis

Data were analyzed as a split-plot design, with the whole plot being feed level and the split plot being treatment by analysis of variance (ANOVA) using the GLIMMIX procedure of SAS with a predetermined significance level of $P\leq0.05$. When significance was indicated by ANOVA, means separations were performed using the LSMEANS and PDIFF functions of SAS.

Results

Overall off-flavor intensity scores were generally low (2.03 to 2.60 on a 15 point scale); as a result there were no significant treatment effects for reducing off-flavor. Trained panelists (Table 2) showed treatments did not contribute to off-flavor ratings ($P=0.10$). Furthermore, the trained panel found no significant differences ($P>0.05$) between fed and nonfed cow beef in regards to tenderness and juiciness.

If off-flavors were present, panelists were asked to identify them. The trained panel characterized 30-40% of cow meat samples as having metallic and sour notes and 10-20% of the samples as having rancid, bloody, salty, and bitter flavor notes (Table 3). Although the trained panel found no significant differences ($P>0.05$) in off-flavor between fed and nonfed cows, they found nonfed cow meat more frequently had bloody, bitter, and burnt off-flavor notes than meat from fed cows ($P<0.05$).

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In contrast to the trained panel, the consumer panel characterized 30% of cow meat samples as having bloody notes and 10-20% of the samples as having livery and metallic flavor notes (Table 4). This may reflect a difference in how consumers interpret the meaning of off-flavor descriptors. Consumers indicated treatments did not significantly add off-flavor notes (Table 4), nor did they identify any significant differences ($P>0.05$) in frequency of off-flavor notes between fed and nonfed cows (Table 5). Consumers found nonfed cow meat to be significantly ($P=0.02$) less tender and have more connective tissue, with a tendency to have more off-flavor ($P=0.15$) and lower ratings for overall like ($P=0.10$).

In conclusion, the hypothesis that the incorporation of commercially available bitter blockers would improve acceptability of off-flavored beef was not supported. The greatest differences for both consumer and trained panel were in comparisons of fed versus nonfed cow beef rather than among the treatments within a feeding regime.

Table 4. Least square means for main effects for consumer panel evaluation for overall-like, tenderness, connective tissue, juiciness, and off-flavor.

Main Effect	Overall like[a]	Tenderness[b]	Connective Tissue[c]	Juiciness[d]	Off-flavor[e]
Treatment					
Control	5.62	4.55	5.32	4.95	2.04
Wixon 12006611	5.47	4.61	5.34	5.11	2.18
IFF 13559607	5.54	4.55	5.25	5.14	1.99
IFF 13673888	5.60	4.68	5.36	5.31	2.18
Givaudan 513409	5.35	4.36	4.94	5.12	2.24
SEM[f]	0.23	0.20	0.18	0.13	0.14
P-value[g]	0.57	0.52	0.22	0.26	0.45
Feeding					
Fed	5.89	4.96[x]	5.61[x]	5.20	1.96
Nonfed	5.15	4.15[y]	4.87[y]	5.06	2.30
SEM[f]	0.29	0.19	0.18	0.11	0.15
P-value[g]	0.10	0.02	0.02	0.36	0.15

[a]Overall like: 1= extremely dislike; 9= extremely like.
[b]Tenderness: 1= extremely tough; 8= extremely tender.
[c]Connective tissue: 1= abundant amount; 8= no connective tissue.
[d]Juiciness: 1= extremely dry; 8= extremely juicy.
[e]Off-flavor intensity: 1= slight amount; 8= extreme amount.
[f]Standard error of the mean.
[g]*P*-value for the main effects from analysis of variance tables.
[x,y]Means with different superscripts within the same column differ significantly ($P<0.05$).

Table 5. Percentage incidence of off-flavor notes by the consumer panel.

Off-flavor note	Fed[a]	Nonfed[b]	SEM[c]	*P* –value
Metallic	13.1	11.7	0.02	0.58
Sour	3.1	3.9	0.01	0.29
Rancid	5.7	4.5	0.01	0.21
Bloody	27.5	30.8	0.03	0.47
Bitter	7.2	7.9	0.01	0.61
Livery	16.6	15.9	0.01	0.72
Salty	4.5	4.5	0.01	0.98
Sweet	4.0	4.0	0.01	0.97

[a]Fed cow beef.
[b]Nonfed cow beef.
[c]Standard error of the mean.

[1]Donald A. Moss, graduate student; and Chris R. Calkins, professor, Animal Science, Lincoln.

[2] This project was funded in part by beef and veal producers and importers through their $1-per-head checkoff and was produced for the Cattlemen's Beef Board and state beef councils by the National Cattlemen's Beef Association.

Masking Off-Flavors in Ground Beef

Donald A. Moss
Chris R. Calkins[1]

Summary

Ground beef derived from fed (high energy diet for at least 60 days) and non-fed cows was combined with one of five commercial bitter blockers to determine if off-flavors could be masked. Off-flavor scores were generally low; no significant treatment effects were observed. Trained panelists more frequently noted sour, fatty, rancid and liver-like off-flavors in nonfed cow beef (and metallic flavors in fed cow beef). Consumers found no differences in flavor notes. Bitter blockers did not affect flavor perception. The greatest differences were between fed and non-fed cow beef.

Introduction

Off-flavors are often reported in cow beef. Some cows are fed a supplemental ration prior to slaughter in an effort to improve the carcass and meat quality. This research was conducted to determine if commercial bitter blocking compounds could mask off-flavors in ground beef. The study also provided the opportunity to compare ground beef from fed and non-fed cows for off-flavor notes.

Procedure

Five boxes of 90/10 nonfed cow trim, and five inside rounds from fed cows were obtained from Skylark Meats (Omaha, Neb.) and delivered to the UNL Loeffel Meat Laboratory. The "fed" inside rounds originated from the Gibbon Packing Inc. (Gibbon, Neb.) Prairie Premium program, which were fabricated from cows 30 months of age or older that have been fed a high energy diet for at least 60 days, possess white fat, grade commercial or higher, and possess a lean score of 1-4 on a 10 point scale with 1=cherry red and 10=extremely dark. The "nonfed" trim was taken from Gibbon's commodity program, which is comprised of cows that do not fall into the branded program. Trim and inside rounds were assigned to either a trained or consumer panel. Six treatments were applied within each replication (n=5), which consisted of a single, ground, inside round (fed) or a box of ground trim (nonfed).

Sample Preparation

Five inside rounds from fed cows and five boxes of nonfed cow trim were obtained and randomly assigned to one of five replications. Replications were trimmed, weighed out to 90% lean and 10% fat, and course ground through a kidney plate and a second grind through a 1/16 in plate. Six samples (1/3 lb) were removed from each replication of ground beef, and randomly assigned to one of six treatments: a control or one of five commercial bitter blockers. A preliminary screening of 12 bitter blockers took place to identify the most promising compounds for this application *(2007 Nebraska Beef Report,* pp. 86-88). Five products were selected for use in ground beef at industry-recommended levels: Wixon #12006611 at 0.25%, International Fragrance and Flavor (IFF) #13559607 at 0.20%, IFF #13673888 at 0.20%, Givaudan #513409 at 0.05%, and Linguagen at 0.40%. All five treatments were represented in each replication. For distribution purposes, each treatment was mixed with water such that addition of 1% of sample weight would deliver the industry recommended level, 0.05%-0.25%, in the final product. Samples were manually mixed for 15 seconds with 1% water (control) or 1% solution with the appropriate bitter blocker. Samples were formed into approximately 1/3 lb patties using a 4 in x 4 in square patty mold, wrapped, frozen and stored at -20°C.

Trained Taste Panel

Patties were broiled on a tabletop broiler to a final internal temperature of 160°F. Immediately before serving the patties were cut into 0.5 in x 0.5 in portions. The panel was trained to evaluate juiciness and identify off-flavors, if present. The panelists received six samples per session. In a given taste panel session all samples were from the same replication of ground beef with all treatments being represented.

Consumer Taste Panel

Patties were cooked as described above and held no more than 10 minutes. Immediately before serving the patties were cut into 0.5 in x 0.5 in portions. The panel was asked to evaluate juiciness and overall like and was also asked to note any off-flavors, if present. The panelists received six samples per session. In a given taste panel session all samples were from the same replication of ground beef with all treatments being represented.

Statistical Analysis

Data were analyzed as a split-plot design, with the whole plot being feed level and the split plot being treatment by analysis of variance (ANOVA) using the GLIMMIX procedure of SAS with a predetermined significance level of $P \leq 0.05$. When significance was indicated by ANOVA, means separations were performed using the LSMEANS and PDIFF function of SAS.

Results

Overall off-flavor scores were generally low; as a result there were no significant treatment effects for reducing off-flavor. In addition, both consumer and trained panelists showed no significant differences ($P>0.05$) in regards to off-flavor ratings (Table 1).

If off-flavors were present, panelists were asked to identify them. Consumers found no significant difference in frequency of off-flavor notes between fed and nonfed cow beef (Table 2). The trained panel found non-fed cow meat more frequently had sour, fatty and rancid off-flavor notes than meat from fed cows ($P=0.001$, 0.05 and 0.002, respectively), with livery approaching significance ($P=0.06$). Fed cow meat more frequently had metallic off-flavor notes ($P=0.008$) for trained panelists than meat from nonfed cows (Table 3).

Consumers found a treatment by feeding interaction for overall like and juiciness ($P=0.04$ and 0.02; Table 4). The IFF #13673888 showed significantly ($P=0.04$) higher overall like rating (0.79) for fed versus nonfed cows. The Wixon #12006611 and Givaudan #513409

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Table 1. Least squares means for main effects for hamburger trained and consumer panel evaluation for off-flavor.

Main Effect	Trained Off-flavor[a]	Consumer Off-flavor[b]
Treatment		
Control	4.95	2.04
Wixon 12006611	5.11	2.18
IFF 13559607	5.14	1.99
IFF 13673888	5.31	2.18
Givaudan 513409	5.12	2.24
SEM[d]	0.13	0.14
P-value[e]	0.26	0.45
Feeding		
Fed	5.20	1.96
Non-Fed	5.06	2.30
SEM[d]	0.11	0.15
P-value[e]	0.36	0.15

[a]Off-flavor intensity trained panel: 0= no off-flavor; 15= extreme amount.
[b]Off-flavor intensity consumer panel: 1= slight amount; 8= extreme amount.
[d]Standard error of the mean.
[e]*P*-value for the main effects.

treatments showed a significantly (*P*=0.001 and 0.03) higher consumer juiciness ratings (0.94 and 0.55) for nonfed versus fed cow beef. Within nonfed cow meat, Wixon #12006611 yielded significantly (*P*<0.05) higher taste panel ratings for juiciness than the other ingredients. Similarly, the trained panelists found a treatment by feeding interaction (Table 5) for salty (*P*=0.01) flavor notes, and juiciness was approaching significance (*P*=0.06). The control, Wixon #12006611 and IFF #13559607 showed a significantly (*P*=0.001, 0.007 and 0.002) higher incidence for salty in fed versus nonfed cow beef. Within fed cow meat, control, Wixon #12006611 and IFF #13559607 showed significantly (*P* <0.05) higher percentages for incidence of salty off-flavor notes.

In conclusion, the hypothesis that the incorporation of commercially available flavor mitigation systems would improve acceptability of off-flavored beef was not supported. The greatest differences for both consumer and trained panel were in regards to comparison of fed versus non-fed cow beef rather than between the treatments within a feeding regime.

Table 2. Percentage incidence of off-flavor notes by the hamburger consumer panel.

Off-flavor note	Fed[a]	Nonfed[b]	SEM[c]	*P*-value
Metallic	13.9	14.3	0.02	0.87
Sour	4.8	5.6	0.02	0.77
Rancid	5.4	14.9	0.03	0.10
Bloody	10.1	10.6	0.01	0.81
Bitter	5.4	8.4	0.02	0.24
Livery	16.9	18.8	0.04	0.72
Salty	7.1	4.0	0.01	0.07
Sweet	5.1	3.1	0.01	0.22

[a]Fed cow beef.
[b]Nonfed cow beef.
[c]Standard error of the mean.

Table 3. Percentage incidence of off-flavor notes by the hamburger trained panel.

Off-flavor note	Fed[a]	Nonfed[b]	SEM[c]	*P*-value
Metallic	26.5[x]	13.3[y]	0.03	0.01
Sour	18.7[x]	31.4[y]	0.02	<0.01
Rancid	51.7[x]	72.3[y]	0.03	<0.01
Bloody	3.2	1.1	0.01	0.18
Bitter	20.0	21.2	0.03	0.75
Livery	1.1	15.8	0.05	0.06
Fatty	0.6[x]	3.1[y]	0.01	0.05
Sweet	3.3	3.8	0.03	0.78

[a]Fed cow beef.
[b]Nonfed cow beef.
[c]Standard error of the mean.
[x,y]Means with different superscripts within the same row differ significantly (*P*<0.05).

Table 4. Interaction effects from consumer taste panel evaluation for overall-like and juiciness[a].

	Overall like[b]			Juiciness[c]		
Treatment	Fed	Nonfed	Fed vs. Non-fed *P*-value[d]	Fed	Nonfed	Fed vs. Non-fed *P*-value[d]
Control	5.79	5.45	0.34	4.23	4.37[x]	0.58
Wixon 12006611	5.80	5.95	0.67	4.19	5.13[y]	<0.01
IFF 13559607	6.02	5.46	0.13	4.53	4.50[x]	0.88
IFF 13673888	6.09	5.30	0.04	4.51	4.32[x]	0.46
Givaudan 513409	5.66	5.47	0.58	4.09	4.65[x]	0.03
Linguagen-AMP	6.06	5.45	0.11	4.50	4.65[x]	0.97
SEM[e]	0.24	0.24		0.18	0.18	

[a]Overall like *P*–value for treatment by feed interaction= 0.04; juiciness *P*-value for treatment by feed interaction= 0.02.
[b]Overall like: 1= extremely dislike; 9= extremely like.
[c]Juiciness: 1= extremely dry; 8= extremely juicy.
[d]*P*-value for the simple effects.
[e]Standard error of the mean.
[x,y]Means with different superscripts within the same column differ significantly (*P*<0.05).

Table 5. Interaction effects from trained taste panel evaluation for juiciness and salty[a].

	Juiciness [b]			Salty[c]		
Treatment	Fed	Nonfed	Fed vs. Non-fed *P*-value[d]	Fed	Nonfed	Fed vs. Non-fed *P*-value[d]
Control	3.95	4.67	0.07	16.2[y]	<0.01	<0.01
Wixon 12006611	3.97	4.96	0.02	12.9[y]	<0.01	0.01
IFF 13559607	4.11	4.60	0.21	14.8[y]	<0.01	<0.01
IFF 13673888	4.61	4.17	0.25	3.3[x]	0.00	0.46
Givaudan 513409	3.84	4.67	0.04	0.0[x]	<0.01	1.00
Linguagen-AMP	4.60	4.81	0.58	<0.01[x]	6.7	0.15
SEM[e]	0.33	0.33		0.03	0.03	

[a]Juiciness *P*–value for treatment by feed interaction= 0.06; salty *P*-value for treatment by feed interaction= 0.01.
[b]Juiciness: 1= extremely dry; 8= extremely juicy.
[c]Salty: Percentage incidence of salty off-flavor note.
[d]*P*-value for the simple effects.
[e]Standard error of the mean.
[x,y]Means with different superscripts within the same column differ significantly (*P*<0.05)

[1] Donald A. Moss, graduate student; and Chris R. Calkins, professor, Animal Science, Lincoln.

[2] This project was funded in part by beef and veal producers and importers through their $1-per-head checkoff and was produced for the Cattlemen's Beef Board and state beef councils by the National Cattlemen's Beef Association.

Enhancement of Beef Chuck and Round Muscles with Ammonium Hydroxide

Adam E. Hamling
Chris R. Calkins[1,2]

Summary

By increasing muscle pH with ammonium hydroxide, shear force values of triceps brachii, biceps femoris, and rectus femoris were decreased and sensory scores for tenderness improved with higher levels of added solution. Any level of treatment was beneficial. In all cases, there were no shear force differences between steaks pumped to 15% and 22.5%. Ultimate pH was strongly related to shear force values. These data suggest adjusting pH in beef with 20% of a solution of ammonium hydroxide can increase tenderness in beef chuck and round muscles.

Introduction

Tenderness is one of the major factors affecting consumer acceptability of beef steaks.

Due to the large tenderness inconsistencies between carcasses, muscles, and locations within a muscle, enhancement procedures have been developed to create a more consistent product. Traditionally enhancement has been done with a solution of water, salt, and phosphates. A new procedure injects a solution comprised of water, salt, ammonium hydroxide, and carbon monoxide. Currently this enhancement procedure is done on high-value cuts from the loin. The objectives of this study were to evaluate the tenderness of low-valued muscles from the beef chuck and round when enhanced with this solution at varying pump levels, and to determine the optimum pump level for the muscles.

Procedure

This study examined four pump levels (0%, 15%, 22.5%, and 30%) on three muscles from the beef chuck and round (triceps brachii, biceps femoris, rectus femoris). Beef clod hearts, sirloin caps, and knuckles (n=60 each) were randomly assigned to each treatment and one of three replications. Subprimals were injected with a solution containing water, salt, ammonium hydroxide, and carbon monoxide (patent pending technology from Freezing Machines, Inc.) at Beef Product Inc.'s facility in Dakota City, Neb. Three steaks were cut from each subprimal to a thickness of 1 inch, trimmed of excess fat and other muscles, vacuum packaged in trays, and frozen. Steaks were then shipped to the University of Nebraska Loeffel Meat Lab where they were used for determination of Warner-Bratzler shear force, pH, and trained taste panel ratings. Thaw loss, cook loss, and cook time were also recorded when steaks were cooked for Warner-Bratzler shear force and trained taste panels. A trained taste panel evaluated steaks for tenderness, connective tissue, juiciness, and off-flavor on eight-point scales (8=extremely tender, no connective tissue, extremely juicy, no off-flavor; 1=extremely tough, abundant amount of connective tissue, extremely dry, extreme off-flavor).

Table 1. Taste panel ratings[1] and shear force values between varying pump levels for each muscle.

Muscle	Tenderness	Connective Tissue	Juiciness	Off-Flavor	Shear force, lbs
Clod (Triceps brachii)					
0%	5.49 [a]	5.44 [a]	5.29 [a]	7.22 [a]	8.97 [a]
15%	6.14 [b]	5.97 [b]	5.77 [b]	7.52 [b]	7.89 [b]
22.5%	6.56 [c]	6.36 [c]	6.17 [c]	7.49 [b]	7.21 [b]
30%	7.07 [d]	6.67 [d]	6.66 [d]	7.52 [b]	6.06 [c]
SE	0.15	0.15	0.18	0.11	0.13
Knuckle (Rectus femoris)					
0%	5.33 [a]	5.11 [a]	5.47 [a]	6.76 [a]	9.59 [a]
15%	6.00 [b]	5.76 [b]	5.58 [a]	7.07 [b]	7.39 [b]
22.5%	6.20 [b]	5.93 [b]	5.84 [ab]	7.08 [b]	6.90 [bc]
30%	6.35 [b]	5.96 [b]	6.18 [b]	7.16 [b]	6.50 [c]
SE	0.21	0.22	0.22	0.11	0.13
Sirloin cap (Biceps femoris)					
0%	5.71 [a]	5.65 [a]	5.61 [a]	6.80 [a]	8.86 [a]
15%	7.12 [b]	6.75 [bc]	6.34 [bc]	7.36 [b]	5.89 [b]
22.5%	7.00 [b]	6.65 [b]	6.24 [b]	7.45 [b]	5.24 [b]
30%	7.46 [c]	7.10 [c]	6.66 [c]	7.46 [b]	4.34[c]
SE	0.16	0.18	0.18	0.13	0.14

[1]Taste panel ratings based on 8-point scale (8=extremely tender, no connective tissue, extremely juicy, no off-flavor; 1=extremely tough, abundant amount of connective tissue, extremely dry, extreme off-flavor.
[a,b,c,d]Means within the same column with different superscripts are significantly different ($P<0.05$).

Results

For all muscles (Table 1), shear force decreased as the target pump level increased ($P<0.05$). In all cases but one (juiciness of the rectus femoris), the control had the least desirable ratings and shear force values ($P<0.05$). There were no significant shear force differences between the 15% and 22.5% pump levels ($P>0.05$). Table 1 shows as percentage pump increased, pH increased. The ultimate pH was strongly related to shear force (r=0.70, 0.80, and 0.55 for Triceps brachii, Biceps femoris, and Rectus femoris, respectively). Generally, a higher pH means a greater amount of water is held within the tissue, often resulting in lower shear force values. Trained taste panels revealed an increase in tenderness, decrease in connective tissue, and an increase in juiciness as pump level increased for all muscles. The optimum target pump level was determined to be 20% due to the fact that muscles pumped to 30% tended to have an uncharacteristic soft and mushy texture, as well as the fact that there were no significant characteristic differences between muscles pumped to 15% and 22.5%.

Data show that enhancement with ammonium hydroxide and salt is effective in low-value muscles from the beef chuck and round. In addition, the optimum pump level for all muscles was determined to be 20%.

[1]Adam E. Hamling, graduate student; and Chris R. Calkins, professor, Animal Science, Lincoln.

[2]This project was funded in part by beef and veal producers and importers through their $1-per-head checkoff and was produced for the Cattlemen's Beef Board and state beef councils by the National Cattlemen's Beef Association.

Effects of Aging on Beef Chuck and Round Muscles Enhanced with Ammonium Hydroxide and Salt

Adam E. Hamling
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Summary

This study was conducted to determine if aging alters the beneficial effects of enhancement with a 20% solution of water, ammonium hydroxide, and salt, on beef steaks. For all muscles (triceps brachii, biceps femoris, rectus femoris), steaks had lower shear force values when compared to non-pumped controls at every aging period (1, 7, 14 days). Also, enhanced steaks received more desirable evaluations for tenderness, juiciness, flavor, and overall acceptability at every aging period from consumer taste panels. These data indicate aging does not decrease the benefits of enhancement.

Introduction

In an earlier phase to this project, it was shown that beef chuck and round muscles enhanced with a water, ammonium hydroxide, and salt solution are more tender than nonenhanced muscles. In addition, enhanced steaks had higher (more desirable) connective tissue ratings, were juicier, and had less off-flavor than nonenhanced steaks. Also, the optimum pump level for these muscles was determined to be 20%.

During aging of meat, proteins that give a muscle its structure and functionality break down. Aged meat is generally more tender than unaged meat. The objectives for this study were to determine if the benefits of enhancing beef chuck and round muscles with ammonium hydroxide and salt are reduced by aging.

Procedure

This study examined effects of aging on enhanced and nonenhanced (control) beef chuck and round muscles. Beef subprimals (clod hearts, sirloin caps, and knuckles; n=72 each) were randomly assigned to each treatment (enhanced or control), aging period (1, 7 14 days), and one of three replications. Enhanced subprimals were injected with a solution containing water, ammonium hydroxide, and salt (patent pending technology from Freezing Machines, Inc.) to a 20% target pump level at Beef Product Inc.'s facility in Dakota City, Neb. Three steaks were cut from each subprimal to a thickness of 1 inch, trimmed of excess fat and muscles, and packaged in a modified atmosphere package (80% oxygen, 20% carbon monoxide). Steaks were then shipped to the University of Nebraska Loeffel Meat Lab. At the end of each aging period steaks were removed from the modified atmosphere package, vacuum packaged, and frozen. Steaks (triceps brachii, biceps femoris, and rectus femoris) were then used for determination of Warner-Bratzler shear force and consumer taste panel ratings. Thaw loss, cook loss, and cook time were also recorded when steaks were cooked to 158° F for Warner-Bratzler shear force and consumer taste panels. Consumer taste panels evaluated steaks for desirability of tenderness, connective tissue, juiciness, flavor, and overall acceptability on an 8-point scale (8 = extremely desirable, 1 = extremely undesirable).

Results

For all muscles, enhanced steaks had lower shear force values than the controls at every aging period. Figure 1 shows the Warner-Bratzler shear force differentials between control and pumped steaks. After aging for one day, shear forces from control steaks were 2.14, 2.27, and 3.04 lb higher than enhanced steaks for the triceps brachii, biceps femoris, and rectus femoris, respectively. At

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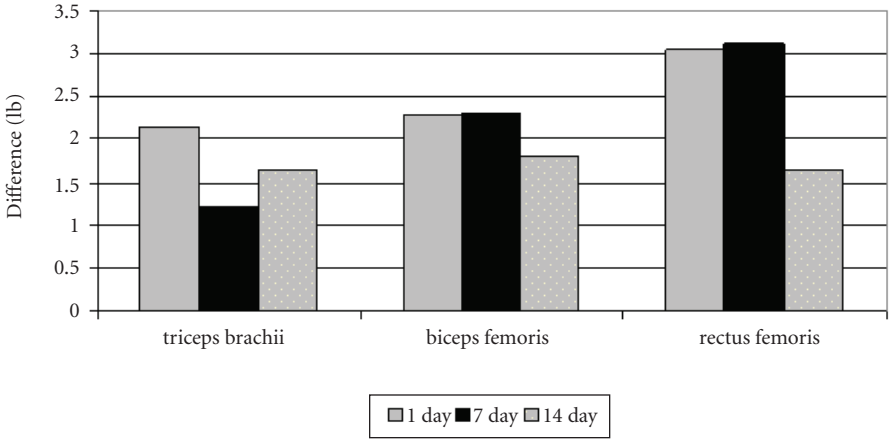

Figure 1. Warner-Bratzler shear force differentials (CONTROL – PUMP) at 1, 7, and 14 days of age.

day 7 of age, shear forces for control steaks were 1.23, 2.31, and 3.11 lb higher than enhanced steaks (triceps brachii, biceps femoris, and rectus femoris, respectively). After 14 days of aging, shear forces for control steaks were 1.65, 1.81, and 1.65 higher than enhanced steaks for the respective muscles above.

Figure 2 shows the differences in consumer taste panel evaluations for overall acceptability between enhanced and control steaks. At day 1 of age, enhanced steaks were rated 1.31, 1.63, and 1.67 points higher than control for the triceps brachii, biceps femoris, and rectus femoris, respectively. At day 7 of age, enhanced steaks were rated 0.91, 1.28, and 1.28 points higher than control steaks for the respective muscles. After 14 days of aging, enhanced steaks were rated 1.30, 1.93, and 1.40 points higher than control steaks for the respective muscles above. Table 1 shows that for every muscle, enhanced steaks were always more desirable than control steaks in terms of tenderness, juiciness, off-flavor, and overall acceptability. These data indicate aging does not decrease the benefits (tenderness, juiciness, and flavor) of enhancement.

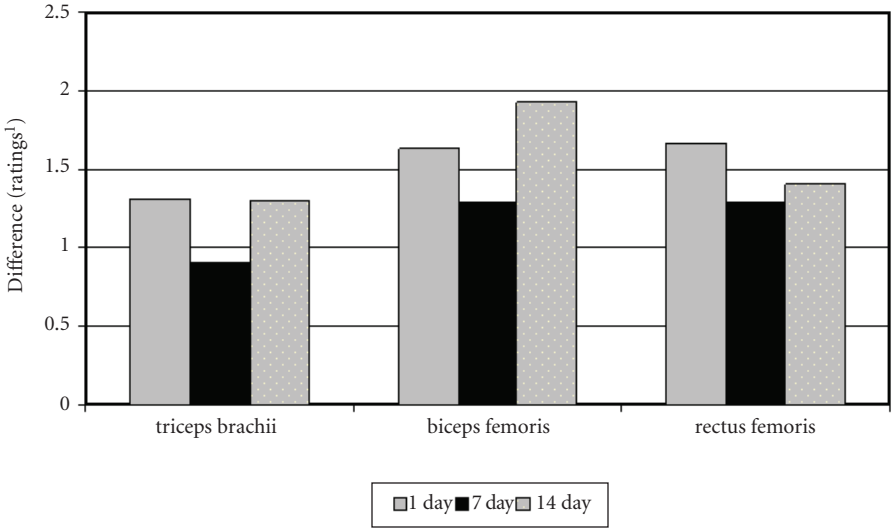

Figure 2. Consumer taste panel differentials for 'overall acceptability' (PUMP – CONTROL) at 1, 7, and 14 days of age.

Table 1. Consumer taste panel ratings[1] and Warner-Bratzler shear force values[1]

	Consumer Taste Panel Ratings[2]				
Muscle	Tenderness	Juiciness	Off-flavor	Overall Satisfaction	Warner-Bratzler shear force2
Triceps brachii					
Control	4.23[a]	4.13[a]	4.10[a]	4.07[a]	10.91[b]
Pump	5.40[b]	5.32[b]	4.93[b]	5.11[b]	9.21[a]
SE	0.09	0.09	0.10	0.10	0.20
Aging time, days					
1	5.24[y]	5.10[y]	5.15[z]	5.16[z]	9.15[x]
7	4.67[y]	4.62[x]	4.57[y]	4.56[y]	10.60[y]
14	4.53[x]	4.46[x]	3.84[x]	4.05[x]	10.43[y]
SE	0.16	0.13	0.11	0.14	0.28
Biceps femoris					
Control	4.62[a]	4.49[a]	4.33[a]	4.32[a]	8.53[b]
Pump	6.23[b]	5.74[b]	5.29[b]	5.55[b]	6.39[a]
SE	0.13	0.11	0.10	0.09	0.11
Aging time, days					
1	5.71[y]	5.36[y]	5.29[z]	5.38[z]	6.75[x]
7	5.41[xy]	5.11[xy]	4.92[y]	5.01[y]	7.28[x]
14	5.16[x]	4.87[x]	4.22[x]	4.42[x]	8.38[y]
SE	0.15	0.12	0.11	0.11	0.14
Rectus femoris					
Control	3.67[a]	3.61[a]	3.72[a]	3.47[a]	10.49[b]
Pump	5.12[b]	4.94[b]	4.79[b]	4.81[b]	7.89[a]
SE	0.15	0.11	0.09	0.10	0.14
Aging time, days					
1	4.59[y]	4.62[y]	4.72[z]	4.53[y]	9.15
7	4.56[y]	4.36[y]	4.37[y]	4.27[y]	9.04
14	4.04[x]	3.85[x]	3.67[x]	3.62[x]	9.41
SE	0.17	0.19	0.15	0.17	0.17

[1]Based on an 8-pt scale: 8 = extremely desirable, 1 = extremely undesirable
[2]Warner-Bratzler shear force is expressed as lb-force
[a,b]Means in the same column (for each muscle) that do not have common superscripts differ ($P<0.05$)
[x,y,z] Means in the same column (for each muscle) that do not have common superscripts differ ($P<0.05$)

[1]Adam Hamling, graduate student; and Chris Calkins, professor, Animal Science, Lincoln.

[2]This project was funded in part by beef and veal producers and importers through their $1-per-head checkoff and was produced for the Cattlemen's Beef Board and state beef councils by the National Cattlemen's Beef Association.

Ranking Beef Muscles for Warner-Bratzler Shear Force and Trained Sensory Panel Ratings

Gary A. Sullivan
Chris R. Calkins[1]

Summary

Combining 60 years of published research, 40 different beef muscles were ranked by Warner-Bratzler shear force. Relative ranks for tenderness, juiciness and beef flavor ratings were also determined. The psoas major and infraspinatus are the two most tender. Sensory tenderness ratings correlated to shear force means (-0.85; p=0.001) where a desirable tenderness rating reflected a low shear force. These data help reconcile differences among various studies of beef tenderness and provide a weighted ranking for beef muscles, which will be useful when selecting muscles for value-added beef products.

Introduction

For over 60 years meat scientists have been investigating characteristics of individual muscles. Through the years scientists have completed studies involving many muscles and few animals; as well as few muscles over many animals. Not surprisingly among studies, the relative tenderness rank of specific muscles has not always agreed. The objective of this study was to create a weighted ranking of muscles based on a comprehensive review of the literature.

Procedure

A comprehensive review of literature began by searching for all papers that studied at least three muscles from a minimum of three animals for any of following: Warner-Bratzler shear force (WBS), sensory panel ratings for tenderness, juiciness, and beef flavor. The muscle number criterion was set to select papers comparing and analyzing individual muscles. At the same time, if fewer than three animals were used, the study offered less comparative value.

Following the initial criteria, 58 papers were identified spanning six decades and many institutions. However, these studies included a wide variety of protocols. Age of animals varied from 10 months to over 11 years of age. Heifers, steers, and bulls from *Bos indicus* to dairy type breeds were used. USDA yield grades ranged from 1 to 5 and quality grades included nearly all grades for both young and mature beef. Aging periods varied from 1 to 28 days. Both steaks and roasts were cooked to an end point temperature ranging from 135 – 185°F using a wide variety of cooking methods. Samples were then evaluated for WBS using .47, .5, .51, .79, or 1 inch cores. Sensory panel rating scales offered 5 to 10 classifications.

Due to these differences, constraints were placed on which papers were used to determine overall rankings. Selection was based around traits typical of the U.S. market beef population. Acceptable studies included steers, heifers, or both under 30 months of age or were A or B maturity carcasses from any quality grade. Purebred *Bos indicus* were excluded, but crossbreds were allowed. Additional constraints were added to handling and testing techniques. Steaks were cooked or frozen from 5 to 14 days post slaughter. Moist cooking methods were excluded for consistency and products were cooked to an end point temperature range of 158 – 171°F. Papers were narrowed to those that used .47-.51 in. cores for WBS. Only trained sensory panels were chosen but no selection was placed on rating scale. Ultimately, 22 papers were used for ranking muscles on the basis of WBS. There were 11 papers for ranking on tenderness ratings, 11 for ranking by juiciness, and six for beef flavor.

Muscles, weighted by number of observations, were analyzed for WBS using Proc GLM and LS Means function of SAS to create a rank. Sensory panel ratings were analyzed in the same method after being standardized to a 100 point scale where 100 is most tender, juicy, or beef flavor. Proc Corr was used to analyze the correlation of ranks and means for WBS and sensory panel.

Muscles were placed in three tenderness groups on the basis of WBS: tender (<8.58 lb), intermediate (8.58 lb<x< 10.12 lb), and tough (>10.12 lb). The sensory panel results were placed in eight groups: <18.75, and in increments of 12.5 beyond that for tenderness, juiciness, and beef flavor. Higher ratings reflect more desirable sensory traits.

Table 1. Abbreviations for the muscles ranked.

Abbreviation	Muscle
ADD	Adductor
BIB	Biceps brachii
BIF	Biceps femoris
BRA	Brachialis
BCO	Brachiocephalicus omotransversarius
COM	Complexus
COB	Cutaneous-omo brachialis
DEP	Deep pectoral (pectoralis profundus)
DEL	Deltoideus
ECR	Extensor capri radialis
GAS	Gastrocnemius
GLU	Gluteus medius
BRA	Gracilis
INF	Infraspinatus
LAT	Latissimus dorsi
LNG	Longissimus dorsi
LDC	Longissimus dorsi (chuck)
LLU	Longissimus lumborum
LTH	Longissimus thoracis
MUL	Multifidus dorsi
OEA	Obliquus externus abdominis
OIA	Obliquus internus abdominus
PSM	Psoas major
QDF	Quadriceps femoris
REA	Rectus abdominis
REF	Rectus femoris
RHO	Rhomboideus
SEM	Semimembranosus
SET	Semitendinosus
SEV	Serratus ventralis
SPI	Spinalis dorsi
SPL	Splenius
SUB	Subscapularis
SPP	Superficial pectora
SPS	Supraspinatus
TFL	Tensor fascia latae
TER	Teres major
TRA	Trapezius
TRI	Triceps brachii
VAL	Vastus lateralis
VAM	Vastus medialis

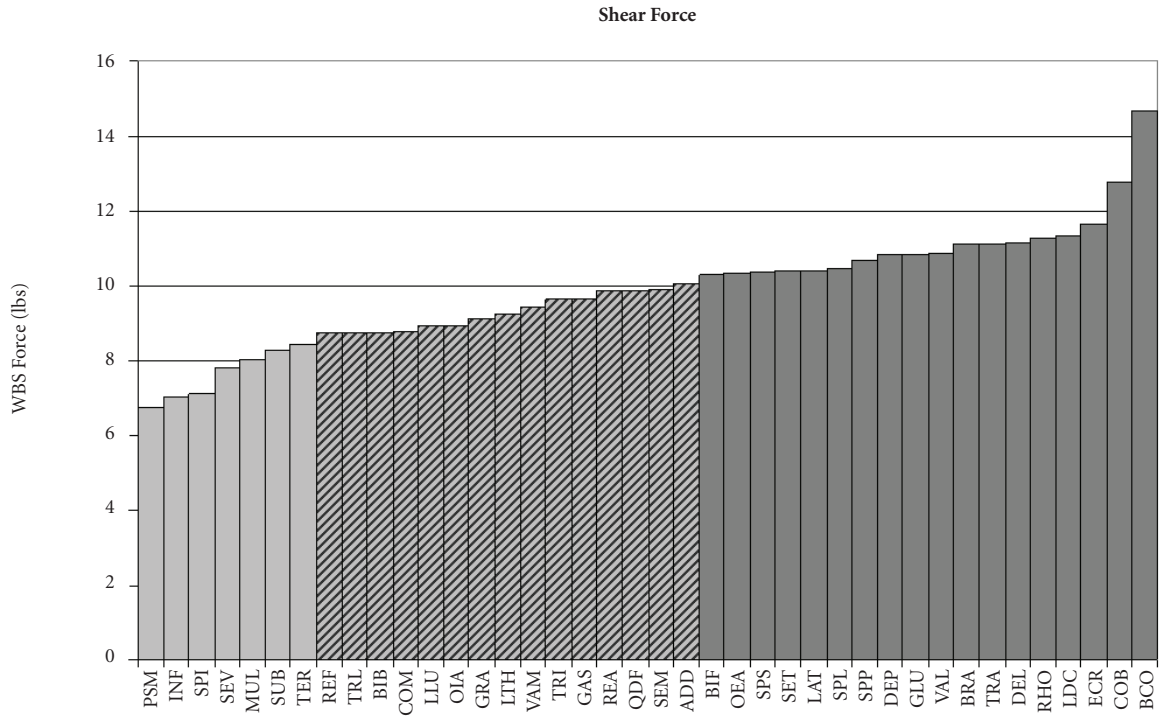

Figure 1. Rank of muscles based on WBS values (n=40).

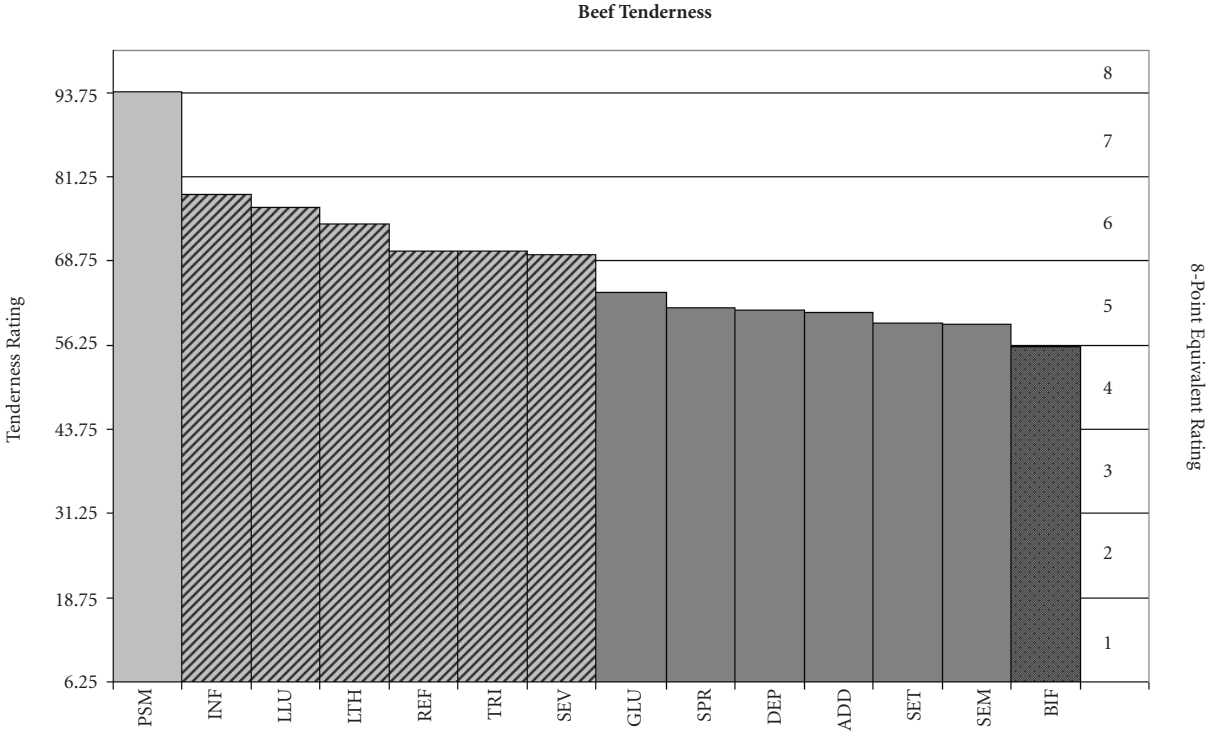

Figure 2. Rank of muscles based on sensory panel ratings for tenderness (n=14).

Results

Of the 40 muscles ranked for WBS (Table 1), psoas major, infraspinatus, spinalis dorsi, serratus ventralis, multifidus dorsi, subscapularis, teres major were classified as tender (<8.58 lb). The psoas major has long been utilized for its tenderness. The multifidus dorsi and spinalis dorsi are found in ribeye steaks. The infraspinatus and teres major have been increasingly utilized as "value cut" steaks. However, the serratus ventralis and subscapularis are under-utilized in relationship to their inherent shear values. The major muscles classified as tough (>10.12 lb) were biceps femoris, supraspinatus, semitendinosus, deep pectoral, gluteus

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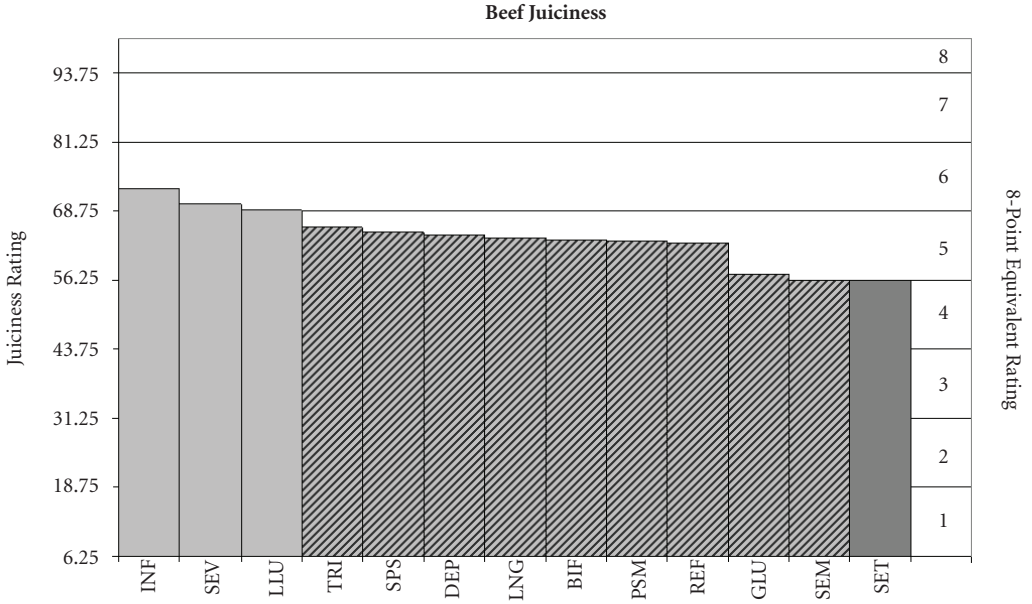

Figure 3. Rank of muscles based on sensory panel ratings for juiciness (n=13).

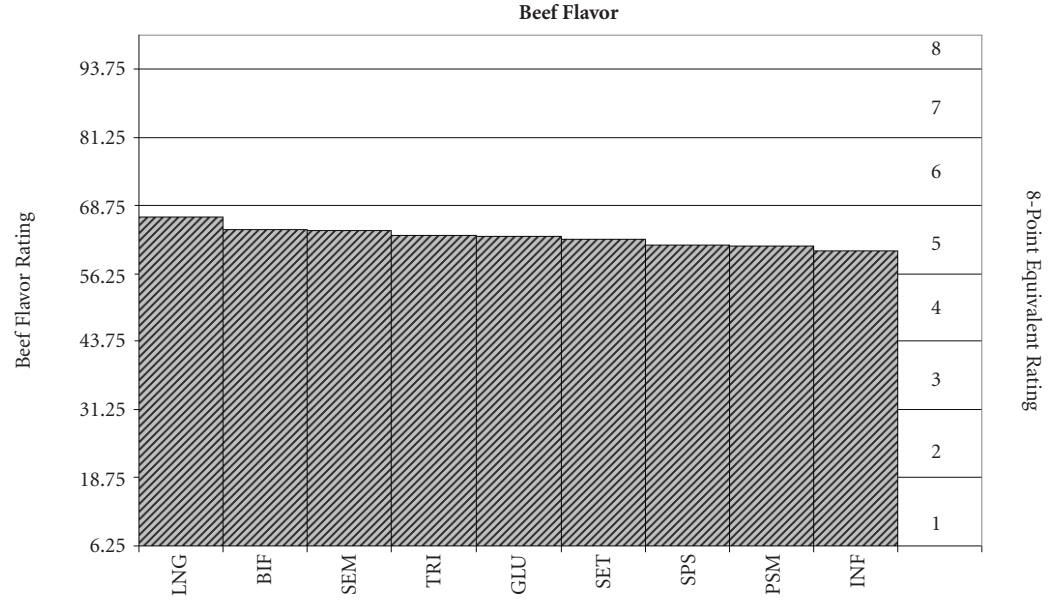

Figure 4. Rank of muscles based on sensory panel ratings for beef flavor (n=9).

medius, vastus lateralis, rhomboideus, and the longissimus dorsi in the chuck region. Although the gluteus medius is often used as a steak, it only ranked 31 of 40 for WBS values.

For muscles analyzed by sensory panel, all steaks that had a tenderness (n=14) rating greater than or equal to a 6 point equivalent on an 8-point scale also had a WBS less than 9.9 lb. For juiciness (n=13), the Infraspinatus, serratus ventralis, and longissimus lumborum were among the highest rated and gluteus medius, Semimembranosus, and semitendinosus were among the least juicy. There were no differences in sensory ratings for beef flavor (n=9).

The correlation between sensory panel tenderness ratings and WBS values for 14 muscles was evaluated. Mean tenderness ratings had a correlation to mean shear force value, by muscle, of -0.85 (*P=0.001*). The numerical ranks had a correlation of 0.74 (*P=.003*). It is well known that muscles vary in tenderness from one end to the other. Unfortunately, authors rarely describe the precise anatomical location from which samples are derived. In addition, differences exist in the relative contribution of connective tissue and muscle fiber tenderness to WBS versus sensory tenderness ratings. These two situations may account for some of the differences in correlation.

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[1]Gary A. Sullivan, graduate student; and Chris R. Calkins, professor, Animal Science, Lincoln.

[2]This project was funded in part, by beef and veal producers and importers through their $1-per-head checkoff and was produced for the Cattlemen's Beef Board and state beef councils by the National Cattlemen's Beef Association.

Hyperspectral Imaging: A Non-Invasive Technique to Predict Beef Tenderness

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Jeyam Subbiah
Chris R. Calkins[1]

Summary

A hyperspectral imaging apparatus was developed and assembled to predict 14 d tenderness of beef steaks. USDA Choice and Select grade longissimus steaks (n=111) from between the 12th and 13th ribs were frozen at 14 days post-mortem, cut to 1-inch thickness, and thawed overnight for scanning, cooking, and obtaining slice shear force data. The model predicted three tenderness categories with 96.4% accuracy, correctly classifying 93 tender, nine intermediate and all five tough samples. One tender sample was misclassified as intermediate, and three intermediate samples were misclassified as tender. This hyperspectral imaging system was effective in predicting beef tenderness.

Introduction

Consumers have shown a willingness to pay a premium for guaranteed tender steaks. To increase consumer satisfaction and value of beef, the industry has a strong interest in tenderness predictors. An accurate, noninvasive, online tenderness instrument is needed for packing plant scenarios. Since beef carcasses are quality and yield graded by USDA employees two days postmortem, and product typically reaches the consumer at 14 days postmortem, the machine would need to accurately predict the ultimate 14 day postmortem tenderness value.

Hyperspectral imaging is a technique whereby multiple reflectance images are captured at regular intervals along a spectral axis. Thus, each pixel in a hyperspectral image has spectral reflectance data. In contrast, near-infrared (NIR) spectroscopy measures spectral reflectance of an entire field of view rather than a single pixel. Thus, hyperspectral imaging would be expected to be much more accurate as a result of the additional information that is captured.

The objective of this research project was to develop and validate an accurate, noninvasive tenderness predictor by scanning steaks at 14 days postmortem to then ultimately develop a system to predict the 14 day tenderness level (tender, intermediate, or tough) by scanning steaks at two day postmortem.

Procedure

Hyperspectral imaging apparatus

A hyperspectral imaging apparatus was constructed by integrating a CCD digital video camera (Model: IPX-2M30, Imperx Inc., Boca Raton, FL) and a spectrograph (Model: Enhanced series Imspector, Specim, Finland). The spectrograph has a spectral range of 400-1,000 nm. Spatial and spectral calibrations were performed. A diffuse-flood lighting system was designed using tungsten-halogen lamps and a dome with a white reflectance coating. Lighting was provided with six 50-W tungsten halogen lamps (Model: MR16, Phillips Lighting Co.). A lamp controller (Model: TXC300-72/120, Mercron Industries, Richardson, Tex.) converted 60 Hz AC voltage to 60 kHz. At this high frequency, tungsten halogen lamps do not respond quickly. This simulates a constant DC voltage power supply. Over the lifespan, tungsten halogen lamps get dimmer. A photodiode was placed near a tungsten halogen lamp that provides feedback to the controller. Based on the feedback, the current input to tungsten halogen lamps is increased to provide a constant intensity output. Over the lamps, a hemispherical dome of 40 cm diameter was placed, providing uniform diffuse light over the steak (Figure 1).

USDA Choice and Select grade longissimus steaks from between the 12th and 13th ribs and cut to 1-inch thickness were placed on metal trays which were then vacuum packaged. The trays contained 6-14 steaks and were placed in a commercial refrigerator for a 24 hour thawing time to an internal temperature of 1-6°C. Steaks and a white reference plate were then placed on a Teflon-coated plate mounted on a linear slide that used a stepper motor for movement. The steak was then scanned by the camera to obtain a three-dimensional data cube (reflectance by two-dimensional position). Scanning takes approximately 30 seconds to collect the image, and each file is approximately 600 mb. Images were obtained at wavelength intervals of 2 nm. Steaks were then cooked immediately on an impingement oven to an internal temperature of 69.5-72.2°C, and slice shear force values were obtained within one minute by an Instron Texture Analyzer.

Statistical Analysis

A 200 by 300 pixel region of the image was selected for analysis. The

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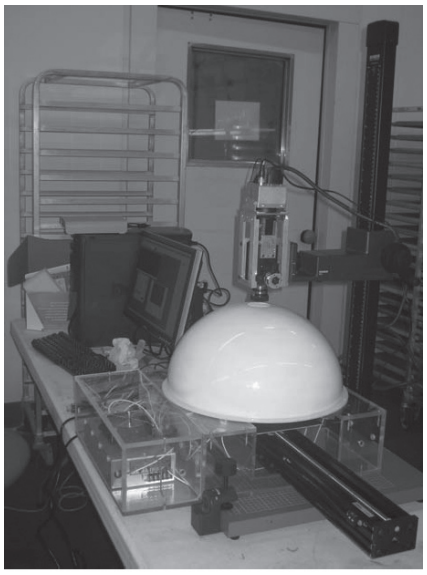

Figure 1. Hyperspectral imaging apparatus

region of interest was in the approximate location where slice shear force samples were obtained. Principal component analysis was carried out to reduce the dimension along the spectral axis. Over 90% of the variance of all bands in the image was explained by the first five principal components. The first four principle components are shown in Figure 2. On each principal component image, co-occurrence matrix analysis was conducted to extract eight image-textural features (Figure 3); thus a total of 40 image-textural features were actually obtained from each steak. To reduce the number of features and predict 3 tenderness categories (tender - slice shear force $\leq$ 21 kg; intermediate – 21.1 to 25.9 kg; tough $\geq$ 26 kg), a canonical discriminant model was developed. Leave-one-out cross validation procedures were implemented to predict the tenderness level. Figure 4 shows the hyperspectral profile of a lean vs. fat pixel.

Results

The model correctly classified 93 tender, nine intermediate, and five tough samples, incorrectly classified three intermediate samples as tender, and incorrectly classified one tender sample as intermediate. All tough samples were correctly identified. Tenderness was predicted by this hyperspectral imaging device with 96.4% accuracy (Table 1).

Implications

This hyperspectral imaging system was effective in accurately predicting 14 day tenderness of beef longissimus steaks. With implementation of a non-invasive, accurate tenderness predictor, beef cuts could be labeled and sold at a premium as "guaranteed tender." With this premium, producers, feedlots and packing plants would reap the benefits together.

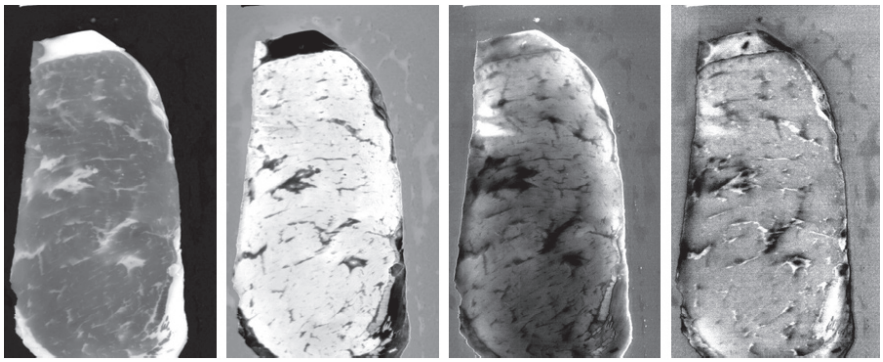

Figure 2. First four principal component images (PC #1,2,3, & 4 from left to right).

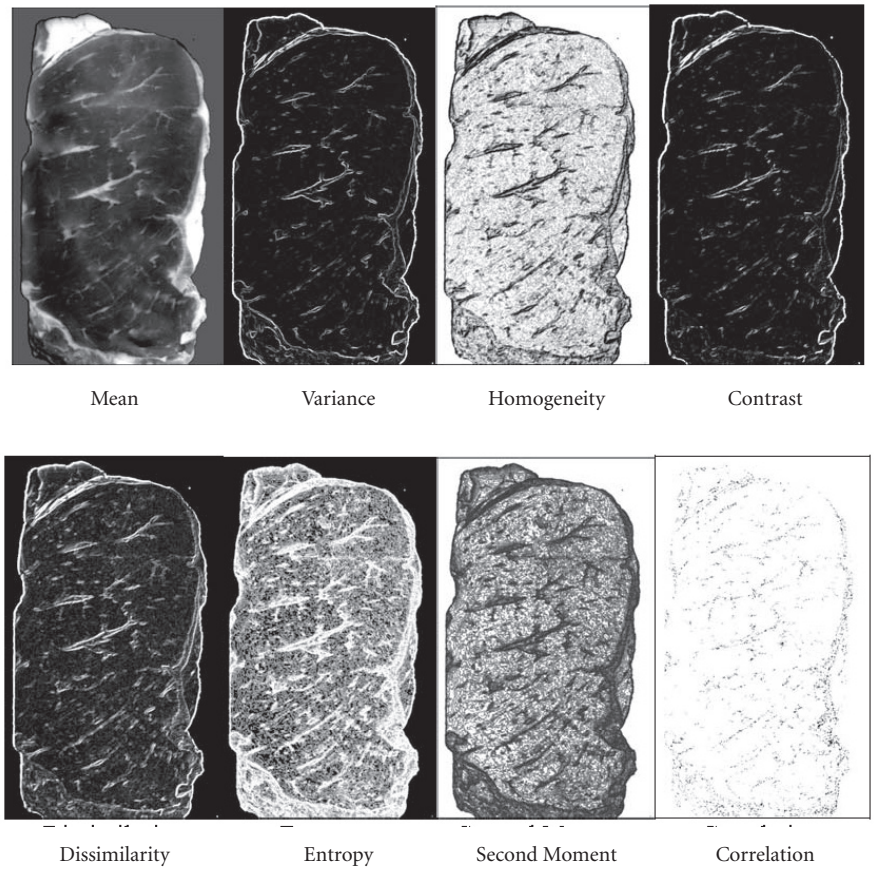

Figure 3. Co-occurrence matrix analysis to extract 8 textural features of beef steak.

Table 1. Hyperspectral tenderness prediction vs. actual shear force tenderness

	Predicted Categories			
Actual Categories	Tender [a]	Intermediate [b]	Tough [c]	Total
Tender [a]	93	1	0	94
Intermediate [b]	3	9	0	12
Tough [c]	0	0	5	5
Total	96	10	5	111

[a] $\leq$ 21 kg slice shear force.
[b] 21.1-25.9 kg slice shear force.
[c] $\geq$ 26 kg slice shear force.

[1]Lauren Grimes, graduate student, Animal Science; Govindarajan Konda Naganathan, graduate student, Biological Systems Engineering; Jeyam Subbiah, assistant professor Biological Systems Engineering, Lincoln; Chris R. Calkins, professor, Animal Science, Lincoln.

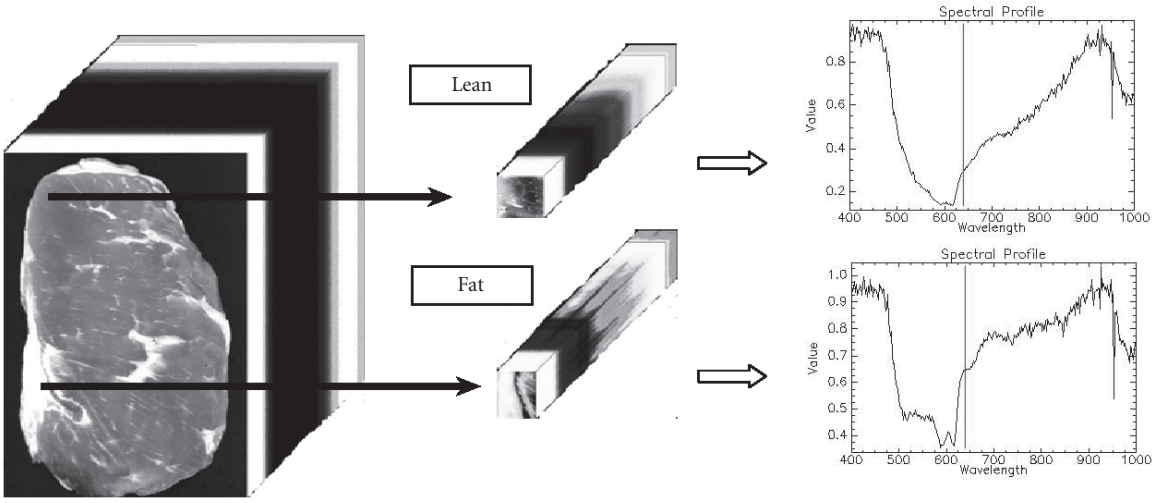

Figure 4. Lean vs. fat hyperspectral pixel profile.

Evaluating Use of Urinary Purine Derivative to Creatinine Ratio as an Estimate of Microbial Protein Production in Steers

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Terry J. Klopfenstein[1]

Summary

Six ruminally and duodenally fistulated steers were fed three diets varying in source and concentration of dietary protein to determine impacts on ruminal metabolism, nutrient digestibility, and microbial crude protein (MCP) production as estimated by urinary purine derivative:creatinine (PD:C) ratio. Steers were fed a steam-flaked corn (SFC)-based diet with or without 1.5% urea, or a corn milling byproduct-based diet. Feeding a corn milling by-product-based diet resulted in greater ruminal pH and less time below ruminal pH 5.6, total tract OM digestibility, and ruminal propionate concentration when compared with either SFC-based treatment. The by-product-based treatment produced greater PD:C and MCP production values when compared with the SFC, no urea treatment. Responses in ruminal pH, MCP production, and PD:C indicate the by-product-based diet provided a more favorable rumen environment compared with SFC-based diets, and that urinary PD:C can be used to estimate differences in MCP production.

Introduction

Previous research (*2007 Nebraska Beef Report*, pp. 103-105) reported that when 1.5% urea was added to a 85% steam-flaked corn (SFC) diet, ADG, DMI, F:G, and purine derivative: creatinine (PD:C) ratio as an estimate of microbial CP (MCP) production were improved. Further enhancements in DMI and MCP production were observed when a 25% SFC, 60% corn milling by-product diet was fed. These results were expected based on the composition of the diets, and supported the use of PD:C as an estimate of MCP production. However, because duodenal purines have traditionally been used to determine MCP production, any alternative method must be validated with duodenal purine measurements. Therefore, this metabolism experiment was conducted to confirm the previous findings and explore ruminal fermentation and intake behavior to explain the differences found in the individual feeding experiment.

Procedure

Six ruminally and duodenally fistulated Holstein steers (1045 ± 82 lb) were used in two 3 x 3 Latin square designs and fed one of 3 diets: 1) a diet containing 85% steam-flaked corn and consisting of 9.6% CP (SFC); 2) the SFC diet with 1.5% supplemental urea resulting in 13.7% CP (UREA); or 3) a corn milling by-product-based diet with 25% SFC, 30% corn bran, and 30% wet corn gluten feed, resulting in 14.1% CP (BYPROD). All diets contained 10% sorghum silage, 320 mg Rumensin®/steer daily and 90 mg Tylan®/steer daily.

Periods were 21 days in length (16-day diet adaptation and five-day data collection) and all animals were fed for ad-libitum intake. Bunks were read once daily at 0700 hours and feed offerings were adjusted accordingly for feeding at 0730 hours. All feed refusals were removed, quantified, and sampled. Steers were individually fed in free stalls from days 1-16 of each period. In the afternoon of day 16, steers were moved and tethered in individual metabolism stalls and were allowed to acclimate to these stalls overnight. Beginning on day 17, steers were fed in individual feed bunks suspended from load cells connected to a computer equipped with software allowing for continuous data acquisition. Feed weight in each bunk was recorded once every minute and continuously stored for each steer throughout the day. Feed intake measurements (days 17-21 of each period) included DMI, rate of intake, number of meals per day, average meal size, total time spent eating, and average meal length.

Submersible pH electrodes were placed into the rumen of each steer through the ruminal fistula on the morning of day 17 of each period and remained in place through the morning of day 21. Each pH electrode was encased in a weighted, four-wire metal shroud to keep the electrode in a stationary suspended position approximately 5 inches above the ventral floor of the rumen. Electrodes were linked directly to a computer equipped with data acquisition software to record ruminal pH every six seconds and average ruminal pH every minute throughout the pH data collection phase. On day 21 of each period the ruminal pH electrodes were removed and steers were returned to their respective free stalls.

Chromic oxide was used as an indigestible marker for determining digestibility and flow. Boluses containing 7.5 g chromic oxide were inserted through the ruminal cannula twice daily (0700 and 1900 hours) from days 8-16. Fecal grab samples were collected 0, 6, and 12 hours post-feeding on days 13-16. On day 20, ruminal fluid samples were collected from each steer immediately before feeding and 3, 6, 9, 12, 18, and 24 hours after feeding for ruminal VFA analyses.

Spot samples of urine and duodenal content samples were collected on days 14-16 (0700, 1200, 1700, 2200 hours). Urinary creatinine was used as a marker to estimate urine volume,

Table 1. Effect of dietary treatment on feed intake and ruminal pH characteristics.

	Treatment[a]				
Item	SFC	UREA	BYPROD	SEM	*P*-value
DMI, lb/day	17.6[c]	18.2[bc]	21.5[b]	1.5	0.09
Rate of intake, %/h	20.4	22.4	24.2	1.4	0.23
Average ruminal pH	5.43[c]	5.58[c]	5.94[b]	0.09	0.01
Time < pH 5.6, min/day	925[b]	715[b]	326[c]	121	0.01
Area < pH 5.6	374[b]	240[bc]	71[c]	70	0.04

[a]SFC = 85% SFC, 9.6% CP; UREA = 85% SFC + 1.5% urea, 13.7% CP; BYPROD = 25% SFC, 30% corn bran, 30% wet corn gluten feed, 14.1% CP.
[bc]Values within the same row with uncommon superscripts differ ($P<0.05$).

Table 2. Effect of dietary treatment on ruminal VFA concentration, purine derivative:creatinine ratio, and MCP production.

	Treatment[a]				
Item	SFC	UREA	BYPROD	SEM	*P*-value
Total VFA, *mM*	108[d]	103[de]	82[e]	8	0.06
Acetate, mol/100 mol	42.8[e]	44.2[de]	50.2[d]	2.4	0.25
Propionate, mol/100 mol	37.0[de]	39.6[d]	32.3[e]	2.8	0.06
Butyrate, mol/100 mol	11.0	10.0	12.7	1.8	0.79
Acetate:propionate	1.16[de]	1.12[e]	1.55[d]	0.18	0.08
PD:C[b]	0.75[e]	0.92[de]	1.06[d]	0.06	0.02
MCP Production, g/day[c]	235[e]	309[de]	395[d]	41	0.02
Microbial efficiency, g of CP/100 g OM digested	5.89	6.34	7.45	0.90	0.40

[a]SFC = 85% SFC, 9.6% CP; UREA = 85% SFC + 1.5% urea, 13.7% CP; BYPROD = 25% SFC, 30% corn bran, 30% wet corn gluten feed, 14.1% CP.
[b]Purine derivative:creatinine ratio.
[c]Derived from duodenal purine assay.
[de]Values within the same row with uncommon superscripts differ ($P<0.05$).

while urinary PD allantoin and uric acid were used as markers for estimation of MCP production. Purine derivatives and creatinine were analyzed by HPLC. Duodenal purine content was also analyzed for estimation of MCP production.

Data were analyzed as a replicated Latin square experimental design using the Mixed procedure of SAS. For nutrient digestibility the model included period and dietary treatment. Intake, ruminal pH, duodenal purine, VFA, and urine data were analyzed as repeated measures. For intake and ruminal pH analyses, the model consisted of period, dietary treatment, day of collection period, and treatment x day. For VFA, duodenal purine, and urine analyses, the model consisted of period, dietary treatment, time of collection, and dietary treatment x time. All models included steer and steer x treatment x period as random effects. Least squares means were separated using the PDIFF statement in SAS when protected by a significant ($P<0.10$) *F*-test. Time of urine and duodenal content collection were analyzed for linear, quadratic, and cubic responses.

Results

Intake and pH data are presented in Table 1. Dietary treatments for this experiment were formulated to produce differences in MCP production, allowing for evaluation of the ability of PD:C measurements to estimate MCP production. Therefore, treatment differences for DMI were expected. Dry matter intake was greater ($P<0.05$) with the BYPROD treatment than with the SFC treatment, measuring 17.6, 18.2, and 21.5 lb/day for SFC, UREA, and BYPROD, respectively. Intake with BYPROD also tended ($P=0.07$) to be greater than with UREA, while no differences ($P>0.10$) in DMI were present between SFC and UREA. The DMI responses are similar to what was observed with an individual feeding experiment (*2007 Nebraska Beef Report,* pp. 103-105), in which DMI was greatest with BYPROD, intermediate with UREA, and lowest with SFC. Rate of intake was 18.6% greater with BYPROD than with SFC; however, this difference was not significant ($P=0.23$).

Average ruminal pH was greater ($P<0.05$) with BYPROD than with SFC or UREA, with no difference ($P>0.10$) between SFC and UREA. The improvement in ruminal pH with the addition of corn milling by-products is likely due to the slower ruminal fermentation rate of by-products compared with that of starch from SFC. Steers consuming the BYPROD treatment spent 325.8 min/day at ruminal pH less than 5.6, which was 65 and 54% lower ($P<0.05$) than the SFC or UREA treatments, respectively. Area below pH 5.6, which is a measure of time below pH 5.6 multiplied by magnitude of pH depression, was lower ($P<0.01$) with BYPROD than with SFC, and tended ($P=0.09$) to be lower with BYPROD than with UREA. A ruminal pH of 5.6 is generally considered to be the point at which subacute ruminal acidosis begins to occur, and decreased and erratic DMI are often cited as symptoms of subacute acidosis. We observed 184 and 119% greater time below ruminal pH 5.6 with the SFC and UREA treatments, respectively, than with BYPROD, and this may explain differences observed in DMI among the treatments.

Total and individual VFA molar proportions are presented in Table 2. Total ruminal VFA concentration was greater ($P<0.05$) with SFC than with BYPROD, and tended ($P=0.06$) to be greater with UREA than with BYPROD, measuring 108.4, 102.9, and 82.1 *mM* for SFC, UREA, and BYPROD, respectively. Acetate molar proportion was greater ($P<0.05$) with BYPROD than with SFC, and tended ($P=0.06$) to be greater with BYPROD than with UREA. Propionate molar proportion was greater ($P<0.05$) with UREA than with BYPROD, with SFC being equal ($P>0.10$) to both treatments. This resulted in a greater ($P<0.05$) acetate:propionate ratio

(Continued on next page)

with BYPROD than with UREA, with SFC being equal ($P>0.10$) to both UREA and BYPROD. No differences ($P>0.10$) among treatments were observed for butyrate molar proportion. The depressed total VFA and propionate molar proportion with the BYPROD treatment would be expected due to differences in substrate and the slower-fermenting corn milling by-products replacing starch, which is quickly fermented in the rumen. The greater quantity of acid present in the rumen with the SFC and UREA treatments helps explain the depressed ruminal pH with these treatments compared with the BYPROD treatment.

Production of MCP as estimated by urinary PD:C was greater ($P<0.05$) with BYPROD than with SFC, tended ($P=0.09$) to be greater with UREA than with SFC, and was not different ($P>0.10$) between UREA and BYPROD (Table 2). Urinary PD:C measured 0.75, 0.92, and 1.06 for SFC, UREA, and BYPROD, respectively. The improvement in PD:C between SFC and UREA was 22.7%, while the improvement between SFC and BYPROD was 41.3%. In an individual feeding study (*2007 Nebraska Beef Report,* pp. 103-105), PD:C was 25.5% greater with UREA than with SFC, and 33% greater with BYPROD than with SFC. In both experiments, the addition of DIP in the form of urea can explain the improvement of UREA over SFC, while the addition of corn milling by-products to provide for a more favorable rumen environment can explain differences the between the BYPROD treatment and the SFC and UREA treatments.

Similar results for MCP production were found with estimates from duodenal purine collections (Table 2). Production of MCP measured 235, 309, and 395 g/day for SFC, UREA, and BYPROD, with BYPROD being greater ($P<0.05$) than SFC and tending ($P=0.06$) to be greater than UREA. Microbial CP flow was 31.4% greater with UREA than with SFC, but the results were not significant ($P>0.10$). Microbial efficiency (Table 2) did not differ ($P>0.10$) among treatments; however numerical improvements were present with measurements of 5.89, 6.34, and 7.45 g of CP/100 g OM ruminally digested for SFC, UREA, and BYPROD, respectively. The numerical improvements in microbial efficiency with BYPROD can be related to improved ruminal pH allowing for increased microbial fermentation.

As was found previously in an individual feeding study *(2007 Nebraska Beef Report,* pp. 103-105), estimates of MCP from PD:C were greater (linear $P < 0.05$) with samples collected later in the day, measuring 0.82, 0.86, 0.96, and 0.98 when samples were collected at 0700, 1200, 1700, and 2200 hours, respectively, and no treatment x time of urine collection interactions ($P>0.10$) were present. Duodenal purine measurements confirmed these results, with MCP measuring 297, 298, 330, and 328 g/day when duodenal samples were collected at 0700, 1200, 1700, and 2200 hours (linear $P < 0.05$). It is important to note that these steers were fed once daily at 0730 hours, and the PD:C response may be a function of feeding time.

Ruminal OM digestibility measured 61.2, 65.2, and 62.1% for SFC, UREA, and BYPROD, and were not different ($P>0.10$). Post-ruminal and total tract OM digestibilities were not different ($P>0.10$) between SFC and UREA, and both treatments were greater ($P<0.05$) than BYPROD. No treatment differences ($P>0.10$) were observed for ruminal, post-ruminal, or total tract NDF digestibility. Ruminal starch digestibility was greater ($P<0.05$) with UREA than with SFC, and BYPROD was not different ($P>0.10$) than either treatment. However, post-ruminal starch digestibility was numerically higher with SFC than with UREA, resulting in no differences ($P>0.10$) among treatments for post-ruminal and total tract starch digestibilities.

Conclusions

The agreement of the PD:C measurements with the duodenal purine data suggest that this method can be effectively used to estimate MCP production in beef cattle.

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Diurnal and Dietary Impacts on Purine Derivative Excretion from Spot Samples of Urine

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Summary

An individual feeding experiment was conducted to estimate diurnal and dietary impacts on microbial CP (MCP) production estimated from urinary purine derivative (PD) and creatinine excretion. Heifers were fed one of three diets formulated to produce differences in MCP production: an 85% steam-flaked corn-based diet (SFC); the SFC diet with 1.5% urea (UREA); or a corn milling byproduct-based diet (BYPROD). Spot samples of urine were collected at 0700 and 1700 hours. No urine collection time x dietary treatment interactions were present for any variable. Dry matter intake, ADG, and F:G were poorest with the SFC treatment. Urinary PD:creatinine (PD:C) ratio was greatest with the BYPROD treatment and lowest with the SFC treatment, measuring 0.94, 1.18, and 1.25 for the SFC, UREA, and BYPROD treatments, respectively. Regardless of diet, PD:C was greater with samples collected later in the day, and differences in PD:C due to diet can be observed regardless of collection time.

Introduction

Quantification of microbial crude protein (MCP) production is important in determining the adequacy of diets fed to feedlot cattle. The most common method of determining MCP production has been through duodenal purine measurement. Purines are a microbial flow marker measured in the small intestine. However, this method requires duodenally fisulated animals, which limits the number of animals in an experiment and relegates these animals to a metabolism setting, which can affect results.

Urinary purine derivatives (PD) allantoin and uric acid are degradation products of purines and have been validated as markers for MCP. In addition, urinary creatinine can be used as a marker of urine output, and is excreted at a constant of 28 mg/kg BW (*2004 Nebraska Beef Report,* pp. 100-102*)*. Therefore, by measuring urinary PD and creatinine, spot samples of urine may be used to estimate MCP. This allows use of greater number of animals, and allows for experiments in a typical production setting.

Estimates of MCP from urinary PD excretion may vary depending on time of urine collection. Therefore, the objectives of this experiment were to evaluate urinary PD:C as a tool to estimate MCP production in a production setting, and determine if time of urine collection impacts MCP estimation using urinary PD and creatinine measurements from spot samples of urine.

Procedure

One hundred-sixteen crossbred heifers (897 ± 71 lb) were arranged into a randomized complete block design with a 3 x 2 factorial arrangement of treatments. Heifers were stratified by weight into one of four individual-feeding barns and fed one of 3 diets formulated to produce differences in MCP production as measured by urinary PD and creatinine excretion: 1) a steam-flaked corn-based diet containing 9.6% CP (SFC); 2) the SFC diet with 1.5% supplemental urea resulting in 13.7% CP (UREA); or 3) a corn milling byproduct-based diet with 25% SFC, 30% corn bran, and 30% wet corn gluten feed, resulting in 14.1% CP (BYPROD). Sorghum silage was included in all diets at 10% of DM. Each diet supplied 320 mg Rumensin/heifer daily and 90 mg Tylan/heifer daily. Heifers were fed once daily and implanted with Revalor-H at the beginning of the experiment. Animals were individually fed using Calan gates, and orts were subtracted from the daily feed offering to determine daily DMI for each heifer. The experiment was 84 days in length.

Spot samples of urine were collected from 58 heifers at 0700 hours and from the remaining 58 heifers at 1700 hours for three consecutive days at the end of three 28-day periods. All heifers within a barn were sampled at the same collection time. Individual animal BW were determined at each urine collection. Heifers were slaughtered at the conclusion of the experiment (Tyson Foods, Inc., West Point, Neb.) and carcass data were collected. Urine collected during the experiment was composited within 28-day period. Purine derivatives and creatinine were analyzed using high pressure liquid chromatography. Urinary creatinine was analyzed to estimate urinary output assuming creatinine output of 28 mg/kg BW.

Data were analyzed as a 3 x 2 factorial within a randomized complete block design using the Mixed procedure of SAS. Individual feeding barn served as the block, and was considered a random effect. Dietary treatment and time of day of urine collection were considered fixed effects, and the interaction between the two was initially tested for all variables. Least squares means were separated using the PDIFF statement in SAS when protected by a significant ($P<0.05$) *F*-test.

Results

No dietary treatment x urinary collection time interactions occurred for any variable, therefore live animal performance data and carcass characteristics are presented in Table 1 as the main effect of dietary treatment. Dietary treatments were

(Continued on next page)

formulated to create treatment differences in MCP production which led to expected differences in live and carcass performance. Heifers consuming the BYPROD treatment had a greater ($P<0.05$) DMI than heifers consuming either the SFC or UREA treatments, and DMI with the UREA treatment was also greater ($P<0.05$) than that of the SFC treatment, averaging 17.4, 19.5, and 22.9 lb/day for the SFC, UREA, and BYPROD treatments, respectively. Differences in DMI can be attributed to a deficiency in DIP with the SFC treatment, while it appears that the BYPROD treatment also may have provided ruminal acidosis control due to the replacement of highly-fermentable starch from SFC with slower-fermenting corn milling by-products. Average daily gain was lower (2.44 lb/day; $P < 0.05$) with the SFC treatment than with either the UREA (3.52 lb/day) or BYPROD (3.69 lb/day) treatments. The UREA and BYPROD treatments did not differ ($P>0.10$) for ADG. Feed conversion (F:G) was poorest ($P<0.05$) with the SFC treatment, intermediate with the BYPROD treatment, and lowest with the UREA treatment, measuring 7.13, 5.54, and 6.21 for the SFC, UREA, and BYPROD treatments, respectively.

Carcass characteristics generally followed the live performance results, with heifers consuming the SFC treatment having lower ($P<0.05$) HCW and 12th rib fat thickness than either the UREA or BYPROD treatments. The BYPROD treatment also produced a greater ($P<0.05$) marbling score than the SFC treatment. No treatment differences ($P>0.10$) were observed for dressing percentage or LM area.

A number of variables currently limit the ability to predict absolute MCP flow values from PD:C values; however, the PD:C ratio can be used to estimate relative differences in MCP flow. Therefore PD:C ratios, rather than MCP estimates, will be presented in this discussion. Heifers consuming the BYPROD treatment produced the greatest ($P<0.05$) urinary PD:C ratios, with the UREA treatment being intermediate, and the SFC treatment being the lowest,

Table 1. Main effects of dietary treatment on live performance and carcass characteristics.

	Treatment[a]			
Item	SFC	UREA	BYPROD	*P*-value
DMI, lb/day	17.4[e]	19.5[d]	22.9[c]	<0.01
ADG, lb	2.44[d]	3.52[c]	3.69[c]	<0.01
F:G	7.13[e]	5.54[c]	6.21[d]	<0.01
Carcass weight, lb	720[d]	772[c]	766[c]	<0.01
Dressing %	62.4	63.1	62.3	0.15
Marbling[b]	501[d]	512[cd]	539[c]	0.03
Longissimus area, in^2	14.0	14.0	14.4	0.54
12th rib fat depth, in	0.38[d]	0.45[c]	0.48[c]	<0.01

[a]SFC = 85% SFC, 9.6% CP; UREA = 85% SFC + 1.5% urea, 13.7% CP; BYPROD = 25% SFC, 30% corn bran, 30% wet corn gluten feed, 14.1% CP.
[b]Marbling score called by USDA grader where 500 = small[0] and 550 = small[50].
[cde]Values within the same row with uncommon superscripts differ ($P<0.05$).

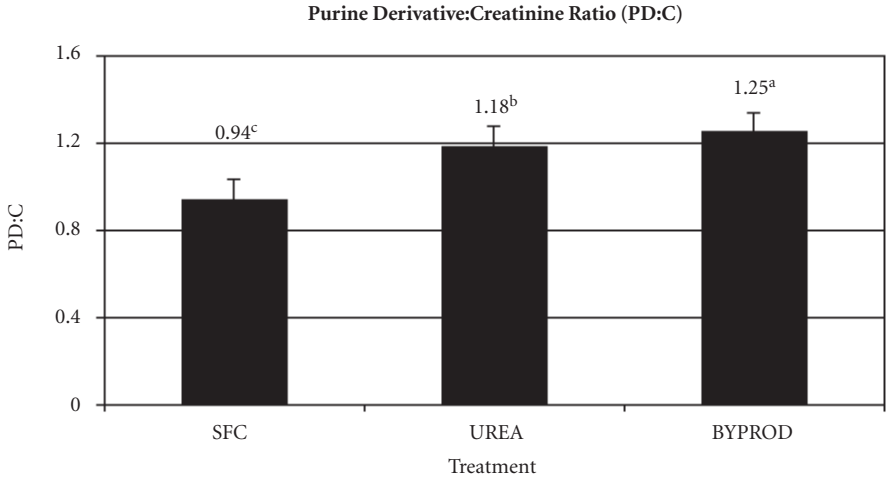

Figure 1. Main effect of dietary treatment on urinary PD:C ratio. Diet $P < 0.01$; Diet x Urine collection time $P=0.98$.
[abc] Unlike superscripts differ ($P<0.05$).

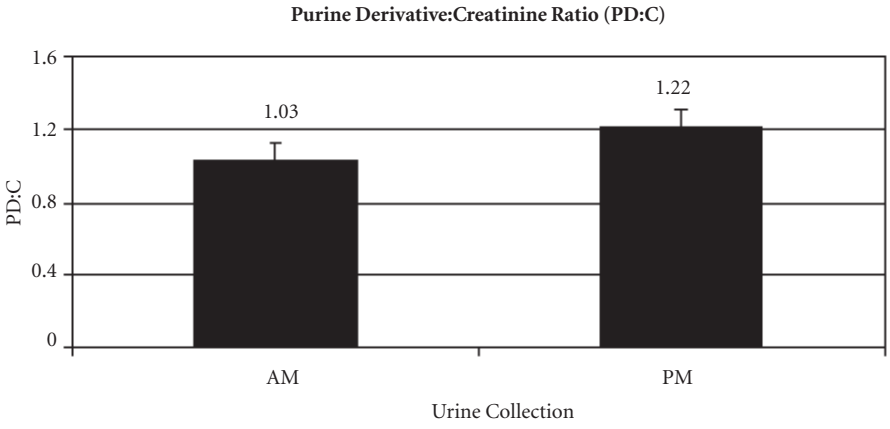

Figure 2. Main effect of urine collection time on urinary PD:C ratio. Urine collection time $P < 0.01$; Diet x Urine collection time $P = 0.98$.

measuring 0.94, 1.18, and 1.25 for the SFC, UREA, and BYPROD treatment, respectively (Figure 1). This indicates that MCP flow was greatest with the BYPROD treatment and lowest with the SFC treatment, suggesting that the BYPROD treatment may have provided a more favorable ruminal environment for MCP synthesis than when diets contained a large proportion of SFC. The SFC treatment had a low CP and DIP content, resulting in the lowest PD:C values among the dietary treatments. Using ruminal digestibility values from a companion metabolism study (*2007 Nebraska Beef Report* pp. 100-102*)*, digestible OM intake with the SFC treatment was 73.9% of digestible OM intake of the BYPROD treatment, and PD:C with the SFC treatment was 75.2% of that of the BYPROD treatment, suggesting that ruminally digestible OM intake explains most of the difference in PD:C. These results were expected based on the composition of the dietary treatments, and suggests that urinary PD:C measurements can be utilized as a tool to estimate treatment differences in ruminal MCP production. When urine samples were collected in the PM, measurement of PD:C to estimate MCP flow was greater than when samples were collected in the AM (Figure 2). It is not yet clear why this diurnal effect is present. It is important to note, however, that these heifers were fed once daily at 0800 h, and this may have an impact on MCP flow, digestion, and subsequent PD:C in urine.

Conclusions

Dietary treatments produced expected differences in PD:C, suggesting that urine measurements can be used to predict treatment differences in MCP production. Urine samples collected in the PM had a greater PD:C than those collected in the morning. The mechanisms to explain this are yet unknown, and require further exploration. There were no dietary treatment x urine collection time interactions, suggesting 1) regardless of diet, PD:C was greater in the afternoon; and 2) differences in PD:C can be observed regardless of collection time.

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Chronic Exposure of Ruminal Fluid Cultures to Treatments That Inhibit Methanogenesis

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Summary

Methanogenesis in ruminal cultures was inhibited by Yucca shidigera, 2-bromoethanesulfonate, and a nitrofuranyl para-aminobenzoic acid derivative. Only the nitrofuranyl para-aminobenzoic acid derivative remained effective beyond 10 days of culture indicating that this may be an effective treatment for chronically inhibiting methane production in cattle.

Introduction

Sustained inhibition of ruminal methane production would result in a retention of feed gross energy and may improve feed efficiency by up to one-third. An historical theme associated with treatments that inhibit methanogenesis is the ability of ruminal methanogens to adapt to the effects of such treatments and become resistant following chronic exposure. For practical purposes an inhibitor of ruminal methane production must: 1) be effective at small enough concentrations that the treatment can be included as a dietary supplement and 2) no adaptation to this treatment should occur. A nitrofuranyl *para*-aminobenzoic acid derivative (NFP) meets the former requirement and was previously reported (*2006 Nebraska Beef Report,* pp. 83-84; compound C33) to inhibit in vitro methane production by > 98% at a concentration of 1.0 mM. Unpublished data from our laboratory also indicate an extract from *Yucca shidigera* (Yucca), which is commercially available and approved for feeding, inhibits methane production by > 65% when included in cultures of ruminal fluid at a concentration of 25 uL/mL. 2-bromoethanesulfonate (BES) is a potent inhibitor of methanogenesis, but ruminal methanogens quickly acquire resistance to the effects of this compound. The objective of our work was to determine the extent to which ruminal cultures acquire resistance following chronic exposure to NFP, Yucca, and BES, a positive control for resistance development.

Procedure

Ruminal fluid from a fistulated heifer receiving a mixed forage and concentrate diet was used to inoculate chronic cultures (n = 8) exposed to no treatment (control) or a low concentration of NFP, Yucca, or BES (100 μM, 2.5 μL/mL, and 10 μM, respectively). In addition to the ruminal fluid inoculum chronic cultures contained McDougall's buffer, distilled H_2O, cellobiose, trypticase, resazurin, a micro mineral solution, and Na_2S. The fermentation media were gassed with CO_2 to create oxygen-free media and then added to a 120 mL glass vial, which contained the respective treatments, as oxygen free gas (H_2/CO_2, 80:20) was projected into each vial. The vials were sealed, pressurized to 100 kPa (1 atmosphere), and allowed to incubate in a water bath (102 F) for 90 d. Every 2 d 50% of the medium from each vial was replaced with fresh culture medium, which contained the same components as the original medium with the exception that clarified ruminal fluid was substituted for fresh ruminal fluid. The fresh medium contained an identical concentration of each treatment as the medium it replaced allowing for the concentration of inhibitor to remain constant for the duration of the experiment.

On day 0, ruminal fluid from the same source used to inoculate chronic cultures was used to inoculate acute cultures (n = 4/treatment) that received no treatment (control), NFP (100 μM or 1,000 μM), Yucca (2.5 μL/mL or 25 μL/mL) or BES (10 μM or 100 μM). On days 2, 10, 22, 32, 40, 60, and 90, media removed from chronic cultures were also used to inoculate acute cultures treated in duplicate with either 0 or 10X the same inhibitor as used for creating the chronic culture inoculum (n = 24/d). Control-inoculated acute cultures were also treated in duplicate as controls and with these 10X doses of NFP, BES, and Yucca (n = 16/d). Excluding inocula source, the acute cultures contained proportionally identical ingredients compared to the chronic cultures and were prepared identically as 4 mL of fermentation media in 10 mL glass vials incubated in a water bath (102°F) for 18 hours. Following incubation, pressure in the headspace of the vials was measured. Methane concentration was determined by gas chromatography using a silica packed column and thermal conductivity detector.

Data were analyzed utilizing the MIXED procedure of SAS. The model for methane produced by day 0 cultures included the fixed effect of treatment. The model for methane produced by days 2, 10, 22, 32, 40, 60 and 90 acute cultures included the fixed effects of previous exposure to a 1X dose of an inhibitor, treatment with a 10X dose of an inhibitor, the random effect of day that the media were removed from continuous cultures and used to inoculate an acute culture, and all appropriate two-way and three-way interactions. Because the same medium was sampled across days a repeated measures covariance structure was used.

Results

Day 0 Acute Cultures

Acute cultures inoculated with ruminal fluid from the same source that

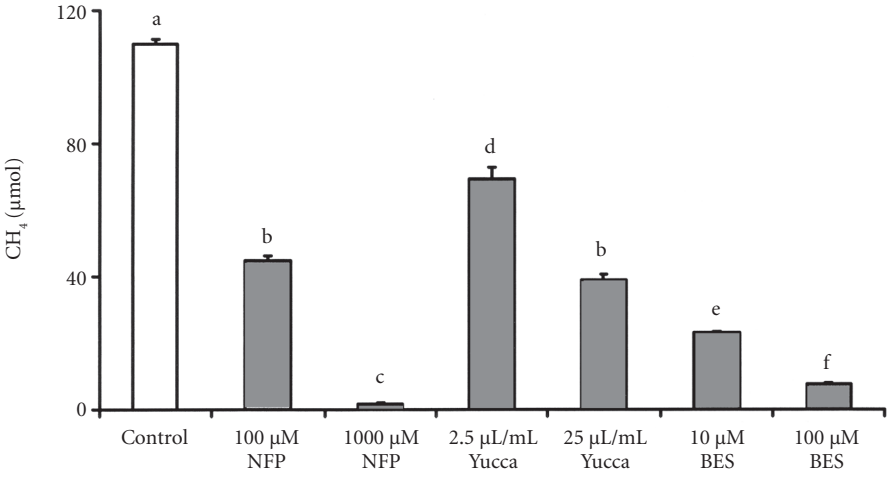

Figure 1. Methane produced by acute cultures inoculated with ruminal fluid from the same source as the ruminal fluid used to inoculate chronic cultures and treated with a high and low concentration of NFP, Yucca, or BES.
[a,b,c,d,e,f]Methane production differs ($P<0.05$).

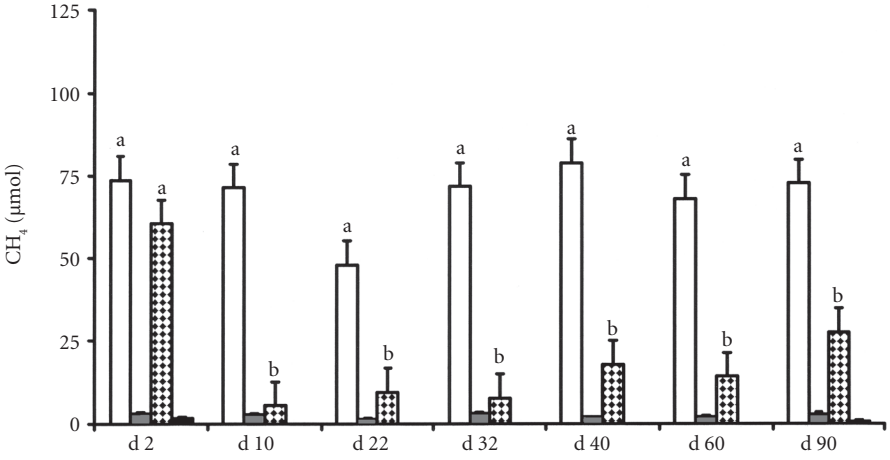

Figure 2. Methane produced by acute cultures inoculated with media from chronic control cultures and receiving no treatment (open bars) or a 10X concentration of NFP (gray bars), or inoculated with media from cultures chronically treated with NFP and receiving no treatment (checkered bars) or a 10X concentration of NFP (black bars).
[a,b]Methane production within day differs ($P<0.05$).

was used to inoculate chronic cultures produced less ($P<0.05$) methane when treated with a low dose of NFP, Yucca, and BES (100 µM, 2.5 µL/mL, and 10 µM, respectively; Figure 1) compared to control cultures. Increasing the concentration of every inhibitor 10X resulted in a further reduction ($P<0.05$) in the amount of methane produced in vitro. Based on previous findings the low dose of each inhibitor, which was used to continuously treat the chronic cultures, was expected to significantly reduce methane production without completely inhibiting in vitro methanogenesis. The results from this acute culture confirmed the concentrations of each inhibitor used were having the desired effect and also indicated the higher dose exacerbates this effect.

NFP

The ability of an inoculum to produce methane following chronic exposure to NFP is presented in Figure 2. The amount of methane produced by all acute cultures treated with a 10X concentration of NFP was less than the sensitivity of our gas chromatograph and these data were excluded from the analysis. There was no difference in the amount of methane produced by cultures inoculated with a medium chronically exposed to NFP and control media on day 2. However, by day 10 acute cultures inoculated with media chronically exposed to NFP produced less methane ($P<0.05$) than did acute cultures inoculated with control media and this relationship persisted for the remainder of the experiment. Exposure to NFP and time did interact to affect amount of methane produced by acute cultures ($P<0.05$), but from day 10 to day 90 there was no difference in the amount of methane produced by acute cultures inoculated with media chronically exposed to NFP. These results indicate chronic cultures did not acquire resistance to effects of NFP and also indicate NFP may be efficacious for chronically inhibiting methanogenesis in cattle.

Yucca

The ability of an inoculum to produce methane following chronic exposure to Yucca is presented in Figure 3. Treatment of acute cultures with a 10X concentration of Yucca inoculated with media from control chronic cultures produced less methane ($P<0.05$) than did control acute cultures receiving the same inoculum on days 10 through 90. With the exception of day 10, treatment of acute cultures with a 10X concentration of Yucca inoculated with media chronically exposed to Yucca resulted in a similar or greater ($P<0.05$) amount of methane produced. Collectively, these data indicate Yucca treatment did maintain its capacity to inhibit methanogenesis for the duration of the experiment, but chronic treatment of cultures with Yucca diminishes the effectiveness of this treatment. Our interpretation is continuous Yucca treatment would not be an effective strategy for chronically inhibiting methane production.

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BES

The ability of an inoculum to produce methane following chronic exposure to BES is presented in Figure 4. The amount of methane produced by acute cultures treated with a 10X concentration of BES and inoculated with media from chronic control cultures was less than the sensitivity of our gas chromatograph and these data were excluded from the analysis. Acute cultures receiving no treatment and inoculated with media from chronic cultures exposed to BES produced less methane ($P<0.05$) than did control cultures on day 2. By d 10 there was no difference in the amount of methane produced by these two groups of acute cultures and this relationship persisted for the duration of the experiment. These data indicate following chronic exposure to BES the cultures became resistant to the effects of this treatment. Treatment of acute cultures inoculated with chronically exposed media with a 10X concentration of BES resulted in a reduction ($P<0.05$) in the amount of methane produced on all days. Therefore, we cannot exclude the possibility that ruminal methanogenesis can be chronically inhibited by increasing the concentration of BES over time.

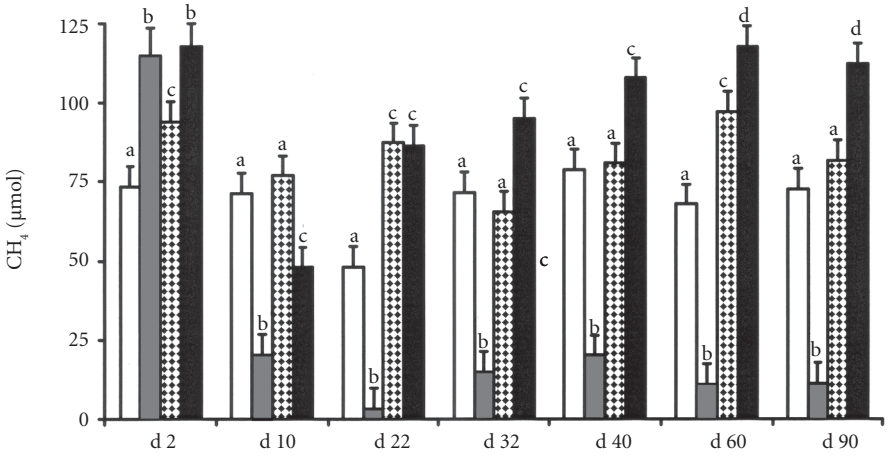

Figure 3. Methane produced by acute cultures inoculated with media from chronic control cultures and receiving no treatment (open bars) or a 10X concentration of Yucca (gray bars), or inoculated with media from cultures chronically treated with Yucca and receiving no treatment (checkered bars) or a 10X concentration of Yucca (black bars).
[a,b,c,d]Methane production within day differs ($P<0.05$).

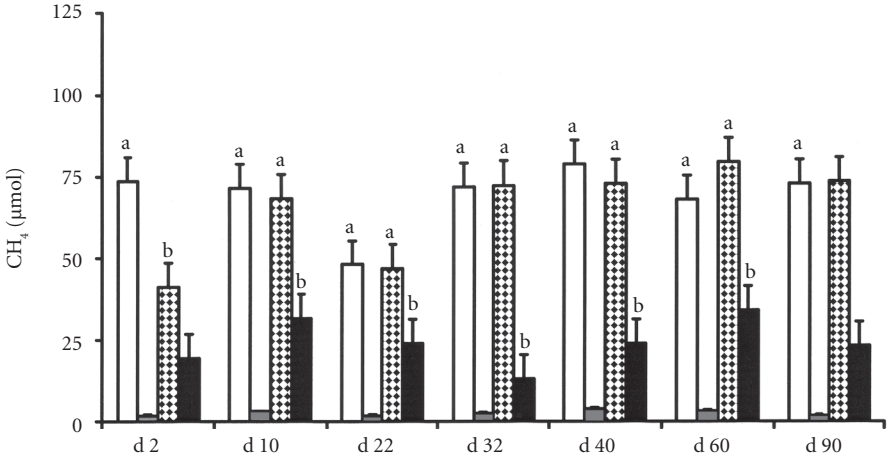

Figure 4. Methane produced by acute cultures inoculated with media from chronic control cultures and receiving no treatment (open bars) or a 10X concentration of BES (gray bars), or inoculated with media from cultures chronically treated with BES and receiving no treatment (checkered bars) or a 10X concentration of BES (black bars).
[a,b,c]Methane production within days differs ($P<0.05$).

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Comparison of *In Vivo* Digestibility to *In Vitro* Digestibility of Five Forages Fed to Steers

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Jim C. MacDonald[1]

Summary

Eight crossbred yearling steers were used in a Latin rectangle design to determine the in vivo digestibility of five different forages. Feed intakes were higher when steers were fed forages with higher IVDMD. In vivo digestibility of the hay used in this trial was highly correlated to in vitro *digestibility. On average, in vitro DMD was 5.4 percentage units higher than in vivo digestibility. Including these five hay samples as standards for in vitro analysis allows researchers to compare samples analyzed across in vitro runs. It also allows researchers to adjust the in vitro DMD to in vivo DMD, which allows for more accurate ration formulation and animal response prediction.*

Introduction

Previous research indicates *in vitro* DMD of forages is highly correlated with *in vivo* digestibility. Including a set of samples within each *in vitro* run which has known *in vivo* digestibilities allows researchers to adjust *in vitro* digestibility of forages to *in vivo* values using regression equations generated from the standards. It has been shown that the regression equations differ within plant type (C3, C4 and legumes) and the same samples run in different laboratories also differ. This is due to a number of factors which include donor animals, diets fed to donor animals, and differences in analytical techniques. *In vitro* runs analyzed in different runs cannot be compared equally because of run variability. Adjusting the *in vitro* results using the equations generated from the standards (with known *in vivo* digestibility) allows researchers to compare estimates from different *in vitro* runs. With these adjustments, forage samples with different species composition, such as grasses vs. legumes, can also be compared because each sample has been adjusted accordingly. The objective of this experiment was to determine the *in vivo* digestibility of five different hay samples and to use these samples as standards in *in vitro* DM digestibility procedures and make comparisons between *in vivo* and *in vitro* digestibility.

Proceedure

This experiment used eight crossbred yearlings in a 5x5 Latin rectangle with five periods and five diets. Diets consisted of five chopped hays including mature brome grass (MBrome), immature brome grass (IBrome), mature alfalfa (MAlf), immature alfalfa (IAlf), and prairie (Prairie). Prairie hay consisted of a mixture of warm season grasses. All hay was chopped on one day, through a 4 inch screen using a tub grinder at the beginning of the trial, mixed, and stored on concrete in an enclosed building. Periods consisted of a 16-day adaptation period followed by a five-day collection period. During the adaptation period steers were fed at ad libitum intake for the first 10 days.

The following six days steers were fed at 95 % of ad libitum intake to minimize feed refusals and reduce variation in measurements of digestion. Steers remained on the restricted DMI throughout the collection period. Steers initially weighed 710 lbs and gained an average of 55 lbs throughout the trial.

Hay samples were taken daily during the last eight days of each period, composited and a sub-sampled for lab analysis. If necessary feed refusals were also collected the last eight days of each period for analysis. Steers were fitted with fecal collection bags during the collection period to measure total fecal output. Bags were emptied and feces weighed and sub-sampled twice daily (7:00 am and 4:00 pm). All feed samples and fecal samples were dried in a 60°C forced air oven and ground through a Wiley mill (1mm screen) for analysis.

In Vitro dry matter digestibility (IVDMD) analysis was conducted on the five hay samples and replicated six times. The IVDMD values from each run were regressed against the *in vivo* DMD. The slopes of each regression line were compared. Differences between regression equations were also tested. Total protein was determined as well as degradable intake protein (DIP) and undegradable intake protein (UIP) using in situ mobile bag technique *(2005 Nebraska Beef Report*, pp. 25-27) using two ruminally and duodenally fistulated Holstein steers.

Results

In Vitro

Crude protein of the diets were 7.9, 7.5, 9.3, 16.3, and 17.6% for Prairie, MBrome, IBrome, MAlf, and IAlf, respectively (Table 1). UIP ranged from 10.1% (% of total CP) for IAlf to 37.2 % for the MBrome (Table 1). Total Tract indigestible protein (TTIDP) follows the same pattern as the UIP (5.0, 8.0, 14.8, 15.3, and 16.6 for IAlf, Malf, IBrome, MBrome, and Prairie, respectively). Digestibility of UIP fraction was highest for MAlf (62.4%) and lowest for IBrome (34.0%). UIP digestibility of these forages are lower than the NRC assumed 80%. These UIP digestibilities agree with results from Haugen et al., (*2005 Nebraska Beef Report,* pp. 25-27) who reported UIP digestibilities lower than the NRC

(Continued on next page)

estimates. There was a wide range in IVDMD between the different hays as well (50.2, 51.2, 56.4, 50.9, and 60.6 % for Prairie, MBrome, IBrome, MAlf, and IAlf, respectively). As digestibility of the hay increased so did DMI ($P<0.001$; Table 1). Intakes were highest when steers were fed either of the alfalfa hays and lowest when fed mature grass hay. There were no differences in intake within the three grass hays or within the two alfalfa hays. This would be expected as it is well documented that cattle intakes increase when fed a highly digestible forage (Figure 1) compared to forages that are lower in digestibility, presumably, due to increased rate of passage.

In vitro DMD and OMD were higher for IAlf than the other four hays (Table 2). Unlike the in vivo DMD data, the IBrome hay was similar ($P>0.05$) to the MBrome and the MAlf and Prairie was similar to the IAlf hay.

In Vivo

In vivo DM digestibility was significantly higher ($P<0.001$)for the IBrome and the IAlf (62.2 and 66.5%, respectively) compared to the other three hays (56.5, 58.1, and 55.5% for MAlf, MBrome, and Prairie, respectively) (Table 2). There were no differences ($P=0.74$) between the Prairie, MBrome, and the MAlf hay. Organic matter digestibility followed the same pattern as DMD, with IBrome and IAlf having greater (P<0.001) digestibility than the other three hays. Neutral detergent fiber digestibility followed the same pattern as DMD and OMD. There were no differences between IBrome and IAlf, but they were significantly higher than Prairie, MBrome, and MAlf.

Regression analysis indicated no significant difference ($P=0.99$) between the slopes of the regression lines (Figure 1). However, there was a difference ($P=0.04$) between the six different runs. This difference between the runs demonstrates the need for standards to adjust *in vitro* values in order make comparisons to *in vivo* digestibility and between different forages. The differences between the *in vitro* runs could be attributed to rumen fluid from

Table 1. Chemical composition of the experimental hays.

	Diet				
Variable	Prairie	MAlf[a]	MBrome[b]	IBrome[c]	IAlf[d]
CP, %	7.9	16.3	7.5	9.3	17.6
IVDMD, %	52.8	58.6	54.5	60.1	67.1
NDF, %	68.3	67.9	69.6	66.7	60.5
ADF,%	43.4	43.7	43.7	40.0	35.2
UIP, %	27.9	14.9	37.2	22.6	10.1
TTIDP, %[e]	16.6	8.0	15.3	14.8	5.0
UIPD,%[f]	40.1	62.4	58.9	34.0	46.0

[a]Mean Mature Alfalfa Hay
[b]Means Mature Brome Grass Hay
[c]Means Immature Brome Grass Hay
[d]Means Immature Alfalfa Hay
[e]Total tract Indigestible Protein
[f] Lower tract UIP Digestibility

Table 2. *In Vivo* **and** *In Vitro* **digestibility of five different hays fed to yearling steers.**

	Diet					Statistics	
Variable	Prairie	MAlf[1]	MBrome[2]	IBrome[3]	IAlf[4]	SEM	P-value
In Vivo							
DMI, lb	11.9^{ce}	14.7^{ad}	13.0^{be}	13.6^{abc}	16.1^{d}	0.6	<0.01
DMD, %	50.2^{cf}	50.9^{ad}	51.2^{be}	56.4^{abc}	60.6^{def}	1.6	<0.01
OMD, %	55.5^{be}	56.5^{ac}	58.1^{d}	62.2^{ab}	66.5^{cde}	1.4	<0.01
NDFD, %	47.1^{cf}	47.0^{ad}	45.2^{be}	57.0^{abc}	53.7^{def}	2.3	<0.01
In Vitro							
DMD, %	52.8^{be}	52.9^{ac}	53.9^{d}	59.1^{ab}	63.9^{cde}	1.6	0.02
OMD, %	49.8^{acd}	54.5^{b}	57.9^{c}	62.4^{a}	64.2^{bd}	2.0	0.03
NDFD, %	43.8^{bd}	43.4^{ac}	48.6	54.0^{ab}	51.5^{cd}	1.6	0.03

[1]Mean Mature Alfalfa Hay
[2]Means Mature Brome Grass Hay
[3]Means Immature Brome Grass Hay
[4]Means Immature Alfalfa Hay
[abcdef] Means with like superscripts differ significantly ($P<0.001$)

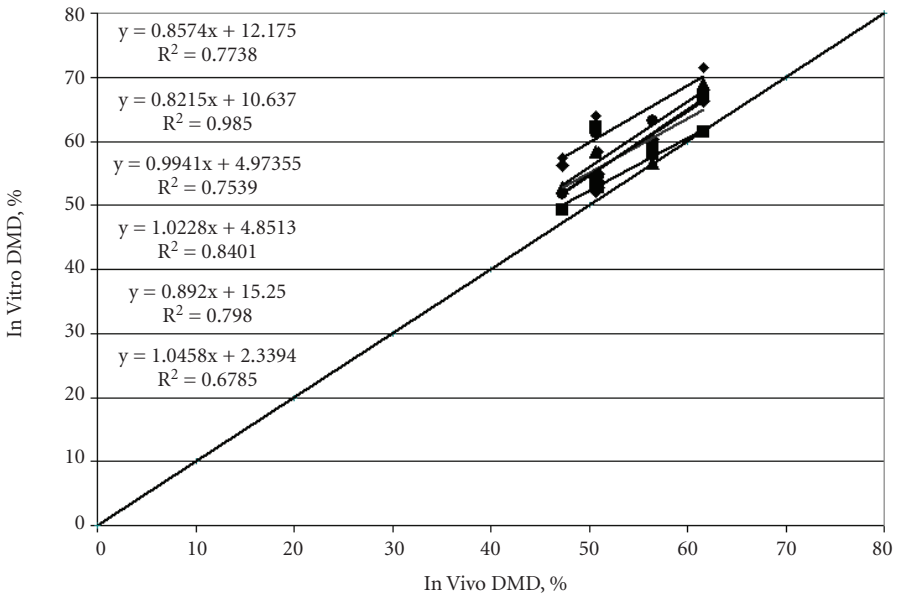

Figure 1. Regression analysis of *in vivo* **vs.** *in vitro* **digestibility.**

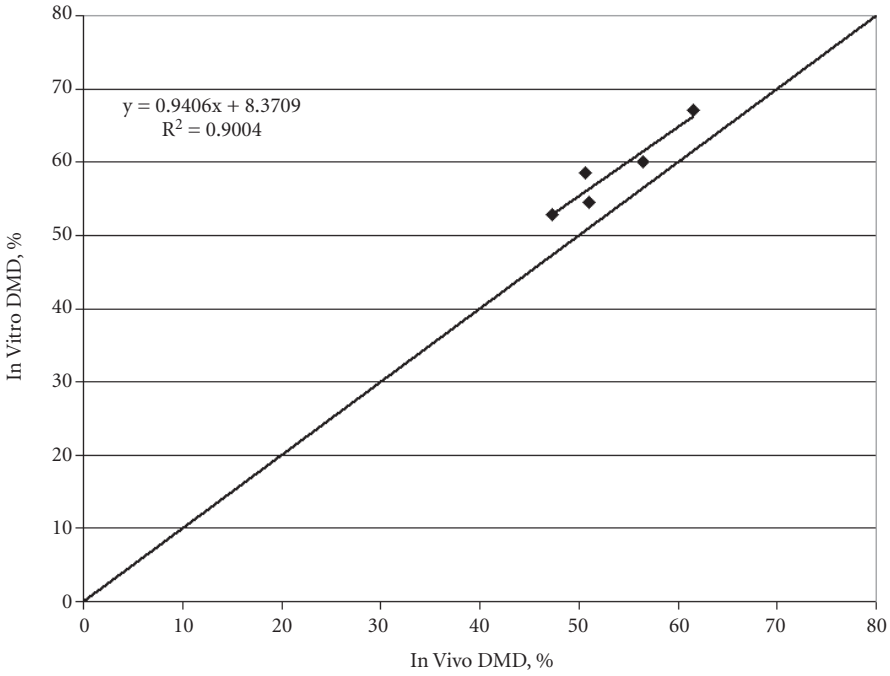

Figure 2. Regression analysis of the average of all six *in vitro* runs. Each point represents the average of each of the five different hay samples.

donor animals, differences in technicians, and the handling of rumen fluid prior placing in the tubes. However, in vitro (test tube) and in vivo (in the animal) digestibilities had good agreement, and were significantly correlated (r = 0.82 to 0.99). When the six runs were averaged (Figure 2) together IVDMD was 5.4 percentage units higher than *in vivo* DMD. This equates to an 8% difference between *in vivo* and *in vitro* digestibility.

Implications

Including these five hay samples with *in vitro* DMD analyse as standards will allow prediction of *in vivo* digestibility for new forages. This is important in research settings where a large number of samples are collected and cannot be included within the same *in vitro* run. Samples can be analyzed at different times and the adjustment allows us to compare different runs.

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Using a Modified *In-Vitro* Procedure to Measure Corn Bran Buoyancy

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Summary

An in vitro *procedure was modified to estimate rumen buoyancy of corn bran and fiber types. Inoculum was obtained from two beef heifers and mixed with McDougall's buffer then distributed to the in vitro tubes for 30 hours incubation at 100°F. Fibrous material formed a matte layer which was measured to describe buoyancy. Tubes contained 6g of a feedlot-type diet with 7.5% fiber type (alfalfa hay, grass hay, corn silage, or corn stalks), with no replacement or 25% replacement of the remaining corn with corn bran. Buoyancy declined over time. Alfalfa hay had the most positive effect on buoyancy of corn bran. This new method offers promise for describing rumen buoyancy.*

Introduction

Corn bran has potentially high digestible fiber (*2005 Nebraska Beef Report,* pp. 39-41), however, rumen retention time determines digestibility. Rumen retention time of corn bran has not been clearly determined within a feedlot steer on a high concentrate diet with little fibrous matte layer.

When fibrous feedstuffs enter the rumen, the microbes attach to the fiber and produce gas which is trapped with the fiber particles. The suspension (or buoyancy) of the fiber particles with trapped gas above the liquid portion within the rumen is considered the matte layer. Buoyancy decreases over time as the fiber particles are digested. Greater buoyancy in the rumen is hypothesized to allow greater fiber retention time and digestibility. In concentrate-fed animals, the presence of a matte layer and fiber buoyancy may be low considering the low fiber content of the diets. Describing buoyancy over time of various feedstuffs, particularly corn bran, can be a useful tool when evaluating fiber characteristics and extent of fiber digestibility. Therefore, the objectives of this project were (1) to develop a technique to describe the buoyancy characteristics of corn bran over time and (2) to evaluate the effect of fiber type on buoyancy.

Procedure

Several modified *in vitro* trials were conducted to establish a procedure for measuring buoyancy over time. Initially, simple substrate samples of grass hay at different levels in 300mL glass test tubes were used. The amount of 150mL inoculum (1:1 ratio of McDougall's buffer and rumen fluid) in the tube was necessary to precisely measure matte layers over time. Two donor heifers on a mixed diet consisting of 70% ground grass hay, 15% dry rolled corn, and 15% soybean meal (DM basis) were used to collect rumen fluid prior to morning feeding. Rumen fluid was strained through four layers of cheesecloth.

Before distribution of the 150mL inoculum, 1.5g of 2mm ground grass hay substrate was placed in each tube. The tubes were incubated in a 100°F water bath for 30 h. Matte layer measurements were taken with a caliper ruler as a means for determining buoyancy over time. Just before these measurements were obtained, the tubes were swirled by hand and placed back into the water bath for approximately 10 minutes allowing the remaining buoyant fiber particles to float and be measured.

In the first experiment, rumen fluid was collected from two heifers consuming a diet of 50% dry rolled corn, 20% wet corn gluten feed, 20% wet distillers grains with solubles, 7% ground alfalfa hay, and 3% dry supplement containing an equivalent 300 mg/hd/day Rumensin® (DM basis). The substrate in each tube consisted of 6g feedlot-type diets containing mostly dry corn. This corn was used to represent a feedlot type diet and to bring the inoculum pH within a range that would be observed shortly after cattle consume a high concentrate meal. Tubes were incubated for 30 hours and matte layer measurements were taken at h 2, 8, 15, 22, and 30 and expressed as mL.

Two 30-hour *in vitro* runs with a 4 X 2 factorial arrangement of treatments were conducted. Tubes contained 6g DM of feedlot-type diets with calculated 7.5% (0.45g) fiber level with four fiber types of alfalfa hay, brome hay, corn silage (assumed 50% fiber), and corn stalks, each ground to 2mm. The remaining 92.5% (5.55g DM) consisted of ground dry corn or 25.0% of the corn replaced with corn bran. The objective of these runs was to evaluate effects of fiber types on the rumen buoyancy of corn bran.

Statistical effects were tested using the mixed procedures of SAS with tube as the experimental unit and time as a repeated measure.

Results

Buoyancy decreased for all treatments across time, which would be expected. As fiber digestion proceeds less substrate is available and therefore gas production decreases. The decreasing gas production allows fiber particles to have higher specific gravity and sink to the bottom of the tube (rumen). Matte layer measurements converged after 14 hours for all treatments, while treatments containing corn bran

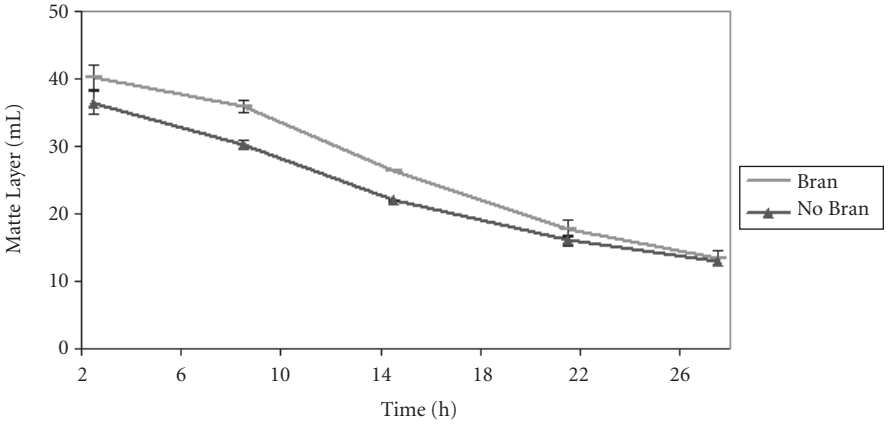

Figure 1. Response of corn bran on matte layer as estimated *in vitro*. Standard error bars indicate variation around the means.

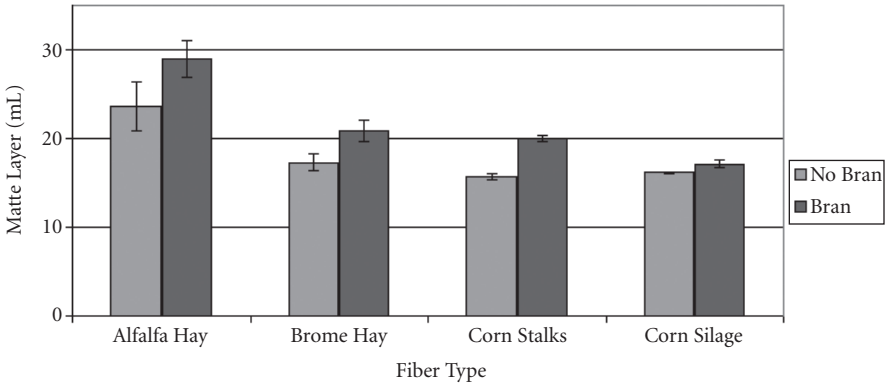

Figure 2. Response of fiber type and influence of corn bran buoyancy on matte layer at 14 hours as estimated *in vitro*. Standard error bars indicate variation around the means.

had increased ($P<0.01$) matte layer measurements through 14 hours compared to treatments containing corn only (Figure 1). Treatments with alfalfa hay had greater ($P<0.01$) matte layer measurements (26.3mL) than the other fiber types (17.9mL) when paired with both corn only and corn with corn bran, indicating longer retention time within the rumen before the fiber particles would pass. There was a four-way interaction ($P<0.01$) including the factors of *in vitro* run, time, fiber type, and corn bran addition. Fiber types did not have a consistent effect on buoyancy of the corn bran on incubation time or on the two *in vitro* runs. This could mean that the procedure is not accurate (precise) or that there are important biological interactions that need to be studied.

Net matte layer values were determined by calculating the difference of treatments containing corn bran minus treatments containing corn alone within each fiber type. While there were five matte layer measurements taken, the mid-point of 14 hours was chosen for representing effect of fiber types on corn bran buoyancy over time (Figure 2). Among the fiber types, alfalfa hay produced the greatest net matte layer, with corn silage and corn stalks being the lowest.

This modified lab procedure of measuring buoyancy with matte layers over time may prove useful to describe fiber retention and potential digestibility of corn bran and fiber types. However, when collecting rumen fluid from concentrate donor animals, there is a considerable amount of gaseous foam that contributes to the fiber buoyancy and calculated matte layers and this may cause variation among *in vitro* replications. The correlation between the new *in vitro* procedure and in vivo procedures has not been established. More research is needed to quantify and describe the results observed when using this procedure.

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Vascular Endothelial Growth Factor Inhibitory Isoform Is Regulated Prior to Ovulation

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Karl V. Moline
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Summary

VEGF normally acts to stimulate vascular development (angiogenesis) and is necessary for ovulation of the dominant follicle. The inhibitory isoform blocks the actions of VEGF angiogenic isoforms; therefore, the objectives of the experiments were to identify the bovine inhibitory isoform, VEGF164b and to determine its expression prior to and after the LH surge. VEGF164b mRNA was upregulated prior to but did not change after the LH surge. Therefore, VEGF164b may be necessary for preparation of the dominant follicle prior to ovulation.

Introduction

During deviation of the dominant follicle from the subordinate follicles, the dominant follicle develops an extensive vasculature network in the theca layer that surrounds the basement membrane. The granulosa cell layer surrounding the oocyte within the basement membrane of the follicle is avascular at this time point. VEGF is expressed by granulosa cells prior to ovulation in the bovine follicle and working via the theca cells to increase vacularization, providing nutrients to the developing follicle. VEGF aids in cell migration, proliferation, and increased microvascular permeability through the stimulation of endothelial cells which are cells that form blood vessels.

Recent studies have identified an anti-angiogenic inhibitory VEGF splice variant, VEGF164b. Vascular Endothelial Growth Factor 164b is the inhibitory isoform of bovine VEGF164. The VEGF inhibitory isoform blocks actions of VEGF pro-angiogenic isoforms.

The objective of the current study was to identify VEGF164b and to determine the expression pattern of VEGF164b in granulosa cells of the bovine follicle prior to and after the LH surge. The hypothesis was that VEGF164b isoform would be differently expressed and may be used to regulate folliculogenesis during the bovine estrous cycle.

Procedure

In the first trial, cows were administered two injections of $PGF_{2\alpha}$ 14 days apart and follicular aspirates were collected at 12, 18, 24, 30, 36, 48, 54, 60, and 72 hours (n=average of 8) after the second injection of $PGF_{2\alpha}$ to obtain granulosa cells prior to the LH surge. Messenger RNA was extracted from granulosa cells and samples were reversed transcribed to cDNA. Progesterone and estrogen concentrations were measured in follicular fluid. A ratio greater than 1 of estrogen to progesterone indicated the follicle was still dominant. The mRNA expression of VEGF164b isoform was determined using real-time quantitative polymerase chain reaction (PCR) at each follicular aspirate time point.

Blood samples were collected every two hours from 12 cows to determine when the cows had an LH surge. Since all the cows had an LH surge from 56 hours to greater than 72 hours, the granulosa cells collected prior to 56 hours were used in the analysis.

A second trial was conducted to obtain granulosa cells after a GnRH induced LH surge. Cows were injected with two injections of $PGF_{2\alpha}$ (25 mg/cow) and 48 hours after the second injection of $PGF_{2\alpha}$ administered GnRH (100 µg/cow). Follicular aspirates were collected at 3, 6, 12, 18, and 24 hours after GnRH (n=average of 10). Messenger RNA was extracted as described previously and expression of VEGF mRNA isoform 164b was analyzed using quantitative real time PCR.

Quantitative RT-PCR data for both trials were analyzed using an ANOVA with SAS. Comparisons of means were tested using a Tukey-Kramer test.

Results

Analysis of newly identified bovine VEGF164b

The VEGF164b inhibitory isoform was subcloned and sequenced in our laboratory. Conventional RT-PCR confirmed the presence of VEGF164b in bovine granulosa cells from dominant follicles (Figure 1). We speculate that every angiogenic isoform of VEGF has an anti-angiogenic isoform that regulates their functions.

Quantitative Real-time PCR (QRT-PCR) for granulosa cells

In the first trial, mRNA expression was measured at 12, 18, 24, 30, 36, 48, and 54 hours post second injection of $PGF_{2\alpha}$ (PG). In Trial 1, the inhibitory isoform, VEGF164b, increased at 18 hours ($P<0.05$); Figure 2.

A second trial was conducted to more accurately simulate the LH surge by an injection with GnRH and to

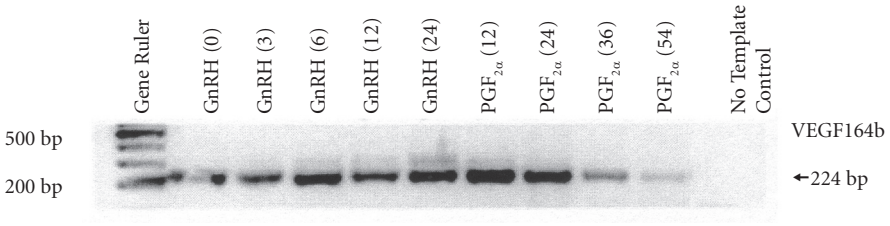

Figure 1. Conventional reverse transcription PCR to detect VEGF164b isoform in bovine granulosa cells collected at 0, 3, 6, 12 and 24 hours after GnRH injection (Trial 2) or 12, 24, 36 and 54 hours after a second injection of PGF_2 (Trial 1).

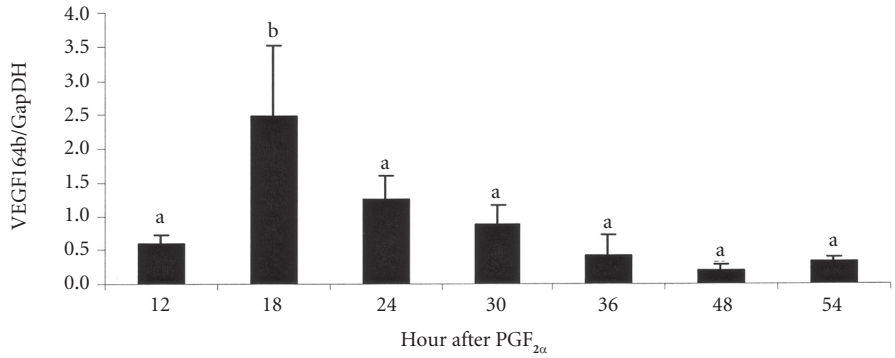

Figure 2. Expression of mRNA for anti-angiogenic VEGF164b isoform using QRT-PCR hours after second injection of $PGF_{2\alpha}$. VEGF isoforms were normalized to GapDH. Messenger RNA expression at each time point is denoted by different letters.

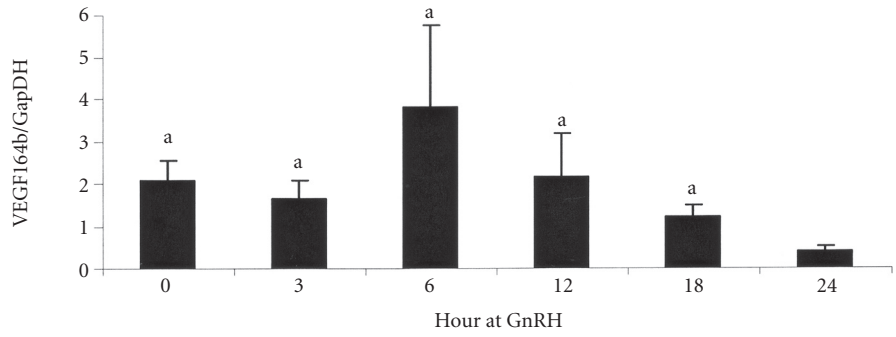

Figure 3. Expression of mRNA for anti-angiogenic VEGF164b isoform using QRT-PCR hours after second injection of GnRH (Trial 2). VEGF isoforms were normalized to GapDH. There were no differences in expression of VEGF164b mRNA as denoted by the same letter for each time point.

collect follicle aspirates after the LH surge. In the second trial, there was no difference in VEGF164b at any of the time points after GnRH (Figure 3). Thus, it appears that the inhibitory isoform may be regulated after corpus luteum regression (Trial 1) but not after the LH surge (Trial 2).

Conclusion

The current studies demonstrate VEGF mRNA isoform expression patterns prior to and after the LH surge. VEGF164b increases 18 hours after CL regression. From these results, we speculate that VEGF mRNA isoform expression is finely regulated by ovarian growth factors and steroid hormones to provide for necessary vascular development and follicle progression. These studies establish a role for VEGF anti-angiogenic isoforms prior to ovulation in the bovine follicle. It is possible that we may be able to use VEGF anti-angiogenic isoforms to manipulate follicle development to more accurately time ovulation in synchronization or superovulation protocols of beef females.

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[1]Robin A. Ten Broeck, graduate student; Debra T. Clopton, research technician; Jeremy L. Martin, graduate student; Karl V. Moline, cow/calf manager; Jeff W. Bergman, agriculture technician; and Andrea S. Cupp, associate professor, Animal Science, Lincoln.

Inhibition of Vascular Endothelial Growth Factor Manipulates Follicles in Beef Females

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Sherrill E. Echternkamp
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Summary

Vascular Endothelial Growth Factor (VEGF) is produced by cells surrounding the egg in the follicle. If VEGF is inhibited, ovulation does not occur. Understanding how VEGF regulates follicle development may allow for manipulation of estrous cycles. In previous studies in our laboratory, blocking the actions of VEGF decreased activation of early stage follicles in neonatal rat ovary cultures. Therefore, we hypothesized inhibition of VEGF actions would also inhibit follicle activation in bovine ovarian cortical cultures. Inhibition of VEGF did inhibit follicle progression, thus regulation of VEGF may be a way to manipulate follicle development and more accurately time ovulation.

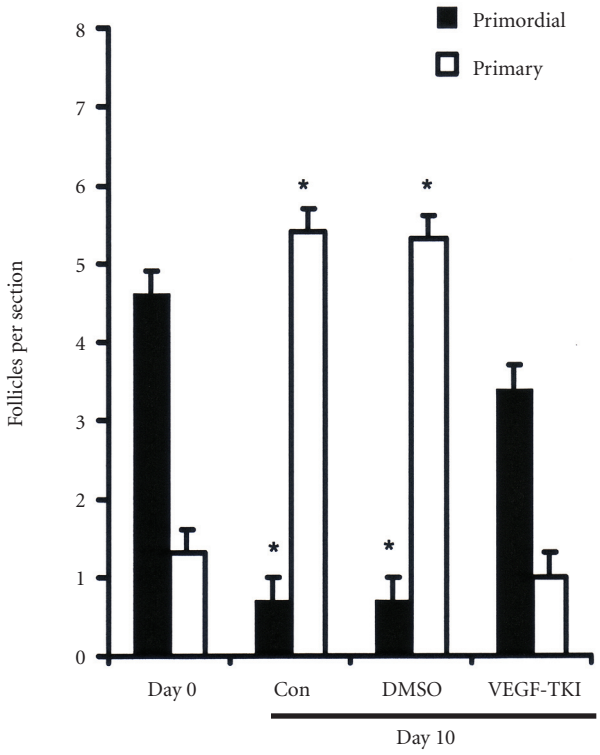

Figure 1. Numbers of follicles per section prior to treatment (day 0) in control, vehicle control (DMSO) and VEGF-TKI (VEGF inhibitor) after 10 days of treatment. There were greater later stage follicles (primary) in Control and DMSO treated cultures than those treated with VEGF-TKI (VEGF inhibitor; $P < 0.05$). The VEGF-TKI treatment had more primordial follicles (earliest stage of follicle development) and less had progressed to the later primary stage.

Introduction

Follicular development within the bovine ovary is a continuous process. It begins prior to birth and continues throughout the cow's reproductive lifespan. Regulatory mechanisms involved in primordial follicle pool development (earliest stage follicle development), progression or depletion in the ovary are poorly understood. Abnormal development or regulation of the primordial follicle pool can lead to ovarian dysfunction, including impairment of reproductive capacity or premature ovarian failure (depletion of follicles all at once at or near puberty). Manipulation of the primordial follicle pool may provide a means to increase reproductive efficiency in females. Specific growth factors must either stimulate or inhibit primordial follicle progression. VEGF has been demonstrated to be an important growth factor in the development of pre-ovulatory follicles, ovulation and formation of corpora lutea. No role has been identified for VEGF in the earlier stages of follicle development; however, research indicates VEGF expression is up-regulated during the primordial to primary follicle transition in postnatal rat ovaries. Therefore, we hypothesized that VEGF and its receptors regulate follicular progression in the bovine ovary.

Procedure

Ovaries were collected by mid-line laparotomy from neonatal calves (n = 5) at 44 ± 1.2 days of age, and the ovarian cortex was dissected from the medulla. *(The cortex of the ovary is the outside portions of the bovine ovary that contain the follicles. The middle portion of the ovary contains the medulla which has mainly vasculature and nerves.)* Ovarian cortical pieces (two pieces/well) were cultured in serum-free medium, with 0, 2, 4 or 8 μM of VEGF receptor tyrosine kinase inhibitor (VEGF-TKI) or DMSO (vehicle control) for 10 days in duplicate wells. VEGF-TKI was

replenished every day and medium changed every other day. On day 0 or day 10, cortical pieces (four pieces/calf/day/treatment) were collected and embedded in LR White resin for morphometric analysis.

Results

In control and DMSO-treated cultures, the number of primordial follicles per section decreased (day 0 = 4.6 ± 0.7 vs. day 10 = 0.7 ± 0.3; $P < 0.001$) and the number of primary follicles per section increased (day 0 = 1.3 ± 0.3 vs. day 10 = 5.4 ± 0.5; $P < 0.001$). Primordial follicle activation was not inhibited by 2 or 4 μM of VEGF-TKI; however, after 10 days in the presence of 8 μM VEGF-TKI, the number of primordial follicles per section was not different from day 0 controls (3.4 ± 0.4 follicles/section), indicating no activation had occurred when VEGF signaling was inhibited. Primordial follicles increased in diameter after 10 days in control and DMSO-treated cultures (day 0 = 16.0 ± 2.1 mm vs. day 10 = 26.0 ± 2.1 mm; $P < 0.05$). Ten days of treatment with 8 μM VEGF-TKI did not inhibit the growth of primordial follicles (30.3 ± 2.1 mM). Thus, VEGF-TKI (8 μM) inhibited primordial follicle activation in bovine ovarian cortical cultures. The current study supports previous results in the perinatal rat and indicates VEGF may be a regulator of primordial follicle activation.

Thus, regulation of VEGF early during bovine reproductive development may be important for inducing follicles to progress and develop. Regulation of VEGF may allow for manipulation of follicle development in the beef female.

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Statistics Used in the Nebraska Beef Report and Their Purpose

The purpose of beef cattle and beef product research at UNL is to provide reference information that represents the various populations (cows, calves, heifers, feeders, carcasses, retail products, etc.) of beef production. Obviously, the researcher cannot apply treatments to every member of a population; therefore, he or she must sample the population. The use of statistics allows the researcher and readers of the Nebraska Beef Report the opportunity to evaluate separation of random (chance) occurrences and real biological effects of a treatment. Following is a brief description of the major statistics used in the beef report. For a more detailed description of the expectations of authors and parameters used in animal science see Journal of Animal Science Style and Form (beginning pp 339) at: *http://jas.fass.org/misc/ifora.shtml*.

- **Mean** – Data for individual experimental units (cows, steers, steaks) exposed to the same treatment are generally averaged and reported in the text, tables and figures. The statistical term representing the average of a group of data points is mean.

- **Variability** – The inconsistency among the individual experimental units used to calculate a mean for the item measured is the variance. For example, if the ADG for *all* the steers used to calculate the mean for a treatment is 3.5 lb then the variance is zero. But, this situation never happens! However, if ADG for individual steers used to calculate the mean for a treatment range from 1.0 lb to 5.0 lb, then the variance is large. The variance may be reported as standard deviation (square root of the variance) or as standard error of the mean. The standard error is the standard deviation of the mean as if we had done repeated samplings of data to calculate multiple means for a given treatment. In most cases treatment means and their measure of variability will be expressed as follows: 3.5 ± 0.15. This would be a mean of 3.5 followed by the standard error of the mean of 0.15. A helpful step combining both the mean and the variability from an experiment to conclude whether the treatment results in a real biological effect is to calculate a 95% confidence interval. This interval would be twice the standard error added to and subtracted from the mean. In the example above, this interval is 3.2-3.8 lb. If in an experiment, these intervals calculated for treatments of interest overlap, the experiment does not provide satisfactory evidence to conclude that treatments effects are different.

- **P Value** – Probability (P Value) refers to the likelihood the observed differences among treatment means are due to chance. For example, if the author reports $P \leq 0.05$ as the significance level for a test of the differences between treatments as they affect ADG, the reader may conclude there is less than a 5% chance the differences observed between the means are a random occurrence and the treatments do not affect ADG. Hence we conclude that, because this probability of chance occurrence is small, there must be difference between the treatments in their effect on ADG. It is generally accepted among researchers when P values are less than or equal to 0.05, observed differences are deemed due to important treatment effects. Authors occasionally conclude that

an effect is significant, hence real, if P values are between 0.05 and 0.10. Further, some authors may include a statement indicating there was a "tendency" or "trend" in the data. Authors often use these statements when P values are between 0.10 and 0.15, because they are not confident the differences among treatment means are real treatment effects. With P values of 0.10 and 0.15 the chance random sampling caused the observed differences is 1 in 10 and 1 in 6.7, respectively.

- **Linear and Quadratic Contrasts –** Some articles contain linear (L) and quadratic (Q) responses to treatments. These parameters are used when the research involves increasing amounts of a factor as treatments. Examples are increasing amounts of a ration ingredient (corn, by-product, or feed additive) or increasing amounts of a nutrient (protein, calcium, or vitamin E). The L and Q contrasts provide information regarding the shape of the response. Linear indicates a straight line response and quadratic indicates a curved response. P-values for these contrasts have the same interpretation as described above.

- **Correlation (r) –**Correlation indicates amount of linear relationship of two measurements. The correlation coefficient can range from –1 to 1. Values near zero indicate a weak relationship, values near 1 indicate a strong positive relationship, and a value of –1 indicates a strong negative relationship.

Animal Science

http://animalscience.unl.edu

Curriculum — The curriculum of the Animal Science Department at the University of Nebraska–Lincoln is designed so that each student can select from a variety of options oriented to specific career goals in professions ranging from animal production to veterinary medicine. Students have unique opportunities to double major in Grazing Livestock Systems (*http://gls.unl.edu*) or complete the Feedlot Management Internship Program (*http://feedlot.unl.edu/intern*).

Careers:

Animal Health
Banking and Finance
Animal Management
Consultant
Education
Marketing
Technical Service
Meat Processing
Meat Safety
Quality Assurance
Research and Development
Veterinary Medicine

Scholarships — Each year the Animal Science Department offers over 20 scholarships to incoming freshmen and 24 scholarships to sophomore, junior and senior Animal Science students.

ABS Global Scholarship
Baltzell-Agri-Products, Inc. Scholarship
Maurice E. Boeckenhauer Memorial Scholarship
Mike Cull Judging and Activities Scholarship
Don Geweke Memorial Award
Parr Young Senior Merit Award
Nebraska Pork Producers Association Scholarship
Waldo Family Farms Scholarship
Frank and Mary Bruning Scholarship
Art and Ruth Raun Scholarship
Animal Science Department Freshman Scholarship
Feedlot Management Scholarship
Robert Boeckenhauer Memorial Scholarship
Burnell Scholarship Fund
Doane Scholarship
Lincoln Coca-Cola Bottling Company Scholarship
William J. and Hazel J. Loeffel Scholarship
Nutrition Service Associates Scholarship
Parr Family Student Support Fund
Chris and Sarah Raun Memorial Scholarship
Walter A. and Alice V. Rockwell Scholarship
Standard Manufacturing Co. Scholarship
Max and Ora Mae Stark Scholarship
D.V. and Ernestine Stephens Memorial Scholarship
Dwight F. Stephens Scholarship
Arthur W. and Viola Thompson Scholarship
Thomas H. Wake, III Scholarship
Franke E. Card Scholarship
Derrick Family Scholarship
G. H. Francke Livestock Judging Scholarship
Eric Peterson Memorial Award
Winkler Memorial Livestock Judging Scholarship