2003

2003 South Dakota Beef Report

Department of Animal and Range Sciences, South Dakota State University

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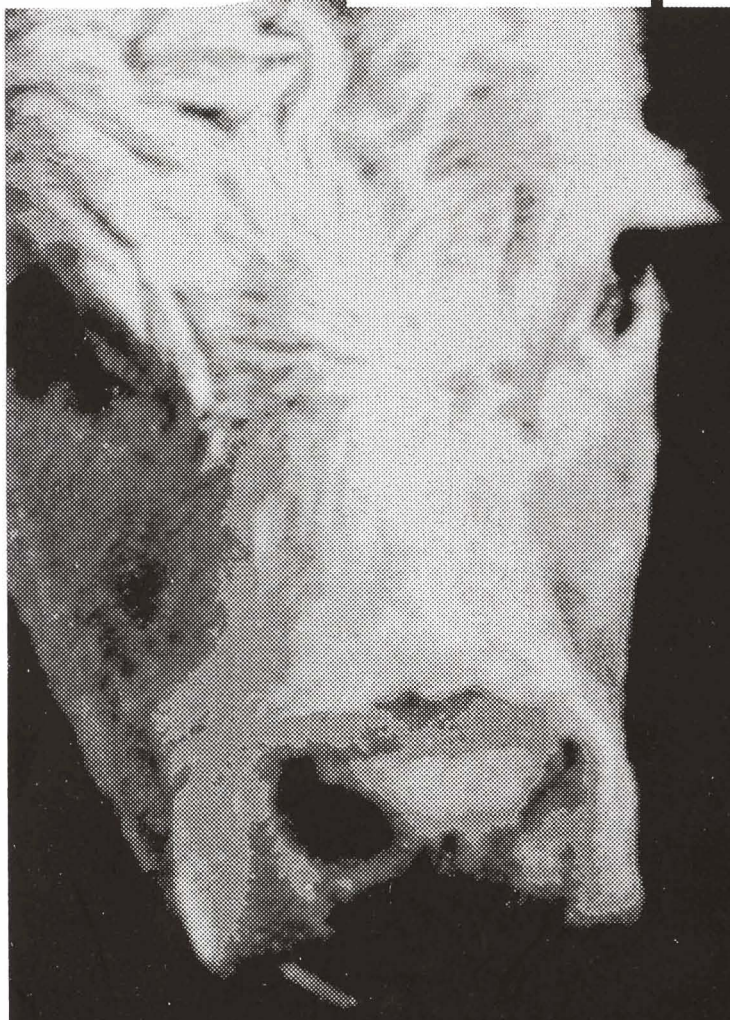
2003 SOUTH DAKOTA

BEEF REPORT



South Dakota State University
College of Agriculture and Biological Sciences
Department of Animal and Range Sciences

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BRUNS, Kelly W.	Live Animal/Carcass Evaluation	Teaching, Research
CLAPPER, Jeffrey A.	Swine Reproductive Physiology	Research, Teaching
DANIEL, Jay	Sheep Reproductive Physiology	Research, Teaching
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GATES, Roger (RC)	Range Management	Extension, Research
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HOLT, Simone	Ruminant Nutrition	Research
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MADDOCK, Robert	Meat Science	Teaching, Research
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THALER, Robert	Swine Nutrition	Extension, Teaching
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WERTZ, Aimee	Ruminant Nutrition	Teaching, Research
WRIGHT, Cody L.	Cow-Calf Management	Extension, Research
WULF, Duane	Meat Science	Research, Teaching

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Protection Against a Bovine Viral Diarrhea Virus (BVDV) Type 1 Challenge in Calves Vaccinated with a Bovine Herpesvirus-1 (BHV-1)-BVDV Recombinant

Heather J. Swan[1], Lyle J. Braun[2], Leonard J. Bello[3], William C. Lawrence[3], Reg D. Neiger[3] and Christopher C.L. Chase[3].
Department of Veterinary Science, SDSU and Department of Pathology, University of PA

BEEF 2003 – 01

Abstract

A recently developed recombinant bovine herpesvirus 1 (BHV-1) virus containing the envelope protein gp53 of bovine viral diarrhea virus (BVDV) type 1, BHV-1 (v1V31), was assessed for its ability to protect against BVDV in calves. Four calves were vaccinated intranasally with the recombinant BHV-1-BVDV vaccine and did not exhibit any clinical signs following vaccination. The vaccine virus was recovered from all vaccinated calves on days 8 through 10 and the replication appeared to be restricted to nasal passages. Twenty-eight days after vaccination, the four vaccinated and four control calves were challenged with the type 1 BVDV, strain NY-1. All calves had slight temperature elevations but the clinical signs were more severe in the control calves. The platelet counts were significantly depressed in the control calves. Prior to challenge, neither group had BVDV serum neutralizing antibody. The vaccinated calves developed higher serum antibody levels 2 months following challenge, indicating a secondary immune response. Necropsy was performed six weeks following infection. No latent BHV-1 virus was detected from the trigeminal ganglion of any of the vaccinated calves. The recombinant BHV-1 virus vaccine containing a single BVDV protein provided partial protection against BVDV infection.

Introduction

Bovine viral diarrhea virus (BVDV) and bovine herpesvirus 1 (BHV-1) infections are a major source of respiratory and reproductive problems in cattle (Fields et al., 1996; Ludwig, 1983). Live attenuated BHV-1 vaccine strains are effective and have been used safely in cattle for several years (Bello et al., 1992). BVDV vaccines fail to control persistent infections, which occur in animals that are infected in utero at 40-120 days of gestation, and result in lifelong viral shedding. Modified-live BVDV vaccines are available, but they are not safe to use in pregnant animals. Inactivated BVDV vaccines can be used in a pregnant animal, but they are inconvenient and ineffective at controlling persistent infections (Baker, 1995).

BHV-1 is useful as an expression and vaccine vector (Bello et al. 1992). Genes from other viruses can be inserted into the BHV-1 thymidine kinase (TK) gene because the TK gene is non-essential for BHV-1 replication in cattle and TK-BHV-1 viruses protect pregnant cows against abortion (Whetstone et al. 1992). This led to the development of the BHV-1-BVDV recombinant virus, BHV-1 (v1V31). The glycoprotein 53 (gp53) of BVDV is the major target for neutralizing antibody against BVD virus. The gp53 from BVDV was inserted into the TK locus of a TK^{--} BHV-1 genome. This work was done by Dr. L.J. Bello and Dr. W.C. Lawrence, University of Pennsylvania (data not published).

The use of a BHV-1-BVDV recombinant virus vaccine in pregnant cattle to control both BHV-1 and BVDV abortions and BVDV persistent infections of the fetuses is an important and promising approach. This preliminary vaccine trial using calves is a model for future trials to protect pregnant cows against BHV-1 and BVDV infection. The objective of this study was to determine if the BHV-1 recombinant virus vaccine was safe and efficacious.

Materials and Methods

Viruses and Cells. The vaccine virus used was the recombinant BHV-1 (v1V31) containing gp53 of the NADL strain of BVDV type 1 was

[1] Undergraduate Student
[2] Sr. Microbiologist
[3] Professor

prepared at the University of Pennsylvania in Philadelphia, PA. The cells used for all assays were bovine turbinate (Bt) cells. The cells were grown in minimum essential media (MEM) containing 5% fetal bovine serum (FBS). The challenge virus used was type 1 BVDV NY-1 from the National Veterinary Services Laboratory in Ames, IA. BVDV Singer type 1 and BVDV A125 type 2 strains were used for the BVDV type 1 and type 2 serum neutralization assays respectively.

Animals. Eight male, BHV-1 and BVDV negative, Holstein calves were used in the study. The calves were four to five months old and ranged in weight from 200 to 300 pounds. Two groups of calves were used, a vaccinated group and a control group, with each group consisting of four animals. The calves were initially housed first in an open enclosure with calf hutches and later moved to an open-front barn in a small pasture enclosure. The study was reviewed and approved by the SDSU Institutional Animal Care and Use Committee (IACUC).

Vaccination and Challenge Studies. Calves were vaccinated and/or challenged intranasally. The calves were secured in a headgate and restrained using a rope halter. A small plastic biosafety bag was placed over their muzzles to induce hypoxia for 1-2 minutes to increase respiration rate and inspiration volume. The bag was removed and the vaccine/challenge was administered with a Chromist TLC aerosol unit (Gelman Sciences) for one minute to each nostril. The bag was again placed over the calves' muzzles and hypoxia was induced. The halter was removed and the calves were released.

The vaccinated calves were intranasally inoculated with $10^{7}TCID_{50}$/2ml of recombinant BHV-1-BVDV vaccine on day 0. Nasal samples were taken day 0 to 14 to monitor for recombinant BHV-1-BVDV excretion. Clinical signs were taken every day. The clinical signs included respiration, attitude, nasal discharge, temperature, and diarrhea. The clinical signs were rated on a 0 to 4 point scale, (i.e. normal nasal discharge=0, whereas thick or crusted nasal discharge=4). Serum samples were taken every seven days starting at day 0 to monitor for seroconversion to recombinant BHV-1-BVDV.

The vaccinated and control group calves were intranasally inoculated with $10^{7.9}TCID_{50}$/2ml of NY-1 BVDV on day 28 of the study. Nasal samples were taken days 28 through 35 to monitor for BVDV excretion. Clinical signs were taken every day with the same categories and ratings as the pre-challenge period. Serum samples were taken every 7-14 days from 0- 90 days to monitor for BHV-1 or BVDV seroconversion. Whole blood was taken days 28 through 38 to count the number of whole blood cells and platelets.

Virus Isolation and Serology. The nasal samples taken after vaccination and challenge were collected and virus isolations were performed. The secretions were collected by aspiration using a vacuum pump. One-half of a milliliter (0.5 ml) of nasal secretions were added to 4.5 ml of MEM containing 1% FBS. This mixture was vortexed, centrifuged and filter sterilized in 0.45 mm filters. Duplicates were plated at 1:5 serial dilutions on Bt cells. The BHV-1 isolation plates after vaccination were read four days after inoculation and the cytopathic effect (CPE) was recorded. Seven days after the inoculation, the cells on the BVDV isolation plates were fixed with 20% acetone, 80% PBS and 0.02% BSA. The plates were dried overnight and frozen at -70°C. Later a BVDV immunoperoxidase test was performed on the cells to detect BVDV in the samples (Saliki, 1997). The viral titers were determined using a $TCID_{50}$ assay (Karber, 1931).

Antibody levels for BHV-1 and BVDV were determined by a virus neutralization assay using two fold dilutions (Manual of Standards for Diagnostic Tests and Vaccines, 1992) by the Serology Section of the Animal Disease Research and Diagnostic Laboratory (ADRDL) at SDSU.

Clinical Pathology. White blood cell and platelet counts were performed by the Clinical Pathology section at the ADRDL of SDSU from the whole blood on days 27-38 (Days –1 to 10 post challenge).

Necropsy. The calves were all euthanized by electrocution at the end of the study on Day 90. The tissues harvested were: tonsil, spleen, thymus, testes, Peyer's patches, trigeminal ganglion, and medistineal, mesenteric, retropharyngeal, and subiliac lymph nodes.

Paired tissue samples were taken, one set was fresh and one set was preserved in formalin. The fresh tissues were frozen in -80°C. Virus isolations were performed on these samples.

Statistical Analysis. The results were analyzed using a student's T-test for statistical significance.

Results

Growth of Recombinant Virus and Clinical Signs following Vaccination. BHV-1 was recovered from all animals from days 3-10 days post-vaccination (Figure 1). The most consistent days were days 8-10. Titers of the recombinant recovered from the nasal secretions were as high as 10^6 TCID50/ml.

The post-vaccination temperatures were normal (Figure 2) and clinical scores for post-vaccination were negligible (Figure 3) with a very slight increase seen from days 5-8.

Clinical Signs and Virus Isolation Following Challenge. BVDV was not detected from any nasal samples after challenge (data not shown). No latent BHV-1 was detected from the trigeminal ganglion of any of the vaccinated calves (data not shown)

The post-challenge temperatures of the vaccinated and control calf groups were similar (Figure 4). The post-challenge clinical scores showed an increase in signs during day 5 to 6 and day 8 to 9 with the control group scores always higher (Figure 5). However none of the differences were significant.

Clinical Pathology. The white blood cell (WBC) count of both the vaccinated and control calf group declined on days 1-2 post challenge (Days 29 and 30) (Figure 6). The vaccinated calves remained slightly lower than normal on days 4-6 post challenge and returned to normal on day 7. The control calves WBC count was returned to normal on day 5 post-challenge and increased significantly on day 7 ($p < 0.10$) (Figure 6). The platelet count of the vaccinated calf group remained normal after challenge, while the control calf group's count was depressed significantly on days 34 ($p<0.1$), 36 ($p<0.001$) and 37 ($p<0.05$) (Figure 7).

Serology. The initial development and kinetics of BVDV type 1 serum neutralization response was similar between the vaccinates and control animals with the exception of the BVDV type 1 titers of the vaccinated group which were higher at day 90 (Figure 8). All of the calves sero-converted to BVDV type 1 by day 56 of the study (28 days post-challenge) (Figure 8). Interestingly none of the vaccinated calves seroconverted to BHV-1 (data not shown). The response to serotype 2 was low indicating low cross reactivity between BVDV type 1 NY-1 strain and BVDV type 2 A125 (Figure 8). The values for Calf #4 were excluded from the data because of a high outlying BVDV type 2 titer on a single day.

Discussion

This study established that a recombinant BHV-1-BVDV was safe to use in calves. The calves showed minimal reactions to the vaccine as measured by body temperatures and clinical scores. These minimal symptoms coincided with the detection of the recombinant BHV-1-BVDV shedding in the nasal secretions of the vaccinated calves (Figure 1). This indicated that local replication occurred. Interestingly, no apparent systemic replication occurred as no latency could be detected in the trigeminal ganglia during the necropsy.

After challenge, the vaccinated animals exhibited less clinical disease than the controls although none of the differences were significant ($p>0.10$). The clinical pathology results indicated a significant increase in white blood cells in the control animals on day 35 while there was no effect on the vaccinated animals. Transient leukopenia normally associated with BVDV infection did not occur in this study. There was a significant thrombocytopenia present in the control animals on days 34, 36 and 37.

Serum neutralizations indicated the development of neutralizing antibody titers to BVDV type 1, but not to the BVDV type 2 (Figure 8). This shows the specificity of type 1 gp53 for type 1 and not for BVDV type 2. After the challenge there was an increase in the vaccinated BVDV type 1 titer at 90 days post vaccination compared to the control BVDV type 1 titers. This represents a secondary immune response in the vaccinated animals, showing the vaccine had induced memory cell development to BVDV.

In conclusion, this small pilot study suggests a role for a recombinant BVDV-BHV-1 vaccine in the control of respiratory and reproductive disease caused by these two viruses. Calves vaccinated with recombinant BHV-1-BVDV virus vaccine showed no adverse reactions to the vaccine and the vaccine replicated locally in the respiratory tract. There were differences in the post-challenge clinical scores and type 1 BVDV serum neutralization titers and significant differences in the WBC and platelet counts between the vaccinated and control calves. The recombinant BHV-1-BVDV vaccine provided partial protection against a BVDV challenge. This study suggests a trial with pregnant cows would provide significant information towards creating a successful vaccine to control both BHV-1 and BVDV abortions and BVDV persistent infections of the fetus.

Acknowledgements

Special thanks to Alicia Sundet, Theodore Stier, Ausama Yousif, the Serology and Clinical Pathology sections of the ADRDL for their help. Joseph F. Nelson Undergraduate Research Mentorship and the ADRDL provided financial support for this project.

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Fig.1 Recombinant BHV-1 shedding in nasal secretions after intra-nasal inoculation.

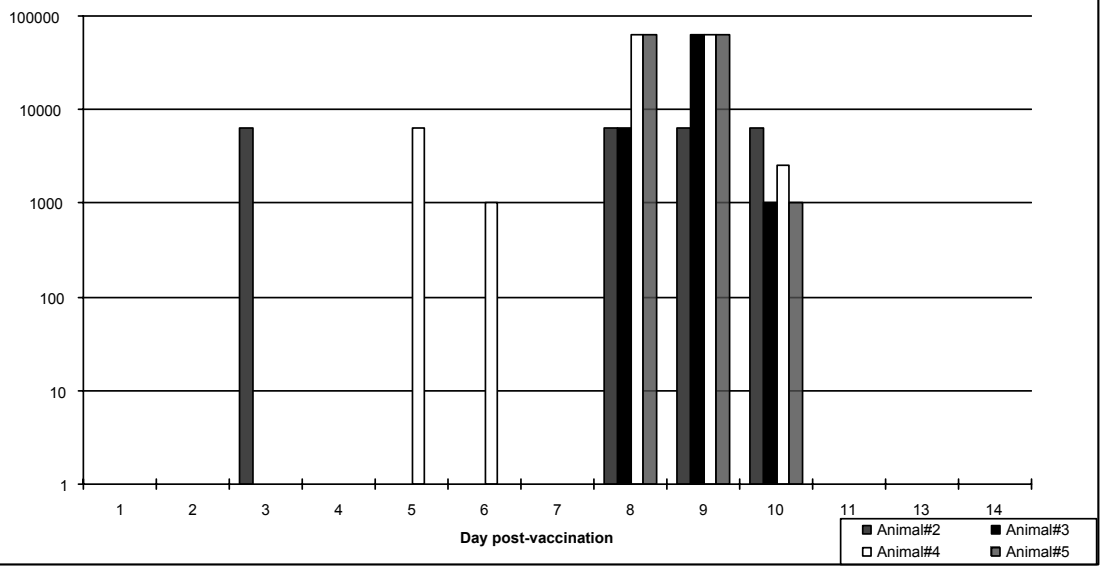


Fig. 2 Post-vaccination average calf rectal-temperature values.

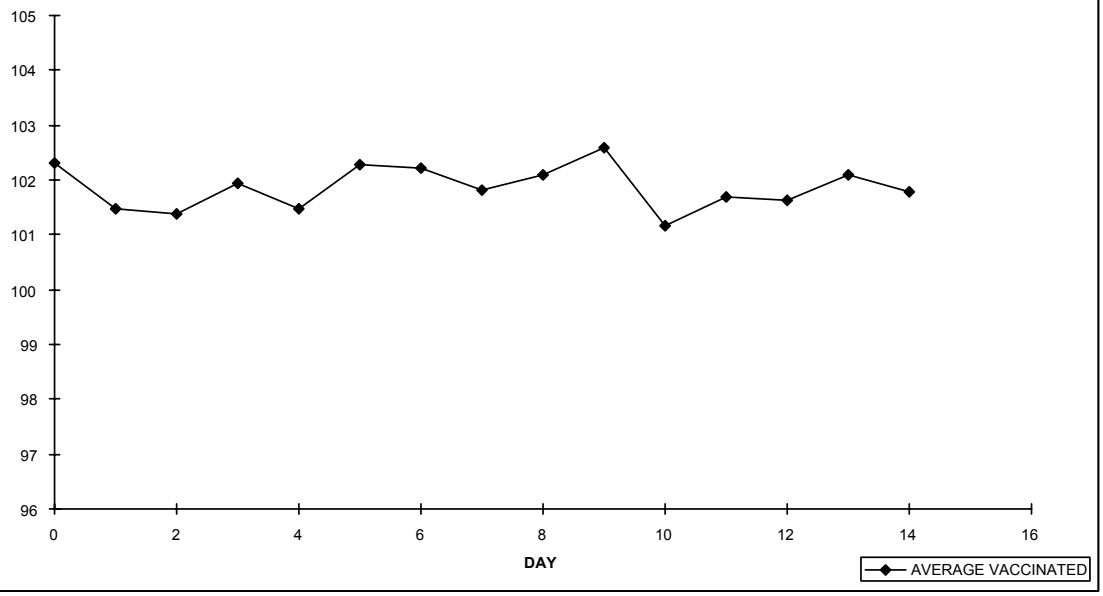


Fig. 3 Average post-vaccination calf clinical scores.

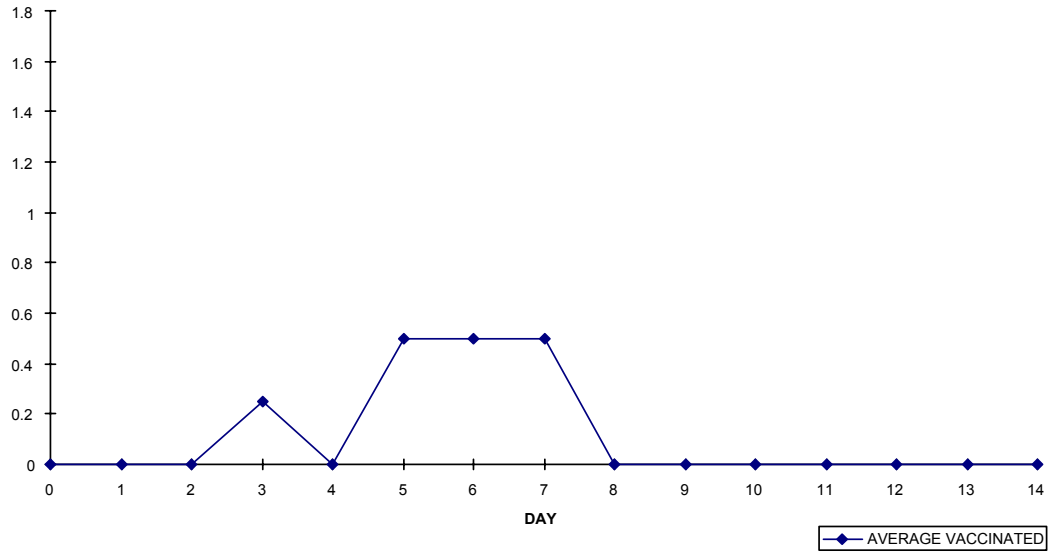
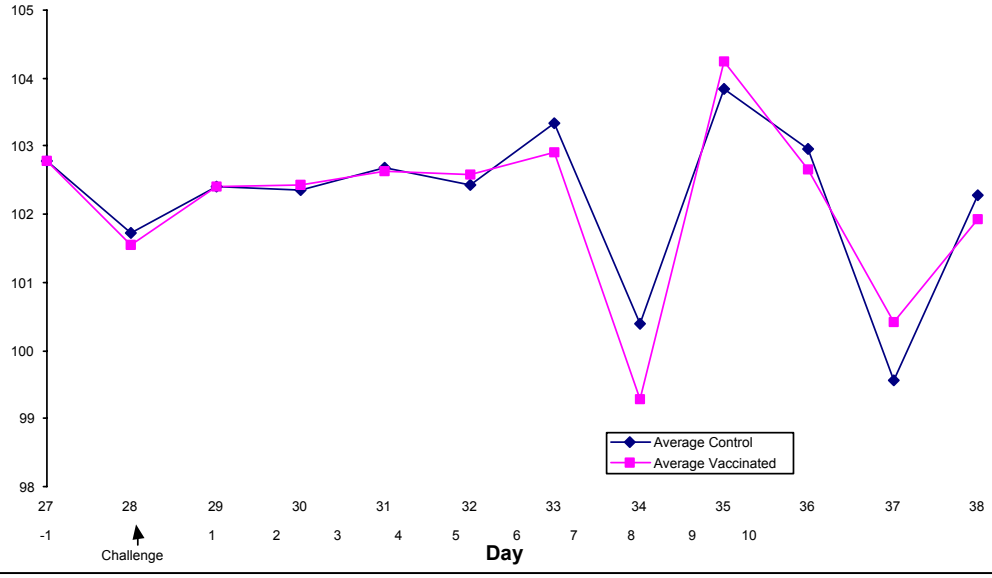


Fig. 4 Body Temperatures following BVDV Challenge



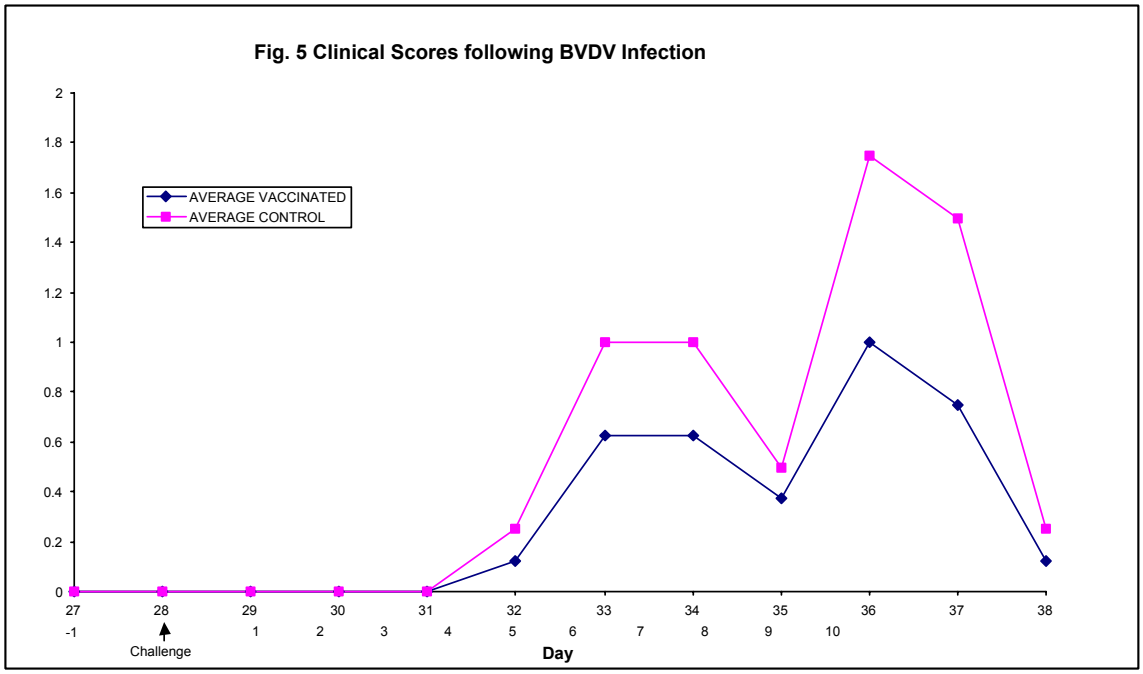


Fig. 5 Clinical Scores following BVDV Infection
AVERAGE VACCINATED
AVERAGE CONTROL
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
27 28 29 30 31 32 33 34 35 36 37 38
-1 1 2 3 4 5 6 7 8 9 10
Challenge
Day

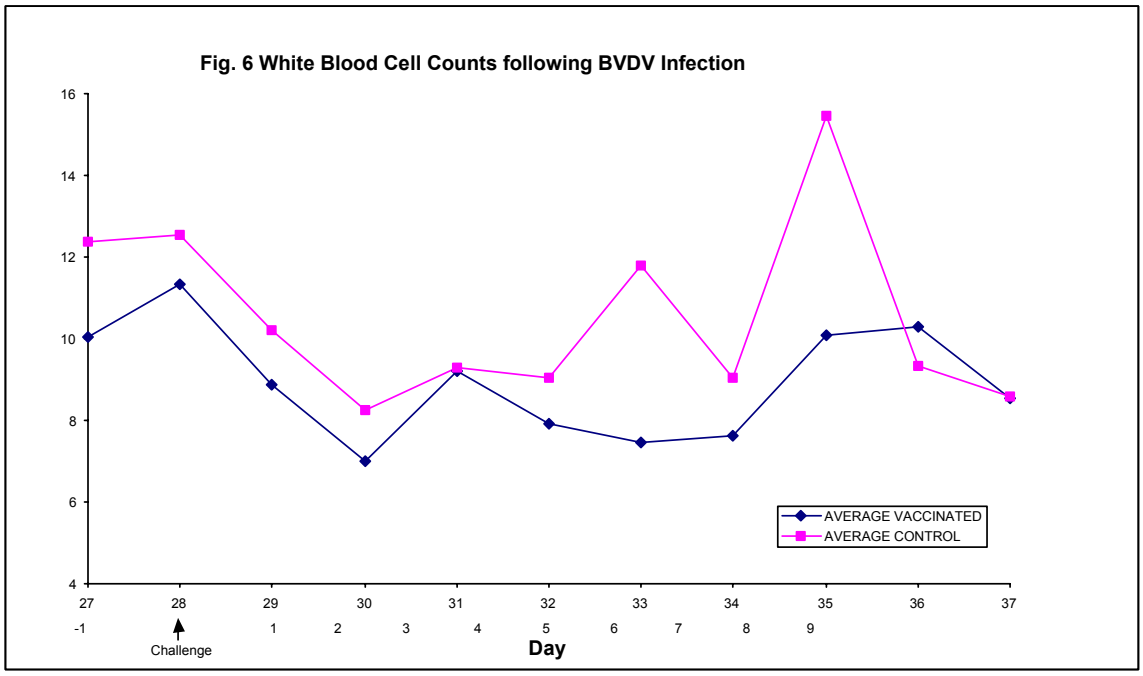


Fig. 6 White Blood Cell Counts following BVDV Infection
AVERAGE VACCINATED
AVERAGE CONTROL
16
14
12
10
8
6
4
27 28 29 30 31 32 33 34 35 36 37
-1 1 2 3 4 5 6 7 8 9
Challenge
Day

Fig. 7 Average calf-blood platelets counts following challenge with NY-1 BVDV.

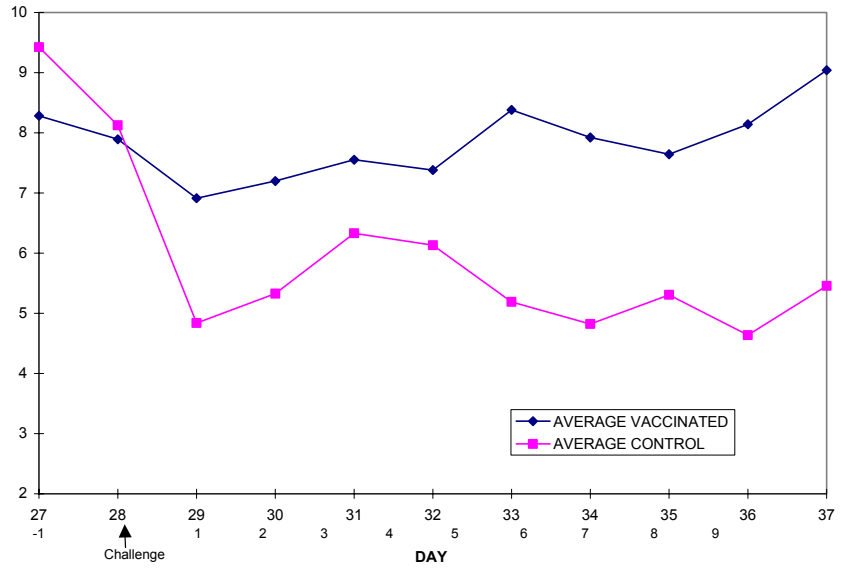
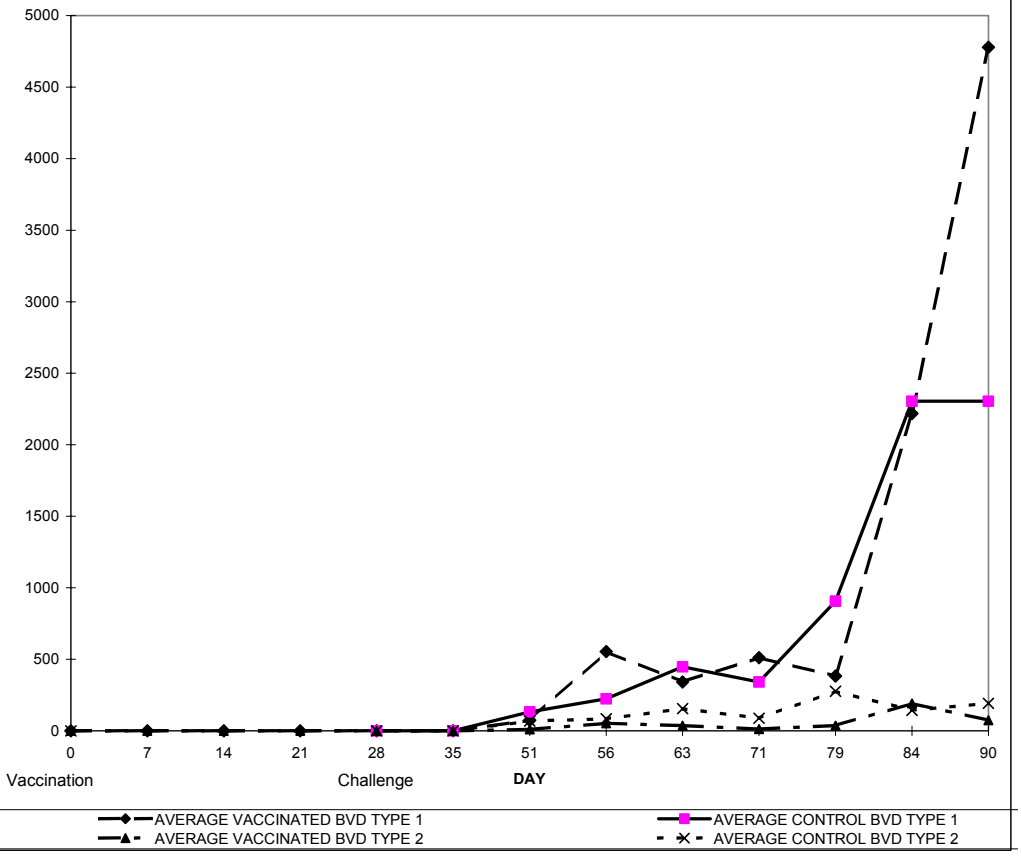


Fig.8: Singer "BVDV-1" and A125 "BVDV-2" average neutralizing antibody titers in sera of vaccinated and control calves.



A Retrospective Case Study Implicating Foster Calves in a Calf Diarrhea Epidemic

William B. Epperson[1]
Department of Veterinary Science

BEEF 2003 – 02

Introduction

Calf diarrhea (scours) is the most common infectious condition affecting beef calves in early life. Surveys of the upper midwest estimate that calf scours affects 11% of calves born (Grotelueschen et al, 1996).

Generally, mortality rates associated with calf scours are low. However, producers incur high medical and labor costs when calf scours cases increase. In addition to immediate costs, calves affected with scours have lower weaning weight (Wittum et al,1994).

A number of general management recommendations, aimed at infection/exposure control, have been forwarded in an attempt to limit calf scours on the herd level. Among these are modification of cow/calf flow, gestating cow nutrition and body scoring, separation of heifers and cows, use of vaccination, isolation of scouring calves, and limitation of additions during the calving season (Clement et al, 1993; Clement et al, 1995; Epperson, 1995; Grotelueschen et al, 1996; Heath, 1992a; Heath, 1992b; Pare et al, 1993; Toombs et al, 1998; Wittum et al, 1994). Cattlemen have been reluctant to adopt these management suggestions, probably because they feel they historically have had little problem with calf diarrhea. This report is a retrospective case study of a herd that experienced a severe calf scours epidemic in 2000. The objective of this study was to determine risk factors at work in this epidemic.

Materials & Methods

The cooperating herd is a commercial cow-calf operation located in eastern South Dakota. The herd features Angus cross females, bred to Angus (heifers) or Charolais (cows) bulls. Cows were moderately large framed. Heifers started calving 3/5/2000. Cows began calving 3/25/2000. More than 80% had calved within 55 days. Date of last calving was 6/1/2000, for a total calving season length of 88 days. With the exception of bulls, and an occasional foster calf, no animals had been added to the herd within the previous 3 years. All replacement heifers were born and raised exclusively at the home operation. Rations were balanced by a consulting nutritionist. The nutritionist periodically did body condition scoring, and body scores prior to calving were judged to be adequate.

A total of 223 calves were born, 63 to heifers (28.3%), and 160 to cows. Heifers were gestated and calved separately from cows. Near the time the first heifer was expected to calf, all heifers were moved from the gestation area to a 25 acre calving pasture (2.52 heifers/acre) with access to a covered calving shed. Pairs were generally maintained in this area following calving. Cows were gestated and fed on 25 acres of cornstalks (6.4 cows/acre). Cows were calved in this area, with no access to shelter. Cow-calf pairs were moved as needed from the calving area to an adjacent 25-acre grass pasture. Both cow and heifer calving areas shared a common water fountain, and had fenceline contact.

The cow herd was on a complete and timely vaccination program with yearly booster of BVD/IBR/PI_3/BRSV/5 way Leptospirosis. Scours vaccination (E. coli/Rotavirus/Coronavirus/ Clostridia) was administered to heifers at 6 weeks and again at 10 days prior to anticipated arrival of the first calf. Cows received scours vaccination in April and again in mid-May. No recent history of a severe scours epidemic had occurred on this farm. In years past, only “several calves” had required treatment.

Data were obtained from written production records and interviews with farm personnel. Production records included birthdate, birthweight, dam ID, sex of calf, age of dam

[1]Associate Professor

(2 yr. old vs. older), date of treatment, illness diagnosis, and treatment. All legible data was entered into a computer spreadsheet for descriptive analysis.

Results

A large calf scours epidemic occurred during the 2000 calving season. Records from this outbreak were used to conduct an epidemiological evaluation to attempt to explore risk factors for scours in this outbreak. A limited number of calf mortalities did occur, but were not recorded. Necropsy was not performed on any mortalities. Fecal samples from 2 affected calves were sent for diagnostic assessment, with only *Cryptosporidium parvum* in moderate number found in 1 sample. Calves were not systemically ill, but developed watery scours without blood, became dehydrated and could die if untreated. Calves were treated with multiple antibiotics and supportives. One antibiotic appeared to effect a positive response in scouring calves. The producer used this antibiotic regimen and limited calf mortality to near zero. However, the calf scours epidemic continued, and many calves required treatment.

Of the 223 live calves born, 163 (73.1%) were affected with scours (Table 1). Most calves were affected between the ages of 6 – 10 days (Figure 1). It appeared there was an increase in cases that started between the 30th and 40th day of the calving season (April 7 – April 17, 2000) (Figure 2).

Figure 1 suggests that calf susceptibility to the agent was not limited to the first 2 weeks of life, and could have extended beyond the 3rd week of life. Assuming susceptibility extended to 21 days of age, calves born between 3/22/2000 and 4/12/2000 would be susceptible to the scours agent if the agent was introduced on 4/12/2000 (day 35 of calving season). This assumption is supported in Table 2, as 50% of calves of heifers born in week 3 were affected with scours, and the proportion rose from that time forward. It appears that the agent(s) was/were transferred to the cow herd very near the beginning of cow herd calving, as a large portion of calves of cows born early in the cow calving season were affected.

As calving progressed, there was a clear trend for a greater risk of scours, and for calves to be affected at a younger age, as reported in Table 2. It is important to note that in weeks 7-9, in the middle of the cow calving season, that 80 – 90% of calves were affected. This suggests near perfect exposure of calves to the scours agent(s). The median age of calves from cows that were affected was 7 days. Assuming exposure within the first 3 days of life, the incubation period for agent(s) in this outbreak is between 4 and 6 days.

Though fewer calves of heifers appeared to be affected (Table 1), this is attributed to introduction and propagation of the agent(s) after the third week of calving, when 25/63 calves of heifers had been born. There was no indication that sex of calf influenced susceptibility ($p = 0.57$).

Records indicate that 3 foster calves were purchased on April 4, 2000. Records are not clear how or when all these calves entered the cow herd. Records do indicate that one calf was fostered onto a cow on April 7. Farm personnel believed that at least 1 of the other 2 was fostered onto a heifer.

Discussion

Because this is a retrospective investigation of an outbreak that took place one year earlier, a full and extensive herd evaluation is impossible. Management in this herd allowed the accumulation of a large number of calves in the relatively small turnout areas. This facilitates agent transmission, thus fueling a scours outbreak. However, historically this herd had used this calf flow scheme with little problem.

Herd nutrition was difficult to evaluate retrospectively. However, the statements and records of a consulting nutritionist, who cooperated with this investigation, suggested that protein, energy, trace mineral, and vitamin nutrition were unlikely to be deficient. Further, body condition scoring was done periodically by the nutritionist and cow body scores were regarded as adequate (i.e. 5-7 on a 9 point scale). Weather conditions in the 2000 winter were not considered severe. Other conditions that would decrease calf viability, such as an increase in dystocias (difficult births) were not observed by the producer.

The only outside additions to this herd were bulls and foster calves. Bulls were not in contact with cows except during the breeding season, so

it is unlikely they would alter the calf scours agents in the herd. However, foster calves are associated with an increased risk of scours (Grotelueschen et al, 1996).

The calf scours epidemic was clearly in swing by the 45th day of the calving season (4/19/2000) and the first cases of the epidemic were observed between the 31st and 40th days (4/5/2000 – 4/14/2000). Prior to 4/5/2000, no scours cases had been observed, despite 39 calves being born. Following 4/5/2000, apart from the birth of more calves, was the introduction of at least 2 foster calves.

Introduction of foster calves into the herd, and contact with other calves could have occurred as early as April 4 (day 30), and did occur by April 7 (day 33 of calving season). Assuming an incubation of 4 – 6 days, one would expect an increase in calf scours cases to commence in the period April 8 – 13 (day 34 – 39 of calving season). This coincides well with the observed increase in calf scours cases in Graph 1. Therefore, it is reasonable to suggest that introduction of foster calves was associated with the initiation of the calf scours epidemic in this herd. Four cases of scours were recorded between April 5 and April 7. It is not known if these were associated with the foster calves or were just sporadic cases. If associated with the introduction of foster calves, these cases had a short incubation time (1 – 3 days). Between April 8 and April 15, no scours cases were observed, then the number increased quickly. It is likely the scours cases on April 5 through 7 were sporadic cases, not associated with the outbreak. However, this is speculative.

The high scours incidence suggests that a "new" agent (or agents) was introduced into this herd. However, the diagnostic investigation performed was unable to support this speculation. The age at onset (7 days) and the response to systemic antibiotics suggests a bacterial agent in this outbreak. Among the likely possible agents is a non-enterotoxigenic *Escherichia coli* (non-ETEC). Diagnosis of non-ETEC often requires intestinal tissue from a recently dead calf. A reliable diagnosis of non-ETEC cannot be made from fecal samples alone. Unfortunately, diagnosis was attempted using only fecal samples in this case. Results of the 2 submitted fecal samples did tend to rule out the presence of other common calf scours agents.

The calf age at first treatment (Table 2) shows a pattern often observed in calf scours outbreaks, moving from older to younger calves as the calving season progresses. The age range observed in this outbreak is very large, and supports speculation that the causative calf scours agent(s) was introduced partway through (i.e. week 5) the heifer calving season and very near the start of the cow calving season. If an agent were introduced in week 5, one would expect some of the calves present to be affected with scours. The proportion affected would be partially dependent on age – the older the calf, the lower the expected risk (expected proportion), and the older those calves would be at first treatment. This is seen very clearly in the heifer data in Table 2. As the epidemic progresses, calves typically become exposed to the agent(s) at progressively earlier times, eventually being exposed within days after birth. These animals all go through a somewhat standard incubation period, and develop clinical scours at a progressively earlier age, due to the fact they were exposed earlier. As age at exposure decreases, one expects a greater proportion of affected calves, and more severe disease.

Summary

Results of this retrospective, records-based investigation suggest that introduction of foster calves was associated with the calf scours outbreak. The outbreak commenced shortly after the introduction of foster calves. Foster calves can introduce pathogens to a herd, and can shed calf scours pathogens in their feces even when feces appear normal. Because of this risk, the introduction of foster calves is not usually recommended. If introduced into a herd, foster calves (with their foster dam) should be isolated from the remainder of the herd until all calves are at least 4 weeks old. At that time, it is generally regarded as safe to commingle foster calf pairs with the remainder of the herd.

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Tables

Table 1. Demographic data

	Heifers		Cows	
Total calves born	63		160	
Total affected with scours	37	(44.4%)	126	(78.8%) *
Mean birthweight (SEM)	75	(1.2)	83	(.9)

*Proportions differ (P < 0.002).

Table 2. Scours risk by week of birth

	Heifers			Cows			Calf age at first treatment (days)	
Birthweek (dates)	Born	Scours	Affected proportion	Born	Scours	Affected proportion	Heifers	Cows
1 (3/5 – 3/11)	3	1	.33	-	-	-	59	-
2 (3/12 – 3/18)	10	2	.20	-	-	-	31.5	-
3 (3/19 – 3/25)	12	6	.50	2	0	0	27.3	-
4 (3/26 – 4/1)	8	5	.63	-	-	-	19.4	-
5 (4/2 – 4/8)	10	6	.60	2	1	.50	13.2	32
6 (4/9 – 4/15)	1	1	1.0	10	5	.50	6.0	9
7 (4/16 – 4/22)	8	8	1.0	34	27	.79	4.6	8.3
8 (4/23 – 4/29)	5	5	1.0	46	39	.85	6.8	8.1
9 (4/30 – 5/6)	3	2	.67	39	36	.92	7.0	8.6
10 (5/7 – 5/13)	-	-	-	11	9	.82	-	6.6
11 (5/14 – 5/20)	1	1	1.0	9	7	.78	6.0	4.9
12 (5/21 – 5/27)	-	-	-	11	9	.82	-	6.6
13 (5/28 – 6/2)	2	0	0	2	0	0	-	-
Totals (mean)	63	37	(.44)	160	126	(.79)	(15.1)	(8.2)

Figures

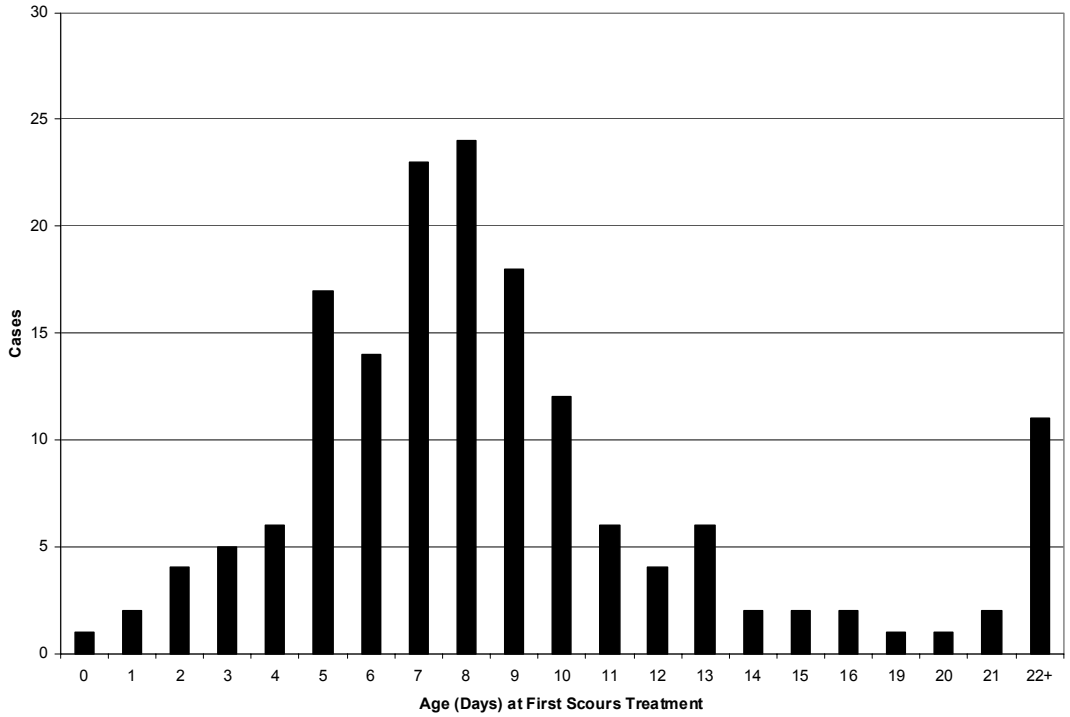

Figure 1. Age at first scours treatment

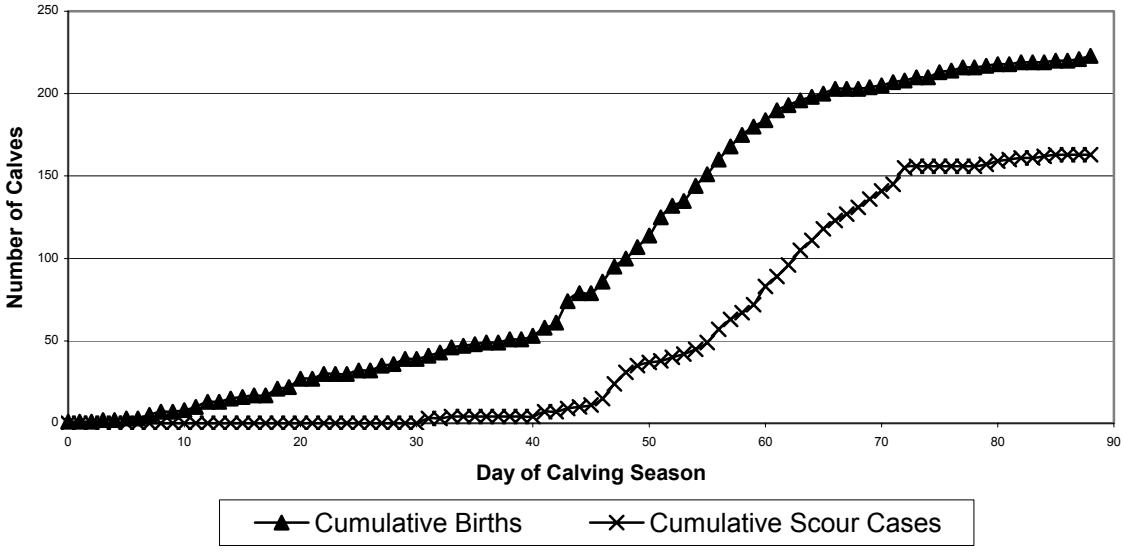

Figure 2. Cumulative calf scour cases by day into calving season

A Preliminary Assessment of Lung Lesion Distribution in Fed Cattle

William B. Epperson[1]
Department of Veterinary Science

BEEF 2003 – 03

Introduction

Lung lesions are a group of lung abnormalities observable in cattle at slaughter. One type frequently seen is pleural adhesions, which are fibrous tissue tags stretching between 2 lung lobes or from 1 lobe to other thoracic viscera. Other types of lung lesions include non-ventilated areas (i.e. consolidated) or areas of active infection. Lung lesions result from inflammation, most likely due to microbial infection.

Previous reports indicate lung lesions are present in 33-76% of slaughtered fed cattle (Bryant, 1997; Wittum et al, 1996). While cattle treated for respiratory disease in the feedlot are more likely to have lung lesions, the vast majority of lesions appear in cattle never detected ill (Griffin et al, 1995). This suggests that lung lesions are a result of a subclinical respiratory illness, occurring sometime prior to slaughter. Lung lesions have been associated with decreased rate of feedlot gain, decreased quality grade, and decreased meat tenderness (Wittum et al, 1996; Gardner et al, 1999).

Lung lesions can be assessed at slaughter by visualization and palpation. The bovine lung is compartmentalized into 8 lobes. Lobes are named according to the relative cranial (forward or toward the head) to caudal (backward or toward the tail) and side (right or left) they occupy. As depicted in Figures 1 and 2 and starting with the most forward lobe, there are 4 right side lobes, named right cranial cranial, right cranial caudal, right middle, and right caudal. On the left side there are 3 lobes, named left cranial cranial, left cranial caudal, and left caudal. The 8th lobe, named the accessory lobe, is located behind the heart under the caudal lobes, and is not easily observed without inverting the lungs.

Depending on the line speed and layout of the packing plant, it may be possible to observe all, some, or no lung lobes of slaughtered cattle. The objectives of this research were to describe the lobar location of lung lesions and determine diagnostic sensitivity of lung lesion detection when only a portion of lobes are evaluated.

Materials & Methods

Lungs from 391 cattle were examined for evidence of lung lesions. Observations were from cattle involved in applied genetic or management studies at SDSU (n = 198), enrolled in the SDSU Calf Value Discovery program (n = 71), or cattle from sources other than SDSU (n = 125). Various breeds were represented, and cattle were 12-15 months of age at slaughter. Cattle were slaughtered between 6/13/2001 – 7/18/2001 at a commercial packer (Caldwell Packing Co., Windom, MN). Line speed at this plant was approximately 80 animals/hour.

Seven lung lobes were visually examined and palpated to determine the presence of lung lesions. The accessory lobe was not observed in this system. Lesions were categorized into lesion type, severity, and lobar location. Lesion types consisted of pleural lesions (fibrous connective tissue adhering lobes to lobes or lobes to other structures), consolidated lesions (non-aerated areas of lung) and active lesions (enlarged bronchial lymph nodes with exudate indicative of acute inflammation, or lung abscesses). Lesion severity was categorized as 1 if lesions were mild and affected <5% of lung, 2 if moderate and affected 5-14% of lung, and 3 if affecting ≥15% of lung (Bryant et al, 1996). Lobar location was the lobe(s) affected by any lesion. If a pleural lesion extended from the right middle lobe to the right caudal lobe, both lobes were considered affected. A total lung score, indicative of lung lesion severity, was calculated by summing lesion severity scores over all 3 lesion types.

Examinations were made immediately after USDA personnel inspected the heart and lungs.

[1] Associate Professor

Results were recorded on paper and transferred to a computer spreadsheet for analysis (Microsoft ® Excel 97, Redmond, WA). Descriptive analysis was performed using spreadsheet software. Correlation coefficients were calculated and forward stepwise regression analysis was performed using JMP version 4.0 (SAS Institute, Cary, NC).

Results

Complete lung examinations were available on 391 cattle. An additional 21 were not fully evaluated and were excluded from analysis. Of the 391 lungs, 173 (44.2%) were affected with lung lesions. Of lungs with lesions, 46% were very mild, with the remaining 54% displaying moderate to severe lesions.

The distribution of lung lesions is described in Tables 1 and 2. The majority (54.3%) of lesions affected only a single lobe. Of the 173 cattle with lung lesions, 67.1% had lung lesions present in the right cranial cranial lobe. The right middle lobe was affected in 31.2% of cattle with lung lesions. Lung lesions affected the right lobes in 75.7% of cases, and lesions were less frequent in caudal lobes.

Table 3 is a correlation table among affected lung lobes, with significant correlations ($P < 0.05$) highlighted. Significant negative correlations are noted between lesions on the right cranial cranial lobe and right middle, right caudal, and left cranial caudal lobes. Significant positive correlations are noted between lesions of the right middle and right caudal lobes, left cranial cranial and left cranial caudal lobes, and left cranial caudal and left caudal lobes.

In an attempt to identify lung lobes strongly associated with lung lesions, stepwise regression was performed, with presence of any lung lesion the outcome, modeled as a continuous variable. The 7 observed lung lobes were taken as explanatory variables, with presence of lesion on a given lobe coded 1, and absence of lesion coded 0. No interaction effects were modeled. The model contained the right cranial cranial, right middle, left cranial caudal, and left cranial cranial lobes as significant explanatory variables. Regression analysis was used to “screen” for significant relationships, and correlation analysis was performed to confirm and visualize these relationships.

Table 4 displays the detection sensitivity of lung lesions, by observation of specific lobe(s). Examination of the right cranial cranial lobe alone detected 67.1% of lungs with lesions. Adding examination of the right middle lobe allowed detection of 86.1% of cattle with lung lesions. Examination of right cranial cranial, right middle, and left cranial caudal together detected 92% of all lung lesions, and adding the left cranial cranial to the previous 3 lobes increased detection to 96.5%.

To examine the effect of lesion severity on diagnostic sensitivity, lungs were stratified into categories of mild, moderate, and severe lesions, according to total lung score, and sensitivity of lesion detection was re-examined (Table 5). Within each row, the diagnostic sensitivity generally increased as lesions progressed from mild to severe (left to right).

Discussion

Results of this study suggest that examination of the right cranial cranial and right middle lobes would diagnose 86.1% of bovine lungs with lesions. Though evaluation of all lobes is required for 100% sensitivity, active examination of all lobes in high-throughput commercial (340 animals/hr) packing houses is not always feasible. In addition to speed, arrangement of the viscera table, location of plant workers, and nuances of viscera table inspectors may impede access to lungs. In the event of limited access to lungs, diagnostic sensitivity in detecting lung lesions is not seriously impaired if access to the right cranial cranial and right middle lobes is possible.

In cattle with lung lesions, 54.3% had lesions affecting only 1 lobe. This suggests that one can miss lung lesions at slaughter with a limited examination. Severe, multiple lobe lesions can be easily visualized from a distance, but these constitute a minority of lung lesions. If an accurate lung health assessment is desired, examination techniques employed must result in good diagnostic sensitivity.

Lung lesions were present in greatest proportion in the right cranial cranial, followed by right middle, then right cranial caudal, right caudal, and left cranial cranial, left cranial caudal, and left caudal lobes (Figure 2). If maximum diagnostic sensitivity with a minimum number of

lobar observations is desired, the probability a given lobe will be affected and the correlation of lobar observations must be considered. In the case of 2 positively correlated observations, similar information is obtained by examination of 1 of the 2 lobes. In the case of 2 negatively correlated observations, different information is gained from each lobe, so observation of both lobes may be necessary.

Figure 3 is a graphical description of the frequency of lesions in a given lobe and the correlation of observations between lobes. It is imperative to examine the right cranial cranial lobe at slaughter because lesions are frequently found there. Since there is a positive correlation between right middle and right caudal, many lesions that affect the right caudal also affect the right middle lobe. Therefore, examination of the right middle lobe alone detects all right middle, and many right caudal lesions. Positive correlation exists among the left cranial caudal and other left lung lobes. Therefore, observation of only the left cranial caudal lobe will detect many lesions affecting the left side.

In this data set, the right cranial caudal lobe does not appear to be significantly correlated with any other lobe, yet is affected in 23% of cattle with lung lesions. However, when the right cranial caudal lobe is affected, a lesion is also observed in 78% of right cranial cranial lobes. Therefore, observation of the right cranial cranial lobe detects the majority of lesions present in the right cranial caudal lobe, making observation of the right cranial caudal lobe unnecessary. The large difference in probability of lung lesions between these lobes is responsible for the insignificant and weak correlation reported in Table 3. The stepwise regression results more accurately reflected this association.

As lesions become more severe, diagnostic sensitivity tended to increase, regardless of the lobar combinations observed (Table 5). However, diagnosis of either very mild or moderate lesions required observation of at least the right cranial cranial and right middle to achieve 80% sensitivity in lung lesion detection.

This is a preliminary study because the population is entirely spring born, “calf fed” animals. Lung lesion distribution and diagnostic sensitivity calculated here may not apply to other populations. However, in this population, lung lesions were reliably diagnosed by observation of the right cranial cranial and right middle lung lobes. Observation of these 2 lobes alone resulted in diagnostic sensitivity of ≥90% for moderate to severe lesions, and 80% for mild lesions. Sensitivity can be enhanced slightly by additional observation of the left cranial caudal lobe, but requires access to lobes on the left side.

Acknowledgements

The cooperation of Dr. Don Marshall, Dr. Emilie Campbell, Dr. Dick Pruitt, and Caldwell Packing Company were essential for generation of this report. Thanks go to Ms. Nancy Grathwohl for data collection assistance.

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Tables

Table 1. Number of lobes affected in lungs with lesions

Lobe(s) Affected[a]	Number	%
1 lobe only	94	54.3
2 lobes	48	27.7
3 lobes	22	12.7
4 or more lobes	9	5.2
Total	173[b]	99.9

[a] 7 lobes examined for lung lesions, accessory lobe not examined.
[b] Total cattle examined = 391; 173 affected with lung lesions (44.2%).

Table 2. Distribution of lung lesions by lung lobe affected

Lobe affected[a]	Number affected[b]	%[c]
Right cranial cranial (RCC)	116	67.1
Right cranial caudal (RCD)	40	23.1
Right middle (RM)	54	31.2
Right caudal (RD)	34	19.7
Left cranial cranial (LCC)	28	16.2
Left cranial caudal (LCD)	21	12.1
Left caudal (LD)	7	4.0
Right lobes only	131	75.7
Left lobes only	17	9.8
Both left and right lobes	25	14.5

[a] Accessory lobe not examined.
[b] Total affected = 173.
[c] Calculated as $\frac{\text{N Affected}}{173}$, % total does not add up to 100 because multiple lobes affected.

Table 3. Univariate correlation of lung lesions by location[a]

	Correlation coefficient[b]						
	RCC	RCD	RM	RD	LCC	LCD	LD
RCC	–	0.12	-0.40[b]	-0.30[b]	-0.06	-0.19[b]	-0.11
RCD	.012	–	0.01	-0.03	0.06	-0.04	0.03
RM	-0.40[b]	0.01	–	0.67[b]	-0.03	-0.02	-0.01
RD	-0.30[b]	-0.03	0.67[b]	–	0.02	0.04	0.05
LCC	-0.06	0.06	-0.03	0.03	–	0.17[b]	-0.01
LCD	-0.19[b]	-0.04	-0.02	0.04	0.17[b]	–	0.55[b]
LD	-0.11	0.03	-0.01	0.05	-0.01	0.55[b]	–

[a] See Table 2 for explanation of abbreviations.
[b] Coefficients differ from 0 *(P < 0.05)*.

Table 4. Sensitivity of lung lesion detection by observation of specific lobe(s) [a]

Observed lobes	Lesions detected	Sensitivity[b] (% of total)
[c] RCC only	116	67.1
[c] RCC and RM	149	86.1
[c] RCC, RM, and LCD	159	92.0
[c] RCC, RM, LCD, and LCC	167	96.5
RCC and RCD	125	72.3
RCC, RCD, and RM	155	89.6

[a] See Table 2 for explanation of abbreviations.
[b] Total lungs with lesions = 173.
[c] Significant in stepwise regression.

Table 5. Sensitivity of lung lesion detection stratified by lesion severity

	Lung lesion severity (% detected)[b]		
Lobe(s) examined [a]	Mild[c]	Moderate[c]	Severe[c]
RCC	53.8	57.9	92.7
RCC and RM	80	89.5	92.7
RCC, RM, and LCD	87.5	97.4	94.5
RCC, RM, LCD and LCC	92.5	100	100
Number of observations (column)	80	38	55

[a] See Table 2 for explanation of abbreviations.
[b] % detected = $\frac{\text{cell N}}{\text{column total}} \cdot 100$.
[c] Mild = total lesion score = 1; Moderate = total lesion score = 2; Severe = total lesion score ≥ 3.

Figures

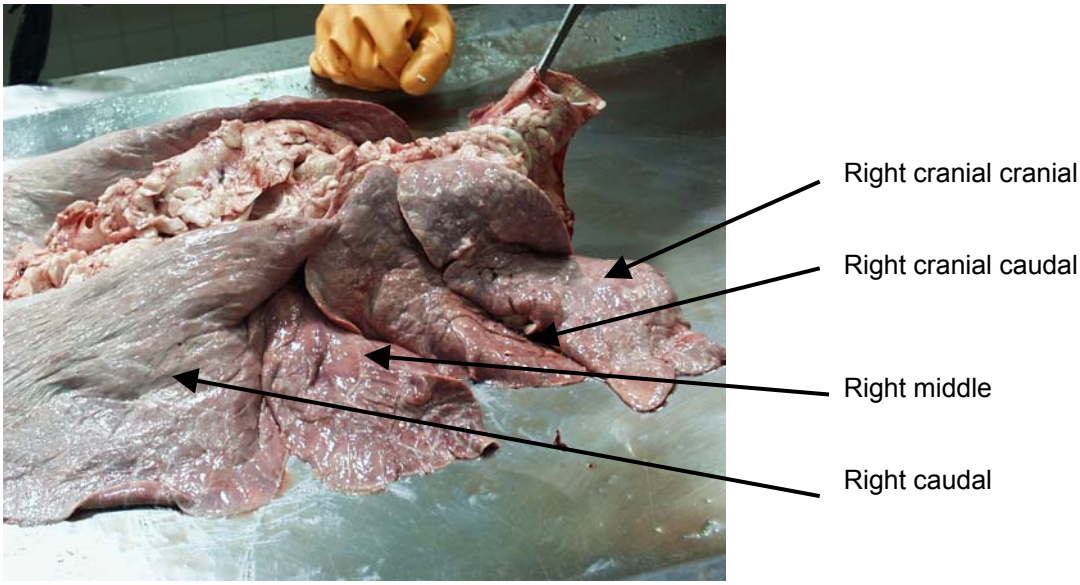


Figure 1. Right lung lobes

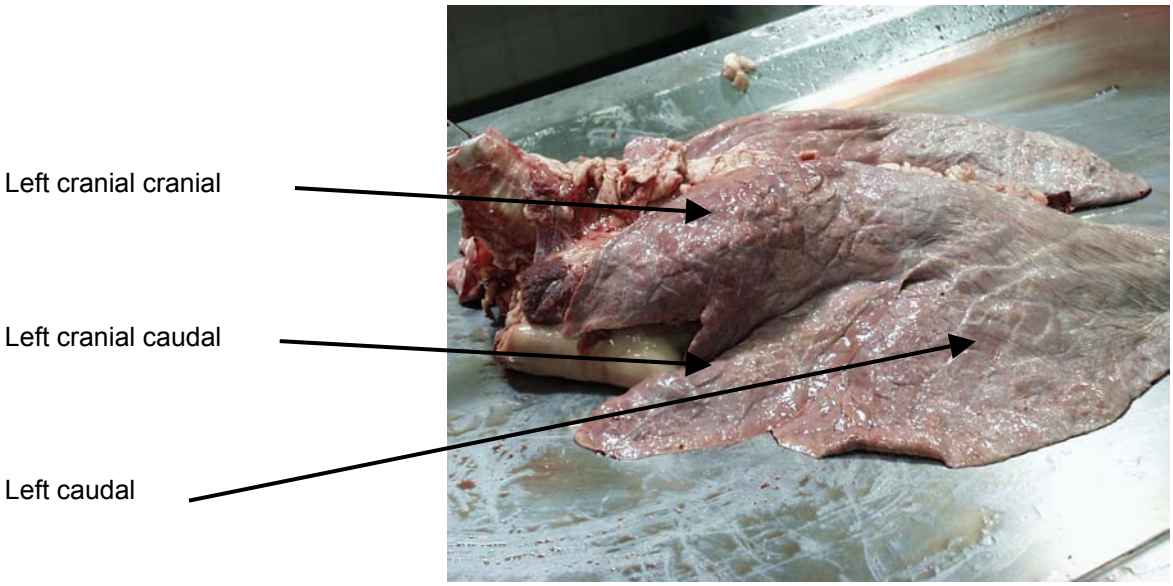
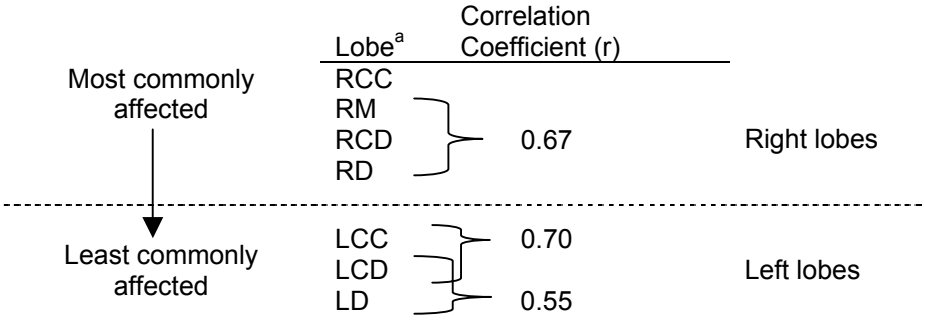


Figure 2. Left lung lobes



[a] See Table 2 for explanation of abbreviations.

Figure 3. Pictorial view of associations and hierarchy for lung lobe selection to maximize sensitivity

Associations of a Leptin Gene Polymorphism with Beef Carcass Traits

Chad D. Bierman[1], Donald M. Marshall[2], Emilie Campbell[3], and Nels H. Granholm[2]
Department of Animal and Range Sciences and Department of Biology and Microbiology

BEEF 2003 – 04

Summary

The objective was to evaluate associations of leptin genotype with fat and muscle traits in cattle. A single nucleotide polymorphism located in exon 2 of the leptin gene in cattle codes for an amino acid change from arginine (R) to cysteine (C). Genotypes for the polymorphism were determined on 492 crossbred calves by AciI digestion of amplified PCR product (C allele: 130bp; R allele: 73bp and 57bp). Data were analyzed by least-squares, accounting for effects of genotype, sex, year, location, breed-type, and calf sire. Genotype was not significantly associated with carcass weight or ribeye area in any of the analyses. Associations of genotype with external fat thickness, KPH fat, and overall cutability were small and generally not statistically significant. Subjective marbling scores (assigned by USDA grader; 350 = slight 50, 400 = small 0, 450 = small 50) were higher (P = .02) for CC (411 units) than for RR (388 units) genotype when adjusted to a constant slaughter age of 433 days. Similar differences between genotypes in marbling scores were observed when adjusting to a constant carcass weight or external fat thickness. Given the relatively modest association between genotype and marbling, potential application of the marker in the industry as a selection tool would be most relevant in herds with a large proportion of market animals possessing marbling scores that are near a price threshold level (e.g., select/choice quality grade).

Key Words: Cattle, Leptin, Gene marker

Introduction

Improving product quality and efficiency of production are goals of the beef industry. The use of DNA-based markers could be particularly beneficial for genetic evaluation of economic traits for which phenotypic measurements are difficult or expensive to obtain (e.g., meat quality and feed efficiency). A large number of DNA-based markers in livestock have been discovered to date, but relatively little is known about which markers could be useful in evaluation of specific traits. Leptin protein is synthesized in adipocytes, or fat cells, and has been implicated as a potential factor contributing to animal-to-animal variation in appetite, energy balance, and body composition. If variability (polymorphism) in the DNA sequence of the Leptin gene is associated with variability in production traits of interest, then a DNA-based diagnostic test could be a potentially useful tool for genetic evaluation. Therefore, the objective of the present study was to determine if a single nucleotide polymorphism in exon 2 of the Leptin gene is associated with variation in carcass traits in beef cattle.

Materials and Methods

Calves used in this study were from dams produced in two-breed rotational mating systems involving crosses of Angus x Hereford, Simmental x Hereford, or Tarentaise x Hereford. Cows were mated either to rotational or terminal (Charolais) sires producing two- or three-breed crossbred calves. Calves were born and reared until weaning at the Antelope Range Livestock Station near Buffalo, SD or the Beef Breeding Research Unit at Brookings, SD. After weaning, calves were transported to either a feedlot located at the Brookings station or a commercial feedlot. Carcass traits were evaluated at a commercial packing facility at an average age of 433 days.

Blood was collected from each calf for subsequent DNA extraction and analysis. Animal genotype for the leptin polymorphism was determined by PCR-RFLP, a technique in which a 130-bp region of exon 2 of the leptin gene was amplified, exposed to digestion with the restriction enzyme AciI, and viewed following

[1]Graduate Student
[2]Professor
[3]Assistant Professor

gel electrophoresis. The polymorphism (C allele: 130bp; R allele: 73bp and 57bp) consists of a single nucleotide switch (cytosine versus thymine), which is associated with an amino switch (arginine versus cysteine) in the Leptin protein molecule. Individual animals were genotyped as CC, CR, or RR.

Data were analyzed by least-squares procedures to evaluate associations of leptin genotype with carcass traits while adjusting for known sources of variation, including calf sex, birth year, breed-type, location of birth/feedlot, and calf sire. Additionally, data were adjusted to one of three endpoints: carcass weight (723 lb), fat thickness (.453 in), or slaughter age (433 days) in three separate analyses. The effects of allele substitution were evaluated in a second set of analyses in which the discrete effect of leptin genotype was replaced by the continuous effect of the number of 'C' alleles present in the genotype (i.e.; 0 in RR, 1 in CR, and 2 in CC). Linear and quadratic effects were evaluated in initial models as indicators of additive and non-additive effects, respectively.

Results and Discussion

Presented in Tables 1-3 are least-squares means of carcass traits by genotype and regressions of each trait on the number of 'C' alleles in the genotype. Genotype was not significantly associated with carcass weight or ribeye area in any of the analyses. Associations of genotype with external fat thickness, KPH fat, and overall cutability were small and generally not statistically significant.

Associations of genotype with marbling score were statistically significant for the age- and fat-adjusted analyses and approached significance in the weight-adjusted analysis. Individuals with two copies of the 'C' allele produced carcasses with marbling scores of about 20 units higher, on average, than individuals with zero copies. This relatively small difference indicates that this marker accounts for a small fraction of the overall population variation in marbling and that other loci, perhaps many, are affecting the trait. Whether this magnitude of difference is sufficiently large to justify genotyping as a means of genetic evaluation in the beef industry depends, among other things, on the current level of marbling in the specific herd or population of interest. Herds in which a large proportion of market animals have marbling scores near the price threshold levels for select/choice or standard/select quality grade would likely benefit more from genotype information compared to herds in which most animals are well below or above a quality grade/price threshold.

The reader should be cautioned that differences attributed to a particular gene marker could possibly be due to a different gene located in close proximity to the marker of interest. It is also possible, in studies utilizing multiple families and breeds, for population structure to cause "artificial" genotype effects. However, the inclusion of breed-type and sire in the statistical model should account for potential bias due to the effect of population structure in the present study. Additional analyses conducted on a within-sire basis tended to confirm the conclusion found in the original analyses: i.e., progeny of 'CC' sires tended to have larger marbling, in general, than those of 'RR' sires.

Implications

The most important result observed in this study was a small association between genotype and marbling score. An increase of one 'C' allele in the genotype was associated with an increase of about 10 marbling units, on average, in this particular mixed-breed population. Results could be different in other populations. The magnitude of difference observed in this study is quite modest, but might be sufficient to justify genotyping in herds or populations in which most market animals have marbling scores near a quality grade/price threshold.

Table 1. Calf Leptin genotypic effects on carcass composition adjusted to a constant final age (433 days)

Trait	CC N	CC LSMean±SE	CR N	CR LSMean±SE	RR N	RR LSMean±SE	F-test P-value	Regression coefficient[a] Linear	Regression coefficient[a] Quadratic
Carcass weight, lb	118	719.57±6.92	276	721.36±5.21	98	721.24±7.40	0.968	NS	NS
Rib-eye area, in^2	118	12.64±.13	276	12.75±.10	98	12.83±.14	0.520	NS	NS
Fat thickness, in	118	.502±.017	276	.468±.013	98	.470±.018	0.113	0.018±0.011^{+}	NS
KPH, %	118	2.74±.06	276	2.63±.04	98	2.69±.06	0.147	NS	0.091±0.046*
Estimated cutability, %	118	49.84±.16	276	50.17±.13	98	50.18±.17	0.115	-0.184±0.104^{+}	NS
Marbling score[b]	118	410.9±6.85	276	404.76±5.31	98	387.21±7.31	0.017	9.73±4.50*	NS
Choice grade, %	118	60.7±5	276	53.4±4	98	48.9±5	0.188	6.4±3.3^{+}	NS

[a] Trait value regressed on number of C alleles in genotype.
[b] Slight = 300 to 399, Small = 400 to 499.
$^{+}P < 0.10$; $^{*}P < 0.05$.

Table 2. Calf Leptin genotypic effects on carcass composition, adjusted to a constant carcass weight (723 lb)

Trait	CC N	CC LSMean±SE	CR N	CR LSMean±SE	RR N	RR LSMean±SE	F-test P-value	Regression coefficient[a] Linear	Regression coefficient[a] Quadratic
Rib-Eye Area, in^2	118	12.69±0.12	276	12.79±0.09	98	12.86±0.13	0.518	NS	NS
Fat thickness, in	118	.510±0.016	276	.474±0.012	98	.476±0.017	0.075	NS	NS
KPH, %	118	2.76±0.05	276	2.64±0.04	98	2.70±0.06	0.113	NS	0.090±0.045*
Estimated cutability,%	118	49.78±0.15	276	50.13±0.12	98	50.14±0.16	0.064	-0.188±0.098^{+}	NS
Marbling score[b]	118	406.98±7.61	276	402.54±5.82	98	387.26±7.95	0.066	9.65±4.51*	NS
Choice grade, %	118	57.8±5	276	50.7±4	98	46.2±5	0.206	5.8±3.3^{+}	NS

[a] Trait value regressed on number of C alleles in genotype.
[b] Slight = 300 to 399; Small = 400 to 499.
$^{+}P < 0.10$; $^{*}P < 0.05$.

Table 3. Calf Leptin genotypic effects on carcass composition adjusted to a constant fat thickness (0.453 in)

	CC		CR		RR		F-test	Regression coefficient[a]	
Trait	N	LSMean±SE	N	LSMean±SE	N	LSMean±SE	P-value	Linear	Quadratic
Carcass Weight, lb	118	710.69±6.70	276	716.93±5.02	98	716.61±7.14	0.653	NS	NS
Rib-Eye Area, in^2	118	12.68±0.13	276	12.76±0.10	98	12.84±0.14	0.627	NS	NS
KPH, %	118	2.70±0.06	276	2.61±0.04	98	2.67±0.06	0.226	NS	0.076±0.044^{+}
Estimated cutability, %	118	50.25±0.09	276	50.30±0.07	98	50.34±0.10	0.750	NS	NS
Marbling score[b]	118	404.05±6.80	276	400.81±5.23	98	382.67±7.21	0.023	10.31±4.31*	NS
Choice grade, %	118	54.5±5	276	49.4±4	98	44.7±5	0.339	NS	NS

[a] Trait value regressed on number of C alleles in genotype.
[b] Slight = 300 to 399; Small = 400 to 499.
$^{+}P < 0.10$, $^{*}P < 0.05$.

Characteristics of Crossbred Progeny of Holstein Dams Sired by Different Beef Breeds: A Review

Bruce C. Shanks[1]
Department of Animal and Range Sciences

SDSU

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Background

Excellent reviews of cattle breed comparisons or breed-cross comparisons have been previously reported by Franke (1980), Long (1980), and Marshall (1994). However, these reviews do not contain information on the calving ease, performance, carcass characteristics, or beef palatability of crossbred progeny of Holstein dams sired by different beef breeds. In many countries dairy females are commonly mated to beef sires; however, in the United States the use of this practice is somewhat limited. Nevertheless, some United States dairy production schemes utilize beef sires on surplus Holstein heifers and cows. Also, some large commercial dairy operations purchase replacement heifers from outside entities, thus permitting optional breeding schemes for some dairy females in their herds. Finally, in the near future, information on crossbred progeny of Holstein dams sired by different beef breeds could become particularly useful if semen and embryo sexing technology becomes practical, allowing for selective matings to generate dairy replacement heifers, thereby freeing other Holstein females to produce terminal progeny. From a genetic and economic standpoint, the crossing of beef bulls to Holstein females could result in improved utilization of existing genetics and an untapped alternative source of business for beef and dairy producers alike. Therefore, the purpose of this review is to 1) compare the birth, weaning, feedlot, and carcass characteristics of progeny from the matings of Holstein females with different beef sire breeds and 2) suggest possible research needs that warrant further consideration.

Review of Literature

Review of the literature for this paper was conducted across a wide array of journals and publications. All articles found, particular to the subject, were included. Publications were not omitted because of differences in study design, scale, or methodology. Overall, it was discovered that there has been relatively little published research conducted on the birth, weaning, feedlot, or carcass characteristics of progeny produced from the crossings of Holstein dams with different beef sires. Furthermore, most of the available information originated from research trials that were conducted outside of the United States. Information from this review is summarized in the ensuing text and tables.

Table 1 contains mean gestation lengths, dystocia percentages, and birth weights of crossbred progeny of Holstein dams sired by different beef breeds. Menissier et al. (1982) found very little difference among gestation lengths for several different breeds of beef sires, but did find that crossbred progeny of Holstein dams sired by beef bulls would be expected to have longer gestation lengths than purebred Holstein contemporaries. Similarly, data in Table 1 revealed that crossbred progeny of Holstein dams sired by beef bulls would also be expected to have more calving difficulty (dystocia) and somewhat larger birth weights than purebred Holstein contemporaries. Undoubtedly, the relationship of gestation length with calving difficulty and birth weight is reflected in these findings. Research conducted by Brown et al. (1976) suggested that Limousin bulls would minimize calving difficulty and reduce birth weights of crossbred progeny of Holstein cows and beef sires relative to other continental beef breeds studied. In this study, larger dystocia percentages and birth weights were found for Simmental and Maine Anjou sires. Likewise, in two separate studies it was reported that birth weights of progeny sired by Simmental (average bull and heifer birth weights = 103.8 lb) and Limousin (average bull and heifer birth weights = 94.5 lb) bulls were somewhat different and favored Limousin (Forrest, 1980; Forrest, 1981). Menissier et al. (1982) reported that crossing Holstein dams with Hereford sires resulted in the least amount of calving difficulty and the smallest birth weights within the beef sires investigated. South Devon, Limousin, Simmental, and Blonde d'Aquitaine

[1] Ph.D. Graduate Student

crosses experienced mean calving difficulties of less than ten percent, whereas Piedmontese, Charolais, Maine Anjou, and Chianina crosses resulted in calving difficulties of greater than ten percent in the same study. Menissier et al. (1982) found that birth weights were fairly variable across breeds and were not always associated with dystocia.

Mean weaning weights, average daily gains to weaning, and average daily gains in the feedlot of crossbred progeny of Holstein dams sired by different beef breeds are presented in Table 2. Although very inconsistent among studies, information in Table 2 generally indicates that crossbred progeny of Holstein dams sired by beef breeds have only small advantages in growth performance when compared to purebred Holstein contemporaries. In three separate papers, Forrest (1977, 1980, and 1981) reported small advantages for average daily gain in the feedlot for Charolais and Limousin steer and heifer progeny and no differences in feedlot gain for Simmental-sired progeny when compared to purebred Holstein contemporaries. Southgate et al. (1982) and Kempster et al. (1982) reported that continental-sired progeny grew faster in the feedlot than Holstein-sired calves, but calves sired by British bulls were at a slight disadvantage when compared to calves sired by Holstein bulls. Furthermore, in studies conducted in Ireland (Keane et al., 1989) and Hungary (Szűcs et al., 1992), beef bulls (Blonde d'Aquitaine and Limousin) sired progeny with the same average daily gains in the feedlot as progeny sired by Holstein bulls.

In general, if beef sires are going to be bred to Holstein females, calves sired by continental beef breeds, especially Charolais, would be expected to grow faster and weigh more at weaning than progeny sired by British beef breeds. However, inconsistent differences in growth potential between continental- and British-sired calves have been reported. In a large French study, Menissier (1982) found that Charolais progeny had the largest weaning weights, followed by Maine Anjou-sired calves. Other continental beef breeds including Blonde d'Aquitaine, Chianina, Limousin, Piedmontese, and Simmental produced progeny with considerably smaller weaning weights than Charolais-sired calves. Hereford-sired calves were found to be the lightest at weaning in this study. Lalande and Fahmy (1975) concluded that Charolais- and Hereford-sired calves had the highest average daily gains in the feedlot, followed by Limousin-sired calves. Another earlier study, found that progeny sired by Charolais bulls had an advantage in average daily gain to weaning when compared to Hereford-sired calves; however, average daily gains in the feedlot were the same between the two sire breeds (Fahmy and Lalande, 1975). Menissier (1982) found that Charolais progeny had the highest average daily gains in the feedlot (average = 4.94 lbs). Several other breeds were intermediate in comparison, and Limousin- (average = 3.25 lbs) and Hereford-sired (average = 3.22 lbs) progeny were found to have the lowest average daily gains in the feedlot in this study. Charolais and Simmental crossbred calves held an advantage in average daily gain over several breeds in research reported by Southgate et al. (1982) and Kempster et al. (1982).

Table 3 contains mean slaughter weights, carcass weights, and dressing percentages of crossbred progeny of Holstein dams sired by different beef breeds. Calves produced by purebred Holstein matings have the ability to reach similar, or perhaps larger slaughter weights than crossbred progeny of Holstein dams sired by different beef breeds. However, at similar slaughter weights, purebred Holstein contemporaries would be expected to have a smaller carcass weight due to their large disadvantage in dressing percentage. Clearly, one of the greatest advantages of progeny produced from the crossing of Holstein females and beef bulls relative to purebred Holstein matings, is dressing percentage.

Results presented in Table 3 suggests that relative to other beef breeds studied, Piedmontese and Blonde d'Aquitaine beef sires would be expected to consistently produce calves with the highest dressing percentages when mated to Holstein cows. Other continental beef sire breeds, notably Limousin and Charolais, would also be expected to produce progeny that would excel in dressing percentage when bred to Holstein females. Simmental was at a disadvantage for dressing percentage when compared to other continental beef breeds according to research reported by Menissier et al. (1982) and Southgate et al. (1982) and Kempster et al. (1982). However, More O'Ferrall et al. (1989) found no difference in dressing percentage between Simmental- and

Charolais-sired progeny when mated to Holstein cows. Hereford and other British breeds (Angus, Devon, South Devon) had the lowest dressing percentages in the majority of studies summarized in Table 3 (Lalande and Fahmy, 1975; Menissier et al., 1982; Southgate et al., 1982 and Kempster et al., 1982; More O'Ferrall et al., 1989).

Table 4 contains mean fat thickness, ribeye area, and marbling scores of crossbred progeny of Holstein dams sired by different beef breeds. In general, crossbred progeny sired by continental or "double muscled" beef sires consistently had much larger ribeye areas than purebred Holstein contemporaries. In fact, in most instances, crossbred progeny sired by continental or "double muscled" beef sires had ribeye areas that were at least 1.55 in^2 larger than those produced by purebred Holstein contemporaries (Forrest, 1977; Forrest, 1980; Forrest, 1981; Southgate et al., 1982 and Kempster et al., 1982; Keane et al.,1989; Szűcs et al., 1992). However, purebred Holstein calves were similar in leanness to crossbred progeny sired by continental or "double muscled" beef sires. Breeds of British origin had larger amounts of external fat, had comparable or smaller ribeye areas, and slightly more marbling than purebred Holstein contemporaries.

Considerable differences existed among beef sire breeds for fat thickness and ribeye area (Table 4). Differences were especially evident between continental and British sires. Lalande and Fahmy (1975) concluded that Hereford-sired progeny had more external fat and smaller ribeye areas than calves sired by either Charolais or Limousin bulls. Fahmy and Lalande (1975) found similar results when comparing Hereford to Charolais, in a separate study. Southgate et al. (1982) and Kempster et al. (1982) reported that Charolais- and Simmental-sired progeny had ribeye areas greater than 9.3 in^2, while Devon, Hereford, Lincoln Red, South Devon, and Sussex sires produced progeny with mean ribeye areas ranging from 7.8 to 8.9 in^2. Angus-sired progeny had a mean ribeye area of 7.4 in^2 in their study. Researchers from Iowa State University (Bertrand et al., 1983) utilized a four-breed diallel design to explore carcass characteristics of progeny from Holstein cows mated to Holstein, Angus, Brown Swiss, and Hereford sires. Brown Swiss bulls sired crossbred calves with the least amount of external fat thickness, the largest ribeye areas, and the least amount of marbling. Conversely, Angus-sired calves had the greatest amount of external fat, the smallest ribeye areas, and the most abundant amount of marbling. Hereford-sired calves from Holstein cows were intermediate in comparison (Bertrand et al., 1983). Based on information in Table 4 it was difficult to detect which sire breed was optimal in terms of producing calves out of Holstein dams with the least amount of external fat thickness. It does seem that Limousin sires would be the most favorable at improving muscling based on research performed by Lalande and Fahmy (1975) and Keane at al. (1989). However, comparisons with "double muscled" beef sires were not evident in the literature.

A small number of researchers (Lalande et al., 1982; Dumont et al., 1987; More O'Ferrall et al., 1989) have compared meat quality traits (tenderness, juiciness, and flavor) of progeny from the matings of Holstein cows with different beef sire breeds (data not shown in tabular form). Lalande et al. (1982) utilized two experiments conducted over two years to study sensory traits of progeny (slaughtered at three different weights) produced by Holstein dams crossed with several different sire breeds (Holstein, Blonde d'Aquitaine, Chianina, Limousin, and Maine Anjou). These researchers found inconsistent differences among sire breeds when slaughtered at different weights. However, they concluded that purebred Holstein contemporaries had slightly superior eating quality at lower slaughter weights when compared with the crosses studied. Dumont et al. (1987) reported that steaks from purebred Holstein heifer carcasses were more tender than steaks from Charolais-sired heifer carcasses; however, taste panel assessment revealed that carcasses from Charolais-sired heifers were more flavorful and juicy. In a study conducted in Ireland, More O'Ferrall et al. (1989) found that Simmental-sired steer calves from Holstein dams had lower average shear force values than purebred Holstein contemporaries or Charolais- and Hereford-cross steer calves. Hereford-cross calves had the highest sensory values for juiciness and flavor. Sensory tenderness scores were similar across breed of sire in this particular study.

Discussion

Crossing Holstein cows with beef breeds could result in increased incidences of dystocia associated with longer gestation lengths and heavier birth weights, indicating that more attention would be necessary during calving to prevent losses. However, if beef sire breeds were mated to Holstein females, resulting progeny could have a slight advantage in growth performance over purebred Holstein counterparts. Dressing percentage would increase substantially if Holstein females were bred to non-British beef sires. Finally, vast improvements in muscling characteristics could also be accomplished by crossing Holstein cows with certain beef breeds, although reducing fat thickness and enhancing meat quality by crossing beef sire breeds with Holstein females could be difficult to achieve. Overall, depending on genetic and management goals, improvements in weaning, feedlot, and carcass characteristics of terminal progeny from dairy herds could be attained by crossing beef sires with Holstein females.

For some traits, there was significant variation in the literature between the different beef sire breeds when mated to Holstein dams. However, no sire breed was recognized as being systematically superior to the others for all traits examined. In order to minimize calving difficulty and reduce birth weights of crossbred progeny of Holstein cows, Hereford and perhaps other British sire breeds would be effective. Limousin bulls, would in general, result in the least amount of calving difficulties and lightest birth weights relative to the other continental breeds reviewed. Progeny from crosses involving Charolais bulls were consistently characterized by more rapid growth to weaning, larger weaning weights, and more desirable gains in the feedlot than other sire breeds. In general, other continental beef breeds sired progeny that were somewhat higher performing than progeny sired by Hereford and other British breeds; however, this was not necessarily always the case. Any of the beef breeds reviewed were capable of producing sufficiently large slaughter and carcass weights, yet Piedmontese-, Blonde d'Aquitaine-, Limousin-, and Charolais-sired progeny from Holstein females were unparalleled in dressing percentage. There was some indication that Simmental would be at a disadvantage for dressing percent when compared to other continental beef breeds. For other carcass characteristics, including fat thickness and ribeye area, sizeable differences were evident between continental and British sire breeds. It was not apparent which continental sire produced the leanest calves when bred to Holstein females; however, Limousin-sired calves excelled in muscling characteristics. South Devon sires produced progeny with the largest ribeye areas relative to other British sire breeds reviewed. None of the studies reporting carcass traits included Holstein-sired calves and calves sired by "double muscled" bulls. These breeds could potentially contribute to even larger effects on cutability traits. Angus-sired progeny from Holstein dams had the highest degree of intramuscular fat in the one study that included data on marbling score. Due to limited information, distinctions between the different beef sire breeds for meat quality traits (tenderness, juiciness, and flavor) were not evident in the literature. In general, sire breed comparisons presented in this review do not differ greatly from studies using non-Holstein dams, except possibly for comparisons to purebred Holsteins, in which heterosis becomes a factor.

In spite of the large numbers of Holstein females present in the United States and other countries there are gaps in our knowledge concerning the birth, weaning, feedlot, and carcass characteristics of crossbred progeny of Holstein dams sired by different beef breeds. Moreover, given the larger utilization of beef sires on Holstein dams in foreign nations, the bulk of the available information is from research conducted in overseas countries. Therefore, genetic differences in the breeds, systems of production, and slaughter ages and weights were particular to the countries involved and, although of some value, the research trials do not provide results that may be readily applied to United States dairy production conditions. Potentially, the commercial crossing of dairy females with beef sires could become more common in the United States because of continued purchase of replacement heifers from outside entities, improved and increased use of semen and embryo sexing technology, or for other reasons. If so, more information will have to become available to characterize the relative advantages and disadvantages of the different beef sire breeds when mated to Holstein females.

Conclusion

This review indicates that, in general, crossing beef sires with Holstein females could result in improved weaning, feedlot, and carcass characteristics of terminal progeny from dairy herds. However, crossing Holstein cows with beef breeds could result in increased incidences of dystocia. For some traits, there was significant variation in the literature between the different beef sire breeds when mated to Holstein dams. However, no sire breed was recognized as being systematically superior to the others for all traits examined. Finally, this review indicates that if the practice of producing crossbred Holstein progeny becomes more common in the United States, more information will have to be available to characterize the relative advantages and disadvantages of the different beef sire breeds when mated to Holstein females.

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Table 1. Breed of sire differences for gestation length, dystocia, and birth weight (Holstein dams)

Breed of sire	n	Sex	Gestation length, d	Dystocia, %	Birth weight, lb	Comments	Source
Holstein	19	B	-	0.0	94.0	Arkansas	Brown et al., 1976
Holstein	33	H	-	3.0	93.2		
Limousin	18	B	-	17.0	100.2		
Limousin	8	H	-	13.0	87.2		
Maine Anjou	17	B	-	24.0	114.1		
Maine Anjou	9	H	-	22.0	96.2		
Simmental	15	B	-	19.0	107.1		
Simmental	11	H	-	9.0	97.1		
Holstein	42	B	-	-	99.3	Canada	Forrest, 1980
Simmental	27	H	-	-	98.9		
Simmental	37	B	-	-	108.6		
Holstein	39	B	-	-	95.8	Canada	Forrest, 1981
Limousin	50	H	-	-	90.3		
Limousin	42	B	-	-	98.5		
Holstein	69	B	284	1.5	85.9	France	Menissier et al., 1982
Blonde d'Aquitaine	168	B	291	8.8	92.5		
Charolais	152	B	289	13.1	101.1		
Chianina	86	B	291	15.7	98.2		
Hereford	165	B	287	4.3	89.4		
Limousin	162	B	292	5.2	93.8		
Maine-Anjou	75	B	287	13.6	97.6		
Piedmontese	67	B	291	12.4	95.4		
Simmental	72	B	291	7.7	98.2		
South Devon	76	B	288	6.5	93.6		

Table 2. Breed of sire differences for weaning weight, average daily gain to weaning, and average daily gain in the feedlot (Holstein dams)

Breed of sire	n	Sex	Weaning weight, lb	Average daily gain to weaning, lb	Average daily gain in the feedlot, lb	Comments	Source
Charolais	28	S	-	-	2.2	Canada	Lalande and Fahmy, 1975
Hereford	26	S	-	-	2.2	Fast-gaining feedlot diet only	
Limousin	29	S	-	-	1.9		
Charolais	30	S	-	2.0	2.8	Canada	Fahmy and Lalande, 1975
Hereford	30	S	-	1.8	2.8		
Holstein	12	S	-	-	2.6	Canada	Forrest, 1977
Charolais	6	H	-	-	2.4	Avg. of 3 growth rate intervals	
Charolais	12	S	-	-	2.9		
Holstein	42	S	-	-	2.8	Canada	Forrest, 1980
Simmental	27	H	-	-	2.3	Avg. of 3 growth rate intervals	
Simmental	37	S	-	-	2.9		
Holstein	39	S	-	-	2.7	Canada	Forrest, 1981
Limousin	50	H	-	-	2.2	Avg. of 3 growth rate intervals	
Limousin	42	S	-	-	2.8		
Holstein	15	B	543.0	-	2.4	France	Menissier et al., 1982
Blonde d'Aquitaine	31	B	529.8	-	3.8		
Charolais	33	B	585.0	-	4.9		
Chianina	18	B	551.9	-	4.5		
Hereford	34	B	507.7	-	3.2		
Limousin	31	B	518.8	-	3.2		
Maine-Anjou	18	B	574.0	-	4.4		
Piedmontese	17	B	518.8	-	3.8		
Simmental	17	B	556.3	-	4.1		
South Devon	16	B	551.9	-	4.2		

Table 2. Continued

Breed of sire	n	Sex	Weaning weight, lb	Average daily gain to weaning, lb	Average daily gain in the feedlot, lb	Comments	Source
Holstein	93	S	-	1.9	1.8	Canada	Southgate et al., 1982
Angus	46	S	-	1.7	1.7	Avg. of 2 production systems	and Kempster et al.,
Charolais	62	S	-	2.1	2.1		1982
Devon	118	S	-	1.9	1.9		
Hereford	90	S	-	1.8	2.0		
Lincoln Red	18	S	-	1.8	2.0		
Simmental	65	S	-	2.0	2.3		
South Devon	47	S	-	1.9	2.0		
Sussex	40	S	-	1.9	2.0		
Holstein	40	S	-	1.7	2.4	Ireland	Keane et al., 1989
Blonde d'Aquitaine	40	S	-	1.6	2.4		
Limousin	40	S	-	1.4	2.5		
Holstein	8	B	-	-	2.3	Hungary	Szűcs et al., 1992
Limousin	8	B	-	-	2.3	Avg. daily gain per day of life	
Charolais	15	H	474.6	-	1.9	United Kingdom	Davies et al., 1999
Charolais	18	S	463.6	-	2.4		
Piedmontese	15	H	465.8	-	1.8		
Piedmontese	18	S	468.0	-	2.2		

Table 3. Breed of sire differences for slaughter weight, carcass weight, and dressing percentage (Holstein dams)

Breed of sire	n	Sex	Slaughter weight, lb	Carcass weight, lb	Dressing percentage	Comments	Source
Charolais	28	S	-	-	56.1	Canada	Lalande and Fahmy,
Hereford	26	S	-	-	55.8	Avg. of 2 feedlot regimes	1975
Limousin	29	S	-	-	56.4		
Charolais	30	S	-	-	56.2	Canada	Fahmy and Lalande,
Hereford	30	S	-	-	56.1	Avg. of 3 slaughter weights	1975
Holstein	12	S	1044.2	591.6	56.7	Canada	Forrest, 1977
Charolais	6	H	1041.9	593.8	57.2		
Charolais	12	S	1037.5	611.5	58.8		
Holstein	42	S	1048.6	589.4	56.3	Canada	Forrest, 1980
Simmental	27	H	1046.4	600.4	57.5		
Simmental	37	S	1044.2	600.4	57.3		
Holstein	39	S	1110.4	578.4	55.7	Canada	Forrest, 1981
Limousin	50	H	1110.4	618.1	59.4		
Limousin	42	S	1108.2	624.7	58.6		
Holstein	14	B	1086.1	587.2	53.9		
Blonde d'Aquitaine	31	B	1094.9	633.6	57.8	France	Menissier et al., 1982
Charolais	33	B	1185.4	664.5	56.8	Cold carcass weight	
Chianina	18	B	1130.2	649.0	56.2		
Hereford	34	B	1057.4	582.8	55.9		
Limousin	31	B	1077.3	613.7	56.7		
Maine-Anjou	18	B	1156.7	649.0	56.1		
Piedmontese	17	B	1101.5	642.4	58.7		
Simmental	16	B	1150.1	633.6	55.2		
South Devon	16	B	1139.1	629.1	55.4		

Table 3. Continued

Breed of sire	n	Sex	Slaughter weight, lb	Carcass weight, lb	Dressing percentage	Comments	Source
Holstein	93	S	1081.7	532.0	49.2	Canada	Southgate et al., 1982
Angus	46	S	911.7	441.5	48.4	Avg. of 2 production systems	and Kempster et al.,
Charolais	62	S	1242.8	638.0	51.3		1982
Devon	118	S	975.7	472.4	48.4		
Hereford	90	S	989.0	485.7	49.1		
Lincoln Red	18	S	1024.3	498.9	48.7		
Simmental	65	S	1167.8	585.0	50.1		
South Devon	47	S	1117.0	558.5	50.0		
Holstein	32	S	1134.7	657.8	-	Iowa	Bertrand et al., 1983
Angus	32	S	1117.0	668.9	-		
Brown Swiss	27	S	1181.0	693.2	-		
Hereford	29	S	1108.2	662.3	-		
Holstein	78	H	1055.2	543.0	52.5	France	Roux et al., 1987
Charolais	80	H	1141.3	624.7	53.9		
Holstein	40	S	1441.5	790.3	54.8	Ireland	Keane et al., 1989
Blonde d'Aquitaine	40	S	1476.8	849.9	57.5		
Limousin	40	S	1410.6	812.4	57.6		
Holstein	218	S	1320.1	721.9	54.7	Ireland	More O'Ferrall et al.,
Charolais	21	S	1404.0	783.7	55.9		1989
Hereford	35	S	1317.9	735.1	55.7		
Simmental	14	S	1326.7	743.9	56.0		
Holstein	8	B	1106.0	635.8	57.4	Hungary	Szűcs et al., 1992
Limousin	8	B	1117.0	664.5	59.4		
Charolais	15	H	962.5	536.4	55.7	United Kingdom	Davies et al., 1999
Charolais	18	S	1024.3	582.8	56.9	Cold carcass weight	
Piedmontese	15	H	986.8	571.7	57.9		
Piedmontese	18	S	1039.7	604.9	58.2		

Table 4. Breed of sire differences for fat thickness, ribeye area, and marbling score (Holstein dams)

Breed of sire	n	Sex	Fat thickness, in	Ribeye area, in^2	Marbling Score	Comments	Source
Charolais	28	S	0.1	10.5	-	Canada	Lalande and Fahmy,
Hereford	26	S	0.3	9.6	-	Slow-gaining feedlot regime only	1975
Limousin	29	S	0.1	11.3	-		
Charolais	30	S	0.2	11.2	-	Canada	Fahmy and Lalande,
Hereford	30	S	0.3	10.1	-	Avg. of 3 slaughter weights	1975
Holstein	12	S	0.5	10.7	-	Canada	Forrest, 1977
Charolais	6	H	0.5	11.9	-		
Charolais	12	S	0.4	12.2	-		
Holstein	42	S	0.4	10.4	-	Canada	Forrest, 1980
Simmental	27	H	0.6	11.5	-		
Simmental	37	S	0.4	11.6	-		
Holstein	39	S	0.4	9.3	-	Canada	Forrest, 1981
Limousin	50	H	0.7	12.1	-		
Limousin	42	S	0.5	11.9	-		
Holstein	93	S	-	8.4	-	Canada	Southgate et al., 1982
Angus	46	S	-	7.4	-	Avg. of 2 production systems	and Kempster et al., 1982
Charolais	62	S	-	10.3	-		
Devon	118	S	-	7.8	-		
Hereford	90	S	-	7.9	-		
Lincoln Red	18	S	-	7.8	-		
Simmental	65	S	-	9.5	-		
South Devon	47	S	-	8.9	-		
Sussex	40	S	-	8.3	-		

Table 4. Continued

Breed of sire	n	Sex	Fat thickness, in	Ribeye area, in^2	Marbling Score[a]	Comments	Source
Holstein	32	S	0.2	12.2	13.9	Iowa	Bertrand et al., 1983
Angus	32	S	0.5	11.5	15.2		
Brown Swiss	27	S	0.2	12.6	12.1		
Hereford	29	S	0.4	11.6	14.1		
Holstein	40	S	-	12.2	-	Ireland	Keane et al., 1989
Blonde d'Aquitaine	40	S	-	14.4	-		
Limousin	40	S	-	14.6	-		
Holstein	8	B	-	13.6	-	Hungary	Szűcs et al., 1992
Limousin	8	B	-	15.7	-		

[a]12 = slight +, 13 = small -, 14 = small, 15 = small +, and 16 = modest

SDSU Cow-Calf Teaching and Research Unit

Dick Pruitt[1], Kevin VanderWal[2], and Anna Drew[3]
Department of Animal and Range Sciences

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The SDSU Cow/Calf Teaching and Research Unit serves as a resource for teaching, research, extension and student organizations. In addition to use in the classroom, cattle are used for the annual SDSU Little International, Block & Bridle activities, field days, and numerous 4-H, FFA, and other educational events. Recent research projects at the Unit include studies on estrus synchronization, winter supplementation, and absorption of colostrum.

For teaching purposes, cattle that vary in calving ease, growth rate, mature size, and maternal value are maintained. It is not feasible to maintain all of the breeds that are important in this region. The herd consists of 100 purebred Angus and Simmental x Angus cows and their calves. Tables 1 and 2 show the average expected progeny differences for the current sires, replacement heifers and the 2002 calf crop.

The general goal of our breeding program is to produce bulls, useful to the commercial beef industry, which fit into the following categories:

- Low birth weight Angus bulls to breed to yearling heifers.
- Higher growth Angus bulls to breed to cows.
- Hybrid bulls that are 50 to 75% Angus and up to 50 % of an early puberty, high cutability breed. These bulls are intended to fit a simplified crossbreeding system that allows production of replacement females with maternal heterosis.

The specific goals of our breeding program are to produce a high percentage of bulls that fit the specifications in Table 3 and 4. At the same time we try to avoid problems that require extra labor and cull cows for foot problems, unmanageable dispositions or udder problems.

In mid-April bulls produced at the Cow/Calf Unit are sold in a "limited auction" managed by the SDSU Seedstock Merchandising Class. The class is responsible for advertising, promoting, organizing, answering customer's questions and conducting the sale. The students employed at the Cow/Calf Unit are responsible for preparing the cattle for sale day and delivering cattle after the sale. The sale provides students an opportunity to learn by interacting with beef cattle producers about the cattle that sell. Table 5 and 6 show the results of our last two sales. There is more information about the Cow/Calf Unit at: ars.sdstate.edu/facilities/ccu/index

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[1] Professor
[2]Ag Foreman/Manager Cow Calf Teaching and Research Unit
[3]Sr. Ag Research Tech

Table 1. Expected progeny differences for Angus[a]

						Ultrasound		
	Birth Weight	Weaning Weight	Milk	Yearling Weight	Scrotal Circum-ference	% Intramus-cular Fat	Rib Eye Area	% Retail Product
2002 AI Sires	+1.1	+41	+22	+82	+.34	+.21	+.35	+.21
2001 born replacement heifers	+1.8	+36	+22	+69	+.39	+.04	+.13	+.04
2002 born calves	+1.8	+38	+21	+72	+.41	+.07	+.15	-.01
National average of non parents	+2.6	+33	+16	+61	+.13	+.02	+.05	+.01

[a] From American Angus Association Spring 2002 evaluation.

Table 2. Multi-breed expected progeny differences for SimAngus[a]

	Birth weight	Weaning Weight	Yearling Weight	Maternal Milk	Maternal Weaning Weight
2002 Simmental & SimAngus AI sires	+.1	+35	+73	+10	+28
2001 born replacement heifers	-1.2	+23	+49	+11	+22
2002 born calves	-2.0	+22	+50	+11	+22
National average for 50% Simmental /50% Angus non parent bulls	-.6	+15	+29	+5	+12

[a] From American Simmental Spring 2002 evaluation.

Table 3. Goals for yearling Angus bulls produced at the SDSU Cow/Calf Unit

	Growth bulls		Low birth weight bulls	
	Specification	Rank within breed[a]	Specification	Rank within breed[a]
Expected progeny differences (Angus)				
Birth weight	< +3.7	top 75%	< +2.1	top 35%
Weaning weight	> +38	top 25%	> +33	top 50%
Milk	> +17	top 50%	> +17	top 50%
Yearling weight	> +70	top 25%	> + 62	top 50%
Scrotal circumference	> +.14	top 50%	> +.14	top 50%
Ultrasound				
% intramuscular fat	> +.00	top 50%	> +.00	top 50%
Rib eye area	> +.04	top 50%	> -.09	top 75%
% retail product	> -.16	top 75%	> -.16	top 75%
Frame score	6		5 to 6	
Scrotal circumference	≥ 34 cm		≥ 34 cm	

[a] Compared to non parent bulls in Spring 2002 evaluation.

Table 4. Goals for yearling SimAngus bulls produced at the SDSU Cow/Calf Unit

	Specification	Rank within breed[a]
Expected progeny differences (ASA Multi-breed)		
Birth weight	< +.5	top 75%
Weaning weight	> +15	top 50%
Yearling weight	> +28	top 50%
Milk	> +1	top 50%
Frame score	6	
Scrotal circumference	> 34 cm	
Marbling	> average	

[a] Compared to 50% Simmental, 50% Angus in the Spring 2002 ASA evaluation.

Table 5. Final bids for 2001 SDSU Limited Auction Bull & Heifer Sale

	Number	Average, $	Range, $
Angus bulls	21	2,390	1,200 – 4,600
SimAngus bulls	8	1,938	1,200 – 3,500
Angus heifers	5	1,220	950 – 1,300
SimAngus heifers	5	1,150	1,150 – 1,150

Table 6. Final bids for 2002 SDSU Limited Auction Bull & Heifer Sale

	Number	Average, $	Range, $
2-yr-old Angus bulls	3	2,067	1,600 – 3,000
Yearling Agnus bulls	19	1,937	1,500 – 3,200
Yearling SimAngus bulls	4	2,475	1,800 – 3,200

SDS Black Destiny 083K
Top selling SimAngus bull in 2001

ASA Multi-Breed EPDs
BW -.2 WW +27 YW +57 Milk + 13 MWW +27
Ratioed 117 for %IMF and 114 for REA

Increasing the Value of the Round and Sirloin Through Pre-Rigor Skeletal Separations

Bruce C. Shanks[1], Duane M. Wulf[2], Brian J. Reuter[1], and Robert J. Maddock[3]
Department of Animal and Range Sciences

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Summary

Thirty crossbred steers were utilized to explore and compare tenderness improvements in beef round and sirloin muscles resulting from various methods of pre-rigor skeletal separations. Animals were slaughtered according to industry procedures and at 60 min postmortem one of six treatments were randomly applied to each side: **A**) control, **B**) saw pelvis at the sirloin-round junction, **C**) separate the pelvic-femur joint, **D**) saw femur at mid-point, **E**) combination of B and C, and **F**) combination of B and D. After 48-h, the following muscles were excised from each side: semimembranosis (**SM**), biceps femoris (**BF-R**), semitendinosis (**ST**), and adductor (**AD**) from the round; vastus lateralis (**VL**) and rectus femoris (**RF**) from the knuckle; and gluteus medius (**GM**), biceps femoris (**BF-S**) and psoas major (**PM**) from the sirloin. Following a 10 d ageing period, samples were removed from each muscle to determine the effect of treatments on sarcomere length and Warner-Bratzler shear force. Sarcomere lengths differed between treatments for SM, AD, ST, GM, and PM. Treatment C resulted in longer sarcomeres than controls for SM, AD, and ST. All pre-rigor skeletal separation treatments yielded shorter sarcomeres for the PM as compared to controls. Warner-Bratzler shear force differed between treatments for RF, ST and PM. For RF, all treatments, except B, resulted in lower (P < 0.05) shear values than for controls. Treatment F resulted in higher shear force values for the PM than controls (P < 0.05). Also, treatments B, D, and F increased shear force of the ST relative to controls (P < 0.05). Correlations between sarcomere length and shear force were found to be low and quite variable between muscles. In general, treatments increased sarcomere length of several muscles from the sirloin/round region, but had mixed effects on shear force values.

Key Words: Beef, Sarcomeres, Skeletal Separation, Tenderness

Introduction

The National Beef Tenderness Survey (Morgan et al., 1991), conducted in 1990, identified problems with tenderness in beef rounds and top sirloin steaks. A follow-up study, the National Beef Tenderness Survey-1998 (Brooks et al., 2000), revealed that improvements in tenderness of retail cuts from the round were still needed. In an effort to improve tenderness, some researchers have centered on physically stretching or controlling the shortening of sarcomeres during rigor development.

Two methods that have been considered and extensively investigated include alternative suspension of carcasses (Herring et al., 1965; Hostetler et al., 1970a,b; Hostetler et al., 1971; Hostetler and Carpenter, 1972; Hostetler et al., 1972; Hostetler et al., 1973; Smith et al., 1979; Barnier and Smulders, 1994; Eikelenboom et al., 1998) and applying tension to muscles with weights or mechanical devices (Buege and Stouffer, 1974; Sonaiya and Stouffer, 1982). Even hind leg "twisting" (Odusanya and Okubanjo, 1983) has been attempted. However, these procedures have not been readily adopted by the industry.

More recently, researchers have studied pre-rigor skeletal cuts (separations) to improve beef tenderness (Cotroneo, 1992; Wang et al., 1994; Wang et al., 1996; Claus et al., 1997; Ludwig et al., 1997; Beaty et al., 1999). This procedure, sometimes referred to as the "Tendercut Process," has been tested on the longissimus muscle and on sirloin and round cuts. Researchers have found tenderness improvements in the longissimus muscle, round, and sirloin; but the greatest improvement has been shown in the longissimus muscle. Furthermore, these researchers have only reported results for one cut location in the round/sirloin region and tenderness improvements have not been reported on all of the major round and sirloin muscles. Therefore, this study was designed to explore and compare tenderness improvements in beef round and

[1] Graduate Student
[2] Associate Professor
[3] Assistant Professor

sirloin muscles resulting from various methods of pre-rigor skeletal separations.

Materials & Methods

Carcass Treatment. Thirty crossbred steers were slaughtered in four groups (two groups per week) at the South Dakota State University Meat Laboratory according to industry procedures. Carcasses were suspended by the Achilles tendon in the common vertical position, split, and one of six treatments were randomly applied to each side: **A**) control, **B**) saw pelvis at the sirloin-round junction, **C**) separate the pelvic-femur joint, **D**) saw femur at mid-point, **E**) combination of B and C, and **F**) combination of B and D. For treatments C and E, connective tissue adjacent to the pelvic-femur joint was either left intact or completely severed for the first two and last two slaughter groups, respectively. Average time between stunning and treatment application was 60 min and ranged from 47 to 76 min.

Carcass Length Measurement. Carcass length was measured from top of the carcass rail to the most anterior point of the first cervical vertebrae prior to and immediately after treatment application and at 24-h after treatment. To compensate for the length of the trolley, 3.25 in was subtracted from each measurement. Average length of control carcasses at treatment time was 99.0 in and at 24-h was 100.7 in. Initial and total 24-h carcass length drops were calculated from carcass length measurements.

Sampling and Storage. Following a 48-h chill period in a 34ºF cooler, carcasses were ribbed, and USDA yield and quality grade data were collected from right sides by experienced evaluators. At 48-h postmortem, the following muscles were excised from each side: semimembranosis (**SM**), biceps femoris (**BF-R**), semitendinosis (**ST**), and adductor (**AD**) from the round; vastus lateralis (**VL**) and rectus femoris (**RF**) from the knuckle; and gluteus medius (**GM**), biceps femoris (**BF-S**) and psoas major (**PM**) from the sirloin. Psoas major muscles were only obtained from the last two slaughter groups. Muscles were then vacuum-packaged and aged until 10 d postmortem in a 35ºF cooler before being frozen and stored (-0.4ºF). At a later date, whole muscles were removed from freezer storage and 1.0 in thick steaks were cut frozen on a bandsaw from similar locations within the muscles. For sarcomere length determination, a 3 to 5 g sample was removed from frozen steaks adjacent to steaks designated for shear force. Shear force and sarcomere length samples were then individually vacuum-packaged or placed in Whirl-Pac's®, respectively, and stored (2ºF) for later analysis.

Warner-Bratzler Shear Determinations. Steaks were thawed for 24-h in a 37ºF cooler and then broiled on Farberware Open Hearth electrical broilers (Farberware, Bronx, NY). Steaks were turned every 4 min during broiling until an internal temperature of 160ºF was reached. Internal temperature was monitored by a digital thermometer placed in the approximate geometric center of each steak. Cooked steaks were cooled to room temperature (≈72ºF) before four to eight cores (0.5 in) were removed parallel to the longtitudinal orientation of the muscle fibers. Individual cores were sheared once on a Warner-Bratzler shear machine. An average shear force was calculated and recorded for each steak.

Sarcomere Length Measurements. Sarcomere length was determined using a modified laser diffraction method (Cross et al., 1980). Approximately four g of tissue was cut from each frozen sample, placed into 15 to 20 ml of cold solution containing 0.25 M Sucrose and 0.002 M KCl, and homogenized until fiber separation was noted. A drop of homogenate was then placed on a slide and sarcomere lengths were measured with a He-Ne laser (Model 155A, Spectra-Physics, Inc., Mt. View, CA). Nine measurements were made per sample. Calculations were performed according to the formula by Cross et al. (1980).

Statistical Analysis. Simple descriptive statistics were computed for live weight and carcass traits to characterize the sample of animals obtained for the experiment.

Data were analyzed (SAS, 1994) as a randomized incomplete block design, with animal serving as the block (six treatments with two treatments per block). For those dependent variables where animal was not a significant ($P > 0.05$) source of variation, the animal effect was removed and data were analyzed as a completely randomized design. Least-squares means were calculated and separated for significant ($P < 0.05$) treatment effects using pair-wise *t*-tests. To examine relationships between sarcomere length and shear force, simple correlations were computed within muscles (SAS, 1994).

Results & Discussion

Mean carcass trait values (Table 1) were generally representative of the population sampled in the 1995 NBQA (Boleman et al., 1998). However, less variation existed among carcasses in this project than in the 1995 NBQA. Therefore, this group of carcasses was an excellent test sample because they were: a) representative of the industry average, and b) consistent.

Table 2 presents means for initial and total 24-h carcass length drop of treated and control sides. Treatment F resulted in the greatest initial carcass length drop (2.93 in); treatments B, D, and E were intermediate; and treatment C resulted in the least amount of initial carcass length drop (1.25 in). Subsequently, sides subjected to treatment F had the largest amount of total carcass length drop at 24-h (4.18 in). However, even though treatment D resulted in a moderate (1.60 in) amount of initial carcass length drop, total carcass length drop at 24-h was minimal (2.38 in) and not different from control sides ($P < 0.05$).

Sarcomere lengths differed between treatments for SM, AD, ST, GM, and PM (Table 3). In general, either treatments B and C individually or combined (treatment E) were the most effective at lengthening sarcomeres. For SM, treatments B, C, E, and F resulted in longer sarcomeres than controls. For AD, treatments B, C, D, and E resulted in longer sarcomeres than controls. For ST, treatment C resulted in longer sarcomeres than controls. For GM, only treatments B and E resulted in longer sarcomeres than control counterparts. Apparently, longer sarcomeres observed in the SM, AD, ST, and GM were due to stretching which resulted from the skeletal separations. Correspondingly, Beaty et al. (1999) found that the Tendercut process, which is analogous to treatment B in the current study, increased sarcomere length in the SM and ST.

All treatments yielded shorter sarcomeres in the PM muscle as compared to controls (Table 3). Herring and colleagues (1965) observed similar complexities; they discovered that horizontal placement versus conventional suspension of carcasses resulted in lengthened sarcomeres for several muscles, but considerably shortened sarcomeres for the PM. In the current study, control sides had an average sarcomere length of 3.52 µm, versus 2.41 µm for the average of treatments B through F. Treatment D resulted in a lesser degree of sarcomere shortening as compared to the other treatments, which was likely due to the greater linear distance between the point of skeletal separation (mid-point of the femur) and the PM muscle. Thus, with treatment D, intact connective tissue and tendons associated with the PM muscle may have maintained adequate resistance, hence keeping sarcomeres from shortening as much as with other treatments. In contrast to treatment D, the posterior insertion of the PM muscle was in close proximity to the site of treatment application for B, C, E, and F. Therefore, shorter sarcomeres found in the PM for treatments B, C, E, and F were probably a result of tension release, which probably occurred when connective tissue and tendons associated with the PM muscle were severed during treatment application.

Treatments had no effect ($P > 0.05$) on sarcomere length for BF-R, VL, or RF. The lack of response observed in sarcomere length for BF-R may have reflected the anatomical location of the BF-R in relation to the treatment sites. For the VL and RF, one could speculate that substantial stretching already occurs with traditional carcass hanging procedures. Thus, the weight and angle of conventionally suspended carcasses may be more effective than pre-rigor cuts at increasing sarcomere length in these muscles. In contrast to our results, Beaty et al. (1999) found that the Tendercut process increased BF-R sarcomere length and Wang et al. (1994) found that the Tendercut process resulted in significantly longer sarcomeres for RF and VL compared to control samples. In a later study, Wang et al. (1996) also found longer sarcomeres for Tendercut treated RF and BF steaks.

For RF, all treatments, except B, resulted in lower ($P < 0.05$) shear values than for controls (Table 3). Inconsistent with our results, some researchers have indicated that a pre-rigor cut at the round/sirloin juncture, identical to our treatment B, enhanced tenderness in the RF muscle (Wang et al., 1994; Wang et al., 1996; Claus et al., 1997). Differences between treatments and controls for shear force values were not found in the present study for SM, AD, BF-R, VL, GM, or BF-S ($P > 0.05$). In agreement with our findings, Beaty et al. (1999) reported no difference in BF-R, ST, and SM

shear force between Tendercut treated and control sides. In contrast to our results, other studies have found that VL (Wang et al., 1994) and GM (Claus et al., 1997) from Tendercut-treated carcasses had lower shear force values when compared to controls. However, Wang et al. (1996) and Claus et al. (1997) discovered no improvement in Warner-Bratzler or Lee-Kramer shear values for Tendercut treated BF steaks. These authors suggested that the location of the BF relative to the treatment site was too far apart to sufficiently stretch the muscle. They also acknowledged that the amount of collagen in the BF could have masked the effect of the treatment.

In the present study, Treatment F resulted in higher shear force values for the PM than controls ($P < 0.05$). Also, treatments B, D, and F increased shear force of the ST relative to controls ($P < 0.05$). Hostetler and Carpenter (1972) showed tendencies for the PM and ST to decrease in tenderness with alternative versus conventional suspension treatments, while other muscles from the round/sirloin region remained unchanged or improved.

Locker (1960) demonstrated that as sarcomere length decreases, tenderness of muscles declines. Previous correlations between sarcomere length and shear force of several different muscles have ranged from –0.34 to –0.80 (Herring et al., 1965; Hostetler et al., 1972; Dutson et al., 1976; Wang et al., 1994). Therefore, one would have expected the muscles in this study with longer sarcomeres to have enhanced tenderness. However, only the RF, which had similar ($P > 0.05$) sarcomere lengths for control and treated sides, responded favorably in tenderness. Even more noteworthy, in the ST, treatments B, D, and F produced substantially longer sarcomeres than controls, but control muscles were more tender ($P < 0.05$). Correspondingly, Barnier and Smulders (1994) observed increases in sarcomere length for the SM, GM, ST, and BF as a result of alternative carcass positioning and Beaty et al. (1999) observed increases in sarcomere length for Tendercut treated BF, ST, and SM, but both studies reported negligible or adverse changes in tenderness.

Correlations between sarcomere length and shear force were found to be low and quite variable among muscles (Table 5). For AD, VL, RF, and PM muscles, significant ($P < 0.05$) negative correlations (-0.26 to -0.36) were detected indicating that longer sarcomeres were associated with lower shear force values. Yet, for SM, BF-R, and GM correlations between sarcomere length and shear force were slight and not statistically different than zero ($P > 0.05$). Indeed, a positive correlation (0.26) was observed for ST indicating that longer sarcomeres were associated with higher shear force values. An earlier series of studies (Hostetler et al., 1970; Hostetler et al., 1972; Hostetler et al., 1973) established that increased sarcomere length in ST was not always associated with improved shear force and taste panel tenderness. Hostetler et al. (1973) also found that increased sarcomere length was accompanied by increased shear force in the BF, and considerable nonlinearity was found between change in sarcomere length and change in shear force for AD, GM, and PM muscles. These authors attributed the lack of tenderness improvement seen with longer sarcomeres to the amount of connective tissue present in the muscles. Another possible explanation for these findings was elucidated in a detailed experiment conducted by Marsh and Carse (1974). Marsh and Carse (1974) detected a “peak” of toughness in muscles which were held in a 25-30% extended state during rigor onset. Hostetler et al. (1972) concluded that sarcomere length is only one of many numerous factors associated with meat tenderness; our findings strongly support this presumption.

Implications

Most of the pre-rigor skeletal treatments studied increased sarcomere length of muscles from the sirloin/round region, but had mixed effects on shear force values, thus clearly demonstrating that meat tenderness is not always positively associated with sarcomere length. None of the five treatments studied appears to have practical application in their current form because they either: a) had only minimal effects on tenderness, or b) increased tenderness in some muscles while decreasing tenderness in other muscles. Because some treatments did improve tenderness in some muscles, it may be possible to modify one or more of the treatments studied in order to elicit only positive effects on tenderness and thereby increase the value of beef cuts from the round and sirloin.

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Tables

Table 1. Means, standard deviations, and minimum and maximum values for live weight and carcass traits

Trait	Mean	SD	Minimum	Maximum
Live weight, lb	1234	30	1189	1281
Hot carcass wt, lb	762	21	727	798
Adjusted fat thickness, in	0.48	0.14	0.25	0.90
Longissimus muscle area, in^2	12.5	1.2	10.7	15.3
Actual kidney, pelvic, and heart fat, %	3.5	0.7	2.4	5.1
USDA yield grade	3.3	0.7	2.0	4.9
Overall maturity[a]	154	11	130	180
Marbling score[b]	413	57	330	570

[a]100 = A^{00}; 200 = B^{00}; etc.
[b]300 = $Slight^{00}$; 400 = $Small^{00}$; etc.

Table 2. Least squares means for initial carcass length drop and total 24-h carcass length drop of control and treated sides

	Treatment[a]						
Trait	A	B	C	D	E	F	*P*
Initial carcass length drop, in	0.00^{b}	1.68^{cd}	1.25^{c}	1.60^{cd}	1.94^{d}	2.93^{e}	< 0.001
Total 24-h carcass length drop, in	1.70^{b}	2.78^{c}	2.85^{c}	2.38^{bc}	3.11^{c}	4.18^{d}	< 0.001

[a]A = Control; B = Saw pelvis at the sirloin-round junction; C = Separate the pelvic-femur joint; D = Saw femur at the mid-point; E = Combination of B and C; F = Combination of B and D.
[b,c,d,e]Means within a row lacking a common superscript letter differ ($P < 0.05$).

Table 3. Least squares means for sarcomere length (μm) of muscles from control and treated sides

	Treatment[a]						
Muscle	A	B	C	D	E	F	*P*
Round							
Semimembranosis (top round)	1.82^{b}	2.00^{ed}	1.91^{cd}	1.88^{cb}	2.04^{e}	1.96^{cde}	< 0.001
Adductor (top round)	1.88^{b}	2.02^{cd}	2.13^{d}	2.03^{cd}	2.02^{cd}	1.93^{bc}	0.005
Biceps Femoris (bottom round)	1.86	1.92	1.92	1.90	1.89	1.86	0.429
Semitendonosis (eye of round)	2.19^{b}	2.46^{cd}	2.19^{b}	2.39^{c}	2.45^{c}	2.54^{d}	< 0.001
Knuckle							
Vastus Lateralis (sirloin tip)	1.99	1.99	2.00	2.01	2.12	2.12	0.107
Rectus Femoris (sirloin tip)	2.26	2.46	2.40	2.28	2.37	2.49	0.192
Sirloin							
Gluteus Medius (top sirloin)	1.79^{bc}	1.96^{d}	1.93^{cd}	1.87^{bcd}	2.11^{e}	1.76^{b}	< 0.001
Psoas Major (tenderloin)	3.52^{b}	2.15^{d}	2.31^{d}	3.22^{c}	2.29^{d}	2.09^{d}	< 0.001

[a]A = Control; B = Saw pelvis at the sirloin-round junction; C = Separate the pelvic-femur joint; D = Saw femur at the mid-point; E = Combination of B and C; F = Combination of B and D.
[b,c,d,e]Means within a row lacking a common superscript letter differ ($P < 0.05$).

Table 4. Least squares means for shear force (lb) of cooked steaks from control and treated sides

	Treatment[a]						
Muscle	A	B	C	D	E	F	*P*
Round							
Semimembranosis (top round)	9.80	9.21	9.91	10.18	9.14	10.15	0.386
Adductor (top round)	9.27	9.34	9.03	9.51	8.92	9.89	0.291
Biceps Femoris (bottom round)	11.81	11.04	12.05	11.52	11.30	11.88	0.768
Semitendonosis (eye of round)	8.29[b]	9.23[cd]	8.48[bc]	9.34[d]	8.65[bcd]	8.90[bcd]	0.053
Knuckle							
Vastus Lateralis (sirloin tip)	10.57	11.10	10.71	10.04	10.40	9.98	0.394
Rectus Femoris (sirloin tip)	9.43[b]	9.07[bc]	7.33[de]	7.62[de]	8.15[cd]	7.06[e]	< 0.001
Sirloin							
Gluteus Medius (top sirloin)	8.76	7.95	7.86	7.92	8.39	8.72	0.252
Biceps Femoris (top sirloin cap)	7.02	7.17	6.73	7.11	6.91	6.75	0.878
Psoas Major (tenderloin)	6.82[b]	7.40[b]	7.81[bc]	7.68[b]	6.62[b]	9.05[c]	0.013

[a]A = Control; B = Saw pelvis at the sirloin-round junction; C = Separate the pelvic-femur joint; D = Saw femur at the mid-point; E = Combination of B and C; F = Combination of B and D.
[b,c,d,e]Means within a row lacking a common superscript letter differ ($P < 0.05$).

Table 5. Correlation coefficients between sarcomere length and shear force for different muscles

Muscle	r	*P*
Round		
Semimembranosis (top round)	0.11	0.418
Adductor (top round)	-0.28	0.028
Biceps Femoris (bottom round)	0.02	0.884
Semitendonosis (eye of round)	0.26	0.046
Knuckle		
Vastus Lateralis (sirloin tip)	-0.26	0.044
Rectus Femoris (sirloin tip)	-0.31	0.015
Sirloin		
Gluteus Medius (top sirloin)	-0.19	0.149
Psoas Major (tenderloin)	-0.36	0.053

Effect of Calving Time and Weaning Time on Cow and Calf Performance - A Preliminary Report

Dick Pruitt[1], Ron Haigh[2], William Epperson[3], Scott Fausti[1], and Doug Young[4]
Departments of Animal and Range Sciences, Veterinary Science, and Economics

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Summary

Cows grazing native range pasture year round in western South Dakota were allotted to 3 management systems: 1) A calving season starting in mid March with calves weaned in late October; 2) A calving season starting in mid March with calves weaned in mid September; and 3) A calving season starting in early May with calves weaned in late October. The effect of management system on pregnancy rate was year dependent. After 4 years of the study, there was no consistent advantage for any particular group. Average weaning weight was consistently higher for the March calving/October weaned group that was older at weaning than the other two groups. In the first year of the study, severe winter weather caused a higher calf death loss that resulted in a lower weaning percentage for the March calving groups compared to the May calving group. The weaning percentage favored the March calving groups in year 4. With the exception of the first year, the pounds of calf weaned per cow exposed were greater for the March calving/October weaned group compared to the other two systems. An estimate of overall calf income was $30 higher per cow exposed for the March calving/October weaned group compared to the May calving group. In deciding the optimum time to calve, the potential to reduce cost of winter feed, equipment, facilities and labor for a specific situation would need to be considered.

Introduction

Dunn (2000) reported that high profit cow/calf producers have lower than average investments and expenses per cow. Measures of reproductive performance were higher than average for high profit producers. Hoyt and Oedekoven (1994) reported that feed costs are approximately two-thirds of the cost of production for South Dakota beef cow herds and that high profit operators have approximately 10 % lower nonpasture feed costs than average.

A common management strategy for high reproduction at reasonable cost is to manage cow winter weight loss and then time the beginning of the breeding season to allow cows to gain weight rapidly on pasture for at least 30 days prior to the breeding season. In western South Dakota this results in a breeding season starting in early June and a calving season starting in March. In this system it is difficult to meet the cow's NRC nutrient requirements during the winter with the forages available without high levels of supplementation. But winter weight loss can be compensated by rapid weight gain before breeding.

Another strategy is to match the cow's production cycle and nutrient requirements to the forage production cycle. In this system the cow's highest requirements after calving are matched with peak pasture forage quality. In western South Dakota this fits a breeding season starting in late July and a calving season starting in May. Later calving also has the potential advantages of reduced calf disease and death loss from severe weather, reduced costs for calving facilities and reduced labor during the calving season. Potential disadvantages of a May calving season include reduced reproductive performance from breeding in the hottest months of the year when forage quality is relatively low and lighter weaning weights if calves are weaned on the same date.

Another approach to reducing winter feed costs is to wean the calves early, which would allow the cows to be in higher body condition early in the winter.

There is strong interest among some cow-calf producers in the potential to change from a late winter calving to a spring calving season. There is limited information to predict how production and cost of production will change with this management adjustment. The overall objectives

[1]Professor
[2]Superintendent, Cottonwood Research Station
[3]Associate Professor
[4]Ag Research Tech, Cottonwood Research Station

of this study are to determine the effect of time of calving season and weaning on: 1) the performance of beef cows managed to optimize the use of native range and 2) the performance of calves from birth through slaughter. The results pertaining to objective 1 are discussed in this paper.

Materials and Methods

This on-going study involves 126 crossbred cows grazing native range pastures at the SDSU Range and Livestock Research Station near Cottonwood, SD from November to May and pastures near Sturgis, SD during the summer. In the spring of 1996 cows were allotted by age and breed composition to 3 management systems (Table 1).

Cows graze native pasture year round and receive 1 lb supplemental crude protein from December 1 to May 1. Grass hay is fed only when snow cover prevents grazing. For the first 3 years of the study cows in estrus during 7 days following a prostaglandin injection were artificially inseminated. Cows were then exposed to bulls for 53 days and rectally palpated to determine pregnancy in November. Beginning in year 4, cows are exposed to bulls for approximately 60 days. Only cows that are not pregnant in November or have physical defects are culled.

To ascertain absorption of colostral antibodies, blood samples are collected after 24 hours of birth. Samples are frozen and later analyzed for serum total protein using refractometry. Blood serum total protein is well correlated to absorption of colostral antibodies, which in turn is related to calf survival and health. If calves have serum total protein concentrations of 5.5 mg/dl or greater, they were considered to have adequate absorption of colostral antibodies.

Following weaning heifers are fed in drylot to gain 1.5 lb per day until May 1 when they are turned out to native pasture. Heifers are bred to start calving 30 days earlier than the cows. They are artificially inseminated to a synchronized estrus and then exposed to a bull for 45 days and rectally palpated for pregnancy diagnosis in the fall.

All male calves are branded, castrated and implanted with Ralgro at an average age of approximately 45 days of age and re-implanted 90 days later with Synovex C. Following weaning, steer calves are transported to the SE Experiment Station, Beresford, SD where they are fed a high grain diet for maximum gain to harvest.

Calf income per cow exposed was estimated from calf prices at western South Dakota sale barns for each year. Regression equations for each year were developed to estimate price per hundred weight based on weaning weight and sex.

Results and Discussion

In 1997 the percentage of calves alive at 1 week ($P = 0.07$) and weaning percentage ($P = 0.10$) were greater for the May calving group than the March calving groups (Table 2). The severe weather during the winter of 1996-1997 resulted in a high number of calf deaths shortly after birth for the March calving groups.

In 2000 the low weaning percentage for the May calving group ($P = 0.05$) was due to the number of cows examined pregnant in the fall that did not calve (Table 3). Absorption of colostral antibodies as indicated by serum total protein was not affected by calving time.

In 1999 and 2000 the means for calf birth weight were lower ($P < 0.10$) for the May calving group compared to the March calving groups (Table 4). In all years the calves born in March and weaned in late October were the heaviest at weaning ($P < 0.05$) due to their older age at weaning. In 1997 the May calving/October weaned group was 23 lb. heavier ($P < 0.05$) than the March calving/September weaned group that were about the same age at weaning. This was due to a higher average daily gain from birth to weaning for the May calving group ($P < 0.05$). In following years, calf weaning weight was similar for the March calving/September weaned and May calving groups.

In 1997 there was a higher percentage of cows in the May calving group in estrus ($P < 0.01$) during the first 7 days of the breeding season following an injection of prostaglandin (Table 5). In following years, the percentage of cows cycling in each group was more similar.

As could be expected, year had a large impact on pregnancy rate (Table 5). In 1997 and 1998 pregnancy rate was not significantly affected by treatment. In the third year, the May calving

group had the highest pregnancy rate. A year later, the May calving group had the lowest pregnancy rate. For the March calving groups, weaning calves in September did not result in an advantage in pregnancy rate or weaning percentage but did result in lower weaning weights compared to the October weaned group.

Table 6 shows calculations of pounds weaned and income per cow exposed based on the preliminary data presented in this paper. Even though average calf weaning weight was lower for the May calving/October weaned group compared to the March calving/October weaned group in 1997, the pounds of calf weaned per cow exposed were nearly identical. Due to a higher estimated price per hundredweight, the income per cow exposed to breeding for the May calving/October weaned group is slightly higher than the March calving/October weaned group for 1997. This was due primarily to differences in calf death loss. In following years, the pounds of calf weaned per cow exposed averaged 68 lb more for the March calving/October weaned group compared to the May calving group.

The estimated gross income per cow exposed is greatly influenced by year, pregnancy rate, calf survival and calf weaning weight (Table 6). The lighter weaning weights of the May calving/October weaned group compared to the March calving/October weaned group was partially offset by higher estimated calf price per hundredweight. This resulted in a difference in calf income $30 per cow exposed. In deciding the optimum time to calve, the potential to reduce cost of winter feed, equipment, facilities and labor for a specific situation would need to be considered. Another way to look at this is that if expenses per cow could be reduced by more than $30 by calving in May, then May calving would be more profitable.

This portion of the project will continue through the fall of 2002. A more complete economic analysis will be done at that time.

Tables

Table 1. Three management systems

Calving Season Starts Weaning Time	March 15 late October	March 15 mid September	May 1 late October
No. of cows	42	42	42
Approximate calving season[a]	3/15 to 5/14	3/15 to 5/14	5/1 to 6/30
Approximate breeding season[a]	6/5 to 8/4	6/5 to 8/4	7/22 to 9/20
Approximate weaning date	10/31	9/14	10/31

[a] The breeding and calving seasons start 30 days earlier for yearling replacement heifers.

Table 2. Calf survival and serum total protein for calves born in 1997

Calving season starts	March 15	May 1	Prob.
% calves alive at 1 week[a]	88.1	97.6	0.07
Weaning percentage[a]	85.5	95.2	0.10
Serum total protein, mg/dl	7.79	8.14	0.14
% calves with adequate total serum total protein	98.6	100.0	0.47

[a] Number of calves alive divided by the number of pregnant cows the previous December.

Table 3. Calf survival and serum total protein for calves born 1998 to 2000

Calving season starts Weaning time	March 15 late October	March 15 mid September	May 1 late October	Prob.
% calves alive at 1 week[a]				
1998	97.6	85.4	90.5	0.14
1999	90.5	92.5	95.1	0.72
2000	92.9	95.2	85.7	0.18
Weaning percentage[a]				
1998	95.2	85.4	85.7	0.27
1999	88.1	92.5	95.1	0.50
2000[b]	95.1	95.2	83.3	0.15
Serum total protein, mg/dl				
1998	7.21	6.85	7.15	0.21
1999	7.05	6.78	6.70	0.31
2000	7.41	7.26	7.43	0.83
% calves with adequate serum total protein				
1998	96.6	100.0	96.9	0.69
1999	100.0	86.4	90.3	0.12
2000	95.0	100.0	90.0	0.19

[a] Number of calves alive divided by the number of pregnant cows the previous December.
[b] March calving 94.1%, May calving 83.3% (P = 0.05).

Table 4. Effect of calving time and weaning time on calf performance

Calving season starts Weaning time	March 15 late October	March 15 mid September	May 1 late October	Prob.
Calf birth weight, lb				
1997	92.5	90.7	89.5	0.47
1998	88.3	87.8	87.1	0.83
1999	92.8[de]	96.1[d]	89.8[e]	0.09
2000	89.3[a]	86.5[ab]	82.8[b]	0.03
Age at weaning, days				
1997	211[a]	175[b]	175[b]	< 0.001
1998	205[a]	175[b]	169[b]	< 0.001
1999	196[a]	159[b]	161[b]	< 0.001
2000	225[a]	176[b]	179[b]	< 0.001
Actual calf weaning weight, lb				
1997	577[d]	492[e]	515[f]	< 0.001
1998	608[a]	531[b]	538[b]	< 0.001
1999	575[a]	508[b]	510[b]	< 0.001
2000	661[a]	558[b]	557[b]	< 0.001
Calf average daily gain, lb/day				
1997	2.32[d]	2.33[d]	2.46[e]	0.08
1998	2.55[d]	2.55[d]	2.68[e]	0.07
1999	2.45[a]	2.60[b]	2.62[b]	0.04
2000	2.53[a]	2.68[b]	2.63[b]	0.03

[a, b, c] Means with uncommon superscripts differ (P < 0.05).
[d, e, f] Means with uncommon superscripts differ (P < 0.10).

Table 5. Effect of calving time and weaning time on reproductive performance

Calving season starts Weaning time	March 15 late October	March 15 mid September	May 1 late October	Prob.
% in estrus during the first week of breeding season[ab]				
1997	27.0	29.4	61.5	< 0.01
1998	55.0	37.1	55.6	0.21
1999	52.6	46.0	66.7	0.18
% pregnant[a]				
1997	91.9	91.2	89.7	0.95
1998	95.0	88.6	88.9	0.54
1999	89.7	97.3	100.0	0.07
2000	92.3	100.0	88.6	0.10

[a]Includes only cows weaning a calf.
[b]Cows were not heat detected or artificially inseminated in 2000.

Table 6. Calculated pounds weaned and income per cow exposed[a]

Calving season starts Weaning time	March 15 late October	March 15 mid September	May 1 late October
1997			
Assumed % pregnant, 1996	90.9	90.9	90.9
Weaning percentage	85.5	85.5	95.2
Actual weaning weight	577	492	515
Lb. weaned per cow exposed	448	382	446
Estimated calf sale price, $/cwt[b]	84.59	86.90	87.26
Calf income/cow exposed, $	379	332	389
1998			
% pregnant, 1997	90.9	90.9	90.9
Weaning percentage	88.8	88.8	88.8
Actual weaning weight	608	531	538
Lb. weaned per cow exposed	491	429	434
Estimated calf sale price, $/cwt[b]	75.30	73.73	77.82
Calf income/cow exposed, $	370	316	338
1999			
% pregnant, 1998	90.8	90.8	90.8
Weaning percentage	91.9	91.9	91.9
Actual weaning weight	575	508	510
Lb. weaned per cow exposed	480	424	426
Estimated calf sale price, $/cwt[b]	91.02	91.33	93.51
Calf income/cow exposed, $	437	387	398
2000			
% pregnant, 1999	89.7	97.3	100.0
Weaning percentage	94.1	94.1	83.3
Actual weaning weight	661	558	557
Lb. weaned per cow exposed	558	511	464
Estimated calf sale price, $/cwt[b]	95.25	97.68	101.52
Calf income/cow exposed, $	531	499	471
Average calf income/cow exposed, $	**429**	**384**	**399**

[a]If affected by treatment (P < 0.10), treatment means are used. If not affected by treatment, overall mean is used.
[b]Estimated from calf prices at SD sale barns, adjusted for calf weight and sex.

Characterization of the Beef Cow-calf Enterprise of the Northern Great Plains

Barry Dunn[1], Edward Hamilton[1], and Dick Pruitt[1]
Departments of Animal and Range Sciences and Veterinary Science

SDSU

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Summary

One hundred eighty five privately owned and operated cow-calf enterprises provided production data on their beef cow-calf operations. 0ne hundred and forty eight of those also provided financial information on a modified cost basis. The enterprises were located in the states of South Dakota, Nebraska, Montana, Minnesota, Iowa, Kansas, Wyoming, and North Dakota. The data were collected at the herd level according to Standardized Performance Analysis (SPA) guidelines during the years 1991-1999. By industry standards these operations were large, averaging just over 11,000 acres and 500 beginning year breeding females. They began calving approximately March 1st, had an average 93% pregnancy rates, and an average 86.7% weaning rate. They weaned at approximately 199 days and the average weaning weight of their calves was 519 pounds. These operations had invested on average $2,087.00 per Beginning Fiscal Year Female. They spent $397.00 of Total Expenses and realized $33.00 of Net Income per Beginning Fiscal Year Female per year. Their average Return on Assets was 3.1%.

Introduction

The cow-calf industry remains a large and dynamic part of the economy of the states in the Northern Great Plains of the United States. As over one-half of the farmers and ranchers in South Dakota have a cow-calf herd as part of their business, it is important to have benchmark data concerning the practices, production levels, and financial performance of these enterprises. The earliest report from South Dakota State University concerning these issues dates to 1930. Latter reports from South Dakota State University were published in 1982 the 1992. These reports add depth, richness and background for future analysis and decision making. The data reported herein was collected using a methodology approved by the cattle industry in 1991 called Standardized Performance Analysis (SPA). Data within this report can be compared to data from other regions if similar methodology was used. However, caution should be advised in comparing these data to reports were SPA methodology was not used, as subtle differences in the definitions of terms and methodology can create misleading differences and could lead to erroneous conclusions.

Materials and Methods

Data were collected from a sample of privately owned and operated commercial cow-calf enterprises. Dr. Edward D. Hamilton of South Dakota State University and Dr. Duane Griffith of Montana State University were the two individuals responsible for the collection of the SPA data. Data were collected from individual operations for the fiscal years 1991-1999. Individuals were invited to participate in the SPA process in a variety of methods. Veterinarians, county agents and educators, and Bootstraps groups hosted SPA workshops. Others contacted the University system through a variety of avenues and were invited to join scheduled workshops or were worked with on a personal basis. Participation was completely voluntary. The motivation of ranchers and farmers to participate was not recorded.

Farmers and ranchers from eight states cooperated in the collection of the data. All participants were asked for the animal production and financial information necessary to complete a SPA. Production data included: 1) breeding herd inventory and dates; 2) pregnancy test inventory and results; 3) female replacement rate; 4) the date the third mature cow in the herd calved; 5) calving distribution; 6) calf death loss; and 7) weaning date and weights. The financial information came from a variety of sources including: 1) cost basis beginning and ending year balance sheets; 2) accrual adjusted income statements; 3) IRS

[1] Professor

Schedule F; and 4) depreciation schedules. This information was entered into one of three software packages used to calculate SPA numbers. They were: 1) CowCalf developed at the Great Plains Veterinary Educational Center of the University of Nebraska; 2) SPA-EZ written by Dr. Edward D. Hamilton, Dr. Daniel Kniffen, and Shawn Walters; and 3) SPA program and software developed at Texas A&M University.

During the spring of 2000, 239 individual SPAs were reviewed. Records from fifty-four herds were not used in the final data set for reasons including: 1) incomplete data entry; 2) obvious data entry inconsistencies; and 3) calculation errors that could not be reconciled by a third party. SPA production and financial measurements were used from 148 herds. ROA was measured by annual net income divided by average total assets. Net income is defined as a pre-tax and pre-family living measurement. Average total assets were calculated by averaging the beginning and ending year balance sheets. Balance sheet values were based on the financial cost of the assets or their book value. These data do not include deferred taxes. All data were collected on a cost basis of assets with accrual adjustments made to income statements. Means, standard deviations and minimum and maximum values were calculated for each SPA variable.

Results and Discussion

The means, standard deviations and minimum and maximum values for SPA production variables can be found in Table 1. Financial variables are reported on a per hundred weight of weaned calf, per beginning year breeding female, per acre in Tables 2,3, and 4 respectively. Table 5 contains financial data on an enterprise level.

Size and Scale of Cow-calf Enterprises: By historic comparison, operations in this sample population were large. The average beginning breeding female inventory was 508 head. As measured by acres and stocking rate, there was great deal of variation in size of operation. This would be expected, as annual rainfall in the geographical region represented in this survey would range from 23-25 inches in the eastern and southern areas to 12-14 inches in the western and northern areas. The average size of operation was 11,147 acres. The average stocking rate was 21.3 acres per exposed female

Reproductive Performance: The mean calving date was the 59.4 day of the year, or approximately March 1st. Calves in this data set were born approximately 58 days earlier than cow-calf operations surveyed by researchers from SDSU for the years 1977 and 1978. The average length of breeding season for these 185 herds was 88.2 days. The average pregnancy percentage was 93.0. The number of calves weaned per exposed female (weaning percentage) was 86.7%. This contrasts to 65% in 1930 and 78% in 1977 and 1978. It is of interest that while definitions for production traits has varied over the years and with different authors, weaning percent was calculated the same way in these historic references as it was in this analysis. While the range in weaning percent in this data set was wide, it does reflect the effect of the environment on the beef cow-calf enterprise of the Northern Great Plains. The lowest weaning percent of 42.5% occurred on a ranch in the north central section of South Dakota for fiscal year 1997. The winter and spring weather of 1996-1997 in this area was abnormally and extremely cold and snowy. The mean calving percentage for cow-calf enterprises in this data set was 91.4. Causes of death loss at calving were not recorded but averaged 4.9%.

The mean female replacement rate was 19.7% with a range of 0-115.4%. While the upper limit may appear high, the decision to expand a herd is a reality in cow-calf enterprises and has been captured in this data set.

The calving distribution of the 138 herds that collected this information in this data set with those records can be found in Table 1. During the first 21 days of the calving period, 56.8% of the calves were born. By the 42nd day, 84.1% of the calves were born and 96% of the calves were on the ground by the 63rd day of the calving season.

Production Performance Summary: The mean calf age at weaning was 199 days. The mean weaning weight of the calves in the 185 herds was 519 pounds. Male calves averaged 529 pounds and female calves 512 pounds. This is very similar to weaning weights reported in recent literature from many mid-western and western states. The average pounds weaned

per exposed female and per acre were 451 and 39 respectively.

Financial Performance Summary. The SPA Financial Summary data on a dollar per 100 lbs. of weaned calf basis, per beginning year breeding female and per acre dedicated to the cow-calf enterprise are presented in Tables 2,3, and 4 respectively. The only published literature using the SPA formulas as outlined in the SPA Guidelines and which correspond to the methodology used in the data collection and calculation of this data set are from Colorado and Texas. The SPA reports from Iowa, Michigan and Illinois are based on an entirely different methodology for the calculation of financial measures. Data collected and reported with farm management methodology, common in some states, uses different inventory adjustments, which makes comparisons of total costs, breakevens, and net income difficult. Farm management methodology and the Iowa and Illinois SPA reports also do not include investment levels on a cost basis, which results in profit reported as net income per cow without regard to differences in levels of productivity or levels of investment required to generate the different levels of net income.

The standard way of selling livestock from farms and ranches is by dollars per 100 pounds of weight. There is also tremendous management value in the understanding of the breakeven prices necessary to cover basic expenses on a per 100 pounds of weight basis. Often referred to as the unit cost of production, this knowledge adds market relevance and sensitivity for managers. The mean investment on a per 100 lbs. of weaned calf, was $441.35. The average total cost on a per 100 lbs. of weaned calf was $85.16. The average breakeven on a per 100 lbs. of weaned calf basis was $70.05. This figure represents the Total Cost minus sources of income not derived from calves; for instance cull cow and cull bull income. It is the minimum amount a hundred weight of calves will have to bring in the market place to cover the expenses not covered by other sources of income. Calf revenue, non-calf revenue, and total revenue on a per 100 lb. of weaned calf was $79.39, 36.09, and 93.92 respectively and are listed in Table 2. Net income per 100 lbs. of weaned calf was $7.77.

Investment per beginning year breeding female was $2087.00. The average total cost per beginning year female was $397.00. The mean breakeven on a per beginning year breeding female basis was $331.00. Calf Revenue per beginning year female was $364.00. Non-calf Revenue and Total Revenue per beginning year female was $66.00 and $430.00 respectively. Cull cow and cull bull income has been the subject of discussions suggesting that it represent between 20 and 30% of the income from cow-calf enterprises. According to SPA guidelines Non-calf Revenue not only includes cull cow and cull bull income, but also accrual adjustments made to the balance sheets for inventory adjustments. When the negative inventory adjustments are added back to the Non-calf Revenue figure, income from cull cows and bulls represents approximately 19.5% of Total Revenue. Even with this being the case, it is important to keep marketing decisions regarding cull cow and bull marketing decisions in perspective. While important, they are not nearly as important as marketing decisions affecting Calf Revenue and cannot make up for problems associated with calf marketing.

The Total Assets invested per acre in these sample cow-calf enterprises were $191.82. This would include land, equipment and machinery, buildings, breeding stock and current assets like feed. The average annual Total Cost was $33.21 per acre. The average breakeven on a per acre basis was $28.02. Calf Revenue, Non-calf Revenue, and Total Revenue on a is listed in Tables 4. Net income per acre was $6.85.

The mean owner's equity was 65% (Table 5). Owner's equity is also referred to as net worth and is a measure of solvency. In a standardized farm or ranch business analysis, analysts would consider 65% owner's equity to be in the cautionary zone. USDA-Economic Research Service estimates owner's equity of the average farm business in the United States to 83.8%.

In general, and by several measures, the enterprises in this sample population were not very profitable. On a per beginning year female basis, they had 508 head which generated only $33.00 per head of Net Income for a total of $16,764.00. That is $16,764.00 to cover family living, unpaid family labor and management and the costs associated with debt service, both interest costs and principle payments. This problem also reflects itself in other figures. The average percentage Return on Assets was 3.1 (Table 5). This measurement has changed little

over time. A 1960 survey reported the return on assets of 20 South Dakota ranches to be 3.09%. In the year 2000, there are less than half of the cattle operations in South Dakota and Nebraska as there were in 1970. While many factors may have had an affect on this trend, the lack of profitability was undoubtedly a significant contributor.

Tables

Table 1. SPA production summary

	N	Mean	SD	Min - Max
Cow-calf enterprise summary				
Total adjusted exposed females	185	523	723	20 - 4806
Beginning fiscal year breeding females	185	508	700	20 - 4945
Total acres	185	11,147	20,033	51.7 - 131,421
Acres/exposed female	185	21.3	10.3	1.6 - 47.3
Reproduction performance measures based on exposed females				
Avg beginning Gregorian calving date	181	59.4	26.6	3 - 213
Length of breeding season, days	182	88.2	49.9	36 - 365
Pregnancy percentage	163	93.0	4.6	70.4 - 100
Pregnancy loss percentage	163	3.1	9.6	0 - 57.5
Calving Percentage	185	91.4	7.3	42.5 - 102.0
Calf death loss percentage	185	3.2	3.8	0 - 30.4
Calf crop or weaning percentage	185	86.7	7.8	42.5 - 100
Female replacement rate	178	19.7	19.4	0 - 115.4
Calving performance measures based on calves born				
Calf death loss rate, %	185	4.9	4.4	0 - 38.5.
% calves born d 1 – 21	138	56.8	15.5	11.0 - 82.0
% calves born d 1 – 42	138	84.1	11.6	38.0 - 100
% calves born d 1 – 63	138	96.0	4.8	77.5 - 100
% calves born after 63 d	138	4.0	4.9	0 - 22.5
Production performance, lb				
Avg age at weaning	185	199.0	28.0	113.0 - 300.0
Avg weaning wt steer (bull)	175	529.1	64.9	381.9 - 720.1
Avg weaning wt heifer	175	511.9	59.0	345.0 - 681.1
Avg weaning wt per calf	185	519.0	60.1	367.0 - 700.1
Lb. weaned per exposed female	185	451.0	71.1	207.0 - 620.0
Lb. weaned per acre used by the cow-calf enterprise	185	39.0	23.8	7.6 - 225.6

Table 2. SPA financial summary, $ per 100 lb of weaned calf

	N	Mean	SD	Min – Max
Investment				
Total assets	148	441.35	302.23	42.81 - 1782.29
Total liabilities	148	137.38	144.65	0.00 - 8.61
Avg real estate	148	289.02	220.63	0.00 - 1589.99
Owner's equity	148	304.28	223.75	23.53 - 1760.82
Expenses				
Veterinary medicine	108	4.08	3.00	0.00 - 14.71
Depreciation	108	11.08	10.33	0.00 - 44.98
Interest	108	8.14	8.91	0.00 - 43.37
Labor and management.	108	7.41	9.45	0.00 - 45.15
Purchased feed	108	13.56	12.43	0.00 - 63.37
Inventory adjustment	108	3.29	18.40	-110.18 - 74.57
Total expenditures	148	85.16	44.68	22.89 - 344.79
Revenue				
Calf revenue	148	79.39	42.21	11.25 - 316.92
Non-calf revenue	148	36.09	10.52	-23.60 - 167.87
Total revenue	148	93.92	36.18	126.20 - 336.57
Profit				
Breakeven	148	70.05	44.43	6.80 - 351.48
Net income	148	7.77	38.26	-15.75 - 81.62

Table 3. SPA financial summary, $ per beginning year female

	N	Mean	SD	Min – Max
Investment				
Total assets	148	2087	1473	156 - 8944
Total liabilities	148	675	783	0 - 4805
Avg real estate	148	892	1055	0 - 6977
Owner's equity	148	1413	1009	-185 - 7726
Expenses				
Veterinary medicine	108	19	14	0 - 59
Depreciation	108	51	44	0 - 192
Interest	108	39	48	0 - 230
Labor and management.	108	33	23	0 - 252
Purchased feed	108	62	57	0 - 248
Inventory adjustment	108	18	96	-377 - 418
Total expenditures	148	397	217	96 - 2009
Revenue				
Calf revenue	148	364	180	63 - 1164
Non-calf revenue	148	66	106	44 - 942
Total revenue	148	430	159	208 - 1125
Profit				
Breakeven	148	331	217	31 - 2048
Net income	148	33	175	-152 - 379

Table 4. SPA financial summary, $ per acre

	N	Mean	SD	Min – Max
Investment				
Total assets	148	191.82	176.40	12.51 - 1282.23
Total liabilities	148	46.57	58.66	0.00 - 630.11
Avg. real estate	148	113.39	155.30	0.00 - 954.17
Owner's equity	148	145.36	143.59	-11.45 - 1089.04
Expenses				
Veterinary medicine	108	2.41	4.09	0.00 - 26.07
Depreciation	108	5.59	8.99	0.00 - 58.46
Interest	108	2.62	3.40	0.00 - 19.55
Labor and management.	108	2.87	2.87	0.00 - 51.91
Purchased feed	108	7.30	6.64	0.00 - 82.72
Inventory adjustment.	108	.84	5.68	143.15 - 80.25
Total expenditures	148	33.21	35.03	4.17 - 210.48
Revenue				
Calf revenue	148	30.99	22.71	2.75 - 180.38
Non-calf revenue	148	5.21	9.32	-9.57 - 72.34
Total revenue	148	36.14	28.85	6.15 - 202.82
Profit				
Breakeven	148	28.02	32.47	1.82 - 212.55
Net income	148	6.85	16.80	-130.48 - 144.48

Table 5. SPA financial summary, owner's equity and return on assets (ROA), %

	N	Mean	SD	Min – Max
Owner's equity	148	65.0	27.3	-80 - 100
ROA	148	3.1	9.8	-37.9 - 31.9

Sorting Cattle – A Review

Kelly W. Bruns[1] and Robbi H. Pritchard[2]
Department of Animal and Range Sciences

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The value of feeder cattle when purchased is based largely on weight, breed type, and subjective evaluation. However, the true value of feeder cattle over time is the difference derived from carcass value and costs of production. Sorting groups of cattle by a trait results in reducing the variation of the trait sorted. The last 15 years we have focused on the concept of value-based marketing. Carcass value is variable and with a "Grid Pricing System" the opportunity for premiums as well as discounts exists. Costs of feeding are affected substantially by the length of the feeding period and the value of the carcass is affected by the composition of the animal at slaughter. Improvement in the classification of feeder cattle would improve the estimation of subsequent performance of individual feeder animals in groups by the assembly of more uniform outcome groups for feeding. Such a result could increase the value of feeder animals, reduce the costs of production, or both (Butts et al, 1980).

Researchers have reported that it is possible to sort cattle prior to slaughter to improve the uniformity of a portion of the cattle (Tatum et al., 1996a; Dolezal et al., 1995; Trenkle 1997). There will be a portion of the cattle however, which do not garner a premium and may even receive discounts. If cattle are not properly sorted and/or are sold on a grid that doesn't fit them, the discount received may reduce the premiums to the point that selling live would be more profitable.

The purpose of this report is to review the most current concepts of sorting cattle. The reader should be aware that individual feedlot programs and markets will dictate the involvement and extent of sorting and its usefulness.

Costs of Sorting at Market Time

In feedlots, the process of sorting involves several hidden costs that have only been addressed by one author in the literature. Stanton (1997) addressed the implications of reworking cattle and sorting to target a specific market may have.

Lost Yardage. Loss of yardage is a substantial loss that can cost feedlot operators or owners who custom feed cattle in lots. For example (Table 1) a 300 head pen of cattle fed for 100 d returns $7500 dollars to the feedlot at .25/hd/d or $525.0/week. If after 100 days one load is sorted out every week for the next 6 weeks, the net result is a loss of $1560.25 or 5.20/hd. Who will pay the loss in yardage? Will custom lots have to increase yardage or will yardage be considered on a per pen basis, if producers wish to have their pens of cattle "topped off". Delaney (2001) reported that the number one priority of feedlots is to manage occupancy. The author also stated that the two largest potential operating expenses within a feedyard are underutilized capacity and labor.

Equipment/Labor. Sorting strategies will require the use of a chute and extra labor. Some commercial feedlots will charge a 1.00/hd to run animals through the chute. If additional equipment and people are used, such as an ultrasound machine and technician, the cost may reach as high as 10.00/head.

Lost Performance. Producers must be aware of the limitations of their facilities and the stress that this can have on cattle. Reworking cattle can have a negative effect on average daily gain (ADG) (Stanton, 1997). Stanton, 1997 reported that average daily gain was reduced 5.6% and feed efficiency was 6.9% poorer.

Do cattle that are sorted for market react in the same way once they are returned to the pens? A hidden cost is the phenomenon of co-mingling cattle. Cattle behave differently when mixed with new cattle or are moved into different sized groups. Feed intakes of newly mixed cattle or pens that have been topped off may be substantially different than what is expected. Too often feed deliveries are cut back based on the average intake of the pen when in reality the

[1]Assistant Professor
[2]Professor

cattle that may have been removed were the faster gaining cattle with higher intakes. If this happens too much feed may be delivered and consequently the remaining cattle may experience some type of metabolic disorder. The loss of one steer in a pen of cattle may off set the value gained by sorting. More research in this area must be done.

Costs of Slower Gaining Cattle. A cost which is often overlooked is the cost of owning the slower gaining cattle longer. The cattle that are marketed first are faster gaining, and when they are removed, the average performance of the pen decreases dramatically. Stanton (1997) divided 62 steers that had been individually fed for 147 d into a top, middle and bottom weight group (Table 2). Steers in the top weight group ate 12% more dry matter and gained 20% more than the bottom third. The author calculated that it would take one month longer for the bottom third of the pen to equal off-test weight of the middle group. Sorting out the best performing, most efficient cattle early in the feeding period and retaining cattle that aren't as efficient is an indirect cost to the cattle owner.

Factors Affecting Cattle

Background. Breed type, weight, condition, frame, and sex have been continuously studied over the last 70 years. (Knox and Kroger, 1946; Reid et al., 1968; Cundiff et al., 1993). Prior to the 1960's, cattle were of primarily British breed descent with U.S. cattlemen only utilizing five breeds of cattle. It wasn't until the late 60's and early 70's that the influence of different breeds added greater variety in biologial type. By 1970, 32 breeds of cattle were being used extensively in breeding programs in the U.S. However, it is important to note that variation does exist within a given breed (Wheeler et al., 1996). Sorting groups of cattle by a trait results in reducing the variation of the trait sorted. Variation is reduced primarily because outliers are removed when cattle are grouped according to the traits of priority. Outliers can be cattle or carcasses that receive discounts and reduce the overall profitability of the group. In our current market system of selling cattle for commodity trade, the reduction of YG 4's, overweight carcasses, and standards can improve the gross value of a load of cattle dramatically.

Breed/Biological Type. Effects of various breeds and their biological type have been studied in depth by researches (Fortin et al., 1980; Eversole et al., 1981; Wheeler et al., 1996). The results of using slow growing, early maturing cattle are carcasses that have excess fat and low cutability. Conversely, extremely fast-growing, late-maturing cattle tend to be lean and have high cutability. A rapid increase in growth can be advantageous in producing more retail product but can have negative effects on intramuscular fat as well as fertility, calving ease, and mature size. In a classical report Cundiff et al. (1993) summarized the performance of F_1 calves from 26 sire breeds. The breeds were ranked by their ability to perform in four areas: 1) Growth rate/mature size; 2) Lean to fat ratio; 3) Age at puberty; and 4) Milk production. The data categorized the breeds into 7 different biological types (Table 3). No one breed excels in all economically important traits because of the antagonistic relationship that exits (Bruns 1994). The utilization of crossbreeding allows the producer to complementarily match breeds for specific market targets without sacrificing production efficiency. A greater number of producers are switching breeding programs to straight-bred programs in an effort to capitalize on uniformity and breed demand. Bruns (2000) summarized data of finishing steers from two sources (Ranch C n=159; Ranch W n=151) in an effort to quantify variation within a producer's calf crop. Group C were crossbred cows (Continental and British breeds) mated to Continental bulls and Ranch W were Limousin and Angus bulls used on Angus cows. Table 4 reports the mean weight and the standard deviation from the mean for each group. Between the two sources of steers there is little difference in the standard deviations for carcass traits. The data would suggest that herds of the same breed origins are not necessarily more uniform when compared to other breeds but that cattle from similar biological types may have similar degrees of variation. Understanding biological type and how crossbreeding complements two different types of cattle is beneficial when sorting cattle relative to outcome groups.

Age. Age of cattle is an important factor for sorting purposes to better-fit cattle to nutritional needs and marketing outcome groups. More importantly under the current USDA Beef Cattle Grading Standards (USDA, 1997) cattle that are B-maturity and do not obtain marbling scores of modest or higher are graded USDA Standard. Delaney (2001) reported that carcasses that are

graded as “hard bones” reflect a price discount of $246.00 per head equivalent to a reduction of feeder calf value of $35.00 /cwt. The effect of age on carcass traits has been reported in an effort to quantify changes in carcass composition (Colemen and Evans., 1986; Tatum et al., 1986a; Dolezal et al., 1995). Cattle are often subclassed by age in to three groups: 1) calves – cattle that are weaned and started on a finishing ration less than 10 mo. of age; 2) short yearling – cattle that are backrounded for a period of time and started on feed less than 14 mo. of age; and 3) long yearlings – cattle that are backgrounded for an extended period of time and started on feed at ages greater than 14 mo. Dolezal et al., (1995) classified feeder cattle relative to the USDA Grades of feeder cattle (1979) and studied the effect of age (calf-fed, short-yearling, and long-yearling) in relation to carcass traits when cattle were harvested at a constant backfat endpoint. The author reported that cattle started on feed at a younger age had greater days on feed (DOF) with lighter carcass weight than short yearlings and long yearlings. Across frame size and muscle score groups long yearling cattle had greater percentages of carcass fat with the greatest proportion being found in the intermuscular depot. The author concluded that age had a significant effect on DOF and harvest weight at a constant fat endpoint. Classifying cattle by age is important in determining DOF and optimum endpoints. It is important to note that age, irresponsive of frame size, is positively correlated to increased weight and carcass fatness. Successful identification of age groups in feeding situations would aid in the determination of DOF and projected endpoint.

Frame size. Frame size can be subjectively evaluated with ease. Researchers (Brown et al., 1973; Tatum et al., 1986a) have documented that height at a given age is positively correlated to mature size. Mature size is inversely related to rate of maturity. When comparing cattle of similar age, but different frame sizes, small-framed cattle are more advanced in their degree maturity and thus have a higher degree of fatness when compared to large frame cattle. Research investigating the outcome of USDA feeder cattle grades (1979), Tatum et al., (1986b) and Dolezal et al., (1995) reported that larger framed cattle, when harvested at similar DOF were heavier and had less condition that their small-framed contemporaries. Trenkle (2001) sorted cattle by frame score into two groups (small framed, SF; large framed, LF) (Table 5). Large frame steers tended to have heavier final weights with less backfat and larger ribeye area. Smaller framed steers consumed less feed (P<.01) and had improved (P<.10) feed efficiency. The data would indicate the opportunity for alternative feeding and marketing strategies for cattle differing in frame size.

Fat thickness/condition score. Extensive research has been conducted on the initial degree of fatness of calves, or on the subsequent relationship to carcass fatness (Butts et al., 1980; Houghton, 1988; Smith et al. 1989; Delehant et al., 1997; Trenkle and liams, 1997; Loy et al., 1998). The use of ultrasound to estimate carcass traits has aided greatly in this endeavor. Trenkle and liams (1997) sorted crossbred steers into low or high initial ultrasound backfat groups at the start of the trial. After a 158 d on feed carcass data was collected. Steers that were assigned to the low backfat group had an increased percentage of yield grade 1 and 2 carcasses (79% vs 50%). Trenkle (2001) reported that initial ultrasound backfat depth is related to carcass back fat. (Table 5) Condition scoring (CS) has been successfully used as an alternative to ultrasound to classify cattle into outcome groups (Loy et al, 1998)(Table 6). Cattle were visually appraised and assigned a CS from 1 – 9. Cattle with higher initial CS had heavier initial weights, required fewer days on feed and had greater fat thickness at harvest. Sorting calves by condition score/backfat could be useful for adjusting dry matter intake NRC (1996). Calves that are fleshier may have greater DMI while animals with less backfat should have a greater compensatory gain potential.

Muscle thickness/score. Extensive work has been conducted to study the effect of muscle shape on carcass composition (Kauffman et al., 1973; Butts et al., 1980; Tatum et al., 1986a; Tatum et al., 1986b; Dolezal et al., 1995). Research would suggest that the largest differences in muscle-to-bone ratios are found between beef and dairy breeds of cattle (Berg and Butterfield, 1968, Broadbent et al., 1976). Kauffman et al., (1973) and Tatum et al., (1986a) concluded that differences in muscle thickness classification can reflect the inherent variation in muscularity and muscle-to-bone ratios. Dolezal et al., (1995) reported that thinly muscled cattle may be perceived incorrectly because they deposit high percentages of

intermuscular fat. There is disagreement on the affect of muscle score on rate of growth. Dolezal et al., (1995) reported that thinly muscled cattle required the most time on feed and had the heaviest weights to reach the desired compositional endpoint, where as Tatum et al., (1986b) reported no difference in the linear rate of growth between muscle classification groups within a given Frame Size.

Ribeye area is an excellent indicator of the amount of muscle in a carcass and the use of ultrasound in quantifying the difference between animals at slaughter has been well proven (Houghton and Turlington, 1992; Herring et al., 1994). The use of initial ultrasound REA measurement to quantify differences in muscularity has also been studied with limited success (Butts et al., 1980; Smith et al., 1989; Trenkle and Iiams, 1997). Research (Smith et al., 1989; Trenkle and Iiams, 1997) has reported that steers with larger initial ribeye area measurements produced carcasses at harvest with correspondingly larger ribeyes. Smith et al., (1989) reported that this relationship was greater in steers that had heavier initial starting weights. It is certainly evident that when sorting cattle on initial ribeye area that initial weight aids greatly in explaining the variation between cattle.

Weight/performance. Weight has long been the primary factor as to how producers, sale barns and feedlots sort calves. In research results mentioned previously weight has been reported to be related to frame, backfat and muscling (Tatum et al., 1986a, 1986b; Trenkle and Iams 1997; Trenkle, 2001). Angus steers (n = 475) were sorted by initial weight into three evenly divided weight groups; heavy 341 kg, medium 319 kg, light 298 kg. The heavy group accounted for 4.6% of the total amount of YG 4's. Yield grade was significantly different between groups with the heavy group having heavier initial weights and higher YG's. However, the heavy group of cattle, with the most backfat, did not have the greatest percentage of carcasses grading choice and higher. Should cattle that perform slowly during the backgrounding phase be sorted off because their subsequent performance will be impaired? Cattle were identified as poor performers if their ADG was one standard deviation below the mean ADG at the end of the backgrounding phase. The data (Table 7) would suggest just because cattle gained slowly during the backgrounding phase does not imply that the same cattle will be poor performers throughout the feeding phase.

Source/calf origin. Cattle producers have increasingly become more aware of the value of effectively identifying source. Source/calf origin encompasses all of the fore mentioned topics. A study was conducted at the SDSU Feedlot research center which utilized 476 head of Angus, Angus cross steers purchased from four producers from West River SD. These steers had an initial weight of 319 kg with a range from 264 to 375 and a standard deviation of 19.8 (Table 8). Source did reveal a difference in the percentage of yield grade 4's (YG) (Table 8). Even though Source 1 had the greatest percentage of YG 4's it still had a higher total value per head, when priced on a traditional grid, than Source 4 because of greater carcass weight. Data on the morbidity rates of the sources reveals that source has a major impact.

Systems to Predict Optimum Endpoints

Ultrasound. Research has been done for the last 20 years trying to improve the accuracy and repeatability of ultrasound. Ultrasound is now being used to sort cattle into similar groups, however cattle may or may not be similar at the end of the finishing period (Iiams & Trenkle, 1997). A trial conducted by Delehart et al (1997), described a method of carcass prediction equations by using real-time ultrasound. One hundred twelve British-cross yearling steers with an average weight of 750 lbs. were utilized. All cattle were individually scanned for BF, REA and IMF every 28 days to establish prediction equations. Parameters describing backfat development were calculated. Backfat per 100 lbs. of body weight had the highest R^2 value for ending ribfat (.81) however body weight accounted for a similar amount of the variation with an R^2 value of .80. Brethour (2001) reported that at the present level of accuracy 75% of feeder cattle can be identified as to their potential to grade Choice or not. The author also reported that it is seldom possible to make backfat projections on incoming cattle because they most often have no measurable back fat thickness. It is necessary to have cattle begin the fattening process so differences can be detected.

Electronic Cattle Management. Researchers and industry personnel have focused on developing a system, which effectively sorts and

identifies cattle to target market endpoints. Fox et al. (1992) and Tylutki et al. (1994) developed a system to predict the energy requirements of cattle, which was adopted by NRC (1996). Perry and Fox (1997) developed prediction equations for carcass composition and individual feed requirements for fed cattle. These systems were used to develop an Electronic Cattle Management sorting and tracking system (ACCU TRAC™; Microchemicals, Inc., Amarillo, TX) which is described by Fox (1996) and Cravey (2001). The ECM predicts carcass and empty body weight composition so incremental costs of gain as well as quality and yield grade can be predicted. An optimal sale point is determined to maximize profitability. During processing, cattle are measured for weight, frame size by video imaging, and ultrasound for backfat depth. The system will then assign them to one of six pens. During the initial measurement the system typically groups the cattle into an early or late maturing group (Cravey, 2001). After 75 DOF, or at re-implant time, the cattle are re-measured and sorted into specific market outcome groups. At harvest all carcasses are individually measured for HCW, BF, and REA. The data is combined with feedlot performance data and provided to the owner.

Management. Delany (2001) described an effective system used at Friona Industries, L.P. Feedlot managers sort cattle based on visual and production data indicators as to how they may fit certain fed cattle pricing grids. Sorting can be effectively done during four phases of production: 1) point of purchase; 2) point of placement; 3) during the feeding period (reimplant time); and 4) point of sale. Managers are trained to sort cattle with the two goals in mind; 1) sort by priority to minimize carcass discounts; and 2) sort by grid intentions to maximize premiums. Profitability can be greatly enhanced by matching cattle to management and implant programs that fit their genetic ability. This philosophy has worked extremely well at eliminating outlier cattle. The program also resists the urge to over sort for purposes of inflating the grid price of cattle, which may cause the overall sale price of the pen to suffer.

Summary

Sorting cattle during the finishing phase can be beneficial if outcome groups are properly identified. At this time there is no foolproof method of properly identifying the cattle that may become outliers. The use of simple cost effective methods can prove beneficial in eliminating non-conformers. Properly identifying source, breed, age, frame, and condition score will help establish the future outcome of the cattle received. The use of ultrasound and other technical methods has shown to properly identify cattle that may be outliners. Visual and/or measured traits of feeder cattle do not address the effects of animal age or health and nutritional history on their future growth and performance. Sorting programs need to be more than just the quantifications of an individual animal's traits. Previous research would indicate that source of origin plays an important role in the management and marketing of calves. Information feedback may be as useful to the producer to quantify traits (morbidity, mortality, genetics) that economically make an impact on the profitability of a pen.

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Tables

Table 1. Costs – Yardage[1]

	Sorted pen	Full pen = 300 hd	Lost yardage
300 hd x 100 d x $.25 =	$7500.00	$7500	$ 0
257 hd x 7 d x $.25 =	449.75	525	75.25
214 hd x 7 d x $.25 =	374.50	525	150.50
171 hd x 7 d x $.25 =	299.25	525	225.75
128 hd x 7 d x $.25 =	244.00	525	301.00
85 hd x 7 d x $.25 =	148.75	525	376.25
42 hd x 7 d x $.25 =	73.50	525	451.50
Total	$9,089.75	$10,650	$1,580.25

[1]Adapted from Stanton (1997).

Table 2. Individual steer performance[a]

Item	Top	Middle	Bottom
No. steers	21	21	20
End wt., kg	655	617	575
ADG, kg	1.98	1.82	1.58
Feed intake, kg	9.0	8.3	8.0
Feed/kg gain, kg	4.55	4.55	5.08
Hot carcass wt., kg	403	378	351
Yield grade	2.32	2.27	2.47
% Choice	59	59	53

[a]Adapted from Stanton (1997).

Table 3. Breeds grouped by biological type[ab]

	Growth rate and mature size	Lean to fat ratio
Low growth rate	X	XX
Moderate growth rate	XXX	XXX
Bos Indicus influence	XXX	XX
High growth and maternal	XXXX	XXXX
High lean/low fat ratio	XXXX	XXXXX

[a] Adapted from Cundiff et al. (1993).
[b] Increasing numbers of x's indicate relatively higher rate.

Table 4. Standard deviations for carcass traits by source

	Ranch C	Std	Ranch W	Std	SEM
End wt, kg[a]	539	47	541	45	3.76
DP[b]	62.5[f]	1.6	61.9[g]	1.5	0.12
HCW, kg	337	31	335	30	2.3
Fat depth, cm	1.51	.37	1.51	0.38	0.031
Ribeye area, cm^2	81.5	7.5	81.4	6.7	0.55
Yield grade[c]	3.26	.59	3.19	0.58	0.047
Marbling score[d]	5.40[f]	.79	5.61[g]	0.88	0.066
Shear force, kg[e]	4.13[f]	.83	3.91[g]	0.78	0.065

[a] Final BW shrunk 4%.
[b] Hot carcass weight/shrunk (4%) final BW.
[c] Calculated by formula.
[d] 4.0 = Slight[o]; 5.0 = Small[o].
[e] Measured by Warner Bratzler Shear Force.
[f,g] Means differ ($P < 0.05$).

Table 5. Effects on feedlot performance and carcass merit of sorting feeder calves based on initial frame score and backfat[a]

	- - - Frame[b] - - -		- - - Backfat[c] - - -		- - - - - - P[d] - - - - - -		
	SF	LF	Less	More	Frame	Backfat	FxBF
Initial hip ht, in.	42.1	44.0	43.0	43.1	0.001	0.73	0.85
Starting wt, lb	477.5	542.5	499.2	520.8	0.01	0.41	0.78
Frame score	4.1	5.0	4.5	4.6	0.001	0.95	0.88
Initial backfat, in	0.080	0.085	0.062	0.103	0.22	0.001	0.72
Initial ribeye area, in^2	6.07	6.68	6.19	6.56	0.01	0.13	0.81
Final hip height, in	49.5	50.9	50.3	50.1	0.001	0.52	0.92
Final wt, lb	1,157.7	1,245.7	1,206.4	1,197.1	0.001	0.62	0.92
Days fed	190.4	191.2	193.5	188.2	0.71	0.02	0.80
Gain, lb/d	3.53	3.63	3.62	3.55	0.01	0.10	0.12
Feed intake, lb DM/d	18.6	19.8	19.2	19.3	0.001	0.68	0.62
Feed/gain	5.29	5.47	5.30	5.45	0.09	0.18	0.59
Carcass wt, lb	720	775.1	752.1	743.2	0.001	0.53	0.81
Dressing %	62.3	62.3	62.4	62.2	0.91	0.49	0.78
Marbling score[e]	435	425	425	435	0.29	0.25	0.46
Backfat, in	0.46	0.43	0.40	0.49	0.13	0.001	0.48
Ribeye area, in^2	12.4	12.9	12.7	12.6	0.001	0.79	0.24
Calculated yield grade	3.11	3.14	3.08	3.17	0.75	0.20	0.61

[a]Adapted from Trenkle (2001).
[b]Frame score calculated from hip height, SF = smaller frame; LF = larger frame.
[c]Backfat measured with ultrasound, L = less; M = more.
[d]P is the probability of statistical difference due to main effects of sorting based on initial frame score and backfat and interaction of frame score and backfat. $P < 0.05$ is statistically significant.
[e]300 = Slight[o]; 400 = Small[o]; 500 = Modest[o]; 600 = Moderate[o].

Table 6. Effect of condition score on performance and carcass traits[a]

	Condition Score			
Item	4.4	5.1	5.6	Linear effect of CS
Initial weight, lb	619	651	663	< 0.03
ADG	3.66	3.53	3.69	NS
Days on feed	185	180	178	< 0.07
Carcass weight, lb	754	758	772	NS
Fat thickness	0.48	0.53	0.61	< 0.05
Ribeye area	12.4	12.9	12.6	NS
KPH, %	2.2	2.2	2.2	NS
Yield grade	3.02	3.03	3.36	< 0.09
Marbling score[b]	1041	1046	1035	NS

[a]Adapted from Loy et al., (1998).
[b]Marbling score 1000 = Small[o].

Table 7. Backgrounding performance

Received	Head	Starter Days	Total Days	Slow starters that were slow finishers
Jan	119	63	117	6 of 16
Nov	118	44	230	3 of 13
Nov	113	41	252	1 of 17

Table 8. Performance and carcass data by source

	Source				
	1	2	3	4	Mean
Head	79	140	172	85	
In Wt	741[a]	710[b]	691[c]	688[c]	704
HCW	755	731	722	709	728
Backfat	0.69[a]	0.60[b]	0.54[c]	0.60[b]	0.59
YG	3.6[a]	3.3[b]	3.0[c]	3.4[b]	3.3
% Ch (pop source)	11/66	23/77	24/65	14/80	72
YG 4's, %	3.6	1.9	.8	1.7	8%
YG 4's/source, %	21.5	6.4	2.3	9.4	
ADG, lb	3.35	3.35	3.29	3.27	3.33
Price/cwt	60.99[a]	63.39[b]	63.18[b]	62.31[d]	63.41
Value $/hd	742.00	751.09	740.08	724.59	796.29
% deads	0	.007	2.5	0	1.25

[a,b,c,d]Means with different superscripts P < 0.01.

A Comparison of Lifetime Implant Strategies for Beef Steers

Robbi H. Pritchard[1], Kelly W. Bruns[2] and Donald L. Boggs[1]
Department of Animal and Range Sciences

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Summary

Lifetime implant strategies were developed and applied to steer calves. The design was intended for evaluating strategies rather than specific implants. Strategies involving increasing potency of products used at common stages of production. Initial implants were administered when calves were approximately 2 mo of age. Implants did not increase BW at weaning or after backgrounding ($P > 0.10$) although they did increase ADG 5% over non-implanted controls during backgrounding ($P < 0.05$). The influence of implants on ADG was more pronounced during the finishing phase of production. Implants increased ($P < 0.05$) finishing phase ADG 18%, DMI 7.2%, and feed efficiency 9.4%. Overall post-weaning ADG increased 12% ($P < 0.05$) due to implants. Performance results changed when evaluating data on a live versus carcass weight basis due to differences in dressing percent. Increasing potency of the implant strategies caused progressive increases ($P < 0.05$) in carcass weight and ribeye area. Implanted steers produced fatter carcasses than did non-implanted steers ($P < 0.05$). There were no advances in skeletal or lean maturity attributable to the potency of the implant strategy. The frequency of carcasses grading Average Choice or better declined with implants. Implant strategies had no relevant influence on shear force. Overall, 12% of carcasses had a shear force > 5.0 kg (undesirable).

Introduction

Growth promotants administered as implants are widely used in cattle production because of their cost-benefit ratio. These products increase ADG and gain efficiency and improve the cutability of beef carcasses. While they have been proven effective in most phases of cattle production, there is limited information on the cumulative influences of these products on production rates and carcass characteristics.

The cattle industry has recently become more aware of the importance of consumer satisfaction in the beef produced. Marbling scores and the percentage of carcasses that grade Choice or higher have declined in recent years, the penalty for dark-cutting carcasses and B maturity has increased, and there is a new awareness of toughness of beef retail product. The compounds used in implants can increase the prevalence of each of the previously mentioned carcass defects. However, there is limited data that can quantify how prudent lifetime management of cattle and their exposure to implants affects cattle production rates or beef carcass quality.

This experiment was designed to evaluate the influence of implants on production efficiencies and carcass traits. In forming these strategies, production was divided into three phases. These phases included the suckling phase, a post-weaning backgrounding phase, and a finishing phase. Implants were selected to provide varying degrees of potency to achieve an overall implant strategy. (Table 1)

Materials and Methods

Two cooperating ranches were identified that could each provide 160 steer calves which would provide a total of 80 steers in each of four implant treatment groups. These ranches were typical of operations in central (Ranch C) and western (Ranch W) South Dakota. They produced spring born calves: March - April on Ranch W and April-May on Ranch C. All calves were individually identified. When calves were approximately 2 months of age (May 28, Ranch W and June 16, Ranch C) they were branded, castrated, dehorned (if necessary), and implanted. As calves were randomly restrained, implants were applied in the sequence of None, Ralgro, Ralgro and Synovex-C. Ranch identification was recorded with the implant administered. After processing, calves were turned back onto range with their dams. At each

[1] Professor
[2] Assistant Professor

ranch, calves were managed in common pastures. No creep feeding was done at either ranch.

In the fall, calves were separated from dams and herdmates and sent directly to the SDSU Research Feedlot in Brookings. This occurred on October 27 (Ranch C) and November 3 (Ranch W). Long-stemmed grass hay and water were available in the receiving pens. Steers were allowed to rest overnight in these pens before being processed. During processing, individual BW were determined and used as the weaning BW and feedlot arrival BW. Unique ear tags were applied and cross-referenced with ranch identification. Post weaning implants were administered based upon treatment assignments made at branding (initial implants). There were 159 of 183 steer records that could be matched from Ranch C and 151 of 160 records that could be matched from Ranch W.

During this initial processing, calves were vaccinated with MLV vaccine for IBR, BVD, PI_3, BRSV (Resvac 4), clostridia sp, and Haemophilus somnus (Ultrabac 7, somubac[1]) and treated for internal and external parasites (Dectomax[2]). Calves were randomly assigned within treatment and ranch to pens. The Ranch C steers were distributed among 8 concrete floor pens (25' x 25') with approximately 10 steers each and 4 earthen floor pens (60' x 160') of approximately 20 steers. Each treatment was represented by two smaller pens and one of the larger pens. The Ranch W steers were distributed among 16 of the smaller pens with 8, 9, or 10 steers per pen. Steers remained in these pens during the receiving phase of the experiment.

The receiving diet (Table 2) was fed throughout the receiving phase. Feed deliveries were made once daily. Long-stemmed grass hay was added to feedbunks in the afternoons of days 1 to 3 following allotment to pens. Calves were evaluated for thriftiness twice daily. The receiving period lasted 44 d for Ranch C and 41 d for Ranch W steers.

At the end of the receiving period, individual BW were determined and calves were moved to a commercial backgrounding yard. Two commercial pens were used, one pen for each ranch. This precluded evaluation of implant strategy effects on DMI or feed efficiency during the backgrounding phase. During this phase, steers were fed a low energy grower diet (Table 2) intended to support 1.75 lb ADG. This phase continued for 58 d (Ranch C) or 57 d (Ranch W).

All steers were returned to the SDSU Research Feedlot for finishing. Upon arrival at the feedlot, steers were individually weighed and received the next scheduled implant. This followed an overnight rest with access to long-stemmed grass hay and water. The following day steers were sorted to pens by ranch and treatment. Allotment was done so that BW was uniformly distributed in all pen replicates of a treatment. This arrangement provided for 16 pens of steers from each source and 8 pens of steers on each implant strategy.

During the finishing phase, a single high concentrate diet was fed twice daily (Table 2). This required programmed increases in feed deliveries for the initial 21 d after which steers were fed ad libitum. Interim BW were determined after 35, 72, and 107 d for Ranch C steers and 35, 70, and 105 d for Ranch W steers. Final BW were determined after 150 d and 132 d on feed for ranches C and W, respectively. Re-implanting was done while processing on d 70 or 72 according to implant strategies.

During the receiving and finishing phases, feed ingredients were sampled once each week and analyzed for dry matter, crude protein, and ash. NDF and ADF were also determined on the fibrous feedstuffs. Diet composition and DMI were then calculated based upon ingredient assays, feed batching, and delivery records. Daily DMI was summarized at 7 d intervals. During the backgrounding phase only as-fed feed records were available.

The original protocol called for harvesting steers when ribfat depth averaged .4 to .5" and for each implant strategy to have common days on feed. Access to packing facilities was delayed, resulting in a 21 d extension in the feeding period for Ranch W. These calves were harvested after a 132 d finishing period and were fatter than intended. To maintain consistency in management, the Ranch C steers were then fed to a similar fat endpoint, which required a 150 d finishing period.

[1] Smithkline Beecham
[2] Pfizer

Bodyweights were determined in the morning before cattle were fed. There was no restriction of access to feed or water prior to weighing the steers. Consequently, fill is a component of all interim BW data. Cumulative weight changes were calculated as final BW shrunk 4% (Pen mean basis) and also by calculating individual final BW as hot carcass weight ÷ .625.

At harvest, individual steer identity was maintained. SDSU personnel recorded carcass weight, measured ribeye area and ribfat depth, and estimated lean and bone maturity. Marbling scores were estimated to the nearest 0.1 score and KPH, (%) were estimated to the nearest 0.5% by the USDA Grader on duty. Grading followed a 72 h chill. After grading, a 3" section of the rib was removed anterior to the point where carcasses were ribbed for grading. This cut was identified and brought back to SDSU for determination of Warner-Bratzler shear force.

Production and carcass data were analyzed in a model that included main effects of ranch, treatment, and ranch x treatment. Individual BW at weaning/feedlot arrival and carcass variables were evaluated by considering each steer to represent an experimental unit. During the receiving phase and finishing phase of the experiment, data (BW, ADG, DMI, and F/G) were evaluated on a pen mean basis. The ADG of backgrounding (i.e. weaning to beginning of finishing) was tested using steer as the experimental unit since pen integrity was not maintained throughout this phase of production.

Results and Discussion

Suckling and Backgrounding Phases. Upon arrival at the feedlot in the fall, records were matched on 79, 75, 78, and 78 steers from treatments 1, 2, 3, and 4, respectively. All of these steers remained as part of the experiment through harvest. The Ranch C steers were younger than the Ranch W steers and were lighter upon arrival at the feedlot (Table 4). Ranch C calves also had a high incidence of pinkeye that required therapy. Otherwise, health problems during the receiving periods were minimal

Weaning weights measured at feedlot arrival were not affected by previous implant ($P > 0.10$). Age and genetics have significant influences on early growth and contribute to a large variance associated with weaning weight. The use of ADG as a test for pre-weaning growth is more sensitive but was not feasible in this experiment.

During the receiving period, implanted steers grew faster and more efficiently than non-implanted steers ($P < 0.01$; Table 4). DMI was not affected by implants. Behavioral aspects of weaning and relocation could override intake stimulatory effect of implants during the short receiving period.

When steers were relocated to the grower pens, treatments were co-mingled within source for 57 or 58 d. Consequently, DMI and feed/gain (F/G) could not be quantified for the entire backgrounding phase. Implants did not cause higher ADG ($P > 0.05$) while in the grower pens. For the entire backgrounding phase, ADG was increased ($P < 0.05$) by implanting, and the ranking of means at this stage was consistent with the perceived potencies of the implants administered (Table 5). When evaluated on a pen mean basis (finishing phase allotment), Treatment 4 did cause higher BW than other treatments at the end of backgrounding (Table 6).

Finishing Phase. The BW at the end of backgrounding was also the initial BW for the feedlot finishing phase. At this point, Ranch C steers were lighter than Ranch W steers (687 vs 726 lb; $P < 0.01$). It was clear that this difference in BW would probably cause differences in time required to achieve condition suitable for harvest. The decision was made to re-implant according to a common timeline and let payout on the final implant be variable. Schedule conflicts caused slight deviations in days between interim weights (Table 3). To simplify the semantics, interim periods during the finishing phase were described as A, B, C, and D. The BW-D (Table 5) is the final live, unshrunk, body weight recorded the day before harvest.

The ADG, DMI, and F/G responses were improved by implant treatments during Period A (Table 6). There was a trend ($P < 0.10$) for Treatments 2 & 3 to cause a higher ADG and lower F/G than Treatment 4. This effect was not evident during Period B. The cumulative early performance (Period A & B) was improved by implanting but did not differ among implant treatments (Table 6). Re-implanting occurred at the beginning of Period C. During the 35 d following re-implanting, implants increased ADG

and DMI and lowered F/G ($P < 0.05$). Steers on Treatment 3 grew faster and more efficiently than steers on Treatments 2 or 4. The advantage of Treatment 3 over Treatment 2 could be anticipated. The previous implant history for these two treatments were identical until the beginning of Period C. At re-implanting a 72 mg Zeranol implant would not have as much growth-promoting activity as 72 mg Zeranol + 140 mg trenbalone acetate (TBA). The cause for improved performance by Treatment 3 over 4 is unclear. It could be a difference in the Zeranol +TBA growth promotion as compared to Revalor-S or an influence of cumulative implant exposure over time causing diminished responses in Treatment 4, or a combination of both factors.

The surge in performance demonstrated by Treatment 3 during Period C was transient. During Period D, ADG was similar among implant treatments. Treatment 3 did sustain higher DMI during this period than occurred with Treatments 2 and 4. Implanted steers continued to consume more feed and grew faster than non-implanted steers ($P < 0.05$) in this final phase of production.

Cumulative performance was calculated on a live weight basis (4% shrink) or by estimating final live BW of each individual as carcass weight ÷ 0.625. On a live basis, implants increased ($P < .05$) ADG and DMI and reduced ($P < 0.05$) F/G (Table 7). Among implants, Treatment 3 tended ($P < 0.10$) to cause higher final BW, ADG, and DMI than Treatment 2. When performance was determined by calculation from carcass weight, Treatment 4 caused higher final BW ($P < 0.05$) and lower F/G ($P < 0.05$) than Treatments 2 or 3. Treatment 3 tended ($P < 0.10$) to cause a heavier final BW and higher ADG than Treatment 2.

Implants in general increased carcass weight and ribeye area and caused a slight increase in carcass maturity while lowering marbling scores. There was a numerical decline in the proportion of higher Quality Grade carcasses as the aggressiveness of the implant strategy increased (Table 8). Repeated use of implants did not cause dark cutters or Standard Grade carcasses. There were no shifts in the frequencies of very tender or tough carcasses characterized as shear force < 3.5 or > 4.9, respectively. There was no biologically relevant shifts in overall mean shear force values attributable to implants (Table 8).

The two sources of cattle were harvested at similar BW and fat endpoints (Table 9). Subjective measures (i.e. KPH, marbling, and maturity) did differ ($P < .05$) between sources as did shear force. These may have been real or may reflect the variability associated with these more subjective determinations. The Ranch C cattle were younger when weaned and exposed to post-weaning implants. Genetics also differed between sources. These factors could have influenced carcass traits. It is important to note that there were no source x treatment interactions applicable to carcass traits. This indicates that the influence of implant strategies was consistent in spite of the differences in age, genetics, and days on feed.

Conclusions

The emphasis of this experiment was on the cumulative influence of implant strategies on finishing phase performance and especially upon carcass traits. Increasing the aggressiveness of the implant strategy increased final BW and improved efficiency in the feedlot. It is interesting that final live BW were similar between Treatments 3 and 4 but that carcass weights differed between these treatments. This should be investigated further to determine if prolonged exposure to higher potency implants would consistently improve dressing percentage.

The results of this experiment suggest that lifetime implant strategies can be adjusted to optimize production efficiencies and quality grades for a specific set of circumstances. These strategies had consistent effects across cattle of different genetic backgrounds (but similar biological type). Finally, it appears that relatively aggressive implant strategies can be applied over the lifetime of a calf without causing increases in unacceptable carcasses or reducing tenderness of the meat produced.

Tables

Table 1. Implant use by production phase

Production phase	Treatment 1	2	3	4
	- Implant Used -			
Suckling	None	Ralgro	Ralgro	Synovex C
Backgrounding	None	Ralgro	Ralgro	Revalor-g
Finishing				
Initial	None	Ralgro	Ralgro	Synovex-S
d70 Re-implant	None	Magnum	Magnum/ Component TS	Revalor-s

Table 2. Diets used[a]

	Receiving	Background	Finish
Grass hay	40.00		6.00
Corn silage		66.55	
Oat hay		13.47	
Wheat straw		10.74	
Cracked corn	50.59		
Whole corn			66.20
Soybean meal	4.50	6.21	2.25
Commercial Liquid A		3.04	
Commercial Liquid B			4.25
Limestone	0.60		0.70
Trace mineralized salt	0.30		
$ZnSO_4$	0.01		
Wheat midds			0.60
Wet corn gluten feed			20.00
Molasses	4.00		
CP[b]	12.4	11.5	12.4
NE_m, Mcal/cwt[b]	77.6	64.1	91.7
NE_G, Mcal/cwt[b]	45.1	40.0	61.3

[a]% DM basis.
[b]Calculated values.

Table 3. Chronology of events

	Source			
	Ranch C		Ranch W	
Event	Date	Elapsed days since previous event	Date	Elapsed days since previous event
Initial implant	6/16	0	5/28	0
Weaning	10/27	133	11/3	159
Begin background	12/11	44	12/15	41
Begin finishing	2/8	58	2/11	57
Finishing BW				
A	3/15	35	3/18	35
B (re-implant)	4/21	37	4/22	35
C	5/26	35	5/27	35
D	7/8	43	6/23	27
Harvest	7/9	1	6/24	1

Table 4. Receiving period production traits by ranch and treatment

	Ranch		
	C	W	Var
Weaning BW, lb	470[a]	516[b]	4.7
End receiving BW, lb	603[a]	654[b]	4.9
ADG, lb	3.03[a]	3.37[b]	0.082
DMI, lb	13.50	13.50	0.149
F/G	4.46[a]	4.06[b]	0.085

	Treatment				
	1	2	3	4	Var
Weaning BW, lb	490	491	491	500	6.7
End receiving BW, lb	615	639	626	635	6.9
ADG, lb	2.94[a]	3.49[b]	3.18[b]	3.20[b]	0.216
DMI, lb	13.26	13.56	13.75	13.43	0.116
F/G	4.51[a]	3.93[c]	4.38[b]	4.22[bc]	0.120

[a,b,c]Means in same row without common superscripts differ (P < 0.01).

Table 5. Body weights and interim ADG based upon individual steer observations

	Treatment				
	1	2	3	4	SEM
n	79	75	78	78	
Weaning BW, lb	493	488	490	498	6.6
End receiving BW, lb	619	635	626	635	7.5
End background BW, lb	699	704	704	720	7.8
Finishing phase					
BW A, lb	842[a]	859[ab]	864[ab]	870[b]	9.3
BW B, lb	978[a]	998[ab]	997[ab]	1012[b]	10.1
BW C, lb	1092[a]	1132[b]	1157[b]	1153[b]	10.9
BW D, lb	1182[a]	1244[b]	1267[b]	1271[b]	11.6
	ADG, lb				
Receiving	2.96[a]	3.47[c]	3.20[b]	3.22[b]	0.066
Growing	1.40[bc]	1.19[a]	1.35[b]	1.48[c]	0.041
Background	2.06[a]	2.15[b]	2.13[ab]	2.22[b]	0.033
Feedlot					
Early	3.93[a]	4.16[b]	4.14[b]	4.11[b]	0.058
Late	2.90[a]	3.51[b]	3.87[c]	3.71[c]	0.067
Cumulative	3.09[a]	3.49[b]	3.64[c]	3.55[bc]	0.045
Overall [‡]	2.66[a]	2.93[b]	3.01[b]	3.00[b]	0.033

[a,b,c] Means without common superscripts differ (P < 0.05).
[‡] 2 vs. 3 (P < 0.10).

Table 6. Steer performance during the finishing phase

	Treatment				
	1	2	3	4	SEM
Initial BW, lb	700[a]	703[a]	704[a]	720[b]	1.4
Period A					
ADG, lb*	4.07[a]	4.43[b]	4.58[b]	4.27[ab]	0.076
DMI, lb	19.32[a]	19.92[ab]	20.34[b]	19.88[ab]	0.156
F/G	4.77[a]	4.51[b]	4.45[b]	4.67[ab]	0.059
Period B					
ADG, lb	3.80	3.90	3.75	3.96	0.096
DMI, lb	22.13[a]	23.76[b]	24.01[b]	23.47[b]	0.245
F/G*	5.85[a]	6.11[ab]	6.49[b]	5.97[ab]	0.067
Early cumulative[d]					
ADG, lb	3.93[a]	4.16[b]	4.16[b]	4.11[ab]	0.055
DM, lb	20.74[a]	21.86[b]	22.20[b]	21.70[b]	0.184
F/G	5.30	5.25	5.35	5.28	0.053
Period C					
ADG, lb	3.24[a]	3.80[b]	4.56[c]	4.03[b]	0.067
DMI, lb	23.33[a]	24.44[b]	25.46[c]	24.77[bc]	0.241
F/G	7.24[a]	6.43[b]	5.61[c]	6.15[b]	0.108
Period D					
ADG, lb	2.54[a]	3.25[b]	3.15[b]	3.38[b]	0.109
DMI, lb	23.06[a]	25.42[b]	26.22[c]	25.36[b]	0.191
F/G	9.15[a]	7.99[ab]	8.50[ab]	7.57[b]	0.291
Late cumulative[e]					
ADG, lb	2.90[a]	3.53[b]	3.88[c]	3.71[c]	0.505
DMI, lb	23.24[a]	24.92[b]	25.84[c]	25.06[bc]	0.163
F/G	8.02[a]	7.09[b]	6.68[c]	6.75[bc]	0.097

[a,b,c]Means without common superscripts differ ($P < 0.05$).

* 3 vs. 4 ($P < 0.10$).

[d]Periods A through B.

[e]Periods C through D.

Table 7. Cumulative finishing phase performance using shrunk or carcass adjusted final body weight

	Treatment				
	1	2	3	4	SEM
Live weight					
ADG, lb[I]	3.09[a]	3.49[b]	3.65[b]	3.55[b]	0.038
DMI, lb[I,*]	21.98[a]	23.37[b]	23.98[b]	23.35[b]	0.123
F/G	7.12[a]	6.70[b]	6.58[b]	6.57[b]	0.057
Final BW, lb[I]	1146[a]	1208[b]	1230[c]	1234[c]	5.5
Carcass adjusted					
ADG, lb[I]	2.99[a]	3.44[b]	3.57[bc]	3.61[c]	0.037
F/G	7.36[a]	6.80[b]	6.73[b]	6.47[c]	0.058
Final BW, lb[I]	1120[a]	1198[b]	1206[b]	1230[c]	5.3

[a,b,c]Means without common superscripts differ ($P < 0.05$).

[I] 2 vs 3 ($P < 0.10$).

*3 vs 4 ($P < 0.10$).

Table 8. Carcass characteristics of implanted steers

	Treatment				
	1	2	3	4	SEM
Dress, %[a]	61.7[e]	62.1[e]	61.9[e]	62.9[f]	0.17
Carcass Wt, lb	700[e]	742[f]	752[fg]	768[g]	2.2
Ribeye area, in^2	12.25[e]	12.45[ef]	12.76[f]	13.10[g]	0.123
Fat depth, in	0.54[e]	0.62[f]	0.61[f]	0.60[f]	0.017
KPH, %	2.51[e]	2.28[f]	2.33[f]	2.23[f]	0.042
Lean maturity[b]	1.53[e]	1.59[f]	1.59[f]	1.59[f]	0.009
Bone maturity[b]	1.47[e]	1.61[f]	1.61[f]	1.62[f]	0.010
Yield grade[c]	3.10[e]	3.34[f]	3.26[ef]	3.18[ef]	0.066
Marbling[d]	5.68[e]	5.54[ef]	5.38[f]	5.38[f]	0.095
Shear force, kg	4.02[ef]	3.84[e]	4.06[ef]	4.15[f]	0.093
	Distributions, %				
Yield Grade					
1 & 2	34	19	31	32	
3	58	67	58	59	
4	8	15	12	9	
Quality Grade					
Avg., High Choice & Prime	25	20	15	14	
Low Choice	56	57	59	58	
Select	19	23	26	27	
Standard	0	0	0	1	
Shear force					
< 3.5, kg	22	32	19	20	
> 3.4 < 5.0, kg	66	58	68	67	
> 4.9, kg	12	11	13	13	

[a]Hot carcass weight/shrunk (4%) final BW.
[b]100 = A^o 200 = B^o.
[c] Calculated by formula.
[d] 4.0 = Slight^o; 5.0 = Small^o.
[e,f,g] Means without common superscripts differ (P < 0.05).

Table 9. Carcass traits by cattle source

	Ranch C	Ranch W	SEM
Dress, %[a]	62.5[e]	61.8[f]	0.12
Carcass wt, lb	744	737	5.0
Ribeye area, in^2	12.7	12.6	0.086
Fat depth, in	.60	.59	0.012
KPH, %	2.49[e]	2.18[f]	0.030
Lean maturity[b]	1.57	1.58	0.007
Bone maturity[b]	1.60[e]	1.56[f]	0.007
Yield Grade[c]	3.26	3.18	0.047
Marbling[d]	5.39[e]	5.60[f]	0.066
Shear force, kg	4.13[e]	3.91[f]	0.065

[a]Hot carcass weight/shrunk (4%) final BW.
[b]100 = A^o 200 = B^o.
[c] Calculated by formula.
[d] 4.0 = Slight^o; 5.0 = Small^o.
[e,f]Means differ ($P < 0.05$).

Feeding Value of Rolled and Whole Shelled Waxy Corn in Finishing Diets

Robbi H. Pritchard[1] and Kelly W. Bruns[2]
Department of Animal and Range Sciences

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Summary

Waxy corn in rolled or whole shelled form was compared with rolled normal corn in finishing diets for cattle. Steers (n = 144; initial BW = 765 lb) were allocated to 18 pens and fed these three grain types in a 123 d experiment. The waxy corn was a sole source grain that tested >99% pure waxy endosperm. The normal rolled was acquired as needed through a commercial elevator. Diets contained 78% grain as NR) normal rolled; WR) waxy rolled; or WW) waxy whole grain. Diet had no effect on DMI and there were no differences for production variables between NR and WR treatments (P > 0.10). When waxy corn was fed in whole grain form there was a 7% reduction (P < 0.05) in ADG and a 5% increase (P < 0.05) in feed required per pound of gain. The reduced ADG caused by WW corresponded to lower carcass weight. The WR treatment caused an increase in KPH (P < 0.05). No other effects on carcass characteristics were observed. In rolled form waxy and normal corn have comparable feeding value in finishing diets. Rolling waxy corn will increase feed value by approximately 5%.

Introduction

The waxy endosperm mutation of corn was found in China in 1909. The starch in waxy corn is 100% amylopectin. In typical dent yellow corn the starch is 75% amylopectin, 25% amylose. Amylopectin is thought to be more digestible than amylose. Waxy corn has been evaluated as a grain source for cattle but results have been inconsistent.

There is a premium market for waxy corn because of its food processing characteristics. Those characteristics may be favorable in finishing diets of cattle. They may also diminish the need for grain processing. We chose to evaluate waxy corn in rolled or whole shelled form relative to rolled normal corn in high concentrate diets being fed to yearling steers.

Materials and Methods

A single diet formulation (Table 1) was used throughout this experiment. Within the constraints of the formulation, the three treatments involved use of either NR) normal (dent yellow) rolled corn; WR) waxy rolled corn; or WW) waxy whole shelled corn. Normal corn was purchased from commercial elevators periodically throughout the experiment. The waxy grain was all from a sole source and purchased in one lot. The waxy corn source was sampled three times, evaluating 800 seeds per sample. Waxy purity in these samples ranged from 99.3 to 99.5%. Diets were formulated to contain 12.75% Crude Protein, 93 Mcal NE_m/cwt and 62 Mcal NE_G/cwt.

The 144 steers used were selected from a population of 178 steers that had been part of a receiving-backgrounding experiment at the research feedlot. Allotment included stratification of the two previous treatments across current treatments.

Management at the ranch of origin affected body weights at allotment and was accommodated by nesting that prior management within replicate pens. After these allowances were made, steers were ranked by body weight (final weight from backgrounding experiment) and assigned a random sequence of treatment codes. Final assignment was for 18 pens (6 pens per corn source) of 8 steers. The feeding experiment began January, 2001.

A one diet step-up program was used. Initially, feed delivery was set at 12.5 lb. Feed delivery was then systematically increased until each pen achieved it's own plateau for voluntary intake. Feed was delivered once daily in the afternoon. The steers were implanted with Revalor-S after 28 d on feed.

Individual body weights were recorded initially and after 28, 56, 84, 112, and 123 d on feed.

[1]Professor
[2]Assistant Professor

There was no restriction of feed or water prior to weighing the steers. Cumulative performance was based upon a final live weight calculated as hot carcass weight/0.625. Diet ingredients were sampled weekly as assayed for DM, CP, and ash. Fiber (NDF and ADF) was determined only for the oat silage. Dry matter intake was quantified by applying ingredient DM contents to feed batching records on a weekly basis. Two animals were removed from the experiment after 56 d as it became apparent that they were bulls. Their body weight records were deleted from the data set, and they were presumed to have consumed the average daily DMI of their respective pens prior to removal.

Steers were co-mingled and shipped to the packing plant (145 mi) 24 h after final body weight was measured. Individual identity of steers was tracked through the slaughter and grading processes. The hot carcass weight, ribeye area, and ribfat depth were measured. USDA graders assigned to the plant made visual appraisals of marbling (nearest 1/10) and KPH (nearest 0.5%). Complete carcass data were recovered on 134 of the 142 steers slaughtered.

Data were analyzed by procedures appropriate for a completely random design with main effects of diet (n = 3) and replicate (n = 6). Performance data (ADG, DMI, and feed/gain) were analyzed on a pen mean basis. Carcass data analyses were conducted by considering each steer to represent an experimental unit. Separation of least squares means were tested using Fishers test in the GLM package of SAS.

Results and Discussion

Normal corn tested higher in crude protein (CP) and ash than did the waxy corn (Table 2). It was also more variable. On average, the difference in CP in corn sources could have altered diet CP by < 0.5% points. Since all diets should have exceeded CP requirements of these steers, this difference probably had little influence on experimental outcomes.

Steers were marketed after 123 d on feed. We observed no grain effects on steer performance during the initial 84 d on feed. Gains were uniformly low during the period of 57 to 84 d. Because of harsh winter conditions, the cattle had gradually accumulated a substantial quantity of mud by March (56 d BW) but had almost completely shed out by the d-84 weight in April. The loss of 40 lb of mud in this 28 d period would affect apparent ADG by 1.43 lb/d. Intake and health records during this period and subsequent performance and carcass data are indications that there were no disease problems associated with the numerical slump in ADG. Because of the short time (11 d) between 112 d and 123 d weights, final period performance was evaluated from 85 to 123 d.

Although interim ADG had been similar ($P > 0.10$), after 123 d body weight was lower ($P < 0.05$) for the WW treatment (Table 3). Cumulative performance indicated the WW grain caused ($P < 0.05$) lower ADG and higher F/G than either rolled grain treatment. No differences in performance were evident among the two rolled grain sources. Feed intake was not affected by treatment.

The whole waxy corn caused ($P < 0.05$) lighter carcasses and a lower dressing percentage (Table 4). The only other carcass trait affected by grain source was KPH, which was higher ($P < 0.05$) for the WR than other treatments. The increase in KPH was not sufficient to affect Yield Grade. The distribution of Yield Grade and Quality Grade frequencies is indicative of quality cattle and was not affected by grain source (Table 5).

Results of this experiment indicate that when feeding rolled corn as the base diet ingredient for finishing cattle, there is no difference in energy value between normal and waxy corn. When evaluating only waxy corn sources, a 7% improvement in ADG and a 5% improvement in feed efficiency were achieved by rolling the grain.

Tables

Table 1. Test diet

	%, DMB
Oat silage	8.00
Corn[a]	78.73
Soybean meal, 44%	9.02
Liquid supplement[b]	4.25

[a] Either as normal-rolled, waxy-rolled or waxy-whole.
[b] Provided monensin and tylosin to make final diet 28 g/T and 11 g/T, respectively; provided vitamins and minerals to meet or exceed nutrient requirements (NRC, 1996).

Table 2. Corn sample analyses based upon weekly samples

	Normal-rolled	Waxy-rolled	Waxy-whole
Dry matter	85.28 ± 0.34	85.52 ± 0.21	86.72 ± 0.13
Crude protein[a]	9.60 ± 0.48	8.80 ± 0.09	8.63 ± 0.06
Ash[a]	1.70 ± 0.25	1.07 ± 0.02	1.04 ± 0.01

[a]DM basis.

Table 3. Interim period and cumulative performance of steers by treatment

	Treatment			
	Normal-rolled	Waxy-rolled	Waxy-whole	SEM
Initial BW, lb	763	768	765	3.0
1 to 28 d				
d-28 BW, lb	909	922	913	4.4
ADG, lb	5.21	5.48	5.24	0.184
DMI, lb	18.23	18.28	18.21	0.105
F/G	3.55	3.35	3.49	0.119
29 to 56 d				
d-56 BW, lb	1045	1052	1037	5.3
ADG, lb	4.88	4.65	4.48	0.137
DMI, lb	22.09	22.44	21.56	0.432
F/G	4.56	4.83	4.83	0.151
57 to 84 d				
d-84 BW, lb	1100	1111	1095	5.6
ADG, lb	1.95	2.10	2.07	0.110
DMI, lb	20.76	21.26	21.05	0.425
F/G	10.74	10.19	10.43	0.636
85 to 123 d				
d-123 BW, lb	1236[b]	1243[b]	1219[c]	3.1
ADG, lb	3.49	3.38	3.18	0.097
DMI, lb	20.60	21.04	20.60	0.323
F/G	6.02	6.37	6.64	0.220
Cumulative, carcass adjusted				
Final BW[a]	1219[b]	1229[b]	1195[c]	4.3
ADG, lb[a]	3.71[b]	3.74[b]	3.49[c]	0.041
DMI, lb	20.44	20.78	20.37	0.275
F/G	5.51[b]	5.55[b]	5.84[c]	0.059

[a] Least squares means.
[b,c]Means without common superscripts differ (P < 0.05).

Table 4. Carcass characteristics by treatment[a]

	Treatment			
	Normal-rolled	Waxy-rolled	Waxy-whole	SEM
Hot carcass weight, lb	766[d]	767[d]	748[e]	6.6
Dress, %[b]	64.25[d]	64.45[d]	63.84[e]	0.180
Ribeye area, in^2	12.43	12.24	12.18	0.156
Ribfat depth, in	0.45	0.46	0.46	0.016
KPH, %	2.00[d]	2.23[e]	1.94[d]	0.050
Marbling[c]	6.1	6.2	6.0	0.149
Yield grade	2.97	3.11	2.98	0.066

[a]Least squares means.
[b]Based upon 4% shrink of final live weight.
[c]$Small^0$ = 5.0; $Slight^0$ = 4.0.
[d,e]Means without common superscripts differ (P < 0.05).

Table 5. Carcass grading distributions by treatment

	Treatment		
	Normal-rolled	Waxy-rolled	Waxy-whole
	%		
Yield Grades			
1 & 2	55	43	61
3	43	54	39
4	2	2	0
Quality Grades			
Prime	16	20	14
Avg. – High Choice	39	33	36
Low Choice	27	35	27
Select	18	13	23

The Effects of Trace Mineral Inclusion Management on the Performance and Mineral Status of Newly Received Feeder Calves

Howard M. Blalock[1], Robbi H. Pritchard[2], William Epperson[3]
Departments of Animal and Range Sciences and Veterinary Science

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Summary

The objective of this study was to determine the effects of trace mineral inclusion management on the performance and mineral status of newly received feeder calves. Steers from 2 pastures at a single ranch in Western South Dakota blocked into non-implanted (**NI**; n = 64; BW = 240 kg), May implanted (**MI**; n = 64; BW 252 kg;) and August implanted (**AI**; n = 66; BW = 248 kg;) groups, then allotted to one of two treatment groups. Treatments consisted of either: a pelleted supplement fed at a fixed amount to meet the gram / daily requirement (**GDR**) of Cu (as $CuSO_4$) and Zn (as $ZnSO_4$) of a growing steer or as a percent of the diet (**PER**). Liver biopsy and blood samples were collected at the initiation of the trial and again after 28 d on feed. The ADG and feed conversion (**F/G**) was not affected by diet treatment. Cumulative DMI tended to be greater ($P < 0.10$) in PER diets (7.31 vs. 7.12 kg). Steers receiving PER treatments tended ($P < 0.11$) to have less of a decrease in hepatic Zn than GDR treatments. The change in hepatic K was affected ($P < 0.05$) by implant with AI steers having the greatest increase. These results suggest that if performance and morbidity are enhanced by feeding Cu and Zn to meet the gram daily requirement of the animal, then Cu and Zn may need to be fed at a greater level to see any differences from this practice.

Keywords: Feedlot, Copper, Zinc, Selenium, Mineral Status

Introduction

Stress is manifested in cattle in a variety of ways. Feeder calves are subjected to many stressors in the process of marketing and transit, therefore, calves new to the feedlot environment may experience a decrease in DMI. This decreased feed intake could potentially result in nutrient deficiencies during this time period causing further strains on the immune system of already stressed calves. Trace mineral nutrition has a potential of being effected during this time period, including those associated with immune function such as Cu and Zn. Therefore, the effects of increasing the diet density of these nutrients on performance and morbidity were selected. The objective of this study was to determine the effects on performance and morbidity of feeding supplemental Cu and Zn either at a fixed amount to meet the gram, daily requirement of growing steers or as a percent of the total diet so that nutrient intake was dependent upon DMI.

Materials and Methods

Single source Angus and Angus-Limousin steers received on November 3 from western South Dakota were used in this trial. Upon arrival, all animals received long stem hay and free access to water. The following day, all calves were weighed, individually identified, vaccinated with a 7-way clostridial vaccine and with a modified live vaccine containing Infectious Bovine Rhinotracheitis Virus (IBR), Parainfluenza 3 (PI_3), Bovine Respiratory Syncytial Virus (BRSV) and Haemophilus Somnus. Calves were treated with doramectin for internal and external parasites.

The 194 steers were blocked into 3 prefeedlot implant treatment groups: non implant (NI), May implanted (MI) at branding, or August implanted (AI). The MI and AI steers were implanted with a Synovex S. The implant treatments were not a part of this study, however, any interaction effects caused by these treatments will be tested for in the statistical analysis. Within the implant treatments, a small percentage of the calves were maintained in a different pasture at the ranch. These calves were stratified across all treatment groups. Within implant groups, animals were assigned to one of two diet treatments. Each diet was replicated by 12 pens (4 pens / implant treatment).

Diet (Table 1) consisted of corn silage, rolled corn, a pelleted ionophore supplement and a

[1] Graduate Student
[2] Professor
[3] Associate Professor

pelleted mineral supplement (Table 2). Copper (as $CuSO_4$) and Zn (as $ZnSO_4$) were included in the mineral supplement (Table 2). The mineral supplement was included in the diet at either a percentage (PER) of the diet (6.5% DMB) or as a total, fixed amount (GDR) of the diet (1 lb. / head / day), which would meet the total daily requirement of the calves. The supplement was included in the GDR diet at 1 lb., until that amount was 6.5% of daily DMI of the pen. The proportion of all other diet constituents were held the same so that the CP and caloric content of the diets would remain equal. Diets were fed once daily in the morning.

Weekly feed samples were analyzed for Cu, Zn, Ca, Fe, Mg, Mn, K, Na, S and P using atomic absorption spectrophotometry and Mo using atomic absorption with graphite furnace during the initial 28 days on feed. These samples were also assayed for Se using the fluorometric method. Subsequent weekly samples were analyzed for the listed minerals as biweekly composites.

Steers were weighed at the time of processing and after 1, 27, 55 and 64 days on feed. Liver biopsy and serum samples were obtained 4 days after arrival and after 27 days on feed from 48 steers (2 steers / pen, 24 steers / diet). Liver samples were analyzed for Cu, Zn, Mo, S, Fe, Na, K, Ca, P, Mg and Mn using the ICP procedure. Serum samples were assayed for Se concentration using the fluorometric method.

Liver biopsy was performed using a JorVet Soft Tissue Biopsy Needle (Jorgensen Laboratories, Inc., Loveland, CO) inserted through a puncture wound at the point where a horizontal line drawn cranial from the middle of the paralumbar fossa crosses the eleventh intercostal space on the right side of the animal. Animals which were biopsied were given a prophylatic dose of long acting penicillin following the procedure. Hepatic tissue was kept at –20° C until shipped to be analyzed. Serum samples were obtained via jugular venipuncture using non-heperanized evacuated tubes. Whole blood was centrifuged for 30 minutes the morning following sampling and serum removed and frozen at –20° C until analysis could be performed.

A morbid steer was identified using criteria based on general appearance of the animal, willingness to eat, as well as other symptoms associated with illness such as coughing, non-clear discharge from the nasal passage, and lameness. Animals considered morbid were treated as outlined in the South Dakota State University Research Feedlot Health Protocol.

Animal performance and mineral data was analyzed as a factorialized design using the GLM procedure of SAS. Pen was the experimental unit used in the analysis of performance variables and animal was the experimental unit used in the analysis of serum and liver mineral concentrations.

Results and Discussion

It took 14 d before DMI was sufficient that 1 lb. of supplement was 6.5% of the diet. The diets fed during the initial 14 d were analyzed for differences in diet composition. Subsequent inclusion levels of ingredients were equal for both treatment groups. Crude protein, DM, NDF and NEg was not different ($P > 0.10$) between the treatments (Table 3).

The mineral content of the diets during the first 14 days on feed (Table 4) were different ($P < 0.01$) in Ca with PER diets containing a greater concentration. Even though Ca levels were statistically different, the relative difference in the values is quite small, so the importance of this difference I believe to be insignificant.

The ADG (Table 5) was not different ($P > 0.10$) between diet treatments during any feeding period or overall. Due to the energy content being similar during the initial 28 d on feed, any effect on ADG should be due to mineral supplementation. Since mineral levels in both diets were similar during the initial 14 d on feed, an affect on ADG probably would not be expected

Dry matter intake (Table 5) was not effected by diet through d 28 and d 55 ($P > 0.10$) on feed, although, cumulative DMI tended to be greater ($P < 0.10$) in PER. Feed conversion (Table 5) was not affected ($P > 0.10$) by diet during any period of the feeding trial. The absence of an affect on DMI and F/G is probably due to the diets fed being similar in nutrient content. A deficiency of many nutrients can decrease DMI. Since diets were similar in nutrient content, an effect on performance and morbidity rate probably would not be expected.

The change in hepatic and serum mineral levels over the initial 28 d was analyzed to determine any affects. The change in hepatic Zn was the only element on which differences were detected. The PER diets tended to cause less of a decrease (*P < 0.13*) in hepatic Zn concentrations than did steers fed the GDR diets (Table 7). The lack of differences due to diet in the trace minerals examined was probably due to the concentrations being similar in the diets. The change in hepatic K concentration was increased (*P < 0.05*) to a greater extent in August implanted cattle than any other implant treatment. Estradiol has been demonstrated to affect Cu and Zn status of rats. Other studies have seen an effect of implants on other macrominerals but to my knowledge an effect on K has not been demonstrated prior to this trial. There appears to be an affect of implants on the mineral nutrition of cattle but more research is needed to better define the involvement. Morbidity rate (5.7%) was not affected by diet or implant treatment.

Tables

Table 1. Diet composition[a]

	Diet	
Ingredient, % DM basis	PER	TDR
Corn silage	60.0	61.6
Rolled corn	30.0	34.3
Ionophore suppl.	3.5	4.1
Mineral suppl.	6.5	(1 lb/hd/day)

[a] Diet contained monensin @ 20 g/ton, 2205 IU Vitamin A/kg, 22 IU Vitamin E/kg.

Table 2. Supplement composition

	Supplement	
Ingredient, % DM basis	Ionophore	Mineral
Soybean meal, 44%	42.8571	81.3846
Ground corn	23.7143	18.5923
Limestone	26.2857	
TM salt[a]	7.1429	
$ZnSO_4$		0.0154
$CuSO_4$		0.0077

[a] Contains not less than 94% NaCl, 37% Na, 0.35% Zn, 0.20% Fe, 0.20% Mn, 0.03% Cu, 0.007% I, 0.005% Co.

Table 3. Composition of diets

Item, DM basis	Diet	
	PER	GDR
d 1 to 14		
DM[a], %	44.8 ± 0.97	45.1 ± 1.09
CP[a], %	10.7 ± 0.10	11.0 ± 0.56
NDF[a], %	31.7 ± 1.25	31.6 ± 0.99
ADF[a], %	18.1 ± 0.10	18.0 ± 0.01
Ash, %	5.13 ± 0.03	5.15 ± 0.02
NE_m[b], Mcal/kg	1.85 ± 0.002	1.86 ± 0.003
NE_g[b], Mcal/kg	1.19 ± 0.10	1.19 ± 0.09
d 15 to 69		
DM[a], %	45.1 ± 0.42	
CP[a], %	11.3 ± 0.09	
NDF[a], %	30.1 ± 0.37	
ADF[a], %	16.8 ± 0.36	
Ash, %	5.13 ± 0.04	
NE_m[b], Mcal/kg	1.85 ± 0.002	
NE_g[b], Mcal/kg	1.18 ± 0.08	

[a] Based on assayed values.
[b] Values calculated based on NRC (1996) tabular feed values.

Table 4. Mineral concentration of diets

Item, DM basis	Diet	
	PER	GDR
d 1 to 14		
Ca, %	0.54 ± 0.01	0.54 0.01
P, %	0.28 ± 0.00	0.29 ± 0.01
Na, %	0.12 ± 0.01	0.12 ± 0.01
K, %	0.81 ± 0.00	0.83 ± 0.02
Mg, %	0.24 ± 0.00	0.24 ± 0.00
S, %	0.14 ± 0.00	0.15 ± 0.01
Cu, ppm	9.87 ± 0.08	10.29 ± 0.53
Mo, ppm	0.85 ± 0.02	0.88 ± 0.04
Zn, ppm	28.56 ± 0.16	29.02 ± 0.51
Se, ppm	0.27 ± 0.00	0.28 ± 0.01
Fe, ppm	122.5 ± 0.50	123.0 ± 1.00
Mn, ppm	25.3 ± 0.10	25.5 ± 0.20
d 15 to 69		
Ca, %	0.55 ± 0.01	
P, %	0.28 ± 0.01	
Na, %	0.12 ± 0.01	
K, %	0.83 ± 0.01	
Mg, %	0.25 ± 0.01	
S, %	0.14 ± 0.00	
Cu, ppm	10.30 ± 0.08	
Mo, ppm	1.03 ± 0.01	
Zn, ppm	30.42 ± 1.07	
Se, ppm	0.24 ± 0.01	
Fe, ppm	112.3 ± 1.71	
Mn, ppm	27.8 ± 0.68	

[a] All values based upon feed assays.

Table 5. Backgrounding phase performance by diet treatment

	Diet			
Item	PER	TDR	SEM	P <
Initial BW, lb	543	544	4.70	NS
Final BW, lb	750	751	7.46	NS
d 1 to 27				
ADG, lb	4.08	4.04	0.14	NS
DMI, lb	12.74	12.41	0.19	NS
F/G	3.13	3.11	0.08	NS
d 28 to 55				
ADG, lb	3.23	3.17	0.10	NS
DMI, lb	16.89	16.51	0.19	NS
F/G	5.31	5.25	0.17	NS
d 56 to 69				
ADG, lb	3.56	3.67	0.24	NS
DMI, lb	18.75	18.14	0.22	NS
F/G	5.54	5.17	0.38	NS
Cumulative				
ADG, lb	3.64	3.61	0.07	NS
DMI, lb	16.12	15.70	0.18	0.10
F/G	4.44	4.36	0.06	NS

Table 6. Backgrounding phase performance by implant treatment

	Implant Treatment			
Item	NI	MI	AI	SEM
Initial BW, lb	529[a]	556[b]	547[b]	5.76
Final BW, lb	739	763	750	9.13
d 1 to 27				
ADG, lb	3.90	4.19	4.10	0.18
DMI, lb	12.41	12.90	12.41	0.24
F/G	3.19	3.13	3.05	0.10
d 28 to 55				
ADG, lb	3.44[a]	3.22[a, b]	2.93[b]	0.13
DMI, lb	16.69[a]	17.24[a, b]	16.16[a, c]	0.11
F/G	4.85[d]	5.42[e]	5.58[e]	0.21
d 56 to 69				
ADG, lb	3.44	3.51	3.88	0.29
DMI, lb	18.24[a]	19.21[b]	17.88[a]	0.26
F/G	5.66	5.63	4.78	0.47
Cumulative				
ADG, lb	3.64	3.66	3.55	0.09
DMI, lb	15.79[a]	16.45[b]	15.48[a]	0.22
F/G	4.34	4.50	4.36	0.07

NI = non-implanted; MI = May implanted; AI = August implanted at the ranch.
[a, b, c] Within a row, mean with different superscript letters differ (P < 0.05).
[d, e] Within a row, means with different superscript letters differ (P < 0.10).

Table 7. Initial and change in hepatic and serum mineral concentrations by diet

	Diet		
Item	PER	GDR	SEM
Initial			
Cu	63.28	66.05	8.01
Mo	2.83	2.92	0.08
Zn	185.0	197.3	7.27
Ca	254.5	243.0	6.17
P	10995	10,868	110
Mg	628.8	614.5	6.20
S	7479	7427	76.3
Fe	362.8	339.3	11.4
Na	3755	3562	100
K	8444	8481	137
Mn	6.47	5.97	0.15
Se[a]	0.085	0.084	0.001
Change			
Cu	29.5	32.3	4.55
Mo	0.12	0.18	0.10
Zn	-45.2[b]	-62.1[c]	7.57
Ca	-15.3	-12.5	8.48
P	-513	-140	135
Mg	29.9	36.8	10.2
S	-103	-134	123
Fe	-78.8	-80.0	14.4
Na	204.6	213.8	133
K	649.6	551.7	168
Mn	0.66	0.85	0.17
Se[a]	0.001	-0.001	0.002

[a] Serum concentration of the element.
[b, c] Within a row, means tended to be different ($P < 0.11$).

Table 8. Initial and change in hepatic and serum mineral concentrations by implant treatment

	Implant Group			
Item, ppm	NI	MI	AI	SEM
Initial				
Cu	73.77	62.29	57.94	9.81
Mo	2.86	2.97	2.79	0.10
Zn	190.6	184.9	197.9	8.90
Ca	247.4	251.4	247.3	7.56
P	10931	10877	10987	135
Mg	627.6	619.3	618.1	7.59
S	7470	7406	7483	93.5
Fe	361.8	329.1	362.2	14.0
Na	3624	3598	3753	123
K	8567	8213	8608	167
Mn	6.30	6.21	6.14	0.18
Se[a]	0.084	0.082	0.088	0.002
Change				
Cu	28.6	31.9	32.1	5.57
Mo	0.26	0.18	0.03	0.12
Zn	-54.4	-47.4	-59.1	9.27
Ca	-8.00	-22.0	-11.7	10.4
P	-435	-171	-375	166
Mg	22.8	27.4	49.8	12.5
S	-155	33.1	-234	151
Fe	-70.8	-68.3	-99.3	17.6
Na	418	163	45.6	163
K	311[b]	916[c]	575[b,c]	206
Mn	0.68	1.01	0.57	0.20
Se[a]	-0.001	0.001	-0.001	0.002

[a] Serum concentration of the element.

[b, c] Within a row, means with different superscript letters tended to differ ($P < 0.13$).

Effect of Diets Containing Soybean Hulls or Rolled Corn on the Performance and Mineral Status of Newly Received Calves

Howard M. Blalock[1], Robbi H. Pritchard[2], William Epperson[3]
Departments of Animal and Range Sciences and Veterinary Science

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Summary

The objective of this study was to determine the effectiveness of soybean hulls as an energy source for newly received feeder calves and their effects on ADG, DMI, gain/feed (**G/F**), morbidity rate and mineral status. Steers from a single source were blocked into previously weaned (**PW**; n = 63; BW = 265 ± 2.9 kg) and non-weaned (**NW**; n = 92; BW = 264 ± 2.4 kg) groups, then allotted to one of two dietary treatment groups. Diets consisted of either rolled corn (**CRN**) or soybean hulls (**SBH**), and oat silage and vitamin/mineral supplements. Liver biopsies and blood samples were collected at the initiation of the trial and again after 28 d on feed. Steers fed CRN had lower ($P < 0.10$) ADG through d 28 compared to SBH. Previously weaned steers had a higher ($P < 0.10$) ADG than NW steers through d 28. The SBH diets caused higher ($P < 0.01$) DMI through d 28 and overall. There was a diet × weaning group interaction ($P < 0.10$) for DMI through d 28. Cumulative feed/gain (**F/G**) was lower ($P < 0.05$) for cattle fed CRN diets. Liver Cu concentrations decreased ($P < 0.01$) by 22% in steers fed SBH, but were unchanged in steers fed CRN diets. Previously weaned steers had a greater loss of liver Cu compared to NW steers ($P < 0.01$). Liver Zn concentration was affected by a diet × weaning group interaction ($P < 0.05$). Morbidity rate (6.5%) was not affected by treatments. These results suggest the use of soybean hulls in newly received calf diets has the potential to stimulate DMI, and that Cu and Zn in soybean hulls may have limited availability.

Key words: Soybean hulls, Rolled corn, Feedlot, Steers, Minerals

Introduction

Soybean hulls (**SBH**) are high in NDF and ADF. It is a common practice to use higher fiber feedstuffs with newly received feeder calves. SBH represent a palatable and digestible fiber source. The use of SBH in diets fed to receiving calves has been reported to increase dry matter intake. This could be advantageous to the calves by helping to stimulate intakes of those calves which intakes are expected to be low. The objectives of this study were to determine the effectiveness of SBH as an energy source in newly received feeder calves and SBH effects on production variables and mineral status.

Materials and Methods

Single source, Angus steers received from a ranch in western South Dakota on October 31 were used in this trial. Upon arrival, all calves received long stem hay and free access to water. The following day, all calves were weighed, individually identified, vaccinated with a 7-way clostridial vaccine and with a modified live vaccine containing Infectious Bovine Rhinotracheitis Virus (IBR), Parainfluenza 3 (PI_3), Bovine Respiratory Syncytial Virus (BRSV) and Haemophilus Somnus. Calves were treated with doramectin for internal and external parasites.

Steers (n = 155) were blocked into two groups, steers not weaned (NW) at the ranch (n = 92, BW = 584 ± 5.3 lb) and steers weaned (PW) approximately 30 d prior to shipment and fed at the ranch (n = 63, BW = 584 ± 6.4 lb). The previously weaned steers were from 2 and 3 year old dams. Within these blocks, steers were then allotted to one of two diets.

Diets consisted of oat silage (45%) and either rolled corn (CRN) or soybean hulls (SBH) making up 45% of the diet. The remaining 10% was comprised of a pelleted supplement (Table 1). The diets were formulated to have similar CP levels and provide adequate metabolizable protein. The caloric content of the diets were allowed to be different while keeping the proportion of CRN and SBH equal. Both diets were formulated to meet or exceed NRC (1996) requirements and to contain similar levels of Cu and Zn. Copper (as $CuSO_4$) and zinc (as

[1] Graduate Student
[2] Professor
[3] Associate Professor

$ZnSO_4$) supplementation were needed in the CRN diet to meet NRC requirements of these minerals. Supplemental Cu and Zn were not required in the SBH diets. Diets were replicated by 9 pens, 4 PW pens and 5 NW pens.

During the initial 28 d on feed, feed samples were analyzed weekly for Cu, Zn, Ca, Fe, Mg, Mn, K, Na, S and P using atomic absorption spectrophotometry and Mo using atomic absorption spectrophotometry with a graphite furnace[1] (Table 3). These samples were also assayed for Se using a fluorometric method. Subsequent weekly feed samples were analyzed for the listed minerals as biweekly composites (Table 4).

Steers were weighed at the time of processing and again after 8 d on feed at which time a Ralgro Magnum implant was administered. Subsequent body weights were recorded after 28, 57 and 74 d on feed. All weights were recorded prior to feeding with no restrictions of feed or water. Liver biopsies and serum samples were obtained 3 d after arrival and after 28 d on feed from 54 steers (3 steers / pen, 27 steers / diet). Liver samples were analyzed for Cu, Zn, Mo, S, Fe, Na, K, Ca, P, Mg and Mn using inductively coupled plasma-atomic emission[2] spectroscopy. Serum samples were assayed for Se concentration using a fluorometric method.

Liver biopsies were performed using a JorVet Soft Tissue Biopsy Needle[3] inserted through a puncture wound at the point where a horizontal line drawn cranial from the middle of the paralumbar fossa crosses the eleventh intercostal space on the right side of the animal. Animals were given a prophylatic dose of long acting penicillin (20 ml, 300,000 IU / ml; sc) following the biopsy procedure. Hepatic tissue was kept at - 20° C until analyzed. Serum samples were obtained via jugular venipuncture using non-heparinized evacuated tubes. Whole blood was centrifuged for 30 minutes the morning following sampling and serum removed and frozen at –20° C until analyzed.

Morbidity was identified using criteria based on general appearance of the animal, willingness to eat, as well as other symptoms associated with illness such as coughing, non-clear discharge from the nasal passage, and lameness. Animals considered morbid were treated as outlined in the South Dakota State University Research Feedlot Health Protocol.

Animal performance and mineral data were analyzed as a factorialized design using the GLM procedure of SAS. Pen was the experimental unit used in the analysis for all performance variables. Animal was the experimental unit used for all physiological mineral variables.

Results and Discussion

The nutrient composition of the diets was based upon laboratory assays (except NE). The CP content was similar between diets, while SBH diets had a greater NDF and ADF content and a lower NEm and NEg content. Diet comparisons were made for first 28 days (Table 3) as well as for the entire feeding period (Table 4) on all mineral constituents. The Cu, Zn, Se, Ca and P levels were lower ($P < 0.01$) in the SBH diets while these diets contained greater ($P < 0.01$) levels of Fe, Mg, Mn and K.

Initial and final body weights did not differ ($P > 0.10$) between diets. Through d 28, steers fed SBH tended to have a greater ($P < 0.10$) ADG than CRN fed steers. This effect on ADG began to diminish through subsequent weighing periods. The increased ADG in steers fed SBH through d 28 may have been caused by fill differences associated with the greater DMI of steers fed SBH.

Steers fed SBH had a higher DMI ($P < 0.01$) than those fed the CRN diets through d 28 and overall (Table 5) (Figure 1). The increase in DMI could be due to cattle having a preference for SBH or may be a function of rumen kinetics. Feed conversion (Table 5) was not affected through d 28, however; overall F/G was greater ($P < 0.05$) in the SBH fed steers compared to CRN fed steers.

Preweaning management was confounded by cow age and sires represented. Accordingly it is not a useful comparison of previous weaning as a management tool. The PW calves were acclimated to total mixed diets that were fortified with trace minerals. since this may affect behavior (especially eating behavior) and

[1] Olson Biochemistry Labs, SDSU
[2] Animal Health Diagnostic Laboratory – Toxicology, Michigan State Univ.
[3] Jorgensen Laboratories, Inc., Loveland, CO

mineral status at feedlot arrival, these data are presented for consideration of diet influences across management group.

Previously weaned steers had a greater (*P* < *0.*10) ADG than NW steers through 28 d on feed. There was no effect of weaning group on ADG for the remainder of the feeding period. The difference in ADG seen in PW steers may also be a result of greater fill caused by higher DMI. The 28 d DMI was also affected (*P* < *0.*10) by a diet x weaning group interaction (Figure 2) in which SBH caused a greater increase in DMI over corn in PW vs NW steers. Previously weaned steers also had a greater DMI (*P* < *0.01*) through d 28 and overall compared to non-weaned steers (Figure 1).

The hepatic and serum mineral concentrations revealed that there could be an availability issue with some of the nutrients in SBH diets. Hepatic Cu levels (Table 6) were decreased (*P* < *0.01)* to a greater extent in steers fed SBH than in steers fed CRN. There was a 22% decrease in liver Cu in SBH fed steers while liver Cu remained unchanged in the CRN fed steers. Lower dietary Cu, lower digestibility of Cu in SBH, or interference caused by elevated Fe levels in SBH may be contributing factors in this response. The decrease in liver Cu concentrations was also greater (*P* < *0.01*) in PW steers compared to NW steers (Table 7). This difference was probably a result of PW steers having a greater (*P* < *0.*01) initial hepatic Cu concentration than NW steers (Table 7). Hepatic Zn concentration included a diet x weaning group interaction (*P* < *0.05*) (Table 7). The decrease in hepatic Zn concentrations for CRN and SBH diets, respectively, was 35% and 30% in PW steers while the decrease in NW steers was 13% and 25% respectively. Previously weaned steers had a greater decrease (*P* < *0.01*) in hepatic P and S concentration (Table 7). Even though 17% of the animals had hepatic Cu levels that were lower than 25 ppm, apparent Cu deficiency symptoms were not present in any of the animals. The morbidity rate in this study was 6.5% throughout the entire trial and neither morbidity nor mortality was affected by diet or weaning group.

Tables

Table 1. Diet composition[a]

Ingredient	Diet	
	CRN	SBH
	---------- % ----------	
Oat silage	45.0	45.0
Rolled corn	45.0	
Soybean hulls		45.0
Supplement		
Soybean meal	7.901	5.029
Ground corn	0.874	4.597
Limestone	0.892	0.055
TM salt[b]	0.298	0.295
Premix	0.027	0.024
$CuSO_4$	0.002	
$ZnSO_4$	0.006	

[a] DM basis.
[b] Contains not less than 94% NaCl, 37% Na, 0.35% Zn, 0.20% Fe, 0.20% Mn, 0.03% Cu, 0.007% I, 0.005% Co.
[c] Premix provided added dietary levels of: monensin at 20g/ton; 1000 IU Vitamin A/lb; 10 IU Vitamin E/lb.

Table 2. Nutrient composition of diets

Item	Diet		SEM
	CRN	SBH	
Dry matter[a], %	68.8	70.3	0.60
Crude protein[a],%	11.8	12.3	0.20
NDF[a], %	26.2	52.2	3.00
ADF[a], %	14.9	34.3	2.24
Ash[a], %	6.10	7.33	0.06
NE_m[b], Mcal/cwt	81	75	2.2
NE_G[b], Mcal/cwt	51	47	0.45

[a] Values based upon feed assays.
[b] Value calculated based on NRC (1996) values.

Table 3. Mineral content of diets for initial 28 days [a]

	Diet		
Item	CRN	SBH	SEM
Ca, %	0.50	0.37	0.03
P, %	0.30	0.20	0.02
Na, %	0.25	0.25	0.002
K, %	1.32	1.69	0.07
Mg, %	0.15	0.19	0.01
S, %	0.20	0.21	0.001
Cu, ppm	13.2	10.2	0.59
Zn, ppm	41.9	33.2	1.68
Mo, ppm	1.34	1.30	0.03
Se, ppm	0.37	0.38	0.01
Fe, ppm	131	327	37.2
Mn, ppm	29.2	37.5	1.56

[a] All values based upon feeds assays.

Table 4. Mineral composition of diets for entire feeding period[a]

	Diet		
Item	CRN	SBH	SEM
Ca, %	0.48	0.38	0.01
P, %	0.30	0.23	0.01
Na, %	0.25	0.25	0.001
K, %	1.31	1.71	0.05
Mg, %	0.15	0.20	0.01
S, %	0.20	0.20	0.01
Cu, ppm	13.0	10.6	0.29
Zn, ppm	43.2	35.1	1.04
Mo, ppm	1.41	1.22	0.07
Se, ppm	0.39	0.38	0.003
Fe, ppm	129	335	23.8
Mn, ppm	30.3	42.8	1.66

[a]All values based upon feeds assays.

Table 5. Backgrounding phase performance by diet treatments

	Diet			
Item	CRN	SBH	SEM	P< [a]
Initial BW, lb	584	582	3.84	NS[b]
Final BW, lb	809	814	5.03	NS
d 1 to 28				
ADG, lb	2.73	2.98	0.22	0.10
DMI, lb	12.8	13.6	0.15	0.01
F/G	5.16	5.07	0.12	NS
d 29 to 57				
ADG, lb	3.15	3.31	0.11	NS
DMI, lb	19.2	21.1	0.26	0.01
F/G	6.10	6.42	0.21	NS
d 58 to 74				
ADG, lb	2.62	2.27	0.18	NS
DMI, lb	21.6	24.1	0.22	0.01
F/G	8.43	11.6	1.11	0.10
Cumulative				
ADG, lb	2.87	2.95	0.15	NS
DMI, lb	16.7	18.3	0.20	0.01
F/G	5.82	6.19	0.11	0.05

[a] Probability.
[b] P > 0.10.

Table 6. Backgrounding phase performance by weaning management groups

	Weaning Group		
Item	NW	PW	P < [a]
Initial BW, lb	582 ± 5.27	584 ± 6.37	NS[b]
Final BW, lb	807 ± 6.57	818 ± 7.92	NS
d 1 to 28			
ADG, lb	2.73 ± 0.20	3.00 ± 0.22	0.10
DMI, lb	12.2 ± 0.15	14.2 ± 0.18	0.01*
F/G	4.47 ± 0.12	4.73 ± 0.13	NS
d 29 to 57			
ADG, lb	3.22 ± 0.11	3.29 ± 0.13	NS
DMI, lb	19.7 ± 0.24	20.7 ± 0.29	0.05
F/G	6.16 ± 0.20	6.36 ± 0.22	NS
d 58 to 74			
ADG, lb	2.47 ± 0.18	2.43 ± 0.20	NS
DMI, lb	22.9 ± 0.22	22.7 ± 0.24	NS
F/G	9.67 ± 1.04	10.4 ± 1.17	NS
Cumulative			
ADG, lb	2.84 ± 0.15	2.98 ± 0.15	NS
DMI, lb	16.8 ± 0.18	11.1 ± 0.20	0.01
F/G	5.92 ± 0.11	6.07 ± 0.12	NS

[a] Probability.
[b] P > 0.10.
* Diet x Weaning group interaction P < 0.10.

Table 7. Initial and change in hepatic and serum mineral concentrations by diet

Item	Diet		SEM
	CRN	SBH	
	- - - - - - - -Initial, ppm - - - - - - - -		
Cu	90	86	8.7
Mo	3.22	3.32	0.09
Zn	189	176	75
Ca	258	251	47
P	11,448	11,569	91.0
Mg	667	667	6.0
S	7,761	7,768	64.6
Fe	341	307	13.5
Na	3,715	3,671	91.9
K	9,426	9,437	103
Mn	6.56[d]	7.00[e]	0.12
Se[a]	0.099	0.095	0.002
	- - - - - - - - Change, ppm - - - - - - - -		
Cu	2.07[b]	-18.8[c]	3.07
Mo	- 0.19	- 0.08	0.08
Zn	- 45.1	-47.3	8.03
Ca	- 22.0	- 13.0	5.55
P	- 1,079	-1,051	117
Mg	- 28.7	- 28.6	7.55
S	-378	-209	71.6
Fe	- 41.9	- 11.6	15.7
Na	21.1	274	120
K	- 700	- 993	174
Mn	0.55[b]	1.43[c]	0.17
Se[a]	- 0.012	- 0.009	0.002

[a] Serum concentration of the element.
[b, c] Within a row, means differ ($P < 0.01$).

Table 8. Initial and change in hepatic and serum mineral concentrations by weaning management group

Item	Weaning Group	
	NW	PW
	- - - - - - - - - - Initial , ppm- - - - - - - - - - - - -	
Cu	55.32 ± 8.16[b]	120.5 ± 9.12[c]
Mo	3.37 ± 0.08	3.17 ± 0.09
Zn	176.9 ± 7.05	188.1 ± 7.88
Ca	234.3 ± 4.42[b]	274.8 ± 4.94[c]
P	11,397 ± 85.8	11,620 ± 95.9
Mg	632.0 ± 5.64	701.7 ± 6.31[c]
S	7,569 ± 60.9[b]	7,959 ± 68.1[c]
Fe	307.4 ± 12.7	340.0 ± 14.2
Na	3,618 ± 86.6	3,769 ± 96.9
K	9,065 ± 97.0[d]	9,798 ± 108[e]
Mn	6.98 ± 0.11[d]	6.58 ± 0.12[e]
Se[a]	0.092 ± 0.002[b]	0.103 ± 0.002[c]
	- - - - - - - - - - - - - Change, ppm - - - - - - - - - - - - -	
Cu	- 0.40 ± 2.90[b]	- 16.3 ± 3.24[c]
Mo	- 0.12 ± 0.07	- 0.16 ± 0.08
Zn*	- 33.3 ± 7.58[b]	- 59.1 ± 8.47[c]
Ca	- 8.20 ± 5.23	- 26.8 ± 5.85
P[d]	- 788.0 ± 111[b]	- 1343 ± 5.85
Mg	1.00 ± 7.12[b]	- 58.3 ± 7.96[c]
S[d]	24.7 ± 67.5[b]	- 612 ± 75.5[c]
Fe	- 24.9 ± 14.8	- 28.6 ± 16.5
Na	119.7 ± 113	175.4 ± 126
K	- 340.3 ± 164[b]	- 1353 ± 183[c]
Mn	0.90 ± 0.16	1.08 ± 0.17
Se[a]	- 0.003 ± 0.002[b]	- 0.017 ± 0.002[c]

[a] Serum concentration of the element.
[b, c] Within a row, means differ ($P < 0.01$).
[d, e] Within a row, means differ $P < 0.05$).
[*] Diet x Weaning group interaction ($P < 0.01$).

Figures

Figure 1. DMI for each treatment group for entire feeding period

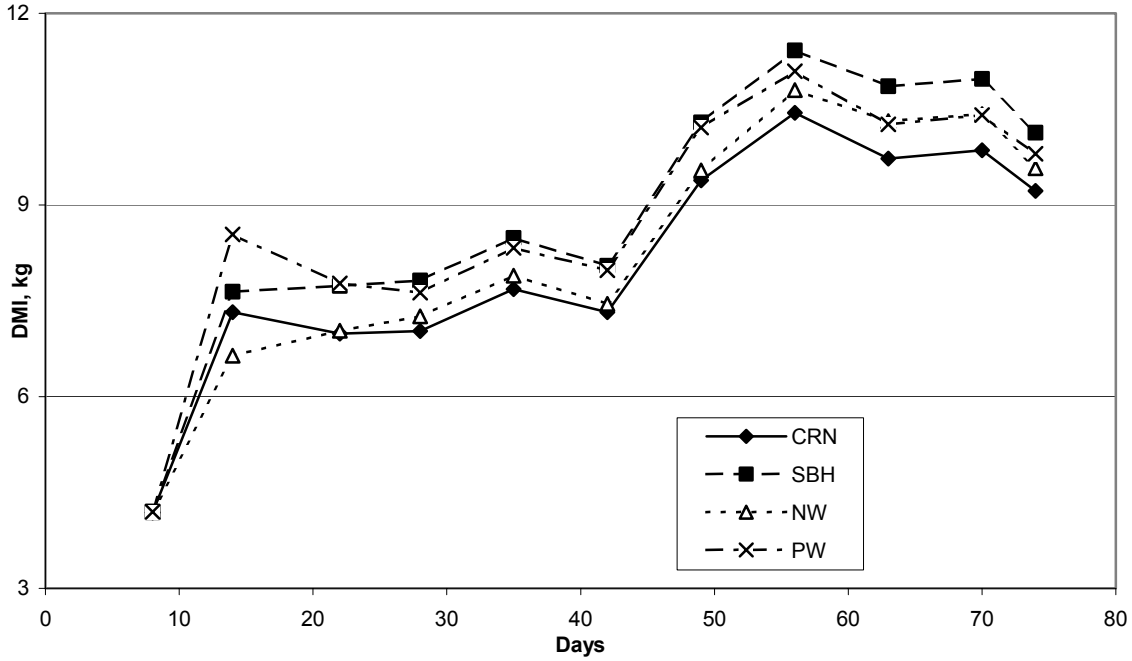
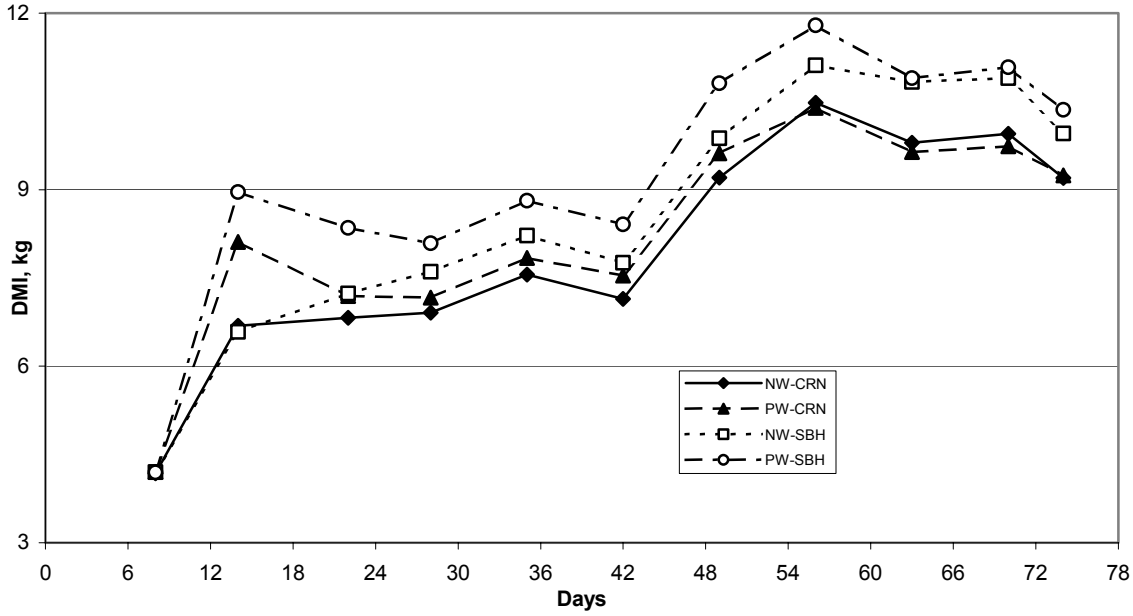


Figure 2. DMI interaction effects



Effects of Water Quality on Performance and Health of Growing Steers

Hubert H. Patterson[1], Patricia S. Johnson[2], Doug B. Young[3], and Ronald Haigh[4]
Department of Animal and Range Sciences

BEEF 2003 – 15

Abstract

Water available to livestock in western South Dakota is often high in total dissolved solids (TDS) and sulfates. Eighty-one crossbred, yearling steers (700 lb) were used to determine the effects of TDS and/or sulfates in water on cattle performance and health. Cattle were stratified by weight and randomly assigned to one of 12 pens (6-7 steers/pen). Pens were randomly assigned to one of four treatments (three pens/treatment) based on supplied water: 1) rural water (RW; 1,019 ppm TDS; 404 ppm sulfates, 2) well water (WW; 4,835 ppm TDS; 3,087 ppm sulfates), 3) dam water (DW; 6,191 ppm TDS; 3,947 ppm sulfates), and 4) DW early switched to 10,000 ppm TDS water mid-summer (DWS). The DWS treatment was not achieved due to less than predicted TDS in dam water late in the summer, resulting in six pens in the DW treatment (three treatments). Dam water was transported from a local stock dam, and well water was pumped from a well on the research station. From June 20 to September 12, steers were fed a diet of grass hay and wheat middlings (NEg = 0.38 to 0.42 Mcal/lb), and the respective water was hauled into each pen. Water intake was lower ($P < 0.10$) for steers supplied WW (10.9 gallons/d) and DW (11.1 gallons/d) than for steers supplied RW (12.6 gallons/d). Steers supplied RW had higher DMI ($P < 0.10$) and gain/feed ($P < 0.05$) than steers supplied WW or DW. Steers supplied RW also had higher ADG ($P < 0.05$) than steers on WW or DW (1.38, 1.02, and 1.02 lb/day for RW, WW and DW, respectively). The incidence of polioencephalomalacia (PEM) was 15 and 12.5% for WW and DW, respectively, compared to no cases in RW ($P < 0.10$). Three steers died of PEM (one from WW and two from DW). Dietary sulfur concentrations were 0.27, 0.74, and 0.93% of dry matter for RW, WW and DW, respectively. It is unclear whether sulfur alone caused the reductions in performance or if other factors associated with TDS were important. Performance and health did not decline as TDS and sulfates increased above that in the WW treatment, indicating a threshold was achieved. Increased TDS and/or sulfates in the water reduced performance and health of growing steers.

Key words: Steers, Water, Performance, Sulfate, Polioencephalomalacia

Introduction

Water available to beef cattle in South Dakota is often high in total dissolved solids (**TDS**) and sulfates. Data from the USDA's National Animal Health Monitoring System (APHIS, 2000) showed samples collected in South Dakota feedlots averaged 2000 ppm TDS and over 1000 ppm sulfates. Data from our laboratory in 2000 and 2001 showed water samples collected from wells and stock dams in western South Dakota to have TDS as high as 15,000 ppm and sulfates as high as 10,000 ppm. The effects of this poor quality water on beef production have not been clearly documented, but high levels of dietary sulfur caused by ingestion of high sulfate water can cause polioencephalomalacia (**PEM**; McAllister et al., 1997). Sulfur induced PEM causes neurological disorder, gastrointestinal stasis, anorexia, blindness, and potentially death.

It is important to determine the effects of water quality on animal performance so that appropriate management practices can be developed. The objective of this study was to evaluate the effects of water from natural sources in western South Dakota that contained various levels of TDS and sulfates on the performance of growing steers during the summer.

[1]Assistant Professor
[2]Professor
[3]Superintendent, Antelope Research Station
[4]Senior Livestock Superintendent

Materials and Methods

The study was conducted at South Dakota State University's Cottonwood Range and Livestock Research Station, near Phillip, SD. The experiment was conducted from June 20 to September 12, 2001. The average daily minimum and maximum temperatures during the study period were 59° and 91°F, respectively. Actual minimum and maximum temperatures were 41° and 108°F, respectively. Eighty-one crossbred steers (700 lb) were stratified by weight and randomly assigned to one of 12 pens (six-seven steers/pen). Pens were randomly assigned to one of four treatments (three pens/treatment) based on the quality of water supplied. Treatments were 1) rural water (**RW**), 2) well water (**WW**), 3) stock dam water (**DW**), and 4) DW early switched to extremely high sulfate DW late in the summer (**DWS**). Due to less than predicted TDS and sulfate in dam water late in the summer, the DWS treatment was not achieved. Therefore, there were six pens in the DW treatment (three total treatments).

The well water was pumped from a well on the research station, and dam water was transported from a local stock dam. The TDS and sulfate concentration the rural water and well water remained consistent throughout the summer, whereas the dam water increased in TDS and sulfates with advancing season (Table 1). Water was supplied in stock tanks to each pen. Water intake was measured by the change in daily water depth adjusted for evaporation and precipitation (measurements of evaporation and precipitation taken from a weather station located near the research feedlot). Depth measurements were converted to liters of water consumed using the surface area of each stock tank.

Steers were housed in dry-lot pens and fed a diet of grass hay (10.8% CP, 60.9% NDF) and pelleted wheat middlings. From June 20 to July 19, the diet consisted of 61% hay and 39% wheat middlings (DM basis; 14.3% CP, 0.38 Mcal/lb NEg, 0.19% S). Due to poorer-than-predicted performance, the ration was changed to 52.6% grass hay and 47.4% wheat middlings (14.9% CP, 0.42 Mcal/lb NEg, 0.19% S) on July 20, and remained constant throughout the rest of the experiment. We did not provide supplemental minerals so that impacts of water quality on the liver mineral stores could be evaluated (data not available to report at time of this publication). Salt was offered free choice at all times. Rations were fed once daily at 0800. Bunks were managed to be slick just prior to feed delivery, and any orts were weighed and recorded. Water samples were analyzed by the SDSU Water Resource Institute, Brookings SD. Feed samples were analyzed by Servi-Tech Laboratories, Hastings, NE.

Steer weights were taken in the morning on three consecutive days at the beginning and end of the experiment. Access to water was denied 12-h prior to weights. At the end of the experiment, all cattle were placed on RW and limit fed a constant amount of diet (approximately 2.0% of BW, DM basis) for 4 d prior to final weights. The 2.0% of BW level was chosen since it was less than that consumed by the pen with lowest intake prior to the final 4-d period. Steer ADG was calculated with dead cattle removed. Feed efficiency was calculated as ADG divided by average daily dry matter intake. Animal health was monitored daily. Cattle were diagnosed with PEM when showing clinical symptoms. Necropsies were performed on all mortalities by a licensed veterinarian, and tissue samples were submitted to the SDSU diagnostic laboratory for analysis.

Steer on-trial weight, off-trial weight, ADG, dry matter intake, feed efficiency, and water intake were analyzed as a completely randomized design in Proc GLM of SAS (SAS Inst. Inc., Cary, NC). Means were separated using the PDIFF option when the overall F-tests were significant *($P < 0.05$)*. Morbidity, mortality, and the incidence of PEM were analyzed with Chi-Square analysis in Proc GENMOD of SAS.

Results and Discussion

Steer gains (Table 2) were not as high as expected. Daily high temperatures averaged 90°F in the first 28 d of the experiment, and daily high temperatures reached 108°F by early August. Reduced feed intake, increased panting, and lethargy were observed on days with high maximum temperatures. The final weights of steers (Table 2) receiving WW and DW were 33 and 35 lb lighter, respectively, than steers receiving RW ($P < 0.05$). Average daily (Table 2) gains were 27% less for WW and DW treatments compared to RW ($P < 0.05$). Water intake (Table 2) was reduced in WW and DW treatments by 1.6 and 1.4 gallons, respectively,

compared to RW ($P < 0.10$). Dry matter intake (Table 2) in WW and DW treatments was 6.2 and 5.0% less, respectively, than RW ($P < 0.10$). Feed efficiency, expressed as gain/feed (Table 2), was increased in RW steers compared to WW and DW ($P < 0.05$). There were no differences between the WW and DW treatments for any of the variables measured ($P > 0.50$).

Similar to results in this study, Loneragan et al. (2001) found linear reductions in ADG and feed efficiency of steers on a corn-based finishing ration when sulfates in water increased from 136 to 2,360 ppm. Weeth and Capps (1972) found a 12.4% reduction in hay intake when water sulfate levels were increased from 110 to 2,814 ppm, but water sulfate levels of 1,462 ppm did not impact intake. In the current study, water sulfate levels of 3,087 reduced dry matter intake, water intake, gain, and feed efficiency compared to 404 ppm sulfate water, but no further reductions were noticed when steers were supplied water containing 3,947 ppm sulfates. It appeared that a threshold was reached with the intermediate level of sulfates.

In the current study, there was no morbidity or mortality in the calves receiving RW, but calves on WW and DW experienced 25 and 15% morbidity, respectively (Table 3; $P < 0.05$). Most of the morbidity was associated with PEM, with WW and DW having a greater incidence than RW steers ($P < 0.10$). There were no differences in mortality ($P = 0.40$), but one steer from WW and two steers from DW died of PEM (confirmed by tissue analysis). One steer in the WW treatment experienced urinary calculi and died after termination of this experiment. It is not clear whether the urinary calculi was due to treatment. Since minerals were not supplemented, the Ca:P ratio was approximately 1:1 in this diet, which could potentially lead urinary calculi problems.

Daily sulfur intake was a likely cause of the PEM in cattle receiving WW and DW. The NRC (1996) gives the requirement and maximum tolerable level of sulfur to be 0.15 and 0.40% of DM intake, respectively. When accounting for sulfur in the water, dietary sulfur was 0.27, 0.74, and 0.93% of DM intake for RW, WW and DW, respectively. This resulted in an average intake of 22, 56, and 71 g/d of sulfur for RW, WW, and DW, respectively. Loneragan et al. (1998) found dietary levels of 0.9% sulfur (from feed) to be associated with PEM.

Implications

Water high in total dissolved solids and (or) sulfates decreased weight gains and feed efficiency of steers on a growing ration. Sulfur in the water was associated with a higher rate of polioencephalomalacia. Since water in South Dakota is often high in sulfates and other salts, substantial impacts on economic returns could occur. More research is warranted to examine the effects of poor quality water on performance of grazing cattle and to develop economic models to evaluate management alternatives.

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Table. 1. Total dissolved solids (TDS) and sulfate concentration of water from various sources in western South Dakota in 2001 (ppm)

	Rural Water		Well Water		Dam Water	
Date	TDS	Sulfate	TDS	Sulfate	TDS	Sulfate
June 20	1048	421	4840	3165	5044	3167
July 17	1008	374	4804	3096	5804	3776
July 30	980	410	4812	3174	5874	3667
August 13	1036	404	4864	3120	6380	4107
August 28	1004	421	4764	3044	6744	4359
September 10	1036	394	4928	2920	7300	4603
Mean	1019	404	4835	3087	6191	3947

Table 2. Intake and performance of growing steers supplied water from various sources in western South Dakota in 2001 (Least squares means ± SEM)

Item	Rural Water	Well Water	Dam Water
Observations	3	3	6
Initial wt, lb	701 ± 4	695 ± 4	699 ± 2
Final wt, lb	816 ± 9[a]	782 ± 9[b]	785 ± 7[b]
ADG, lb/d	1.38 ± 0.07[a]	1.02 ± 0.07[b]	1.02 ± 0.04[b]
Water intake, gallons/d	12.6 ± 0.5[c]	10.9 ± 0.5[d]	11.1 ± 0.3[d]
Dry matter intake, lb/d	17.7 ± 0.4[c]	16.5 ± 0.4[d]	16.8 ± 0.2[d]
Gain/Feed	0.078 ± 0.004[a]	0.061 ± 0.004[b]	0.061 ± 0.003[b]

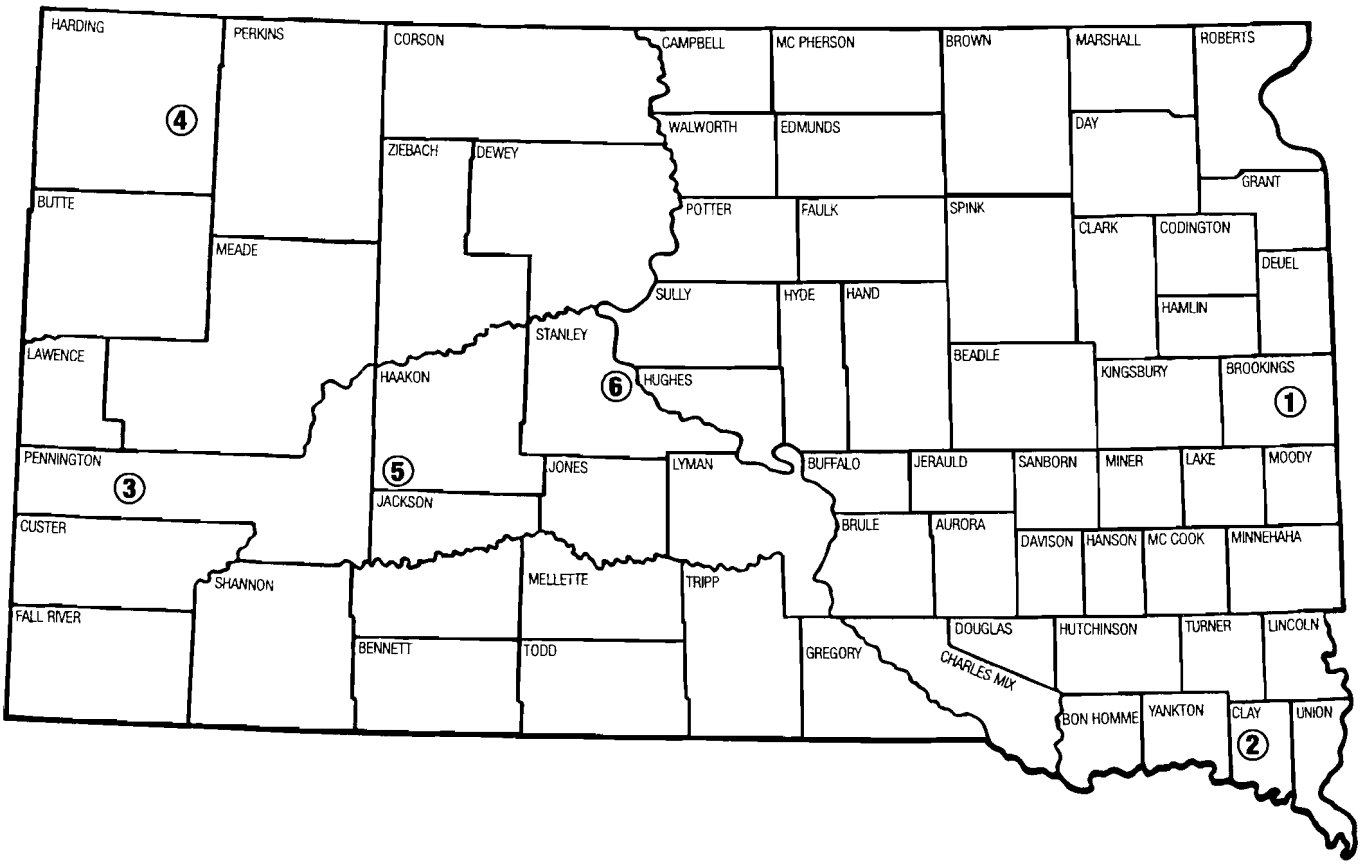
[a,b]Within a row, means without a common superscript letter differ *(P < 0.05).*
[c,d]Within a row, means without a common superscript letter differ *(P < 0.10*).

Table 3. Health of steers supplied water from various sources in western South Dakota in 2001[a]

Item	Rural Water	Well Water	Dam Water
Morbidity, %[b]	0.0	25.0	15.0
Mortality, %	0.0	5.0	5.0
Polioencephalomalacia, %[c]	0.0	15.0	12.5

[a]Data analyzed by Chi-Square analysis (observations = 12; events = 81).
[b]*P < 0.05.*
[c]*P < 0.10.*

Animal and Range Sciences
Research and Extension Units



1 Brookings: SDSU campus, Agricultural Experiment Station, Cooperative Extension Service

2 Beresford: Southeast South Dakota Research Farm
Beef cattle nutrition
Swine nutrition and management

3 Rapid City: West River Ag Research and Extension Center
Professional research and Extension staff in Animal & Range Sciences, Plant Science, Economics, 4-H, and Extension administration

4 Buffalo: Antelope Range Livestock Station
Beef cattle breeding and range beef herd management
Sheep nutrition, management, and breeding

5 Philip: Range and Livestock Research Station
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Range management

6 Ft. Pierre: Hughes-Stanley County Extension Office
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