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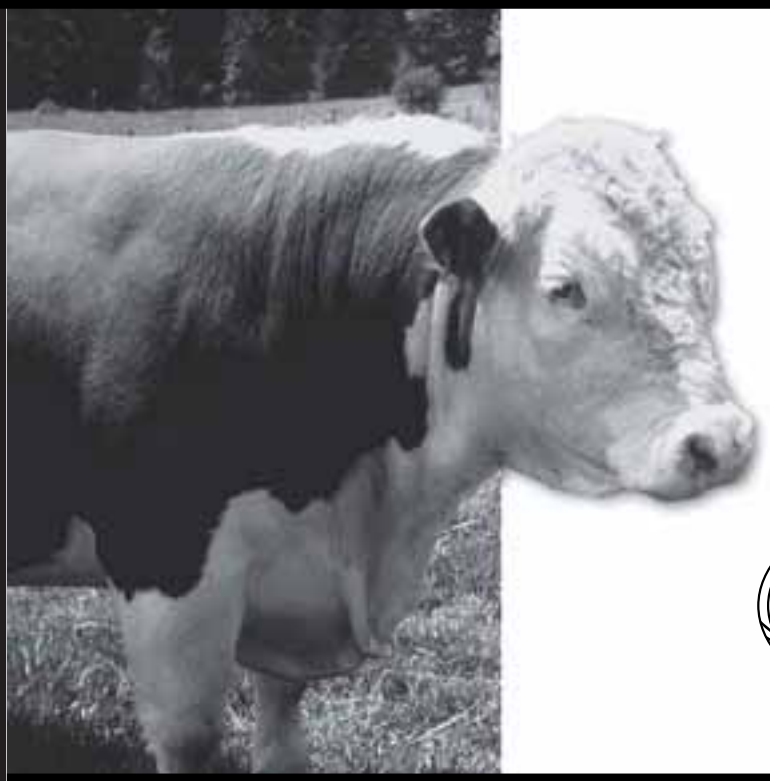

Report of Progress 978

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

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Contribution No. 07-179-S from the Kansas Agricultural Experiment Station.

ALTERED INSEMINATION TIMING IMPROVES PREGNANCY RATES AFTER A CO-SYNCH + CIDR PROTOCOL

C. A. Dobbins, D. E. Tenhouse, D. R. Eborn, S. K. Johnson, K. R. Harmoney, and J. S. Stevenson

Summary

Our objective was to determine the optimal time to inseminate lactating beef cows after applying the CO-Synch + CIDR protocol [injection of GnRH given seven days before and 48 to 72 hr after an injection of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) concurrent with AI, with a controlled internal drug release (CIDR) insert containing progesterone placed intravaginally for seven days between the first GnRH injection and $PGF_{2\alpha}$.]. Using 605 beef cows located at three Kansas locations, the CO-Synch + CIDR protocol was administered as follows: an injection of GnRH was given concurrent with a vaginally placed, progesterone-releasing CIDR insert, seven days later the insert was removed, and $PGF_{2\alpha}$ was injected. Blood samples were collected 10 days before initiating the protocol and at the time of GnRH injection and CIDR insertion to determine concentrations of progesterone. Cows in each herd were inseminated at four different times after the $PGF_{2\alpha}$ injection: 48, 56, 64, or 72 hours. At insemination, each cow received a GnRH injection to induce ovulation. Pregnancy was diagnosed at 32 days after insemination and again at 63 days after insemination to confirm pregnancy survival. Pregnancy rates were greatest for those cows inseminated at 56 or 64 hours.

Introduction

Ability to synchronize estrus, ovulation, or both presents many options to cattle producers who desire to use artificial insemination. Programs are available that use fixed-time insemination and produce acceptable pregnancy rates. Applying synchronization programs to facilitate use of artificial insemination allows greater opportunity to increase genetic progress and selection of desirable, economic traits. Results from well managed Kansas herds indicate 40 to 60% of cows may be cycling at the beginning of the breeding season. When winter conditions are harsh, forage availability limited, or winter supplementation insufficient, a majority of cows may not be cycling at the onset of the breeding season. Thus, synchronization protocols that induce ovulation in both anestrous as well as cycling cows are essential.

When no detection of estrus is possible or desirable, the best protocol must include GnRH to stimulate ovulation (manage follicle populations) in noncycling and cycling cows, a source of progestin to alter uterine function and tighten ovulation synchrony, and $PGF_{2\alpha}$ to control corpus luteum function. The CO-Synch + CIDR protocol seems to provide these desirable benefits that are needed in a timed insemination program. Optimal timing of artificial insemination, however, in the CO-Synch + CIDR protocol has not been determined. The objective of the current study was to determine the optimal timing of insemination when applying a CO-Synch + CIDR protocol.

Experimental Procedures

In spring 2005, lactating beef cows from three Kansas herds were utilized. The three herds consisted of purebred Angus, Hereford, and Simmental cows (n = 144) from the Kansas State University Purebred Beef Unit (PBU), Angus-Hereford crossbred cows (n = 249) from the Kansas State University Cow Calf Unit (CCU), and crossbred Angus cows (n = 212) from the Agriculture Research Center in Hays (ARCH). No 2-year-old cows were treated at the ARCH location.

The CO-Synch + CIDR protocol was administered to each cow as follows: an 100-µg injection of GnRH (2 mL of OvaCyst™, IVX Animal Health, St. Joseph, MO) was given concurrent with vaginal placement of a progesterone-releasing CIDR insert (Eazi-Breed CIDR® insert, Pfizer Animal Health, New York, NY); seven days later the insert was removed, and 25 mg of $PGF_{2\alpha}$ (5 mL of Lutalyse, Pfizer Animal Health, New York, NY) was injected (Figure 1). Cows within herds were sorted by calving date, age, and breed, and then assigned randomly to be inseminated at four different times after the $PGF_{2\alpha}$ injection: 48, 56, 64, or 72 hours. At insemination, each cow received another GnRH injection to induce ovulation.

Blood samples were collected 10 days before and at the time of GnRH injection and CIDR insertion to determine concentrations of progesterone. Cows having progesterone concentrations of at lease 1 ng/mL in either of the two blood samples were defined to be cycling. When both samples contained less than 1 ng/mL, the cows were considered to be anestrous or not cycling.

Pregnancy status was determined via transrectal ultrsonography on day 32 (range of 27 to 35) after insemination and pregnancy status was reconfirmed on day 63 (range of 60 to 68).

Results and Discussion

Before the CO-Synch + CIDR protocol was initiated, 60% of the 605 cows across all three herds had initiated estrous cycles. The rate of cyclicity was 40% in the PBU cows, 65% in the CCU cows, and 68% in the ARCH cows. As expected, cyclicity rates were less ($P<0.001$) in 2-year old cows (30%) compared with 3-year old cows (55%) and older cows (73%). In the current study, fewer 2-year-old cows were cycling, despite calving, on average, 23 and 20 days earlier ($P<0.001$) than the 3-year-old and older cows, respectively.

Pregnancy rates of cows by treatment, cycling status, herd, age, and days postpartum are summarized in Table 1. Insemination at 56 hours improved ($P<0.01$) pregnancy rates compared with inseminations made at 48 and 72 hours, and tended ($P = 0.06$) to improve pregnancy rates at 56 hours compared with 64 hours. The pregnancy response fit ($P<0.001$) a quadratic curve, indicating the pregnancy rates peaked between 56 and 64 hours. The pregnancy rate response was uniformly similar between cows that were cycling and not cycling before the initiation of the CO-Synch protocol (Figure 2). Noncycling cows had greater ($P<0.05$) pregnancy rates than cycling cows (55.8 vs. 51.2%, respectively). No differences in pregnancy rates, however, were detected among herds, age groups, or days postpartum categories.

At the two locations in which cows of all ages were treated, a treatment × age group interaction ($P = 0.05$) was detected. This was interpreted to mean that the optimal insemination timing may differ according to age of the cow. Figure 3 illustrates these results. In 2-year-old cows, the 56-hour timing was clearly best. In contrast, in 3-year-old cows, 56 or 64 hours was superior to other insemination times. Among older cows, however, inseminations made between 56 and 72 hours seemed to be best.

Actual calving rates of cows in the 48-, 56-, 64-, and 72-hour treatments were 71.3, 77.7, 80.6, and 76.8%, respectively. Because calving rates did not differ among treatments, conception rates of cows in the 48- and 72-hour treatments in response to natural mating (clean-up bulls) was normal. Actual calving intervals were 369, 359, 363, and 365 days for the 48-, 56-, 64-, and 72-hour treatments.

Implications

The window for timed inseminations for younger cows may be smaller than for mature cows, but more information is needed before specific age recommendations might be made for beef cows. Our results indicate that those wishing to use fixed-time insemination with a CO-Synch + CIDR protocol may have a broader window of insemination times from 56 to 64 hours after $PGF_{2\alpha}$. This larger window may facilitate application of the CO-Synch + CIDR protocol in a wider range of production settings.

Table 1. Overall Pregnancy Rates According to Time of Insemination (treatment), Cycling Status, Herd, Age, and Days Postpartum at the Beginning of the Breeding Season

Item	Number of Cows	Pregnancy Rates, %
Treatment, hours after $PGF_{2\alpha}$		
48	136	42.6 [a]
56	157	62.4 [b,*]
64	170	54.1 [a,b]
72	142	51.4 [a]
Cycling status before treatment		
Cycling	363	51.2 [a]
Not cycling	242	55.8 [b]
Herd		
Agriculture Research Center-Hays	212	51.8
Cow-Calf Unit	249	56.2
Purebred Beef Unit	144	49.3
Age (years)		
2	114	52.4
3	162	49.6
4+	329	57.0
Days postpartum at $PGF_{2\alpha}$		
< 60	235	51.1
60 to 75	164	52.1
> 75	206	55.5

[a,b]Means having different superscript letters differ ($P<0.01$).

*Tended ($P = 0.07$) to differ from 64 hours.

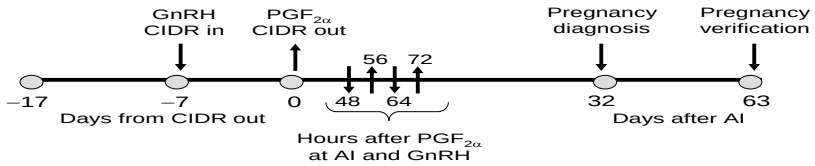

Figure 1. Experimental Protocol. Blood samples were collected at days –17 and –7 for later determination of concentrations of progesterone.

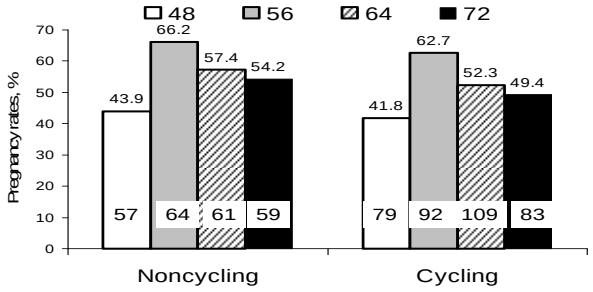

Figure 2. Pregnancy Rates of Lactating Beef Cows According to Time of Insemination (48, 56, 64, or 72 hours) and Whether They had Initiated Estrous Cycles (cycling versus non-cycling) Before the Onset of the CO-Synch + CIDR Protocol. Numbers of cows represented per bar are listed across the bottom of each bar.

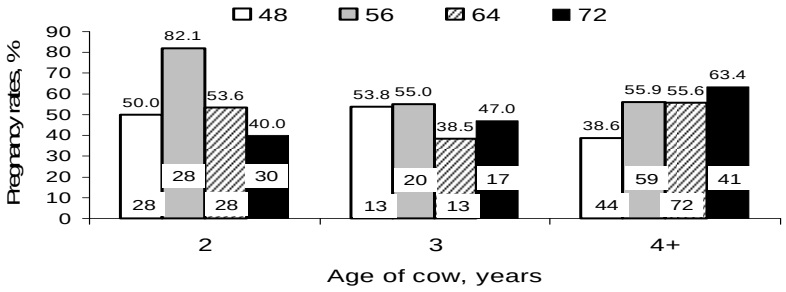

Figure 3. Pregnancy Rates of Lactating Beef Cows at the Purebred Beef Unit and Cow-Calf Unit Locations According to Time of Insemination (48, 56, 64, or 72 hours) in Each Age Group. Numbers of cows represented per bar are listed across the bottom of each bar.

EVALUATION OF HUMAN CHORIONIC GONADOTROPIN AS A REPLACEMENT FOR GnRH IN AN OVULATION SYNCHRONIZATION PROTOCOL BEFORE FIXED-TIME INSEMINATION

M. G. Burns, B. S. Buttrey, D. R. Eborn, J. E. Larson[1], B. J. Lovaas[1], G. C. Lamb[1], KC Olson, and J. S. Stevenson

Summary

Two experiments were conducted to evaluate the difference between gonadotropin-releasing hormone (GnRH) and human chorionic gonadotropin (hCG) given at the beginning of a timed AI protocol and their effects on fertility. In Experiment 1, beef cows (n = 672) at six different locations were assigned randomly to treatments based on age, body condition, and days postpartum. On day –10, cattle were treated with GnRH or hCG and a progesterone-releasing controlled internal drug release (CIDR) insert was placed in the vagina. An injection of $PGF_{2\alpha}$ was given and CIDR inserts were removed on day –3. Cows were inseminated at one fixed timed at 62 hr (day 0) after CIDR insert removal. Pregnancy was diagnosed at 33 days (range of 32 to 35) after insemination to determine pregnancy rates. For cows that were pregnant after the first insemination, a second pregnancy diagnosis was conducted 35 days (range of 33 to 37) after the first diagnosis to determine pregnancy survival. Pregnancy rates were reduced by the hCG injection compared with the GnRH injection (39.1 vs. 53.5%). In Experiment 2, cattle were assigned randomly to three treatments, balanced evenly across the two treatments (GnRH vs. hCG) applied in Experiment 1. Cows were injected with GnRH, hCG, or saline seven days before the first pregnancy diagnosis of cows inseminated in Experiment 1. At the time of pregnancy diagnosis, cattle found not pregnant (n = 328) were given $PGF_{2\alpha}$ and inseminated 56 hours later. A second pregnancy diagnosis was conducted 35 days (range of 33 to 37) after the second insemination to determine pregnancy rate at the second AI. Injections of GnRH, hCG, or saline had no effect on pregnancy rates of cows already pregnant to the first insemination. Pregnancy rates after second insemination in cows given an injection of hCG or GnRH, however, tended to be reduced. Percentage of cows pregnant after two timed inseminations exceeded 60% without any need to detect estrus.

Introduction

Timed insemination after the CO-Synch + CIDR protocol generally has produced pregnancy rates more than 50%. The CO-Synch protocol was adapted from the Ovsynch protocol used in the dairy industry. Ovsynch is initiated with an injection of GnRH to induce ovulation of a follicle and is followed in seven days by an injection of PGF. The purpose of the $PGF_{2\alpha}$ injection is to lyse either the corpus luteum formed after GnRH-induced ovulation or the original corpus luteum present at GnRH injection. A second injection of GnRH is usu-

[1]University of Minnesota, Grand Rapids.

ally given 48 hours after $PGF_{2\alpha}$ to induce ovulation. Fixed-time insemination is conducted 12 to 24 hours after GnRH. The CO-Synch protocol combines the second GnRH injection and insemination into one step in order to reduce the number of times that cows must be gathered and restrained.

The CO-Synch + CIDR protocol employs a progesterone-releasing, intravaginally-placed controlled internal drug release (CIDR) insert for seven days at the beginning of the ovulation synchronization protocol. Previous work conducted at KSU demonstrated that insemination 56 or 64 hours after the $PGF_{2\alpha}$ injection and CIDR removal resulted in pregnancy rates of 50 to 60%. See the accompanying report entitled "Altered Insemination Timing Improves Pregnancy Rates after a CO-Synch + CIDR Protocol" in this publication.

In previous studies, hCG administered before or after insemination has been effective at inducing ovulation of follicles, lengthening the estrous cycle, increasing size and function of a corpus luteum, and improving cow fertility. Human chorionic gonadotropin is more effective than GnRH at stimulating ovulation in dairy cattle. Therefore, our objective was to substitute hCG for GnRH in two different ovulation-synchronization protocols and assess its effects on fertility of lactating beef cows. The protocol could potentially allow cattle producers to inseminate cows twice during the first 35 days of the breeding season and still have sufficient time for a 25-day natural-service period in a 60-day breeding season.

Experimental Procedures

Ovulation in beef cattle at six different locations were synchronized using a CO-Synch + CIDR protocol, and then ovulation was re-synchronized 26 days (range of 25 to 28) after the first timed AI. Locations of cattle assigned to treatments included 1) purebred Angus, Hereford, and Simmental cows (n=106) at the Kansas State University Purebred Beef Unit; 2) Angus × Hereford crossbred cows (n = 277) at the Kansas State University Commercial Cow-Calf Unit; 3) Angus, Hereford, and Simmental crossbred cows (n = 181) at the Thielen Ranch, Dorrance, KS; and 4) purebred Angus cows (n = 116) at the North Central Research and Outreach Center, University of Minnesota, Grand Rapids, MN.

In Experiment 1, ovulation in beef cattle was synchronized using a CO-Synch + CIDR protocol (Figure 1). A CIDR was inserted and 100 μg of GnRH (2 mL of OvaCyst, IVX Animal Health, St. Joseph, MO) or 1,000 IU of hCG (1 mL of Chorulon, Intervet Inc., Millsboro, DE) was given intramuscularly on day –10. On day –3, the CIDR was removed and 25 mg of $PGF_{2\alpha}$ (ProstaMate, IVX Animal Health) was injected intramuscularly. Fixed-time insemination was carried out 60 to 64 hours (day 0) after $PGF_{2\alpha}$ injection. Pregnancy was diagnosed 33 days after insemination. For cows diagnosed pregnant at that time, pregnancy survival was verified 35 days later (68 days after the first timed AI).

In Experiment 2, seven days before all cows in Experiment 1 were diagnosed for pregnancy, each cow of unknown pregnancy status received either 2 mL of OvaCyst, 1 mL of Chorulon, or 2 mL of saline (control) on day 26 after the first insemination. On day 33, pregnancy diagnosis was carried out by using transrectal ultrasonography, and cattle that were not pregnant were given 5 mL of Prostamate. Cattle that received Prostamate received one fixed-time insemination 56 hours later. Pregnancy was diagnosed 35 days after this insemination.

Results and Discussion

Pregnancy rates after the first timed AI are summarized in Table 1. Injection of GnRH resulted in greater ($P<0.001$) pregnancy rates than hCG (53.7 vs. 39.1%). Injection of

GnRH, hCG, or saline (Experiment 2) had no effect on first insemination pregnancy rates (GnRH = 47.1%, hCG = 45.4%, or saline = 46.9%). Pregnancy survival did not differ between GnRH and hCG treatments in those cows that conceived after the first insemination (Table 1).

Pregnancy rates of cows in Experiment 2 are summarized in Table 2. Injections of GnRH and hCG, compared with saline, tended ($P = 0.07$) to reduce second-service pregnancy rates. Future experiments should be conducted to address whether GnRH or hCG is needed in this resynchronization application for beef cattle.

In the current experiments, cattle that were not pregnant after the first insemination (Experiment 1) were treated with either GnRH, hCG, or saline (Experiment 2) seven days before the first pregnancy diagnosis. Within 35 days of the beginning of the breeding season, cattle had 2 chances to conceive to AI and no detection of estrus was necessary. Pregnancy rates after two timed inseminations are summarized in Table 1. Rates ranged from 56.8 to 67.9%, but did not differ among treatments.

Implications

The AI protocols examined in these experiments allow cattle producers to inseminate cows twice during the first 35 days of the breeding season and still have sufficient time for a 25-day natural-service period in a 60-day breeding season. These protocols were designed for cattle producers who do not have the labor or facilities to detect estrus. Injection of hCG had a negative effect on pregnancy rates of cattle treated with the CO-Synch + CIDR protocol in Experiment 1 and therefore is not a suitable replacement for GnRH. In Experiment 2, it was concluded that a GnRH or hCG injection may not be necessary to initiate a CO-Synch protocol for cows identified as not pregnant by transrectal ultrasound 33 days after AI. Further work is needed to verify this finding.

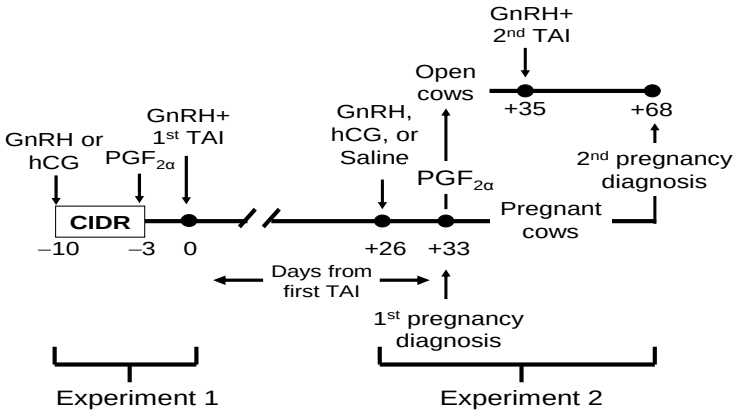

Figure 1. Experimental Design for Experiments 1 and 2.

Table 1. Pregnancy Rates and Pregnancy Survival Rates After the First Timed AI

Experiment 1 Treatments	Experiment 2 Treatments	Pregnancy Rate at First AI, %	Pregnancy Survival Between First AI and 68 Days Since AI, %	Pregnancy Rate After Two Inseminations
		% (no.)		
GnRH	Saline	54.5 (112)	90.2 (61)	67.9 (112)
	GnRH	55.2 (116)	92.2 (64)	64.3 (115)
	hCG	51.4 (109)	96.4 (56)	65.1 (109)
	Total	53.7[a] (337)	92.8 (181)	65.8 (336)
hCG	Saline	39.1 (110)	93.0 (43)	62.7 (110)
	GnRH	38.3 (107)	97.6 (41)	61.7 (107)
	hCG	39.8 (118)	95.7 (46)	56.8 (118)
	Total	39.1 (335)	95.4 (130)	60.3 (335)

[a]Different (P<0.001) from hCG.

Table 2. Pregnancy Rates of Cows Reinseminated at 56 Hours After $PGF_{2\alpha}$ (injected at the time of not-pregnant diagnosis; Experiment 2)

Treatment (Experiment 1)	Treatment (Experiment 2)		
	Saline	GnRH	hCG
	% (no.)		
GnRH	40.0 (45)	26.1 (46)	29.2 (48)
hCG	40.3 (62)	37.7 (61)	31.8 (66)
Total	40.2[a] (107)	32.7 (107)	30.7 (114)

[a]Tended (P = 0.07) to differ from hCG + GnRH.

GnRH REMOVAL IN THE 7-11 CO-SYNCH FOR TIMED INSEMINATION OF BEEF HEIFERS

D. R. Eborn and D. M. Grieger

Introduction

The use of artificial insemination can improve genetics, shorten the calving season, and increase weaning weights by having more calves born earlier in the breeding season. Reasons that this technology has not been used by many producers may include poor conception rates, time, and cost. Research has been directed at shortening the synchronization time and controlling time of ovulation to eliminate estrous detection using a timed artificial insemination.

Use of a progestin, like the Eazi-Breed CIDR[1] or melengestrol acetate (MGA), is desirable because they are effective in synchronizing estrus and they can also induce cyclicity in anestrus or prepubertal females. In addition, gonadotropin releasing hormone (GnRH) is commonly included in a synchronization plan because it induces ovulation and synchronizes follicular development.

The most common synchronization protocol for beef heifers consists of feeding MGA for 14 days, a prostaglandin injection 17 to 19 days later followed by five days of heat detection for a total duration of 36 to 38 days. Recent research suggests that acceptable conception rates can be achieved when shortening the time of MGA to seven days. One example is the 7-11 CO-Synch which is comprised of seven days of MGA feeding followed by the CO-Synch protocol starting on day 11 (see Figure 1). We have obtained greater then 60% conception rates using the 7-11 CO-Synch in previous years. The feeding of MGA not only synchronizes the estrous cycle but provides exposure to a progestin that may induce prepubertal heifers to begin cycling. The GnRH injection at day 11 should synchronize the follicular wave which will tighten the timing of ovulation and improve timed insemination conception rates. The disadvantage to this synchronization protocol is that it requires the heifers to go through the chute four times. It is also believed that heifers are less responsive to GnRH than cows. Thus we tested this protocol with or without the day 11 GnRH injection on conception rates of beef heifers.

Experimental Procedures

Two groups of yearling heifers (n=107) from the Kansas State University Purebred Unit and the Cow-Calf Unit were used in this study. Heifers were randomly assigned to one of two treatments; GnRH or control. Heifers were group fed to consume 0.5 mg/heifer/day of MGA (Pharmacia Animal Health, Kalamazoo, MI) in a grain sorghum carrier beginning on day one. On the last day of feeding (day seven), heifers were injected with ProstaMate (5 c.c. dose, intramuscular); (IVX Animal Health, St. Joseph MO). On day 11, heifers in the GnRH treatment group received 2 c.c. (intramuscular) of OvaCyst (IVX). On day 18,

[1]Eazi-Breed CIDR is a registered trademark of Pharmacia Animal Health.

all heifers received an injection of ProstaMate. Timed insemination followed 54 hours later at which time heifers were injected with Ova-Cyst. Purebred heifers were rebred after observed estrus for 45 days after the first insemination. Cleanup bulls were introduced to the commercial heifers seven days after insemination. Conception rate to the first insemination was determined by ultrasonography 31 days after insemination. Purebred heifers were checked again by ultrasound 40 days following the initial pregnancy check. Commercial heifers were pregnancy diagnosed by rectal palpation in the fall where fetal age was estimated.

Results and Discussion

Overall, 62 of 107 (58%) heifers conceived to the first insemination. Treatment differences between the GnRH and control groups in pregnancy rate were 36 of 54 (67%) and 26 of 53 (49%) respectively (P = 0.08). Treatment effects within herd are shown in Figure 2. Pregnancy rates for the purebred heifers in the control group were 45% (13/29) and in the GnRH group were 69% (20/29). For the commercial heifers pregnancy rates were 54% (13/24) and 64% (16/25) for the control and GnRH treatments, respectively. By 30 days after the beginning of the breeding season 73% of the commercial heifers and 79% of the purebred heifers were pregnant.

Implications

When using the 7-11 CO-Synch protocol, the use of GnRH at day 11 appears to improve conception rates to a fixed time insemination.

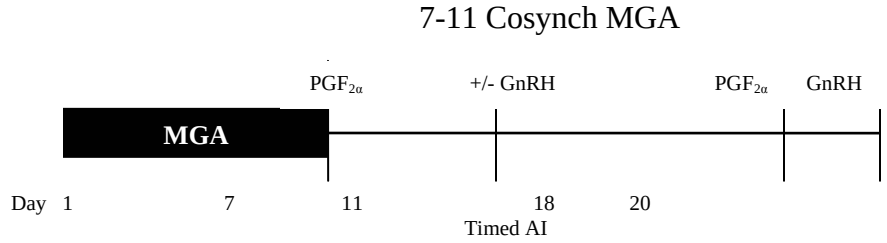

Figure 1. Experimental Protocol. Heifers in the GnRH treatment group received an injection of GnRH on day 11 of the protocol.

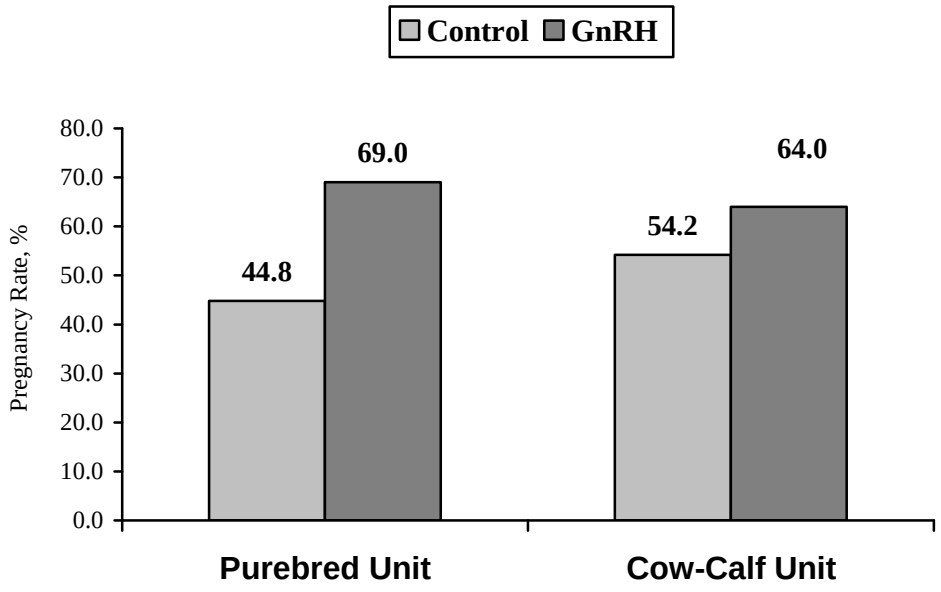

Figure 2. Treatment Effect on Pregnancy Rates of Heifers within Group.

COMPUTER AND INTERNET USAGE OF COW-CALF PRODUCERS IS GROWING

S. J. Breiner, K. M. Boone, D. A. Blasi, S. A. Grau, T. C. Schroeder, B. B. Barnhardt, R. M. Breiner and A. M. Bryant

Introduction

While the world continues to evolve toward enhanced computer and Internet usage, the agricultural arena has been slower to follow. The objective of this survey was to examine the computer utilization practices of cow-calf producers through a nationwide mail survey. By understanding the demographics of today's producers, as well as if and how they are using their personal computers and the Internet, the industry can work toward educating producers about the benefits of this technology.

Experimental Procedures

Surveys were administered to cow-calf producers in the spring of 2006. A panel of experts at Kansas State University completed content validity testing. Participants were selected from a mailing list of cow-calf producers with more than 100 cows. *BEEF®* Magazine provided the mailing list and a random sample of 1,000 producers was selected. Three mailings were sent to each participant over a two-month time period. Non-respondents received a fourth mailing to further encourage response. Mailings included: 1) pre-notice letter, 2) survey packet and cover letter, 3) postcard thank you/reminder, and 4) replacement questionnaire with monetary incentive. Data were collected by Prism Business Media, Inc., and analyzed by both Prism Business Media, Inc. and Kansas State University.

Results and Discussion

A total effective mailing of 972 resulted in 522 completed surveys for an effective response rate of 53.7%. Producers from 41 states where represented in the survey. 77.8% of respondents were over the age of 45 with an average herd size of 160 head.

These data indicate that more than half (54.8%) of respondents noted using a personal computer within their cattle operations (Table 1). This shows some increase from earlier surveys, but still shows a large portion of producers (43.7%) have no personal computer available in their operations.

Table 1: Do You Use a Personal Computer Within Your Cattle Operation?

	Number Reporting	Percent Reporting
Yes	286	54.8%
No	228	43.7%
No answer	8	1.5%

N = 522.

Of those who use a personal computer, 59.1% use it once a day or more. The majority, 80.8%, use a personal computer several times a week or more (Table 2).

Table 2: How Often Do You Use Your Computer?

	Number Reporting	Percent Reporting
Several times a day	84	29.4%
Once a day	62	21.7%
Several times a week	62	21.7%
Several times a month	53	18.5%
Once a month or less	21	7.3%
No answer	4	1.4%

N = 286 – (Computer users only).

In addition, 74.1% of users used their computer for email access, 68.2% for financial management, and 65.4% for maintaining livestock records (Table 3). More than half also cited using their computers for inventory purposes. Machinery and labor records both ranked lower as uses for personal computers.

Table 3: For Which of the Following Activities Do You Use Your Computer?

	Number Reporting	Percent Reporting*
E-mail	212	74.1%
Financial management	195	68.2%
Livestock records	187	65.4%
Inventory	146	51.0%
Machinery records	68	23.8%
Labor records	59	20.6%
Other	38	13.3%
No answer	5	1.7%

N = 286 – (Computer users only).
*Percents may reflect multiple answers.

More than three-quarters of producers reported that their newest computer was less than 3 years old. One-quarter said their newest computer was less than a year old.

Table 4: How Old Is Your Newest Computer?

	Number Reporting	Percent Reporting
Less than 1 year	73	25.5%
1 to 3 years	144	50.3%
4 to 6 years	56	19.6%
More than 7 years	11	3.8%
No answer	2	.7%

N = 286 – (Computer users only).

Of those producers who used a personal computer, 88.5% had Internet access for use within their operations (Table 5). Therefore, we conclude that 48% of the 522 respondents have Internet access available for use in their operations.

Table 5: Do You Have Access to the Internet for Use Within Your Cattle Operation?

	Number Reporting	Percent Reporting
Yes	253	88.5%
No	29	10.1%
No answer	4	1.4%

N = 286 – (Computer users only).

Implications

More than half of cattle producers are using personal computers within their operations, while almost half have Internet capabilities. This shows the growth of this technology in the industry, as well as its potential for future outreach.

VETERINARIANS ARE MOST POPULAR SOURCE OF INFORMATION UTILIZED BY COW-CALF PRODUCERS

S. J. Breiner, K. M. Boone, D. A. Blasi, S. A. Grau, T. C. Schroeder, B. B. Barnhardt, R. M. Breiner and A. M. Bryant

Introduction

Sources and channels of information used among agriculturalists have long been important issues in Cooperative Extension. A source is an entity that originates a message. By understanding from whom producers receive messages, there exists a better framework to deliver information. Moreover, when considering the demographics of today's producers, as well as the sources of information utilized, the industry can work toward better educating and understanding the concerns of these individuals.

Experimental Procedures

Surveys were administered to cow-calf producers in the spring of 2006. A panel of experts at Kansas State University completed content validity testing. Participants were selected from a mailing list of cow-calf producers with more than 100 cows. *BEEF®* Magazine provided the mailing list and a random sample of 1,000 producers was selected. Three mailings were sent to each participant over a two-month time period. Non-respondents received a fourth mailing to further encourage response. Mailings included: 1) pre-notice letter, 2) survey packet and cover letter, 3) postcard thank you/reminder, and 4) replacement questionnaire with monetary incentive. Data were collected by Prism Business Media, Inc., and analyzed by both Prism Business Media, Inc., and Kansas State University.

Results and Discussion

A total effective mailing of 972 resulted in 522 completed surveys for an effective response rate of 53.7%. Producers from 41 states responded to the survey, with 77.8% of respondents being over the age of 45 and having an average herd size of 160 head.

The objective of the study was to understand how producers received information. More than 63% of cattle producers reported membership in a beef cattle organization. State or local cattlemen's groups made up the largest set of respondents, with 47.3% reporting membership. Breed associations and the National Cattlemen's Beef Association were the second highest selected categories, with each group receiving 20.3% of responses. Nine percent of respondents cited membership with the Rancher's and Cattlemen's Action Legal Fund (Table 1). The top five breed associations reported by producers were the American Angus Association, American Hereford Association, American Simmental Association, Red Angus Association of America, and American Charolais Association, respectively.

Data on sources of information utilized by producers data showed the importance of veterinarians as a source. Producers cited veterinarians as their number one source of information for their beef operations. "Other cattle producers" and "farm and feed dealers" were also frequent responses (Table 2). Although 63.6% of cattle producers reported membership in some type of beef cattle organization,

producer utilization of these organizations as a source of information was relatively low. Private consultants received the least responses by a large margin with a median response of 0.

Implications

Producers greatly value the opinions of veterinarians, as well as those of other cattle producers and farm and feed dealers, when using/seeking sources of information.

Table 1: Are You a Member of Any of the Following Organizations?

	Number Reporting	Percent Reporting*
State or Local Cattlemen's group	247	47.3%
Breed Association	106	20.3%
National Cattlemen's Beef Association	106	20.3%
Ranchers and Cattlemen's Action Legal Fund	47	9.0%
Other	32	6.1%
No answer	190	36.4%

N = 522.
*Percentages may reflect multiple answers.

Table 2: How Often Do You Use the Following Sources of Information in Your Beef Operation?
(0 = Never use and 5 = Always use)

	N Valid	Mean	Std. Deviation	Rank
Veterinarian	504	3.70	1.211	1
Other cattle producers	462	3.19	1.335	2
Farm and Feed dealers	475	3.03	1.381	3
County Extension agent	463	2.28	1.560	4
Beef industry organization	413	2.16	1.624	5/6
University specialists	438	2.16	1.665	5/6
Private consultant	409	1.03	1.477	7

VALUE OF ANIMAL TRACEABILITY SYSTEMS IN MANAGING A FOOT-AND-MOUTH DISEASE OUTBREAK IN SOUTHWEST KANSAS

D.L. Pendell[1] and T.C. Schroeder[2]

Introduction

Concerns regarding management of animal disease and related perceptions about food safety have escalated substantially in recent years. Terrorist attacks of September 2001, discovery of bovine spongiform encephalopathy (BSE) in a dairy cow in December 2003 in Washington, subsequent discoveries of BSE-infected animals in Texas in 2005 and Alabama in 2006, and recent worldwide outbreaks of highly contagious animal diseases (i.e., foot-and-mouth disease [FMD] and Avian influenza) have made apparent the need for animal traceability in U.S. livestock production and marketing. In addition, animal identification systems are rapidly developing throughout the world, effectively increasing international trading standards.

One way to combat and more quickly arrest spread of contagious diseases is through animal ID. Capability to rapidly identify locations where an animal has been affects the ability to isolate, trace, and arrest spread of a disease. Animal ID systems are rapidly developing throughout the world and the U.S. is behind many other countries in this development. Efforts to develop animal ID systems in the U.S. were launched prior to the initial BSE discovery, but they gained considerable momentum afterwards. The National Animal Identification System is intended to identify specific animals in the U.S. and record their movement over their lifetime. The goal is to enable a 48-hour trace-back of the movements of any diseased or exposed animal. This will limit spread of animal diseases by enabling faster trace-back of infected animals; limit production losses due to disease presence; reduce the costs of government control, intervention, and eradication; and minimize potential international trade losses[3].

The purpose of this research is to determine the economic implications of increased improvements in animal ID systems in the event of an FMD outbreak in southwest Kansas. Specifically, a disease spread model is used to determine the probable spread of a hypothetical FMD outbreak. Results from the disease-spread model are integrated into an economic framework to determine economic impacts.

Experimental Procedures

To accomplish the objectives of this study, an epidemiological disease-spread model, using alternate intensity levels of animal ID, was used to simulate a hypothetical FMD outbreak using alternate intensity levels of animal ID.

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[1]Colorado State University, formerly Department of Agricultural Economics, Kansas State University.
[2]Department of Agricultural Economics.
[3]Other potential benefits of trace back systems include better supply chain coordination, increased consumer confidence in meat products, and verifiable credence attributes.

This study evaluates contagious animal disease spread for three different animal identification levels in cattle, referred to as high, medium, and low levels of identification intensity. High animal identification intensity is a system that has a 90 percent success rate of both direct and indirect trace-back within 24 hours. In other words, the trace-back of a herd will be successful 90 percent of the time when coming in direct and indirect contact with an infected herd. This would be roughly akin to an animal identification system that has 100% industry-wide adoption. Medium- and low-level identification systems have 60 percent and 30 percent trace-back success rates, respectively. A 30 percent trace-back is roughly where US beef industry is today. Because a majority of swine are owned and managed by one entity in the geographic area where an out break is hypothetically introduced in this study, only one level of animal identification for swine is assumed at the herd level at 75% trace-back. The results from the disease-spread model, including total number of fed and feeder cattle, market hogs that were destroyed, and total costs associated with the FMD outbreak, were integrated into an economic model. The economic framework consists of a set of supply and demand equations for beef, pork, and poultry sectors that provides horizontal and vertical linkages within the farm-retail marketing chain. The economic model was used to evaluate consumer and producer losses for beef, pork, and poultry sectors.

Results and Discussion

Two factors—total number of infected animals and time of disease outbreak—matter most in determining potential economic impact of an infectious disease outbreak. As the level of surveillance and ability to trace cattle increases, the number of animals that have to be destroyed and related costs decrease (Figure 1). With a low-level ID system, approximately 790,000 head of livestock were destroyed. The numbers destroyed at medium and high surveillance levels were lower (550,000 and 265,000, respectively). This is equivalent to a reduction in Kansas fed cattle of 14% with low-intensity animal identification, 10% with medium-, and 5% with high-intensity identification.

Table 1 reports changes in consumer and producer welfare, assuming a 2% decrease in beef and pork demand and a 1% increase in poultry demand for the short run in the event of an FMD outbreak. In general, as animal surveillance levels increased, consumer and producer losses associated with an FMD outbreak became smaller. The simulation models estimate that total losses (cattle producer, beef processor, and beef retailer) at $584 million, $502 million, and $405 million with low-, medium-, and high-level animal ID systems, respectively. Total consumer losses in the short run were $271 million, $220 million, and $154 million for low, medium, and high animal surveillance levels, respectively.

These results estimate the potential value of animal identification systems in mitigating economic losses associated with a contagious disease outbreak. As the intensity of animal identification increases, the number of animals destroyed decreases, as does the associated disease-related costs. Further, increases in animal traceability levels result in smaller consumer and producer losses.

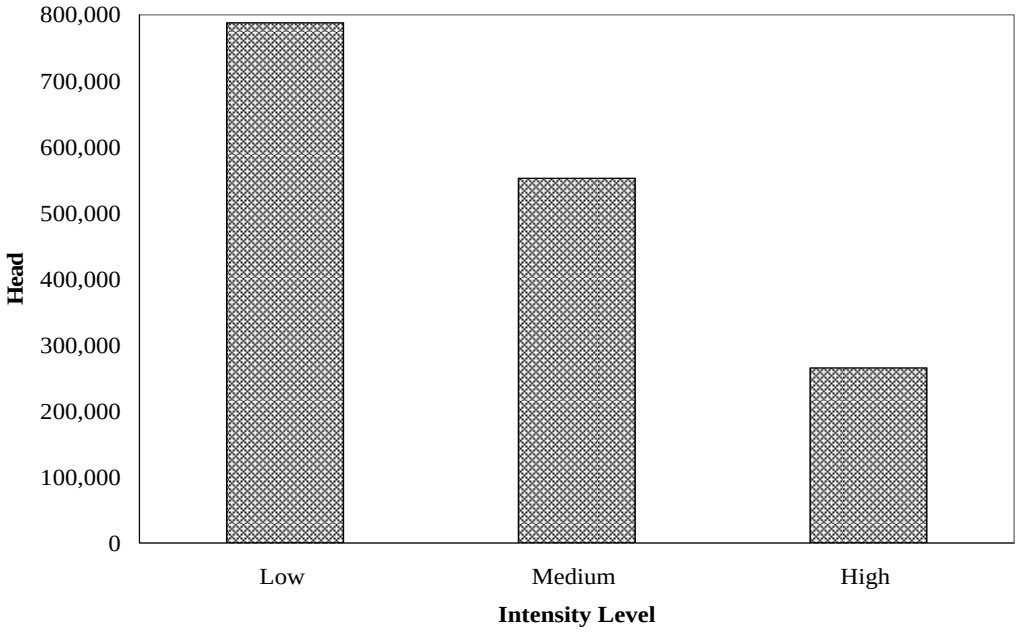

Figure 1. Cumulative Number of Animals Destroyed in a Hypothetical FMD Outbreak in Southwest Kansas with Varying Levels of Animal Traceability Intensity.

Table 1. Changes in Consumer and Producer Welfare in Short-Run with 2% Decrease in Beef and Pork and 1% Increase in Poultry Demand (in millions of dollars)

	Animal Identification Intensity		
Beef Production Sector Loss:	Low Level	Medium Level	High Level
Retailers	-238.72	-228.29	-214.89
Wholesale/Processors	-144.76	-121.79	-92.18
Other States' Fed Cattle Producers[a]	-65.46	-57.69	-48.10
Kansas Fed Cattle Producers	-69.27	-43.51	-22.21
Other States 'Feeder Cattle Producers	-64.51	-48.51	-27.62
Kansas Feeder Cattle Producers	-1.18	-2.06	-1.16
Total Beef Industry	-583.91	-501.85	-405.00
Total Pork Industry	-80.33	-84.58	-90.05
Total Poultry Industry	129.29	114.59	95.76
Total Meat Industry Production Sector Loss	-534.95	-471.83	-399.29
Retail Consumer Loss:			
Retail Beef	-188.79	-149.73	-99.21
Retail Pork	-51.52	-47.88	-43.59
Retail Poultry	-30.68	-22.18	-11.30
Total Retail Consumer	-270.98	-219.80	-154.11

[a]Other States refers to the U.S. excluding Kansas.

TRAILER-MOUNTED RFID READER SCANS EID TAGS DURING CATTLE SHIPMENTS

B. B. Barnhardt, A. M. Bryant, M. P. Epp, M. F. Spire and D. A. Blasi

Introduction

One of the challenges regarding implementation of a national animal identification system is the logistics of reading and reporting EID (electronic identification) tag numbers as cattle move through the production cycle. Many small producers would have difficulty justifying the investment required to install an RFID (radio frequency identification) reader system that would only be used seasonally to track relatively small numbers of cattle that are entering commerce. A proposed solution to this issue is to install an RFID reader on commercial cattle trailers so that cattle can have EID tags read as they are loaded and unloaded during transport from one premise to the next. With such an arrangement, the RFID equipment would be used often by a small number of highly trained people in the transport sector and the cost could be spread over a large number of cattle hauled over the life of the reader. The goal of this study was to evaluate the performance of a trailer-mounted RFID reader, in one location, using four prominent brands of commercially available EID tags.

Experimental Procedure

Fifty tags from each of the four selected tag manufacturers were purchased through an independent distributor in an effort to be certain that the tags used in the project were of "off the shelf" quality and typical of what a producer would purchase for commercial use. All of the tags were tested in a laboratory environment using a trolley system that presented the tags to two different brands of panel readers at the best orientation (the front of the tag facing the reader). Read distances for all 200 tags were analyzed to reveal whether the measurements recorded by the two different readers correlated. The correlation between readers was 0.47 which indicated that the read distances from the two readers were not similar or comparable. The tag testing data from the reader produced by a company that is not a producer of RFID tags was used for the experiment, assuming that this reader would be less biased toward any certain brand or design of tag and tuned in a more neutral manner. Average read distances were calculated for each tag brand. Thirty tags from each brand, which were closest to the mean read distance, were selected in an effort to eliminate tags that were inferior or exceptional in read range performance. The tags that were placed in the cattle were randomly selected from the thirty retained from each brand.

Twenty-four mixed breed steers (650 lb) were used for the reader performance testing. These steers were divided into four groups of six head that represented the four tag brands. After completing the brand group testing, these same cattle were reassigned as three groups of eight head with two tags of each brand making up each mixed group. Four hundred reads per brand of tag as brand groups and mixed groups were needed to generate the statistical confidence intervals desired for this experiment.

Reader testing was completed in sessions. Each session consisted of six round trips on

and off the trailer, or twelve runs through the reader. Each tag brand was tested during one session per day over six days. This schedule created seventy-two read opportunities per session multiplied by six sessions, yielding a total of 432 read opportunities per brand. The mixed-tag-brand groups were tested following the brand specific groups. Each of the nine mixed tag testing sessions consisted of eight runs. This schedule also yielded 432 read opportunities per tag brand. By dividing the testing into sessions, the cattle were not overworked, leg and hoof injuries were avoided, and changes in reader performance due to weather or environment could be observed. Unfortunately, the weather conditions varied only slightly throughout the entire testing period.

The cattle were loaded and unloaded through a 31-inch wide, 20-foot long, steel framed, semi-portable loading chute with a wood floor that is quite typical of what would be used at a commercial facility. The trailer used was a 1983 Wilson 96-inch wide by 48-foot long, all aluminum double deck with a 36-inch wide door. This unit is also very typical of what is used for commercial livestock transport. The cattle were loaded and unloaded from the upper deck of the trailer only. Preliminary testing revealed that this was the safest means for the cattle to enter and exit the trailer repeatedly. The floor of the upper deck was covered with rubber stall mats and wood shavings to create a surface that was quiet, dry and easily negotiated by the cattle. The trailer ramp and loading chute floor were also covered with wood shavings to improve the footing and protect the cattle from hoof and leg injuries.

Results and Discussion

Reader performance varied greatly across different brands of tags. Tag construction dictates how sensitive a tag will be to changes in orientation. Orientation is the position that the tag is in when it is presented to the reader. The orientation that produces the best read distance and performance is parallel orientation. This means that the face of the tag is parallel with the reader panel. Perpendicular tag orientation decreases read distance and tag performance. This means that the face of the tag is at a 90-degree angle to the reader panel. Sensitivity to orientation varies greatly across brands of tags and will differ with the use of various readers. Tags from brand A and brand B have copper wire that is wound to form the field used to receive the energy from the panel reader. Because of this design these two brands are less sensitive to orientation changes and therefore have greater read rates. Brands C and D have a flat copper disc used to form the field and receive the energy emitted from the reader panel. This design prevents optimal performance, as the tags read poorly at an orientation perpendicular to the reader panel. The following tables show reader performance using the four brands of tags in brand specific groups, mixed groups, and as an aggregate. Read rates for cattle entering the trailer (loading) are noticeably greater than read rates for cattle exiting the trailer (unloading). This is likely due to the speed and bunching at the door that occurred as cattle were moving through the reader while unloading. Movement through the reader at loading was much slower and the animals maintained a single-file order that resulted in better read rates.

Implications

Performance of RFID systems depends strongly upon tag quality and interactions between tags and readers. Trailer-mounted readers present an option for recording and reporting cattle movements to the proper authorities without the investment and training required with ownership of an RFID system.

Table 1. Read Rates of Tag Brands with Brand Groups and Mixed Groups Combined; Presented as Total Reads, Loading and Unloading

Brands	Read Opportunities	Tags Read	Percentage Read	Percentage Missed
Tag Brand A	734	702	95.6	4.4
Loading	378	360	95.2	4.8
Unloading	356	342	96.1	3.9
Tag Brand B	788	691	87.7	12.3
Loading	402	367	91.3	8.7
Unloading	386	324	83.9	16.1
Tag Brand C	782	349	44.6	55.4
Loading	396	217	54.8	45.2
Unloading	386	132	34.2	65.8
Tag Brand D	716	380	53.1	46.9
Loading	366	221	60.4	39.6
Unloading	350	159	45.4	54.6

Table 2. Read Rates of All Brands Combined; Presented as Total Reads, Loading and Unloading

Brands	Read Opportunities	Tags Read	Percentage Read	Percentage Missed
All Brands	3020	2122	70.3	29.7
Loading	1542	1165	75.6	24.4
Unloading	1478	957	64.8	35.2

ATTITUDES OF COW-CALF PRODUCERS TOWARD NAIS ARE GUARDED

S. J. Breiner, K. M. Boone, D. A. Blasi, S. A. Grau, T. C. Schroeder, B. B. Barnhardt, R. M. Breiner and A. M. Bryant

Introduction

The introduction of a National Animal Identification System (NAIS) into the United States has generated much confusion and controversy. The goal of the NAIS is to utilize 48-hour traceback in the event of an animal disease outbreak, identify all animals that have had contact with the diseased animal, and link animals to their premises of origin. The NAIS has led to new technology and guidelines with the potential to change the production and marketing landscape of the beef industry. Moreover, these advances have led to public policy issues that have changed the rhetoric of the industry. The objective of this study was to examine perceptions and attitudes of cow-calf producers toward emerging beef technologies and policy issues through a nationwide mail survey. By understanding the demographics of today's producers in addition to their current practices, the industry can work toward better educating and understanding the concerns of these producers.

Experimental Procedures

A panel of experts at Kansas State University completed content validity testing of the prepared survey instrument. Participants were selected in the spring of 2006, from a mailing list of cow-calf producers with more than 100 cows. *BEEF®* Magazine provided the mailing list and a random sample of 1,000 producers was selected. Three mailings were sent to each participant over a two-month time period. Non-respondents received a fourth mailing to further encourage response. Mailings included: 1) pre-notice letter, 2) survey packet and cover letter, 3) postcard thank you/reminder, and 4) replacement questionnaire with monetary incentive. Data were collected by Prism Business Media, Inc., and analyzed by both Prism Business Media, Inc. and Kansas State University.

Results and Discussion

A total effective mailing of 972 surveys resulted in 522 responses for an effective response rate of 53.7%. Producers from 41 states responded to the survey, and 77.8% of respondents were over the age of 45 with an average herd size of 160.

The first step in implementing the proposed NAIS is to obtain a premise registration number. Of those surveyed, almost one-third had received a premise ID number (Table 1).

Table 1: Have You Received or Registered Your Operation for a Premise Identification Number?

	Number Reporting	Percent Reporting
Yes	171	32.8%
No	341	65.3%
No answer	10	1.9%

N = 522.

Producers were asked to rate their concerns regarding four issues surrounding the implementation of a national ID plan. Liability to producer was the greatest concern of producers. It was followed by cost to the producer, reliability of technology, and confidentiality of information, respectively (Table 2).

Table 2: Please Rate Your Concerns Regarding the Following Issues Surrounding the Implementation of a National Animal Identification Plan:
(1 = not concerned, 2 = somewhat concerned, 3 = concerned and 4 = very concerned)

	N Valid	Mean	Std. Deviation
Cost to producer	513	3.02	0.976
Confidentiality of information	487	2.94	1.050
Reliability of technology	489	2.95	0.943
Liability to producer	496	3.12	0.965

Participants also evaluated the importance of a national animal identification system. Disease monitoring and regaining foreign markets were the most frequently perceived benefits of a national animal identification system. The majority of producers did not feel such a system was important to increase profitability in their operations (Table 3).

Table 3: How Important Do You Feel a National Animal Identification System is to the Following:
(1 = not important and 6 = critical)

	N Valid	Mean	Std. Deviation
Monitoring disease	498	4.13	1.627
Increasing consumer confidence	495	3.95	1.709
Increased profitability	490	3.03	1.674
Regaining foreign markets	493	4.09	1.680
Managing the supply chain	481	3.23	1.711
Enhancing food safety	493	3.71	1.731

Producers were asked to rate their level of agreement with several statements on a scale of 1 to 6, with 1 being strongly disagree and 6 being strongly agree. Forty-one percent of producers agreed to some degree that the NAIS is necessary. Almost 30% felt the implementation of such a program was overdue. More than 59%, however, felt the implementation timeline was not practical (Table 4).

Table 4: Please Rate the Following Statements About the National Animal Identification System (NAIS) In Order of Agreement:
(1 = strongly disagree and 6 = strongly agree)

	N Valid	Mean	Std. Deviation
NAIS is necessary	495	3.35	1.683
NAIS implementation timeline is practical	466	2.97	1.492
The implementation of NAIS is overdue	471	2.97	1.723

Respondents also were asked to rate their level of understanding regarding the proposed NAIS, also on a scale of 1 to 6, with 1 being no understanding and 6 being complete understanding. The majority of producers showed some degree of understanding of the program. Similarly, they were asked to rate their familiarity with electronic ID systems available to producers (Table 5). While most producers felt they were aware of available systems and technology, the margin was small, with a mean of 3.29. The capability of these producers to implement and adopt the NAIS was also evaluated on a scale of 1 to 6, with 1 being incapable and 6 being completely capable. The majority of producers felt they were capable of adopting the program (Table 5).

Table 5: Familiarity With and Capability to Adopt NAIS

(1 = no understanding and 6 = complete understanding)

	N Valid	Mean	Std. Deviation
Familiarity with NAIS	512	3.63	1.302
Familiarity with electronic ID systems	511	3.29	1.419
Capability to adopt NAIS	504	3.87	1.649

Support of a national identification system for cattle was evaluated on a 1 to 6 scale, with 1 being strongly supportive and 6 being strongly opposed. This question showed the most variation within the group, with about 49% supportive and about 48% opposed to some degree. Data showed a mean of 3.53 with a standard deviation of 1.672. Also important to note is the even distribution of producers across all possible responses (Table 6).

Table 6: Generally Speaking, Are You in Favor of a National Identification System for Cattle?

(1 = strongly supportive and 6 = strongly opposed)

	Number Reporting	Percent Reporting
1 - Strongly supportive	78	14.9%
2 - Supportive	74	14.2%
3 - Somewhat supportive	106	20.3%
4 - Somewhat opposed	85	16.3%
5 - Opposed	77	14.8%
6 - Strongly opposed	86	16.5%

N = 506. *Mean = 3.53, s.d. = 1.672

Implications

The data ultimately indicates that there is no strong support for or opposition to a national animal ID system. This shows the controversial nature of the issue and a need for further education.

DESPITE NAIS CONCERNS ELECTRONIC IDENTIFICATION USE BY COW-CALF PRODUCERS IS INCREASING

S. J. Breiner, K. M. Boone, D. A. Blasi, S. A. Grau, T. C. Schroeder, B. B. Barnhardt, R. M. Breiner and A. M. Bryant

Introduction

The proposed U.S. National Animal Identification System has generated concerns among producers relative to implementation of the system. Many of these concerns stem from the USDA's Bovine Identification Working Group's recommendations to use electronic identification. The U.S. Animal Identification Plan Bovine Working Group has recommended radio frequency identification as the technology to individually identify cattle. Understanding and implementing an electronic identification system for cow-calf producers is believed to be one of the greatest challenges of implementing the National Animal Identification System.

Experimental Procedures

A panel of experts at Kansas State University completed content validity testing of the prepared survey instrument. Participants were selected in the spring of 2006 from a mailing list of cow-calf producers with more than 100 head of cows. *BEEF®* Magazine provided the mailing list and a random sample of 1,000 producers was selected. Three mailings were sent to each participant over a two-month time period. Non-respondents received an additional fourth mailing to further encourage response. Mailings included: 1) pre-notice letter, 2) survey packet and cover letter, 3) postcard thank you/reminder, and 4) replacement questionnaire with monetary incentive. Data were collected by Prism Business Media, Inc., and analyzed by both Prism Business Media, Inc. and Kansas State University.

Results and Discussion

A total effective mailing of 972 resulted in 522 completed surveys for an effective response rate of 53.7%. Producers from 41 states responded to the survey. 77.8% of respondents were over the age of 45 with an average herd size of 160 head.

Investigators wanted to determine the types of identification systems producers already had in place. While a large majority of producers (94.1%) reported using some type of animal identification system, less than 10% of producers utilized electronic ear tags.

Table 1: Which of the Following Animal Identification Systems Do You Currently Use?

	Number Reporting	Percent Reporting*
Visual ear tag	441	84.5%
Brand	293	56.1%
Tattoo	117	22.4%
Electronic ear tag	40	7.7%
Other	22	4.2%
None	25	4.8%
No answer	6	1.1%

*Percents may reflect multiple answers.

In 2005, 7.3% of respondents purchased electronic ear tags for identification purposes (Table 2). The number more than doubles, with 16.5% of producers planning to purchase electronic ear tags in 2006 (Table 3).

Table 2: In 2005, Did You Purchase Any Electronic Ear Tags for Identification Purposes?

Purchased in 2005	Number Reporting	Percent Reporting
Yes	38	7.3%
No	479	91.8%
No answer	5	1.0%

N = 522.

Table 3: Have You Purchased, or Do You Plan to Purchase Any Electronic Tags for Identification Purposes in 2006?

Plan to Purchase in 2006	Number Reporting	Percent Reporting
Yes	86	16.5%
No	410	78.5%
No answer	26	5.0%

N = 522.

A small number of producers (5.4%) reported current use of electronic identification and monitoring in their herds (Table 4).

Table 4: Do You Use Any Electronic Identification/monitoring On Your Cattle?

	Number Reporting	Percent Reporting
Yes	28	5.4%
No	487	93.3%
No answer	7	1.3%

N = 522.

Implications

This data provides us with a better understanding of how producers are preparing for the implementation of a national animal identification system. Based on these data, usage will likely double in 2006.

MATURE OPEN COWS ARE RARELY PERSISTENTLY INFECTED WITH BOVINE VIRAL DIARRHEA VIRUS

B. J. White[1], R. L. Larson[1], D. U. Thomson[1]

Introduction

Bovine viral diarrhea virus (BVDv) is an immunosuppressive virus affecting cattle in a multitude of ways. The varied presentation makes this disease difficult to identify in cow herds and the signs of a BVD infection may be very subtle. The syndrome causes economic problems by reducing herd fertility and increasing disease rates.

The persistently infected (PI) animal is a unique reservoir for BVDv. These cattle are the result of *in utero* exposure to the noncytopathic biotype of BVDv prior to the development of a competent fetal immune system at about 125 days of gestation. Persistently infected animals are the primary method for the disease to propagate over time. PI cattle consistently shed BVD virus in relatively high levels and this exposure to the breeding herd can result in new PI calves. PI animals propagate BVDv in the herd and decrease pregnancy percentages compared to herds without PI animals.

Farms must assess risk and manage for biosecurity when purchasing adult animals with an unknown history of disease exposure. Breeding herds that introduce new animals to the herd face the risk of importing a BVD PI animal. To mitigate this risk, PI animals must be accurately identified prior to herd introduction, but visual appraisal is not an accurate method of discovering these animals. Multiple diagnostic tests are available to determine the BVD status of incoming animals and all have an associated cost.

Economic feasibility of determining the BVD PI status of animals depends to a large degree on the frequency with which PI animals occur in a population. Previous research has illustrated that PI calves entering the feedyard phase of production are fairly rare (about three per 1,000 calves); however, very little work has been done in mature animals. This project provides an estimate of BVD PI frequency for a specific population. This assessment should allow the formulation of a BVD-specific risk management plan which addresses the economic efficiency of testing mature females upon arrival.

The primary objective of this research is to determine the prevalence of BVD PI animals in a population of young (3- to 6-year-old) cows purchased as non-pregnant mature animals. The results can guide biosecurity decisions for producers when purchasing and introducing this class of animal to the herd.

[1]Department of Clinical Sciences, College of Veterinary Medicine.

Experimental Procedures

Individual ear skin samples were collected from 1,509 open cows on arrival at a facility near Manhattan, KS, between November 2005 and June 2006. The cows were mixed breeds and were assembled by multiple-order buyers in western states. Samples were submitted to the Kansas State University Veterinary Diagnostic lab for analysis with an antigen capture ELISA test. Prevalence was determined by calculating the proportion of positive samples in the population tested.

The official calfhood vaccination (OCV) tattoo on each animal was examined and the year the animal was vaccinated was recorded. According to federal law, animals must be vaccinated between 6 and 12 months of age; thus, the year of vaccination serves as a proxy for estimating animal age.

Results and Discussion

Examination of tattoos revealed age information on 63.4% (956) of the animals. Most of the cattle in the survey population were young to early middle-aged (vaccinated in 2000 or later; Table 1.). The cattle were purchased as non-pregnant females and pregnancy status may have played a role in their removal from the herd of origin. The population tested represents mature animals that were removed from production systems for a variety of reasons and sold. The demographics are very similar to animals that a herd owner would encounter when buying mature replacement animals for the breeding operation.

Antigen capture ELISA test results were negative on all 1,509 animals. This test does not evaluate animals for acute infections, but rather should only identify persistently infected animals. In this population, there were no persistently infected animals.

Table 1: Number of Cows by Year of Brucellosis Vaccination

Year of OCV Vaccination	Number of cows	% of Group:
Unknown	553	36.6%
1996	1	0.1%
1997	10	0.7%
1998	16	1.1%
1999	31	2.1%
2000	108	7.2%
2001	124	8.2%
2002	218	14.4%
2003	337	22.3%
2004	107	7.1%
2005	4	0.3%
Total:	1509	

Biosecurity to prevent herd exposure to PI cattle is important. Individual testing of all animals that arrive on a farm provides the highest level of security, but is often economically infeasible. Resources should be allocated to areas presenting the highest risk of disease entry. This project indicates that mature, open animals are at relatively low risk for being a persistent carrier of the virus. The tests did not look for acute (or transient) BVDv infections; however, the risk of transfer of virus to the herd of origin from an actively infected animal can be effectively mitigated by keeping the new arrivals segregated for 30 days. Therefore, testing and biosecurity efforts should be placed in other areas known to contribute to formation or introduction of BVDv PI animals.

All replacement heifers and bulls that enter the breeding herd, whether raised or purchased, should be tested and confirmed as PI-negative prior to the start of breeding. If a pregnant animal is purchased, it should be segregated from the breeding herd until both the dam and the calf are confirmed to be PI-negative. Although the dam is unlikely to be persistently infected, current testing methods can not determine the status of the fetus until

it is born. These new calves should be tested after birth and prior to introduction to the breeding herd. Fence-line contact with neighboring cattle should be managed so that stocker cattle are not adjacent to the breeding herd during early gestation (< 130 days), and other cowherds are not adjacent unless they also have a strict biosecurity and vaccination program in place.

Implications

Based on this research, importing mature open animals poses a very low risk for introducing a persistently infected animal; although still a potential risk, younger animals and the fetuses/calves carried by pregnant cows of any age are considered a much greater risk for introducing BVD to a herd.

ULTRASOUND SORTING INCREASES FEEDLOT PROFITABILITY

A. Garmyn and D. Moser

Introduction

Feedlot managers often market entire pens as mixed groups, resulting in lower-quality, over-finished, or heavyweight carcasses. As the cattle industry has moved towards value-based marketing systems, finding a cost-effective tool that predicts future carcass merit and sorts cattle into outcome groups, thus producing a more uniform product at harvest, is of great interest to feedyard managers. The objective of this research was to determine the profitability of sorting feedlot cattle at re-implant time by using ultrasound and computer technology to group cattle into uniform market groups.

Experimental Procedures

The study was conducted in cooperation with Champion Feeders, Hereford, Texas, using 311 crossbred feedlot steers owned by Broseco Ranches, Inc. Live weight of the steers at scanning ranged from 785 to 1275 pounds.

Steers were scanned with a real-time ultrasound machine at re-implant time by personnel of Designer Genes Technologies, Inc. (DG), Harrison, AR, in 2004. Live animal measurements recorded during the scanning session were live weight, 12th rib backfat, ribeye area, and estimated percentage of intramuscular fat (IMF) within the ribeye. Images were interpreted chute-side and used to sort steers into one of four projected outcome groups and determine an implant protocol. The sorting models are proprietary, but included live weight, backfat estimation, ribeye area estimation, an estimation of percent intramuscular fat, average daily gain, and ribeye shape.

Test group steers were assigned by the DG system to one of three levels of the implant regime — none, moderate, and aggressive. Animals assigned to the moderate level received Revalor[1] IS. Steers assigned to the aggressive level received Component[2] TES. All control animals received Component TES according to the feedyard's implant protocol.

The four test groups were harvested based on projected marketing times generated from the DG sorting system at 83, 97, 113, or 125 days after scanning. The control group was harvested in a single group on a date selected by feedyard management 97 days after the scanning date.

Carcass values collected by the slaughter facility with the aid of the Computer Vision System were hot carcass weight, actual fat thickness measurements, actual ribeye area measurements, and yield grade. In addition, official USDA quality grades were recorded

[1]Revalor is a registered trademark of Intervet, Inc.
[2]Component is a registered trademark of Ivy Animal Health, Overland Park, KS.

for each carcass. A corresponding quality grade number was assigned to each quality grade (USDA Choice = 5, USDA Select = 4, no roll = 3). No-roll carcasses did not meet USDA minimum marbling requirements for USDA Select or possessed defects, such as blood splash or dark cutting, which prevented them from qualifying for an official USDA grade upon initial examination.

To determine initial value to access profitability, value was assigned to the steers at re-implant based on their weight at that time. Calf value was estimated using the USDA market reports for the week cattle were sorted, extrapolated from the 850-lb feeder steer price at Oklahoma City and the Panhandle direct slaughter price that week. Cost of gain was calculated from total cost of feed and total gain per pen. Base carcass price was set at $134.26, the five-state-area, weighted-average, dressed price for steers 35% to 65% Choice for the harvest week of the control group. Premiums of $2.00, 1.50, and 8.00 per carcass hundred weight were given to Yield Grade 1, Yield Grade 2, and Choice carcasses, respectively. Discounts of $10.00, $20.00, $11.00, and $30.00 per carcass hundredweight were given to Yield Grade 4, Yield Grade 5, no roll, and heavyweight carcasses (>1,000 lb), respectively. Premiums and discounts were based on the pricing model for Ranchers Renaissance[4]. Profit was calculated for the period from re-implant and sorting to harvest. Profit was defined as carcass value less the cost of feed, implant, and ultrasounding and the value of the steer at the time of scanning.

Results and Discussion

At scanning, steers in the control group had a similar (P = 0.154) body weight as the test groups (Table 1). The sorted steers were fed 11.4 more days than the control steers (P = 0.001).

Table 1. Initial, Performance, and Carcass Traits of Control and Sorted Steers

Trait	Control	Sorted
N	146	137
Initial Traits		
Scan weight lb	996.5	1012.1
Performance Traits[1]		
Days on feed	97.0	108.4*
Average daily gain lb/d	3.40	3.33
Carcass Traits		
Hot carcass weight lb	823.0	852.0*
Backfat thickness in	.44	.51*
Ribeye area in^2	14.9	14.6
Yield grade	2.5	2.8*
Quality grade number[2]	4.2	4.5*
Percent Choice	37.7	51.8

[1]Performance traits were evaluated only between sorting and harvest

[2]Quality grade number 5 = USDA Choice, 4 = USDA Select, 3 = no roll

*indicates a significant difference between control and sorted steers for a particular trait (P<0.05).

Ribeye areas (REA) were similar (P = 0.442) for sorted and unsorted steers. The average hot carcass weight for sorted steers was 29 pounds heavier (P = 0.004) than the control steers. The sorted steers averaged 0.07 inches greater backfat (P = 0.015) than the non-sorted steers. Consequently, due to heavier carcass weights and greater backfat thickness, the average yield grade for sorted steers was 0.3 higher (P = 0.005) than that of non-sorted steers.

Initial value was similar (P = 0.155) for

[3]CVS, Research Management Systems, USA Inc., Fort Collins, CO.

[4]Englewood, CO.

sorted and non-sorted animals (Table 2). This should be expected, because initial value was based on live weight at scanning and there were no significant differences in body weight at scanning. Total production costs were $27.39 higher (P = 0.001) per head for sorted cattle compared to non-sorted cattle. Most of this difference can be attributed to feed costs, which were $21.96 higher (P = 0.001) per head for sorted steers. Implant cost was $0.57 lower (P = 0.001) per head for sorted animals. Although all animals were scanned to evenly distribute steers between the control and test groups, ultrasound costs were not included in the total cost for control animals.

Carcass value was $63.07 higher (P = 0.001) per head for sorted steers than control steers (Table 2). Yield grade premiums were similar (P = 0.147) between sorting type. Quality grade premium was $1.27 higher (P = 0.001) per carcass hundredweight for sorted steers. Weight discounts were similar (P=0.202) between sorting type. When discounts and premiums were accounted for, the DG sorting system was more profitable (P = 0.014) by $22.93 per head over control steers. Increased profitability was primarily due to premiums for higher quality cattle.

Table 2. Economic Performance of Steers

Items	Control	Sorted
Cost ($ per hd)		
Feed	150.42	172.38*
Implant	2.85	2.28*
Ultrasound	0.00	6.00
Discounts and premiums ($ per cwt)		
Yield premium	.75	.00
Quality premium	1.27	3.93*
Weight discount	-.69	-.09
Carcass value	1112.91	1175.98*
Initial value[1]	940.57	953.32
Costs	153.27	180.66*
Profit[2]	19.07	42.00*
Difference		22.93

[1]Initial live value was determined at scanning based on live weight.
[2]Profit based solely on time between sorting and harvest.
*Indicates a significant difference between control and sorted steers for a particular trait (P<0.05).

Implications

Sorting feedlot cattle at re-implant time using ultrasound and computer technology to group cattle into uniform market groups is a cost-effective tool that can predict future carcass merit and increase profitability.

VALIDATION OF COMMERCIAL DNA TESTS FOR BEEF QUALITY TRAITS[1]

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Introduction

Gene mapping and discovery programs have resulted in the detection of numerous DNA 'markers' for various beef cattle production traits. Prior to commercializing genetic markers, it is important to validate their purported effects on the traits of interest in different breeds and environments, and assess them for correlated responses in associated traits. One of the biggest challenges in achieving this objective is the availability of cattle populations with sufficient phenotypic data to assess the association between various traits and newly discovered genetic markers. Results from such validation studies to date have not been widely published and genetic marker tests sometimes may be commercialized prior to the collection of field validation data. In addition, conflicting reports about some commercially available markers, as well as the recognized occurrence of well-proven bulls with a high EPD for a given trait but carrying two copies of the "wrong" (unfavorable) marker for that trait, have made some producers wary of investing in DNA-based testing. Producers want to know whether DNA-based tests perform in accordance with the claims of the marketing company and are interested in third-party, independent validation of these tests. The objective of this study was to validate three commercially-available genetic tests (GeneSTAR Quality Grade[8], GeneSTAR Tenderness[8], and Igenity *Tender*GENE[9]).

Experimental Procedures

Validation Process. The National Beef Cattle Evaluation Consortium (NBCEC, www.NBCEC.org) conducts independent validations of commercially-available genetic tests for beef cattle production traits. This process is a collaboration of owners of the DNA and phenotypes (e.g., breed associations) and commercial testing companies, facilitated by the NBCEC.

DNA Testing Companies and Sample Populations. Phenotypic data and DNA were mostly collected as part of the Carcass Merit Project funded by the Cattlemen's Beef Board and cooperating breed associations. Each

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[1]This research is a condensed version of a research manuscript accepted for publication in the Journal of Animal Science with Alison Van Eenennaam as the first author.

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[8]GeneSTAR Quality Grade and GeneSTAR Tenderness are registered trademarks of Bovigen, LLC.
[9]Igenity *Tender*GENE is a registered trademark of Merial.

commercial testing company selected the breed groups to be used for the validation.

Bovigen, LLC (Harahan, LA), chose to validate its two GeneSTAR 'marker' panels on both Charolais sired calves (n = 400) out of commercial Angus dams and Hereford-sired cattle (n = 285) primarily out of Hereford or Hereford × Red Angus dams. The GeneSTAR Tenderness panel was validated on two populations of Brahman-sired cattle (Brahman dams, n = 674). Approximately half of the Brahmans (n = 318) were Carcass Merit Project cattle from the USDA-ARS SubTropical Agricultural Research Station in Brooksville, FL. The remaining Brahmans were the offspring of 68 Brahman sires bred to Brahman cows at the Louisiana State University Agricultural Center. Merial (Duluth, GA) used the same Charolais-sired and the Carcass Merit Project Brahman-sired cattle populations, plus cattle sired by Red Angus (Red Angus and Red Angus cross dams; n = 310) and Brangus (Brangus and Brangus cross dams; n = 181) for Igenity *Tender*GENE test validation.

Genetic Tests. Genotyping for the GeneSTAR Quality Grade and GeneSTAR Tenderness marker panels (Bovigen, LLC) and the *Tender*GENE marker panel (Merial) was done by the respective companies. The 2 tenderness panels share two common μ-calpain and similar but different calpastatin markers. The μ-calpain enzyme system is primarily responsible for tenderization that occurs during aging. Calpastatin is an inhibitor of the calpain enzyme system, so high levels of calpastatin are undesirable.

Phenotypes. Traits analyzed were longissimus lumborum (loineye) Warner-Bratzler shear force (WBSF) and subjectively recorded marbling score. Muscle sections were harvested 24 to 48 hours postmortem from numerous processing plants, with nearly all using relatively high-voltage electrical stimulation. Steaks (1 inch thick) were vacuum packaged and aged at 1° to 2°C until 14 days postmortem. Steaks were cooked to an internal temperature of 71°C at 163°C. After reaching the endpoint temperature, steaks were cooled at 1° to 2°C for 24 hours, and eight 1/2-inch-diameter cores were removed parallel to the muscle fibers and sheared with a WBSF V-blade attached to an Instron Universal Testing Machine. A numeric score was used to record marbling, with 400 corresponding to Slight^{00}, 500 corresponding to Small^{00}, and 600 corresponding to Modest^{00}, etc. Quality grade was analyzed as percentage qualifying as USDA Choice or Prime based entirely on marbling score ≥ 500 (all carcasses were A maturity).

Statistical Analyses. The basic model was y = CG + marker effect + sire + e, where CG denotes a fixed contemporary group and sire was a random effect. For GeneSTAR Tenderness and Igenity *Tender*GENE marker panels, there were two linked markers, so the regression was on the expected number of copies of each of the four haplotypes (one of which was rare). Genotype frequencies were estimated and analyses carried out with SAS Proc HAPLOTYPE and Proc Mixed, respectively (SAS 9.1.3, SAS Inst. Inc., Cary, NC).

Results

Allele Frequencies. The sample genotypes and allele frequencies for each of the markers included in the commercial tests in this validation study are shown in Table 1. Some alleles were extremely rare (< 0.5%) in certain populations. Specific haplotype frequencies are reported in Table 2. Haplotypes are combinations of genes affecting different traits.

GeneSTAR Quality Grade. One of the Quality Grade (QG) alleles was almost fixed in the Hereford-sired sample population, so the analysis included only the 387 Charolais-sired × Angus cattle (Table 1). The GeneSTAR QG test was not associated with marbling score; however, an increase in the percentage of Choice plus Prime approached

significance (P≤ 0.06; Table 3). The association of the test with quality grade was primarily attributable to the effect of the favorable allele of the QG marker. Bovigen, LLC categorizes the different genotypes into categories of 0, 1, or 2 "stars". In this sample population, the average effect of each "star" (0, 1, or 2) of the GeneSTAR QG test was associated with a 6.2% increase in the percentage of Choice plus Prime.

GeneSTAR Tenderness. Improved tenderness was associated with substituting a T allele at Calpastatin-T1 and a C allele at both μ-calpain loci. The GeneSTAR Tenderness analysis included 1302 cattle (372 Charolais × Angus, 260 Hereford, and 670 Brahman). The association of calpastatin-T1 and the μ-calpain haplotypes with WBSF were each highly significant (P<0.01), as was the combination of these markers (P<0.0001). Each calpastatin T was associated with a decrease of 0.33 lb. in WBSF, and substituting the Calpain T2-T3 C-C haplotype for the Calpain T2-T3 G-T haplotype was associated with a decrease of 0.75 lb in WBSF (Table 4).

Igenity TenderGENE. Improved tenderness was associated (P<0.001) with substituting a C allele at calpastatin and a C allele at both μ-calpain loci. The association of calpastatin and the μ-calpain alleles with WBSF were each highly significant (P<0.001), and the combination of all three even more so (P<0.0001). Table 5 shows the improvement in WBSF for each of the possible haplotypes contrasted to the least tender genotype (calpastatin GG, μ-calpain TT, μ-calpain GG) calculated from a combined analysis of 1209 cattle (181 Brangus, 400 Charolais × Angus crosses, 310 Red Angus and 318 Brahman). In this sample population, each calpastatin C was associated with a decrease of 0.42 lb in WBSF and substituting C-C for G-T at CAPN1 was associated with a decrease of 0.73 lb of WBSF. Combined genotypic effects for GeneSTAR Tenderness and Igenity *Tender*GENE are presented in Table 6. There was a 2.2 lb difference in WBSF between the most and least tender genotypes in both panels.

Discussion

Our study did not show a significant association of the GeneSTAR Quality Grade marker with marbling score, but there was a definite trend (P = 0.06) toward increased quality grade associated with substituting the favorable allele in Charolais × Angus crossbred cattle that had been fed for less than 250 days. However, the binary trait of percentage of Choice plus Prime represents a considerable loss of information compared to the continuous trait of marbling score. The association of quality grade with the results from the GeneSTAR Quality Grade test in the absence of a significant association with marbling score was probably the result of a high proportion of animals on the borderline of the USDA Select/Choice grade. The absolute improvement in quality grade associated with any marker will always be dependent upon marbling endpoint, which emphasizes the importance of environment and management on results derived from validation studies.

The genotype effects of the two tenderness panels, GeneSTAR Tenderness and Igenity *Tender*GENE, were very similar to each other (Table 6), suggesting that the two calpastatin alleles are marking the same tenderness-associated region of the genome. The magnitude of the WBSF reduction associated with the most favorable genotypes compared to the least favorable genotypes is distinctly greater than the difference in tenderness that has been recorded between Select and low Choice quality grades, as well as being greater than the tenderness difference between Select and "premium" Choice (upper two-thirds of Choice) beef. From the perspective of genetic improvement, it is interesting to observe that the frequency of the μ-calpain G-T haplotype is relatively high (Table 2). This suggests that the beef industry may have the opportunity to

improve tenderness by increasing the frequency of the μ-calpain C-C haplotype.

Failure to achieve statistical significance should never be interpreted as evidence that an effect is zero. In this case, the major allele frequency in one or more validation populations may be so high that there is no real opportunity to evaluate the effect of the test. This should not be considered a negative result, but rather a 'no result' (e.g. the GeneSTAR QG test in the Hereford population in this study). Given these considerations, it is perhaps not surprising that few marker validation studies in cattle have been published. However, validation of the effects of genetic markers in independent populations is likely to be vital to the success of genetic testing technology, as producers are likely to be reluctant to invest in unproven markers.

Validation studies can also serve to generate information that is essential for the process of incorporating DNA tests into cattle evaluation. Although there is a tendency to label DNA tests as being associated with one particular trait, markers with a large effect on any one trait are also likely to have correlated effects on other traits because most genes influence a variety of traits. The widespread adoption of marker-assisted selection in the industry will likely depend upon the successful integration of marker information into cattle evaluation schemes to enable eventual development of "DNA marker-assisted EPDs."

Implications

Tenderness could be markedly improved by selecting for the favorable calpastatin and μ-calpain genotypes included in GeneSTAR Tenderness and Igenity *Tender*GENE marker panels. Using the GeneSTAR Quality Grade marker panel could result in an increased percentage of USDA Choice plus Prime carcasses.

Table 1.

Marker	Favorable allele	Population description	Genotype (%) 0	1	2	No. animals	Frequency unfavorable	Frequency favorable
GeneSTAR Calpastatin T1	T	Charolais × Angus	1	11	88	409	0.06	0.94
		Hereford	16	50	34	322	0.41	0.59
		Brahman	11	46	43	674	0.34	0.66
Igenity TenderGENE Calpastatin UoG	C	Charolais × Angus	5	33	62	412	0.21	0.79
		Brangus	5	32	63	203	0.21	0.79
		Red Angus	8	36	56	305	0.26	0.74
		Brahman	33	47	20	344	0.57	0.43
GeneSTAR µ-calpain T2	C	Charolais × Angus	27	54	19	435	0.54	0.46
		Brangus	20	51	29	219	0.45	0.55
		Red Angus	26	54	21	307	0.53	0.47
		Hereford	71	25	4	305	0.84	0.16
		Brahman	88	11	1	674	0.94	0.06
GeneSTAR µ-calpain T3	C	Charolais × Angus	58	37	4	435	0.77	0.23
		Brangus	67	31	2	217	0.82	0.18
		Red Angus	59	36	5	307	0.77	0.23
		Brahman	96	4	0	674	0.98	0.02
		Hereford	56	40	4	309	0.76	0.24
GeneSTAR Quality Grade Thyroglobulin	T	Charolais × Angus	62	34	5	409	0.78	0.22
		Hereford	81	18	1	324	0.90	0.10
GeneSTAR Quality Grade		Charolais × Angus	63	33	4	420	0.79	0.21
		Hereford	97	3	0	311	0.99	0.01

Table 2. μ-Calpain Allele Frequencies

μ-Calpain	G-T	C-T	G-C	C-C	N
Charolais × Angus	0.51	0.03	0.26	0.20	400
Brangus	0.45	0	0.37	0.17	181
Red Angus	0.51	0.01	0.25	0.23	310
Brahman	0.92	0	0.07	0.02	318
Hereford	0.12	0.04	0.64	0.20	260

Table 3. Effects of GeneSTAR Quality Grade Panel Results on Marbling Score and % of Animals Grading Choice and Prime Phenotypes from 387 Charolais-sired × Angus Cattle

Trait	Marker	Estimate, effect	SE	*P*
Marbling Score	GeneSTAR Quality Grade[2]	5.7	4.2	0.18
% Choice and Prime	GeneSTAR Quality Grade[2]	6.2	3.2	0.06

[1]Average effects of Quality Grade favorable alleles.

Table 4. Effects of GeneSTAR Tenderness Panel Results on Warner-Bratzler Shear Force (lb) Phenotypes from 372 Charolais-sired ×Angus, 260 Hereford, and 670 Brahman Cattle

No. Head	Marker	Allele/ Haplotype	Sample Frequency	Estimated Effect (lb)	SE
1302	Calpastatin T1	T	0.72	-0.33	0.23
		C	0.28	0.00	
1302	μ-calpain T2-T3	C-C	0.11	-0.75	0.37
		C-T[1]	0.02	-0.35	
		G-C	0.23	-0.40	0.31
		G-T	0.64	0.00	

[1]The low number of animals with the C-T haplotype in this study made it difficult to accurately estimate their effects.

Table 5. Effects of Igenity *Tender*GENE panel results on Warner-Bratzler Shear Force (lb) Phenotypes from 181 Brangus, 400 Charolais-sired × Angus Cross, 310 Red Angus and 318 Brahman Cattle

No. Head	Marker	Allele/ Haplotype	Sample Frequency	Estimated Effect (lb)	SE
1209	CalpastatinUoG	C	0.72	-0.42	0.11
		G	0.28	0.00	
1209	μ-calpain	C-C	0.16	-0.73	0.15
		C-T[1]	0.01	0.00	0.50
		G-C	0.22	-0.40	0.13
		G-T	0.61	0.00	

[1]The low number of animals with the C-T haplotype in this study made it difficult to accurately estimate its effect.

Table 6. Combined Three-marker Genotype Effects, and Frequencies for the Two Tenderness Panels GeneSTAR Tenderness and Igenity *Tender*GENE[1]

Genotype GeneSTAR's T1 or Igenity's Calpastatin UGa	T2	T3	GeneSTAR Tenderness		IgenityTenderGENE	
			Estimate (lb)	%	Estimate (lb)	%
2 or CC	2 = CC	2 = CC	-2.2	0.8	2.2	1.5
		1 = CT[1]	-.1.8	0.7	-1.1	0.7
		0 = TT[1]	-1.3	0.0	-0.2	0.0
	1 = CG	2 = CC	-.1.8	5.5	-2.0	5.0
		1 = CT	-1.3	6.1	-1.5	10.2
		0 = TT[1]	-1.1	1.0	-0.4	0.7
	0 = GG	2 = CC	-1.5	4.2	-1.5	2.7
		1 = CT	-1.1	11.0	-1.3	15.0
		0 = TT	-0.7	24.7	-0.9	17.5
1 or CG	2 = CC	2 = CC	-1.8	0.4	-1.8	0.7
		1 = CT[1]	-1.5	0.2	-0.7	0.1
		0 = TT[1]	-1.1	0.0	-0.4	0.0
	1 = CG	2 = CC	-1.5	2.9	-1.5	3.5
		1 = CT	-1.1	1.9	-1.1	6.1
		0 = TT[1]	-0.7	0.5	0.0	0.3
	0 = GG	2 = CC	-1.1	4.8	-1.3	1.9
		1 = CT	-0.7	4.1	-0.9	7.5
		0 = TT	-0.4	21.9	-0.4	16.9
0 or GG	2 = CC	2 = CC	-1.5	0.0	-1.5	0.2
		1 = CT[1]	-1.1	0.1	-0.2	0.1
		0 = TT[1]	-0.7	0.0	-0.9	0.0
	1 = CG	2 = CC	-1.1	0.7	-1.1	0.6
		1 = CT	-0.7	0.5	-0.7	0.7
		0 = TT[1]	-0.4	0.5	-0.4	0.0
	0 = GG	2 = CC	-0.4	1.3	-0.9	0.4
		1 = CT	-0.4	1.2	-0.4	2.5
		0 = TT	0.0	5.2	0	5.2

[1]Estimated from 1302 (372 Charolais-sired × Angus, 260 Hereford, and 670 Brahman), and 1209 (181 Brangus, 400 Charolais-sired × Angus Cross, 310 Red Angus and 318 Brahman) Cattle, Respectively

[2]These rows include genotypes involving the rare *CAPN1* 316/4751 C-T haplotype. The low number of animals with the C-T haplotype in this study made it difficult to accurately estimate its effect.

SUPPLEMENTATION OF STOCKER STEERS GRAZING NATIVE FLINT HILLS PASTURE WITH A PROTEIN AND MINERAL SUPPLEMENT INCREASES AVERAGE DAILY GAINS

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Introduction

Supplementation of range cattle with minerals is a common management practice that is used to maximize performance. Flint Hills grasses provide an adequate amount of protein for the diet through the first half of a double-stock grazing period, but declining protein content of native grasses during the latter parts of the grazing season typically cause decreases in forage digestibility and daily gains. The goal of this experiment was to measure differences in performance between steers that were supplemented with a) loose salt for the entire grazing period, b) a stocker mineral supplement for the entire grazing period, or c) a stocker mineral supplement for the first half of the grazing period followed by supplementation with a combination of protein and mineral for the second half of the grazing season.

Experimental Procedure

This experiment used 239 crossbred beef steers (589 lb) of Tennessee origin. Steers were held in a dry-lot receiving facility for 50 days prior to placement in grazing paddocks. The steers were individually identified, weighed, and randomly assigned to treatments. Ivomec[1] injectable, Bar-vac 7 with somnus (clostridial vaccine), and Reliant[1] plus (viral vaccine) were given during the receiving period. Revalor[2]-G (a growth promoting implant) was given to all cattle immediately before the grazing period.

The grazing season began on May 3 and ended on August 1. Steers were assigned to treatment by weight, with three treatments and four replicates per treatment. The first treatment consisted of free-choice loose salt with Chlortetracycline (CTC) added at a rate of 300 mg/lb for the entire grazing season (SALT). The second treatment consisted of summer stocker mineral containing CTC for the entire grazing period (MIN). The third treatment consisted of a free-choice mineral supplement containing CTC for the first half of the grazing period, followed by a protein-mineral supplement containing CTC during the second half of the grazing period (PROMIN). All feeders were placed near a water source for the first week before being moved to a central area within each paddock. Loose salt was blended with the protein mineral as needed to achieve the desired intake levels.

The contents of the mineral feeders were weighed on a weekly basis to measure intake. On day 45, all of the steers were gathered and held overnight without feed or water at the centrally located processing facility. The fol-

[1]Ivomec and Reliant are registered trademarks of Merial.
[2]Revalor is a registered trademark of Intervet, Inc.

lowing morning, steers were weighed individually and returned to their respective grazing paddocks. During the weighing process, cattle received Ivomec pour-on for control of internal and external parasites. Also, on day 45, the PROMIN feeder contents were weighed and replaced with the protein-mineral supplement. The supplement contained a combination of protein sources with different levels of rumen degradability. This 35% crude protein formulation was developed to provide a constant supply of nitrogen to rumen microbes. The formulation also contained macro minerals, trace minerals and CTC in amounts equal to the stocker mineral supplement. Consumption of the protein and mineral supplement at the desired levels increased the total protein level of the diet by two percentage points.

During the grazing period, forage samples were collected every two weeks from one paddock representing each of the pasture treatments. Forage samples were collected by clipping all plants within a two-foot square with electric garden shears. At the end of the grazing period, cattle were gathered and held overnight without feed and water, then weighed individually the following morning before shipment.

Results and Discussion

In comparing SALT to MIN there were no significant differences in average daily gain (ADG) or gain per acre ($P>0.10$). There was however, a significant economic benefit to feeding the mineral supplement, as the additional gain of 0.088 lb/d (1.506 vs. 1.594) generated an estimated 200% return on extra dollars invested. In comparing MIN to PROMIN for the last 45 days of the grazing season, there were significant differences in ADG ($P<0.01$) and gain per acre ($P = 0.01$). Gains for PROMIN were 2.12 lb/d as compared to MIN at 1.62 lb/d for the last 45 days of the grazing period. Overall consumption of the protein mineral plus salt that was used as a limiter was 16 oz. per head daily. Cattle fed the SALT treatment consumed 2.2 oz. per head daily over the entire grazing period and cattle fed the MIN treatment consumed 4.3 oz. per head daily over the entire grazing period.

Implications

Providing a protein and mineral supplement during the last half of a 90 day summer grazing season can dramatically increase average daily gains and gain per acre when grazing steers on native Flint Hills pastures.

Table 1. Grazing Performance of Steers

Item	SALT[1]	MIN[2]	PROMIN[3]	SEM
Number of steers	80	85	74	-
Number of pastures	4	4	4	-
Stocking rate, lb/acre	237	236	232	-
Starting weight, lb	588	589	589	2.03
Day 45 shrunk weight, lb	653	657	654	4.62
Final shrunk weight, lb	725	733	752	7.66
ADG day 1 to day 45, lb	1.48	1.58	1.46	0.09
ADG day 46 to day 90, lb	1.54	1.62	2.12	0.10
ADG day 1 to day 90, lb	1.51	1.61	1.81	0.07
Gain per acre during day 46 to day 90, lb	29	31	38	1.84

[1]SALT: receiving salt with CTC for the entire grazing season.
[2]MIN: summer stocker mineral with CTC for the entire grazing season.
[3]PROMIN: summer stocker mineral with CTC from day 1 to day 45 and protein mineral with CTC from day 46 to day 90.

Table 2. Chemical Analyses of Forages Taken from Experimental Pastures

Date	DM%	CP%	NDF%	ADF%	P%	Cu ppm	Se ppm	Mo ppm	Zn ppm	S%
11 May	43.0	8.82	60.1	35.1	0.127	8.91	0.05	1.03	26.38	0.11
31 May	42.3	7.94	62.2	37.6	0.124	10.66	0.05	1.03	27.17	0.10
14 June	45.7	7.84	63.0	37.1	0.113	10.26	0.20	1.03	25.67	0.10
29 June	47.6	6.21	64.4	36.2	NA	8.62	0.05	1.03	22.75	0.08
10 July	50.3	6.07	60.3	35.3	0.092	9.23	0.04	1.06	27.40	0.08
25 July	51.7	6.02	62.1	36.5	0.085	7.85	0.04	1.02	21.16	0.07
7 August	52.5	5.95	58.7	34.2	0.086	8.58	0.06	1.03	30.18	0.09

ENERGY SUPPLY AFFECTS LEUCINE UTILIZATION BY GROWING STEERS

G. F. Schroeder, E. C. Titgemeyer, and E. S. Moore

Introduction

In growing pigs, when protein supply is adequate, protein deposition increases with an increase in energy intake. However, when amino acid supply is limited, protein deposition does not respond to increases in energy intake. These relationships between energy, protein supply and protein deposition, which are observed in monogastric animals, have been described as protein- and energy-dependent phases of growth. These relationships indicate that energy supply does not affect the efficiency of amino acid utilization, allowing the assumption of a constant efficiency across a broad range of energy intake. Although this type of relationship is assumed for cattle by most of the nutrient requirements systems, our previous experiments indicate that energy supply increases the efficiency of methionine utilization, challenging the assumption of a single efficiency of amino acid use. It is unknown, however, if the positive effects of energy supply on methionine utilization are of similar magnitude for other amino acids. The objective of our study was to determine the effect of energy supply on leucine utilization in growing steers.

Experimental Procedures

Six ruminally cannulated Holstein steers (330 lb initially) were allocated in a 6 × 6 balanced Latin square design. The steers were limit-fed (5.1 lb/day dry matter) a diet based on soybean hulls (83%), wheat straw (7.6%), cane molasses (4.1%) and vitamin-mineral mix. All steers received additional energy supply (1.9 Mcal of gross energy/day) by ruminal infusion of 100 grams/day of acetic acid, 75 grams/day of propionic acid, and 75 grams/day of butyric acid, as well as abomasal infusion of 200 grams/day of glucose. In addition, all the steers received a basal infusion into the abomasum of a mixture containing all the essential amino acids; this was done to prevent limitations in protein synthesis by amino acids other than leucine, thereby allowing protein deposition to the point where either energy or leucine supply became limiting. The treatments were arranged as a 3 × 2 factorial, with the factors being three levels of leucine (0, 4, or 8 grams/day) and two energy levels (0 or 1.9 Mcal of gross energy/day). Energy supplementation was achieved by continuously infusing 100 g of acetate/day, 75 g of propionate/day, and 75 g of butyrate/day into the rumen and 200 grams/day of glucose into abomasum. Therefore, steers receiving the energy supplementation treatment received a total energy infusion of 3.8 Mcal of gross energy/day (1.9 Mcal/day from the basal infusion plus 1.9 Mcal/day from the treatment), whereas control steers received only 1.9 Mcal/day from the basal infusion.

Each experimental period consisted of two days for adaptation and four days for sample collection. Nitrogen balance was used as a measure to estimate protein deposition by the steers.

Results and Discussion

The interaction of leucine × energy supplementation tended to be significant (P=0.06) for nitrogen retention, indicating that the effects of increasing leucine supply were different depending on energy supplementation level (Figure 1). When energy was

not supplemented, nitrogen retention was increased by increasing leucine supplementation from 0 to 4 grams/day, but there were no further changes with additional increases in leucine supplementation. These results indicate that the supplemental leucine requirement was, at most, not much greater than 4 grams/day in those conditions. On the other hand, when the steers received additional energy, there was a linear increase in nitrogen retention in response to leucine supplementation (Figure 1). Therefore, when steers received additional energy supply, the potential for protein deposition was greater, which increased the ability of the steers to respond to higher levels of supplemental leucine supply and, thus, the leucine requirement. Consequently, when steers were provided an additional 1.9 Mcal of gross energy/day, the supplemental leucine requirement was at least 8 grams/day.

When leucine was limiting (from 0 to 4 grams of leucine/day) the estimated incremental efficiency of supplemental leucine use was $\geq$ 26% for control and 30% for energy-supplemented steers. Those values are much lower than that predicted (66%) by the most recent National Research Council *Nutrient Requirements of Beef Cattle*. Additionally, the estimated efficiency of use of dietary leucine, when leucine was not supplemented, was numerically increased from 75% to 79% by energy supplementation. These results suggest that additional energy supply improved the efficiency of leucine utilization, challenging the assumption of a constant efficiency proposed by most of the nutrient requirement systems.

In previous studies with a similar experimental model, when methionine limited protein deposition, energy supplementation also increased the efficiency of methionine utilization. The improvement in efficiency of methionine use was greater than we observed here for leucine. These two essential amino acids are metabolized differently in the body, and these differences in metabolic pathways and the factors that regulate them may partially explain the differences in magnitude of response to energy.

Implications

The present study, in conjunction with our previous studies, indicates that the assumption of a constant efficiency of amino acid utilization for all the essential amino acids and across different levels of energy supply may not be appropriate for estimating amino acid requirements of growing steers. Thus, modeling of amino acid requirements in growing cattle may require consideration of the amount of dietary energy supplied.

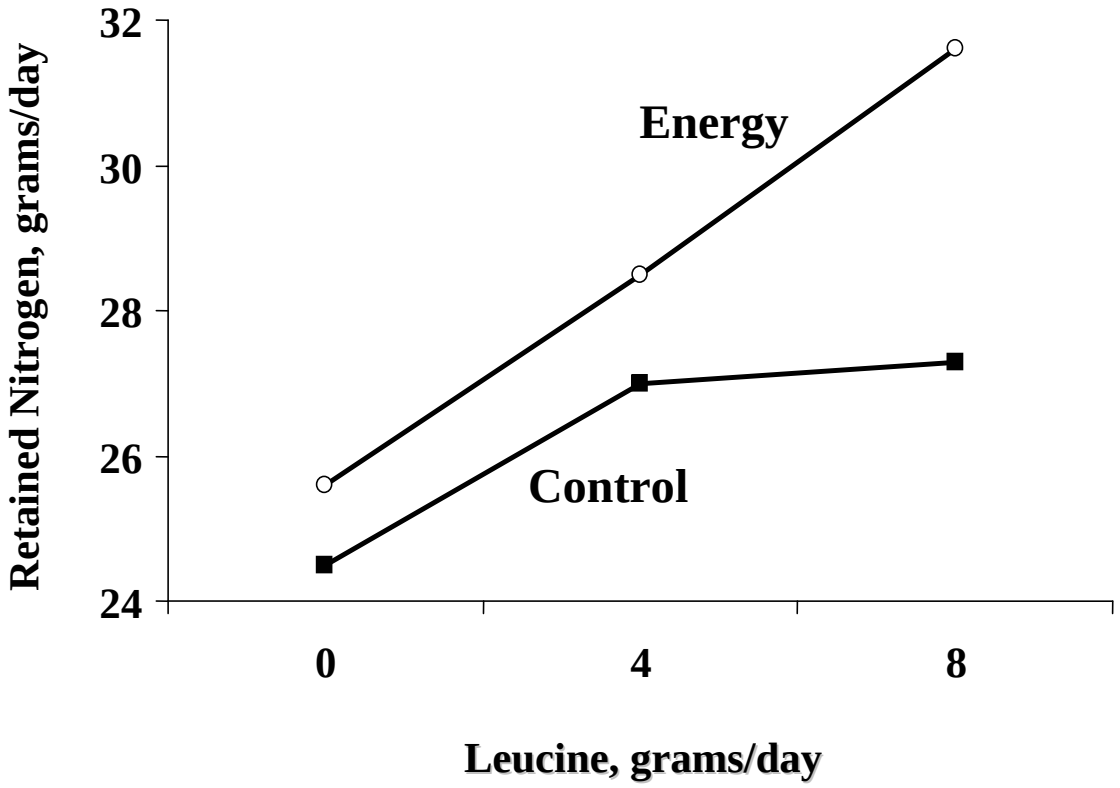

Figure 1. Effects of Energy [Control (none) or Energy (1.9 Mcal gross energy/day)] and Leucine Supplementation on Nitrogen Retention. Linear effect of leucine ($P<0.05$). Effect of energy ($P<0.05$). Interaction leucine × energy supplementation ($P=0.06$).

LIMIT-FEEDING A HIGH-CONCENTRATE DIET MAY ALTER NUTRIENT ABSORPTION

J. O. Wallace, W. F. Miller, B. J. Johnson and C. D. Reinhardt

Introduction

Feeding newly arrived cattle is commonly characterized by a few days of feeding long-stemmed hay followed by a series of step-up diets, wherein concentrate levels are increased to promote ruminal adaptation to a high-concentrate finishing diet. This is done to give the rumen microbes time to adjust to larger amounts of readily fermentable starches in cereal grains. Rumen epithelial adaptation may be achievable by limit-feeding a finishing diet, with gradual increases in feed intake, until the cattle are on full feed. If this can be achieved without causing ruminal disorders and days off feed, then the cost of feeding cattle can be reduced. By limit-feeding, the higher roughage step-up diets are replaced with a single high-concentrate diet. The cost of grain is less than that of roughage, and there are decreased costs in terms of storage space, waste disposal (due to decreased manure production), and mixing and hauling of rations. The purpose of this experiment was to examine the effects of a traditional step-up program versus a limit-fed finishing diet in terms of dry matter intake, acetate to propionate ratio, and ruminal dilution rate. Diet effects on volatile fatty acid concentration and absorption were also examined by using valerate as a marker for volatile fatty acid absorption.

Procedures

In February 2006, cannulated steers (n = 4; average starting weight = 948 lb) were assigned to one of two ration adaptation treatments: 1) limit-fed finishing diet beginning at 1.25% of body weight daily with daily increases of 0.5 lb (LIMIT); or 2) *ad libitum* access to three sequential high-roughage step-up diets and a subsequent finishing diet beginning at 1.5% of body weight daily with daily increases of 1 lb (STEP). If there was more than 0.5 lb of feed refused, feed delivery was not increased the subsequent day. Cattle were stepped up over a 28-day period with seven days per step. Steers were housed in the tie-stall barn at the KSU Dairy Teaching and Research Unit. At the end of the 28 days, steers were placed in an outdoor pen and fed prairie hay and a soybean meal supplement for 21 days. After the three-week rest interval, they were started anew on the adaptation trial, with diets being switched to the opposite of those fed during the first period.

Rumen fluid was collected on days 0, 7, 14, 21 and 28; samples were collected on each collection day over an 8-hour period at 0, 0.5, 1, 1.5, 2, 3, 4, 6, and 8 hours. A basal sample was collected and then each steer was given a single, 1-liter, pulse dose of a 1 molar solution of valerate, with the pH adjusted to 6.0. Samples were analyzed for volatile fatty acids and cobalt, which was a marker for liquid passage from the rumen. Diet samples were collected on each day as the diet was mixed. At the end of the experiment, feed samples were composited and analyzed for neutral detergent fiber and crude protein.

Results

There was an overall diet and day effect on dry matter intake ($P<0.05$). This was due to experimental design. Once all cattle achieved

ad libitum intake during the fourth week of the experiment, there were no effects of step-up treatment on daily dry matter intake. There was no treatment by week effect on acetate to propionate ratio. There was an overall treatment by week effect on total volatile fatty acid concentrations (P = 0.05), but this may be attributable to differences in intake, which were by design. Total volatile fatty acid concentration was different between LIMIT and STEP during weeks 1, 3, and 4 (P<0.05). It was higher for STEP cattle during weeks 1 and 3, but was greater in LIMIT cattle during week 4. There was a tendency for total volatile fatty acids to be higher for STEP cattle during week 2 (P = 0.06). During weeks 1 and 4, valerate absorption differed between treatments (P≤0.05) and tended to differ (P = 0.09) during week 2. Valerate absorption was greater for LIMIT steers during week 1 and tended to be higher during week 2, but during week 4 it shifted and was greater in STEP cattle. This may indicate that the conventional step-up diet is more effective at adapting the rumen epithelium to absorb nutrients once cattle are consuming a finishing diet *ad libitum* or may simply reflect changes in the consumptive behavior of cattle as the amount of feed is increased. Total valerate disappearance was affected by treatment during week 4 (P = 0.05) and treatments tended to differ during week 1 (P = 0.08). Total valerate disappearance tended to be higher in limit-fed cattle during week 1, and was greater in the conventionally fed steers during week 4. No diet by week effects were observed for liquid dilution rate, rumen volume, or rumen turnover.

Discussion:

Due to the current high cost of roughage and its relatively low nutrient content, the cost of conventional step-up programs for adapting cattle to high concentrate diets is greater than limit-feeding them a finishing diet as a means of ruminal adaptation. Limit-feeding the finishing diet during adaptation proved equally effective to a conventional high roughage step-up program with regard to dry matter intake once *ad libitum* intake of the final finishing diet was achieved by all steers. Valerate, a volatile fatty acid normally present in the rumen at low concentrations, is considered a good marker for absorption of other volatile fatty acids. Therefore, as demonstrated by reduced valerate absorption, limit-feeding may alter the ability of the animal to absorb nutrients due to changes in the rumen epithelium.

Table 1. Composition (dry matter basis) of Three Step-up Diets and Finishing Diet

	% Concentrate			
Item, %	60	71	81	92
Steam-flaked corn	49.51	60.04	70.56	81.09
Ground alfalfa hay	40.00	29.33	18.67	8.00
Corn steep liquor	5.00	5.00	5.00	5.00
Vitamin premix[a]	3.26	3.40	3.55	3.68
Feed additive premix[b]	2.23	2.23	2.23	2.23
Nutrient Composition				
NDF, %	27.17	22.73	21.56	15.94
Crude protein, %	16.01	15.68	16.10	14.78
Calcium, %	0.70	0.73	0.75	0.78
Phosphorus, %	0.35	0.35	0.35	0.36
Potassium, %	0.99	0.90	0.82	0.73
NEg, Mcal/lb.	0.55	0.59	0.64	0.69

[a]Premix formulated to provide final diet: 0.14 ppm Cobalt, 10.79 ppm Copper, 0.67 ppm Iodine, 64.76 ppm Manganese, 0.27 ppm Selenium, 64.69 ppm Zinc, and 1.29 KIU/lb Vitamin A.
[b]Formulated to provide 300 mg/day Rumensin, and 90 mg/day Tylan.

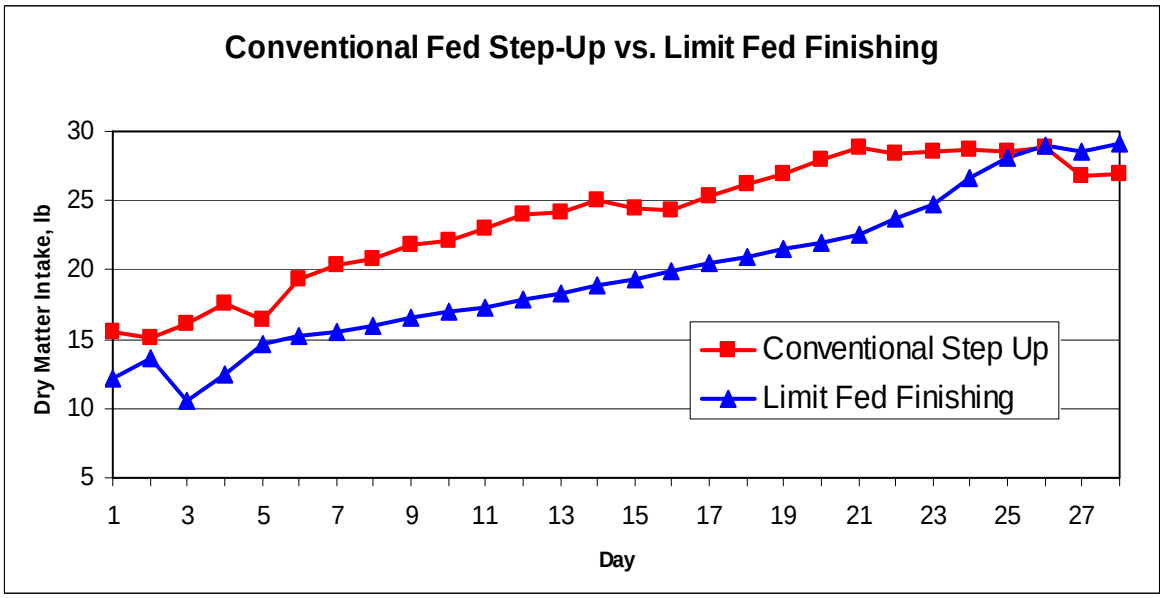

Figure 1. Daily Dry Matter Intake.

Table 2. Ruminal Effects of Conventional Step-up Dietary Adaptation vs. Limited Intake of the Finishing Diet

	Treatment[a]			
Item	Step-up[b]	Limit Fed[c]	SEM[d]	P-value
Week 1				
Acetate:propionate ratio	1.49	1.42	0.14	0.61
Total volatile fatty acid, mmol/liter	116.34	99.67	9.42	0.02
Total valerate disappearance, %/hour	0.39	0.56	0.06	0.08
Liquid dilution rate, %/hour	0.13	0.09	0.03	0.41
Valerate absorption, %/hour	0.27	0.46	0.06	0.02
Rumen volume, liters	27.16	29.30	6.88	0.79
Turnover, hours	8.50	13.90	2.36	0.19
Week 2				
Acetate:propionate ratio	1.38	1.23	0.07	0.18
Total volatile fatty acid, mmol/liter	132.84	108.89	8.85	0.06
Total valerate disappearance, %/hour	0.39	0.48	0.04	0.17
Liquid dilution rate, %/hour	0.13	0.07	0.03	0.20
Valerate absorption, %/hour	0.26	0.41	0.05	0.09
Rumen volume, liters	28.67	34.55	8.70	0.58
Turnover, hours	10.85	39.97	19.91	0.34
Week 3				
Acetate:propionate ratio	1.00	1.04	0.07	0.73
Total volatile fatty acid, mmol/liter	120.82	97.52	10.42	0.04
Total valerate disappearance, %/hour	0.65	0.69	0.17	0.76
Liquid dilution rate, %/hour	0.10	0.10	0.03	0.94
Valerate absorption, %/hour	0.55	0.59	0.17	0.81
Rumen volume, liters	39.81	35.85	8.50	0.69
Turnover, hours	15.94	11.37	4.13	0.45
Week 4				
Acetate:propionate ratio	1.64	1.77	0.44	0.48
Total volatile fatty acid, mmol/liter	99.85	107.81	2.80	0.03
Total valerate disappearance, %/hour	0.67	0.39	0.09	0.05
Liquid dilution rate, %/hour	0.13	0.16	0.05	0.81
Valerate absorption, %/hour	0.55	0.23	0.08	0.05
Rumen volume, liters	28.19	22.44	5.56	0.36
Turnover, hours	9.48	13.09	5.17	0.58

[a]Step-up = steers fed three step up diets and a finishing diet increasing from 60% to 92% concentrate; Limit Fed = steers fed restricted amounts of the 92% concentrate diet as a means of adaptation.
[b]Week 1 = 60% concentrate; Week 2 = 71% concentrate; Week 3 = 81% concentrate; and Week 4 = 92% concentrate, all diets fed for *ad libitum* intake.
[c]Weeks 1, 2, and 3, limit fed 92% concentrate diet starting at 1.25% BW daily and increased 0.5 lb/head daily; during week 4 steers were fed *ad libitum*.
[d]SEM = Standard error of the least squares means; n = 4 steers/treatment.

COMPARISON OF FEED EFFICIENCY RANKINGS OF HEIFERS FED LOW AND HIGH ENERGY DENSE DIETS

J. A. Christopher and T. T. Marston

Introduction

Concepts related to energy efficiency in cattle have been the basis for many research projects. Even though differences in individuals have long been recognized, little effort has been focused on the causes of the observed variations. The concept of residual feed intake was first introduced in 1963, and is calculated as the difference between actual feed intake by an animal and its expected feed intake based on body weight and growth rate. Residual feed intakes are phenotypically independent of the production traits used to calculate expected feed intake. Consequently, residual feed intake values can be useful in comparing individuals differing in level of production during a test period. These feed efficiency calculations have been shown to be a more accurate indicator of genetic variation in efficiency because they are independent of production traits. Thus, selection for improved residual feed intake makes it feasible to reduce feed intake without compromising growth performance. Hence, this trait could have great economic value to all segments of the beef industry. Energy density of cattle diets varies substantially and the selection for the ability to efficiently utilize high roughage diets does not guarantee efficient utilization of high grain diets. The objective of this study was to determine if energy density of the diet influences the ranking of cattle within a contemporary group and to determine if residual feed intake is influenced by changes in body composition and diet digestibility.

Experimental Procedures

Twenty-six weaned, spring-born Angus-Hereford crossbred heifer calves were used in this experiment. No growth promoting implants or oral antibiotics were used during this experiment. Heifers were individually fed using Calan gate feeders. Feed offerings were made once daily and feed refusals were measured weekly. Composition of the diets from each feeding period can be found in Table 1. The low energy feeding period (Period 1) consisted of *ad libitum* amounts of chopped brome hay and 4.4 lb of supplement for 70 days. During the high energy feeding period (Period 2, also 70 days) heifers were fed approximately an 80% concentrate ration *ad libitum*. During both periods, heifers had *ad libitum* access to a commercial vitamin/mineral supplement (Ca = 12%, P = 12%, NaCl = 12%) and water. Body weight, ultrasound measurements, hip height, and feed disappearance were recorded and analyzed. Predicted daily dry matter intakes were estimated by using a linear regression model which included the average metabolic body weight of the feeding period, rate of gain, and changes in carcass composition (ΔBF = change in backfat, ΔMarb = change in marbling score) and height (ΔHt = change in hip height) as independent variables. The model for this regression analysis was: DM intake = $\beta_o + \beta_1$ average $BW^{0.75} + \beta_2$ ADG + β_3 ΔBF + β_4 ΔMarb + β_5 ΔHt + error. Residual Feed Intake values were calculated as the difference between the individual's actual and predicted dry matter

feed intakes. Partial correlations were performed to determine significant relationships between feed efficiency traits, performance and body composition. Heifers were then ranked within each period (diet energy density) for residual feed intake. Spearman rank order procedure was then used to determine if the ranking orders for residual feed intake were similar between periods.

Results and Discussion

For the first feeding period (low energy dense diet) heifers averaged 611 pounds at the beginning and achieved an average daily gain of 1.65 pounds (see Table 2). The average daily dry matter intake was 15.4 pounds. Therefore, heifers' average feed consumption was 2.30% of body weight with a feed to gain ratio of 9.33:1. Residual feed intake values ranged from -1.1 to 1.9 pounds with an average value of 0.0007 pounds. he average residual feed intake value should theoretically equal 0 because the actual average was calculated from within the contemporary group and not a general population. The range of residual feed intake values was approximately 19.5% in feed efficiency within the group of heifers when fed the high forage, low energy diet.

For the second feeding period (high energy diet), heifers averaged 760 pounds at the beginning and achieved an average daily gain of 2.61 pounds (see Table 2). Daily dry matter intake was 23.8 pounds. Therefore, average feed consumption was 2.8% of body weight with a feed to gain ratio of 9.14:1. Several of the heifers experienced bloat, which was attributed to not including ionophores in the diet. Because of the bloat, diet composition was adjusted by adding small increments of prairie hay to the diet. Therefore, diet energy concentrations were calculated on an individual basis. This could have affected the feed to gain ratio of some cattle. Again, by definition, the average residual feed intake of the heifers was 0. The range in residual feed intake values was approximately 11.72%, which appears to be less variable than the observed range in the first feeding period.

Neither the Pearson nor the Spearman rank correlation coefficients were significant ($P>0.80$) between the residual feed intake values from the low energy and high energy diets (see Table 3). Correlation coefficients generally explain the proportion of the total variability of one value that is accounted for by another variable. The Pearson correlation coefficient assesses the linear association between two variables while the Spearman rank correlation coefficient indicates if the heifers remained in the same order (rank) between the first and second feeding periods.

Implications

Cattle producers wishing to use residual feed intake values in selection criteria to improve feed efficiency need to carefully consider what diet type best reflects their production environments.

Table 1. Nutrient Profiles of Diet Components for Low Energy Diet (Periods 1) and High Energy Diet (Period 2)

	Period 1		Period 2	
Nutrients[a, b]	Supplement	Hay	Concentrate	Hay
Amount fed, kg/d	2.03	*Ad libitum*	8.55	2.5
Dry matter, %	91.75	92.13	87.63	91.51
Crude protein, %	21.04	7.48	10.80	8.77
Crude fiber, %	26.95		11.025	
NE_g, Mcal/ kg	0.37	0.25	0.615	0.26
NE_m, Mcal/ kg	0.70	0.58	0.94	0.59
Total digestible nutrients (TDN)	62.78	53.82	81.25	54.76
Fat (EE)	1.63		3.785	
Ash, %	6.84		3.375	
Acid detergent fiber (ADF), %		44.41		43.21
Neutral detergent fiber (NDF), %		68.01		68.32

[a]Nutrients expresses as percent on a dry-matter basis.
[b]Nutrient content based on lab analysis performed by SDK Laboratories, Inc., Hutchinson, KS.

Table 2. Phenotypic Correlations Between Performance Traits and Residual Feed Intake During the Low Energy, Forage-based Feeding Period

Trait	Average Value	Correlation Coefficient with Residual Feed Intake
Starting weight, lb	611	-0.005
Ending weight, lb	726	-0.004
Birthdate, Julian	61	-0.35 *
Gain		
Daily gain, lb	1.66	0.001
Hip height, inches	2.4	0.003
Backfat, inches	0.001	-0.0006
Marbling[a]	0.11	-0.0004
Dry matter intake, lb/day	15.4	0.70 ***
Residual feed intake, lb/day	0.0007	1.00

[a]Marbling score scale: 4.0 = Slight 00, 5.0 = Small 00, etc.; therefore, each 1.0 gain equals a gain of one marbling score.
*P<0.05.
**P<0.01.
***P<0.001.

Table 3. Phenotypic Correlations of Measures of Feed Efficiency and Performance Traits During High Energy, Concentrate-based Feeding Period

Trait	Amount	Correlation Coefficient with Residual Feed Intake
Starting weight, lb	760	-0.00007
Ending weight, lb	942	-0.0002
Birthdate, julian	61	-0.21
Gain		
Daily gain, lb	2.61	-0.0002
Hip height, inches	2.1	-0.0001
Backfat, inches	0.11	-0.00007
Marbling[a]	0.40	0.00002
Dry matter intake, lb/day	23.8	0.49 **
Residual feed intake, lb/day	0.0	1.00

[a]Marbling score scale: 4.0 = Slight 00, 5.0 = Small 00, etc., therefore each 1.0 gain equals a gain of one marbling score.
*P < 0.05.
**P < 0.01.
***P < 0.001.

Table 3. The Correlation Coefficients Between Residual Feed Intake of Heifers Fed Either Low or High Energy Dense Diets

	Pearson Coefficient	Spearman Rank Coefficient
R^2 value	-0.049	0.051
P value	0.81	0.81

WET DISTILLER'S GRAINS WITH SOLUBLES IN BEEF FINISHING DIETS COMPRISED OF STEAM-FLAKED OR DRY-ROLLED CORN

M. L. May, J. S. Drouillard, M. J. Quinn, and C. E. Walker

Introduction

The purpose of this experiment was to determine optimal levels of distiller's grains in finished diets with steam-flaked corn or dry rolled corn. Distiller's grains have been used extensively in regions of the country in which dry-rolled and high-moisture grains are prevalent. Production of fuel ethanol is now expanding into the High Plains, where feedlots more commonly use steam flaking. The cost to produce flaked corn is higher than the cost to produce dry rolled corn, and with rising energy costs (especially natural gas), this spread is becoming more dramatic. Comparing the use of wet distiller's grains fed in conjunction with these grains provides useful information concerning optimum use level.

Procedures

In November 2005, 624 crossbreed yearling steers were used in a finishing trial. Dietary treatments consisted of steam-flaked corn or dry-rolled corn each, containing 10, 20, or 30% wet distiller's grains on a dry matter basis. Cattle were blocked by initial weight and randomly allocated, within block, to each of the eight treatment groups. A total of three weight blocks were used, providing a total of 24 pens with 25 to 26 animals per pen. Cattle were maintained in dirt-surfaced outdoor pens. The dimensions of each pen were 32.5 feet wide × 150 feet deep. Each pen provided 12 to 13 linear inches of bunk space per animal. Cattle were fed once daily (morning) *ad libitum*. Upon arrival, cattle were processed with a combination estradiol/trenbolone acetate implant, seven-way clostridial bacterin, a four-way viral vaccine, and a topical parasiticide. Pen weights were taken before delivery to a commercial slaughter facility in Emporia, KS. Cattle were harvested by block on days 69, 96, and 119. At slaughter, hot carcass weight and incidence and severity of liver abscesses were recorded. After a 24-hour chill period, measurements were taken for USDA yield grade; USDA quality grade; marbling; 12th rib fat thickness; kidney, pelvic and heart fat; rib-eye area; and incidence of dark cutting beef.

Results and Discussion

Dry matter intakes were less for cattle fed steam-flaked corn than cattle fed dry-rolled corn. Intakes also decreased in steam-flaked corn and increased in dry-rolled corn diets as the wet distiller's grains percentage increased in the diet. Feed-to-gain and average daily gain were not different among treatments. Cattle fed dry-rolled corn with 10% wet distiller's grains showed efficiencies that appear to be fairly close to those of steam-flaked corn with no wet distiller's grains. Feeding dry-rolled corn produced a higher percentage of Choice carcasses. Marbling scores also showed that cattle fed dry-rolled corn had more marbling than steam-flaked corn cattle. Cattle fed wet distiller's grains had a lower percentage of cattle grading 1. The other yield grades showed no differences, but these cattle were quite lean and the averages for the groups all were very close to 2. There was no change in liver abscess, back fat over the 12th rib, and rib eye area. Kidney, pelvic, and

heart fat percentages were higher in cattle fed dry-rolled corn compared to steam-flaked corn.

Cattle fed steam-flaked corn diets showed little improvement when wet distiller's grains were added to the diets. Adding wet distiller's grains to the diet when dry-rolled corn is the grain processing method used could have similar performance values when compared to cattle fed steam-flaked corn. Price of wet distiller's grains is the most important factor to consider if it is feasible to include the by-product in the diet of finishing cattle. With the increase in production, many areas have an excess of the product and prices of wet distiller's grains vary from region to region. Factors should also include market strategy (i.e., live marketing versus a grid program). Market strategies should also be a consideration when feeding wet distiller's grains; the reason is cattle showed trends to deposit more external fat. The overall cost of the product has many factors that go past inclusion into the diet.

Table 1. Composition of Diets Fed to Steers During Finishing Periods

	Dry-Rolled Corn				Steam-Flaked Corn			
Wet distiller's level	0	10	20	30	0	10	20	30
Item, % Dry Matter								
Dry-rolled corn	83.75	78.84	---	59.89	---	---	---	---
Steam-flaked corn	---	---	---	---	83.75	78.84	68.89	59.89
Alfalfa hay	6.00	6.00	---	6.00	6.00	6.00	6.00	6.00
Wet distiller's grains	0	10	---	30	0	10	20	30
Corn Steep	5.00	---	---	---	5.00	---	---	---
Rumensin /Tylan premix[1]	2.23	2.23	---	2.23	2.23	2.23	2.23	2.23
Supplement[2]	3.42	---	---	---	3.42	---	---	---
Supplement high[2]	---	2.93	---	1.88		2.93	1.88	1.88
Nutrients Formulated								
Diet dry matter %	83.35	78.84	---	59.89	85.87	79.84	---	65.82
Crude protein	14.00	14.00	---	16.89	14.00	14.00	14.40	16.89
Calcium	.70	.70	---	.70	.70	.70	.70	.70
Phosphorus	.28	.34	---	.50	.28	.34	.42	.50
Non-protein nitrogen	3.46	2.17	---	---	3.46	2.17	---	---

[1]Formulated to provide 300 mg/day Rumensin, 90 mg/day Tylan.
[2]Formulated to provide 0.1 ppm cobalt, 8 ppm copper, 0.5 ppm iodine, 48 ppm manganese, 0.25 pm selenium, 48 ppm zinc, and 1000 IU/lb vitamin A in the diet dry matter.

Table 2. Performance Data for Steers Fed Wet Distiller's Grains

	Dry-Rolled Corn				Steam-Flaked Corn					
Wet distiller's level	0	10	20	30	0	10	20	30		
Item									SEM	P-Value
Number of pens	8	8		8	8	8	8	8	-	-
Number of steers	77	77	-	78	78	78	78	78	-	-
Initial weight, lb	998	999	-	997	997	999	997	997	0.88	0.45
Final weight, lb‡	1241	1268	-	1281	1262	1257	1243	1233	15.46	0.13
Dry matter intake, lb*†‡	20.53	21.67	-	21.83	20.27	20.07	19.90	19.13	0.48	0.001
Average daily gain, lb[1]	2.52	2.87	-	3.08	2.83	2.72	2.59	2.53	0.21	0.21
Feed gain, lb[1],[2]	8.06	7.51	-	7.10	7.13	7.33	7.64	7.51	0.01	0.67
Feed cost/lb gain, $[3]	0.465	0.440	-	0.446	0.437	0.445	0.456	0.457	-	-

[1]Average daily gain and efficiency were computed by using carcass-adjusted final weights. Final live weight = hot carcass weight /63.5% dress.
[2]Statistics were performed as gain:feed, reported as feed:gain.
[3]Assumptions: Corn purchased at $2.25, WDGS purchased at $31/ton, $1.50/ton for dry rolling, $6.00/ton for steam flaking, $10/ton margin on feed.
* Grain interaction P < 0.05, † Linear interaction P<0.05, ‡ Quadratic interaction P<0.05

Table 3. Carcass Performance for Cattle Fed Wet Distiller's Grains

	Dry-Rolled Corn				Steam-Flaked Corn					
Wet distiller's level	0	10	20	30	0	10	20	30		
Item									SEM	P-Value
Hot carcass weight, lb	788	805	-	814	801	798	789	783	9.82	0.13
Choice %	26.85	32.69	-	30.97	28.61	21.79	31.33	15.38	5.45	0.21
Select %	66.78	64.74	-	64.08	67.44	73.08	64.82	78.21	6.02	0.59
No roll, %	6.37	2.56	-	5.28	3.95	2.13	2.56	6.41	2.82	0.89
Dark cutter, %	0.00	0.00	-	0.00	1.28	0.00	1.28	0.00	0.66	0.47
Marbling score[1]*	358	381	-	379	353	362	362	357	8.86	0.53
Yield grade average, %	1.98	2.05	-	2.22	2.03	2.00	2.15	1.98	0.09	0.35
Yield grade 1, %	28.48	23.29	-	17.95	24.61	29.48	18.00	24.36	3.75	0.17
Yield grade 2, %	43.73	52.67	-	44.87	50.67	42.31	49.38	56.41	6.78	0.61
Yield grade 3, %	24.10	21.37	-	32.05	18.21	26.92	27.38	12.82	6.71	0.34
Yield grade 4, %	2.47	1.28	-	3.85	3.90	1.28	3.95	3.85	1.74	0.78
Yield grade 5, %	0.00	1.39	-	0.00	1.33	0.00	0.00	1.28	0.84	0.47
Liver abscess, %	8.99	6.41	-	10.36	3.90	10.25	9.13	8.97	3.14	0.68
Kidney, pelvic, and heart fat, %*†	2.51	2.47	-	2.47	2.44	2.37	2.48	2.36	0.04	0.92
12th Rib fat, inches	0.37	0.41	-	0.42	0.41	0.40	0.43	0.38	0.02	0.18
Rib eye area, square inches	13.46	13.78	-	13.75	13.54	13.72	13.26	13.49	0.23	0.11
Dress, %	64.3	64.1	-	64.6	63.9	63.8	63.4	63.9	0.005	0.37

[1]Marbling Score 300 = Slight; 400 = Small. *Grain interaction P<0.05, † Linear interaction P<0.05.

DRIED DISTILLER'S GRAINS IMPROVE THE PERFORMANCE OF BEEF CATTLE INTENSIVELY GRAZING EARLY SUMMER BLUESTEM PASTURE

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Introduction

Distiller's grains are byproducts of the production of ethanol from grains and are an excellent source of protein and energy for cattle. The most prevalent use of distiller's grains is in the finishing beef production sector. There is limited research available that has evaluated effectiveness of distiller's grains as a supplement for grazing beef cattle. Digestible protein content in grass begins to decrease in midsummer, resulting in lower average daily gains. The objective of this study was to measure the daily gain of yearling steers supplemented with different levels of dried distiller's grains while grazing double-stock Flint Hills pastures.

Experimental Procedures

Three hundred forty-six steers (573 lbs ± 51.0 lbs) were used to evaluate performance of dried distiller's grains in an intensive Flint Hills grazing system (250 lbs/acre for 90 days). The dried distiller's grains were exclusively sorghum grain, pelleted for improved handling and shrink characteristics. All steers were backgrounded at a commercial yard between 30 and 45 days before arrival at the Beef Stocker Unit, Kansas State University, Manhattan, KS.

A single grazing period was used from May 1 to August 3, 2005. Pastures consisted of warm-season perennial grasses with big bluestem (*Andropogon gerardii*) and Indiangrass (*Sorghastrum nutans*) dominant forage species, as well as subdominant forage species of little bluestem (*A. scoparius*) and sideoats grama (*Bouteloua curtipendual*). The following four treatments were randomized over 16 pastures: No supplementation (CON), and sorghum dried distiller's grains supplemented at 0.25% (LOW), 0.50% (MED), and 0.75% (HIGH) of body weight (dry matter basis; Table 1). The dried distiller's grains were 34.6% crude protein and 8.8% crude fat (dry matter basis). Supplemental treatments were fed once daily from June 15 through August 3 in feed bunks located in each pasture. Cattle weights were estimated based on projected average daily gain of 1.8 lb/day from May 1 through June 14 (45 days). Supplements were adjusted every two weeks based on projected ADG of 2.0 lbs/day during the supplement period (June 15 through August 3). Free-choice mineral with a sub-therapeutic dose of oxytetracycline for control of foot rot and pinkeye was provided to all steers until mid-June. Salt in block form was provided to all cattle throughout the entire grazing period. On August 4 the steers were shipped to a commercial feedyard where final weights were taken. Steers were sorted into one of four pens according to dried distiller's grains treatment received on pasture. Grazing and feedyard performance were calculated for each treatment group (Table 2).

Forage quality throughout the grazing period was measured using four ruminally cannulated steers via the rumen evacuation procedure. Rumens were evacuated and rinsed three times, cattle were allowed to graze for 20 minutes, rumens were re-evacuated to obtain consumed forage, and then original rumen

contents were put back into each steer. Four pastures, one from each dried distiller's grains treatment, were sampled. The sampling periods were as follows: May 24, June 28-29, and July 28-29. The same pastures were sampled each sampling period. Crude protein (Figure 1) and ADF (i.e., digestibility; Figure 2) of the forage were analyzed.

Results and Discussion

All cattle fed dried distiller's grains had a significantly greater average daily gain than unsupplemented (Control) cattle (Table 2). In general, weight gain increased as levels of dried distiller's grains increased. However, subsequent performance in the feedyard was lowest for steers fed the highest level of dried distiller's grains during the grazing period.

Implications

Supplementation of dried distiller's grains increases average daily gain of steers in an intensive grazing system; however, subsequent performance in the feedyard appears to decrease.

Table 1. Sorghum Dried Distiller's Grains Supplemented per Head from June 15 to August 3 by Treatment Level

	Treatment Level		
	Low	Medium	High
As-fed lbs	98	170	258
DM lbs	88	151	229

Table 2. Effects of Dried Distiller's Grains (DDG) on Average Daily Gain of Steers Intensively Grazing Native Bluestem Grass and Subsequent Finishing Performance in the Feedyard

	Summer Grazing	Feedyard Performance[e]	
DDG Treatment (% BW, DM basis)	ADG, lbs.	ADG, lbs.	Feed:Gain
0% (Control)	2.31 [a]	3.77	5.71
0.25% (Low)	2.53 [b]	3.58	6.49
0.50% (Medium)	2.59 [b,c]	3.68	5.93
0.75% (High)	2.74 [c]	3.36	6.12
SEM [d]	0.065	-	-

[a,b,c]Differing superscripts between DDG levels vary (P<0.05). Control vs. DDG (P<0.001). Linear effect of DDG (P<0.05).
[d]SEM = Standard Error of Mean.
[e]Pen replication of pasture treatments was not done in feedyard.

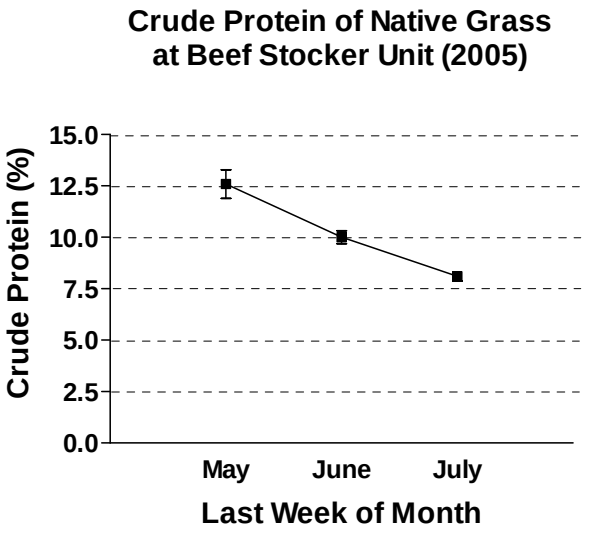

Figure 1.

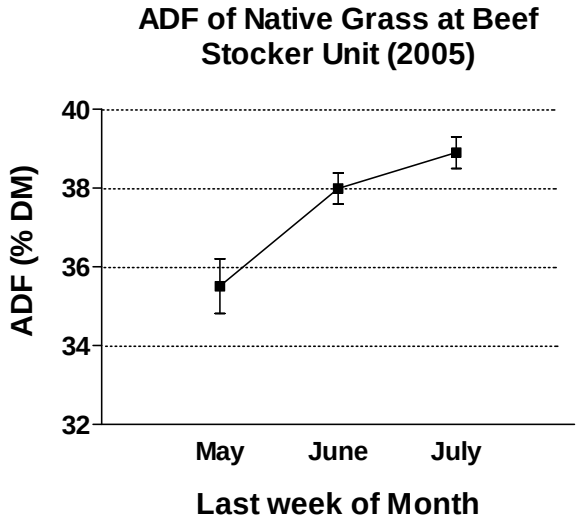

Figure 2.

OPTIMIZING USE OF DISTILLER'S GRAINS WITH SOLUBLES (DGS) IN FINISHING CATTLE DIETS

B. E. Depenbusch, J. S. Drouillard, E. R. Loe, M. E. Corrigan, and M. J. Quinn

Introduction

Rapid expansion of the fuel ethanol industry has increased availability of distillery byproducts. Distiller's grains with solubles (DGS) are the predominant byproduct of fermenting grains to fuel ethanol. During this process, the majority of starch is removed from the grain, and residual components of the grain are concentrated into the distiller's byproduct. Distiller's grains with solubles contain the bran, which is high in fiber; the germ, which is high in fat; and the protein. Given the relatively high fiber content of DGS, it is conceivable that DGS could serve as a replacement for roughage in finishing diets.

One of the major expenses incurred with production of distiller's byproducts is the energy needed to dehydrate byproducts to acceptable moisture levels. Moisture content is critically important because it directly impacts transportation costs, storage characteristics, and handling properties of the feed. Dehydration of byproducts also may alter the nutritive value of the DGS. Generally speaking, extensive heating can result in the formation of indigestible complexes between carbohydrates and proteins, potentially reducing energy availability and efficiency of nitrogen utilization. Consequently, there is significant potential for creating differences in nutritional value of DGS as a result of drying.

Corn and sorghum are the predominant grains used for ethanol production in the United States. The type of grain used is largely determined by the geographical location of the ethanol plant. For example, sorghum grain frequently is produced as a dryland crop in low rainfall areas of the Plains, and corn is produced in the High Plains and Corn Belt regions. In some regions, both corn and sorghum DGS may be available for use in livestock feeding; however, relatively little data is available pertaining to comparative nutritional values of DGS derived from corn and sorghum.

The objectives of this study were to compare 1) sorghum-based DGS with corn-based DGS, 2) wet DGS with dry DGS, and 3) performance of cattle fed diets containing DGS with and without added roughage.

Experimental Procedures

Two hundred and ninety-nine crossbred-yearling steers (800 lb) were obtained from a common source and used in a finishing study. Upon arrival at the feedlot, steers were offered *ad libitum* access to long-stemmed prairie hay and fresh water. Two days after arrival, cattle were identified with uniquely numbered ear tags in both ears and received injections of Bovishield 4 and Fortress-7 vaccines. One week later, animals were revaccinated with

[1]Revalor is a registered trademark of Intervet, Inc.

Bovishield 4, administered Phoenectin pour-on, and implanted with Revalor[1] IS growth implants. Sixty-seven days after the first implant, steers were re-implanted with Revalor IS. Steers were housed in 49 concrete-surfaced pens (392 ft^2) with overhead shade covering the bunk and half of the pen. Pens included an automatic water fountain and 10.5 linear feet of bunk space. Finishing diets were formulated to be isonitrogenous at 14% crude protein. Distiller's grains with solubles were added to the diets at 15% on dry matter basis and alfalfa hay was added at 6% on dry matter. Finishing diets are further described in Table 1. Yearling steers were harvested on two different days (day 101 and day 132) with average days on feed of 116 days. Cattle were shipped to a commercial abattoir in Emporia, KS, where carcass data were collected. Hot carcass weight and liver abscess scores were obtained at the time of harvest. Measurements taken following a 24-hour chill were ribeye area; subcutaneous fat thickness over the 12^{th} rib; kidney, pelvic, and heart fat; marbling score; USDA quality grades; and USDA yield grades. Final body weight was calculated by dividing hot carcass weight by a common dressing percentage of 63.5.

Apparent total tract digestibility of dry matter and organic matter were determined for 21 pens (three pens/treatment) over a 72-hour period during the finishing phase. On day 115, prior to the daily feeding, feed that had not been consumed by the steers was removed, and concrete pen surfaces were thoroughly cleaned. After 24, 48, and 72 hours, feces were collected from each pen, weighed, and a representative sample (~2%) collected from each pen. Daily samples from each pen were composited and frozen for subsequent analysis. Daily feed refusals were also collected at 24, 48, and 72 hours, weighed, and samples were retained for analysis. Samples of feed ingredients, feed refusals, and feces were analyzed for dry matter and organic matter content. Apparent total tract dry matter digestibility was calculated as: [1 – (fecal dry matter output/dry matter intake)] × 100% and apparent total tract organic digestibility as [1 – (fecal organic matter output/organic matter intake)] × 100%.

Results

Addition of 15% DGS had no significant effect on dry matter intake, average daily gain, feed efficiency, or final body weight. However, apparent total tract digestibility of dry matter and organic matter were reduced by approximately 3% ($P<0.05$) when DGS were added to the diet. In addition, steers fed DGS had significantly lower dressing percentages. Observed values were not significantly different among diets with and without 15% DGS for ribeye area; marbling score; kidney, pelvic, and heart fat; 12th rib fat thickness; and USDA quality and yield grades.

Distiller's grains with solubles derived from corn and sorghum resulted in similar growth performance and apparent total tract digestibilities for dry matter and organic matter. However, steers fed the corn DGS tended to be more efficient than the steers fed sorghum based DGS. Generally speaking, carcass characteristics did not differ between steers fed corn-based or sorghum-based DGS. However, steers fed corn-based DGS did have a higher dressing percentage than steers fed sorghum-based DGS.

Steers fed dried DGS tended to consume less feed and were not as efficient when compared to the steers fed wet DGS. Average daily gain, apparent total tract digestibility for dry matter and organic matter, and carcass characteristics were not significantly different between wet and dried DGS. However, steers fed wet DGS had a higher dressing percentage compared to steers fed dried DGS ($P<0.05$).

Dry matter intake and average daily gains decreased in response to removing alfalfa hay from the diet, but feed efficiency was not affected. Apparent total tract digestibility for dry matter and organic matter improved by approximately 4% when alfalfa hay was removed from the diet. Steers fed 6% hay had poorer dressing percentages than steers fed diets without hay. There were no differences between treatments for marbling score; percent USDA Choice or better carcasses; ribeye area; kidney, pelvic, and heart fat; and liver abscesses.

Implications

This study suggests that the addition of 15% DGS to flaked-corn finishing diets reduced overall diet digestibility. Sorghum-based and corn-based DGS have comparable nutritional value for feedlot cattle when added to finishing diets at 15% of dry matter. Likewise, wet DGS and dry DGS are comparable feed ingredients. Distiller's grains with solubles are not suitable as a replacement for all of the dietary roughage.

Table 1. Composition of Finishing Diets (% of dry matter)

		Sorghum Dry DGS		Sorghum Wet DGS[a]		Corn DGS (6% Hay)	
Item	Control	0% Hay	6% Hay	0% Hay	6% Hay	Dry	Wet
Ingredient							
Steam-flaked corn	81.1	75.7	70.0	75.3	69.8	69.8	69.8
DGS	-	15.0	15.0	15.0	15.0	15.0	15.0
Concentrated separator byproduct	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Alfalfa hay	6.0	-	6.0	-	6.0	6.0	6.0
Limestone	1.9	3.5	3.2	3.2	3.0	3.0	3.0
Soybean meal	4.2	-	-	-	-	-	-
Urea	1.4	-	-	0.8	0.6	0.5	0.5
Supplement[a]	0.4	0.8	0.8	0.7	0.6	0.7	0.7
Nutrient %, calculated							
Dry matter	82.2	82.7	83.1	66.5	66. 8	83.0	68.6
Crude protein	14.0	14.4	14.0	14.0	14.0	14.0	14.0
Fat	3.8	4.6	4.5	4.9	4.8	4.8	4.7
Calcium	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Phosphorus	0.3	0.3	0.3	0.4	0.4	0.3	0.4

[a]Formulated to provide 300 mg Rumensin[2] and 90 mg Tylan[2] per steer daily.

[2]Rumensin and Tylan are registered trademarks of Elanco Animal Health, Indianapolis, IN.

Table 2. Growth Performance of Yearling Steers

		Sorghum Dry DGS		Sorghum Wet DGS		Corn DGS (6% Hay)			Contrast[z]			
Item	Control	0% Hay	6% Hay	0% Hay	6% Hay	Dry	Wet	SEM	1	2	3	4
No. of head	43	43	41	43	42	44	43	-			-	-
No. of pens	7	7	7	7	7	7	7	-			-	-
Days on feed	114	114	114	114	114	114	114	-			-	-
Initial weight, lb	803	798	802	803	804	792	800	32.4	0.61	0.24	0.32	0.69
Final weight, lb[y]	1155[a]	1100[b]	1150[a]	1134[a]	1142[a]	1149[a]	1146[a]	24.6	0.47	0.94	0.37	0.01
Dry matter intake, lb/day	20.6[a]	19.1[b]	21.1[a]	19.2[b]	20.7[a]	20.9[a]	20.3[a]	0.59	0.64	0.22	0.13	0.01
Average daily gain, lb/day	3.18[a]	2.70[b]	3.11[a]	2.98[a]	3.03[a]	3.19[a]	3.11[a]	0.10	0.49	0.43	0.61	0.01
Feed:gain	6.49[a]	7.06[b]	6.77[ab]	6.45[a]	6.80[ab]	6.54[a]	6.53[a]	0.16	0.33	0.12	0.14	0.78
Apparent digestibility, %												
Dry matter	83.8[bc]	83.9[cd]	82.6[abc]	86.4[d]	80.1[a]	81.2[ab]	82.0[abc]	0.90	0.03	0.79	0.74	0.01
Organic matter	86.8[cd]	86.4[bc]	85.2[abc]	89.0[d]	83.4[a]	84.0[ab]	85.0[abc]	0.85	0.02	0.79	0.39	0.01

[abcd]Means within a row that do not share similar superscripts are different (P<0.05).

[y]Carcass adjusted final weight was calculated by dividing carcass weight by a common dress yield of 63.5%.

[z]Orthogonal contrast:

1 = Control vs. DGS; (Control vs. sorghum dry DGS with hay, sorghum wet DGS with hay, corn dry DGS, and corn wet DGS).

2 = Sorghum DGS vs. Corn DGS; (Sorghum dry DGS with hay and sorghum wet DGS with hay vs. corn dry DGS and corn wet DGS),

3 = Wet DGS vs. Dry DGS; (Sorghum wet DGS with hay, sorghum wet DGS without hay, and corn wet DGS vs. sorghum dry DGS with hay, sorghum dry DGS without hay, and corn dry DGS),

4 = Sorghum DGS with hay vs. Sorghum DGS without hay; (sorghum dry DGS with hay and sorghum wet DGS with hay vs. sorghum dry DGS without hay and sorghum wet DGS without hay).

Table 3. Carcass Characteristics of Yearling Steers Fed Various Steam-flaked Corn Based Finishing Diets

		Sorghum Dry DGS		Sorghum Wet DGS		Corn DGS (6% Hay)			Contrast[z]			
Item	Control	0% Hay	6% Hay	0% Hay	6% Hay	Dry	Wet	SEM	1	2	3	4
Hot carcass weight, lb	734[a]	698[b]	731[a]	720[a]	725[a]	729[a]	727[a]	15.6	0.47	0.94	0.37	0.01
Dressing percentage	61.3[c]	60.6[ab]	60.3[a]	61.3[c]	60.6[ab]	61.1[bc]	61.3[c]	0.2	0.03	0.01	0.01	0.01
Ribeye area, sq inches	13.0[b]	12.2[a]	12.7[ab]	12.8[b]	12.6[ab]	12.8[b]	12.7[ab]	0.27	0.18	0.52	0.44	0.51
Kidney, pelvic, and heart fat, %	2.7[ab]	2.6[a]	2.7[ab]	2.7[ab]	2.7[ab]	2.8[b]	2.7[ab]	0.06	0.70	0.58	0.32	0.50
12th rib fat, inches	0.45[ab]	0.43[ab]	0.50[a]	0.42[b]	0.47[ab]	0.44[ab]	0.49[ab]	0.03	0.35	0.46	0.92	0.03
USDA yield grade												
YG 1, %	13.3	4.4	7.1	14.3	4.4	4.1	4.8	0.04	0.10	0.76	0.47	0.42
YG 2, %	46.6[ab]	65.0[a]	42.4[ab]	49.3[ab]	40.3[b]	64.0[ab]	48.0[ab]	0.09	0.83	0.09	0.11	0.07
YG 3, %	37.8[ab]	25.9[a]	45.2[ab]	34.4[ab]	52.5[b]	29.6[a]	40.1[ab]	0.08	0.65	0.09	0.19	0.02
YG 4, %	2.4	4.8	2.4	2.0	2.9	2.4	7.1	0.03	0.61	0.35	0.65	0.73
YG 5, %	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.01	0.56	0.19	0.29	0.19
Average YG, %	2.29	2.31	2.51	2.24	2.54	2.30	2.50	0.12	0.22	0.31	0.62	0.05
USDA quality grade												
Prime, %	4.8[a]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.01	0.01	1.00	1.00	1.00
Choice, %	76.2	67.4	75.7	69.7	70.1	79.3	74.2	0.09	0.85	0.57	0.61	0.52
Select, %	19.0	32.6	24.3	27.9	29.9	20.7	23.5	0.09	0.46	0.46	0.83	0.64
No roll, %	0.0	0.0	0.0	2.4	0.0	0.0	2.3	0.01	0.65	0.31	0.10	0.31
Marbling score[y]	474[a]	441[ab]	458[ab]	431[b]	447[ab]	458[ab]	458[ab]	15.6	0.20	0.67	0.51	0.21
Liver abscess, %	2.4	2.5	4.8	7.2	0.1	2.4	2.4	3.16	1.00	0.99	0.99	0.41

[abc]Means within a row that do not share similar superscripts are different (P<0.05).

[y]300 to 399 = Select, 400 to 499 = Choice, 500 to 599 = Prime

[z]Orthogonal contrasts:

1 = Control vs. DGS; (Control vs. sorghum dry DGS with hay, sorghum wet DGS with hay, corn dry DGS, and corn wet DGS),

2 = Sorghum DGS vs. Corn DGS; (Sorghum dry DGS with hay and sorghum wet DGS with hay vs. corn dry DGS and corn wet DGS),

3 = Wet DGS vs. Dry DGS; (Sorghum wet DGS with hay, sorghum wet DGS without hay, and corn wet DGS vs. sorghum dry DGS with hay, sorghum dry DGS without hay, and corn dry DGS),

4 = Sorghum DGS with hay vs. Sorghum DGS without hay; (sorghum dry DGS with hay and sorghum wet DGS with hay vs. sorghum dry DGS without hay and sorghum wet DGS without hay).

DEGERMED CORN DISTILLER'S GRAINS WITH SOLUBLES (DGS) HAVE FEED VALUE SIMILAR TO TRADITIONAL DISTILLER'S GRAINS

B. E. Depenbusch, J. S. Drouillard, E. R. Loe, M. J. Quinn, and M. E. Corrigan

Introduction

Rapid expansion of the fuel ethanol industry has greatly increased availability of distillery byproducts. Distiller's grains with solubles (DGS) are the predominant byproduct of fermenting grains into fuel ethanol. During this process, starch is removed from the grain and the residual components of the grain are concentrated in the DGS. Improvements in the conversion of cereal grains to ethanol have been fueled by recent changes in the production process. Broin Companies (Sioux Falls, SD) have developed a technology that removes the germ before the fermentation process. The resulting byproduct contains more protein, less crude fat, and less phosphorus compared to traditional distiller's grains. Feeding even modest levels of DGS can contribute to greater phosphorus excretion from feedlots, suggesting that strategies aimed at reducing phosphorus levels are well warranted. The objective of this study was to compare diets based on steam-flaked corn with and without DGS and to compare a high-protein, low-fat, low-phosphorus byproduct to more traditional distiller's grains.

Experimental Procedures

Six hundred and ten crossbred-yearling heifers (765 lb) were used in a finishing study comparing three diets. All three diets were based on steam-flaked corn and were formulated to contain 14% crude protein. The first diet served as the control and it contained no DGS. The second diet contained 13% of corn dried distiller's grains with solubles (DDGS), and the third diet contained 13% of a partially degermed (DEGERM) corn DDGS.

Upon arrival at the feedlot, heifers were offered *ad libitum* access to chopped alfalfa hay and fresh water. Two days after arrival, cattle were identified with uniquely numbered ear tags in both ears and received injections of Bovishield 4 and Fortress-7 vaccines. In addition, animals were administered Safe-Guard[1] via an oral drench and implanted with Revalor[2] H. Twenty-four pens were used in this study with eight pens per treatment and 24 to 25 animals per pen. Heifers were allowed *ad libitum* access to four step-up diets leading to the final finishing diet (Table 1). Heifers were housed in dirt-surfaced pens (~210 ft^2/animal) with automatic water fountains and 33 linear feet of bunk space.

[1]Safe-Guard is a registered trademark of Hoechst Celanese Corporation.
[2]Revalor is a registered trademark of Intervet, Inc.

Starting on day 97, chromic oxide (indigestible marker) was included in the ration at 0.21% (dry basis) and was fed for seven days. On day 104, fecal samples were collected from each animal. Diet samples were also collected daily from day 97 through day 103, pooled together, and sub-sampled. Subsamples were frozen and retained for determination of dry matter, organic matter, phosphorus, and chromic oxide concentrations.

On day 118, cattle were shipped to a commercial abattoir in Emporia, KS, where carcass data were collected. Carcass weight and liver abscess scores were obtained at the time of harvest. Measurements taken after a 24-hour chill were ribeye area; subcutaneous fat thickness over 12th rib; kidney, pelvic, and heart fat; marbling score; USDA quality grades; and USDA yield grades. Final body weight was calculated by dividing carcass weight by a common dressing percentage of 63.5.

Results and Discussion

Animal performance data are summarized in Table 2. Average daily gains and feed efficiencies were statistically similar among the control diet and the two diets with DGS. Heifers fed the degermed DGS consumed the least feed whereas those heifers fed the traditional distiller's grains consumed the most feed. This study suggests that DGS derived from the new generation of ethanol plants have a feeding value similar to the traditional distiller's grains.

Total tract digestibility values (Table 3) demonstrate some of the challenges with feeding DGS. When highly digestible steam-flaked corn was replaced with the less digestible DGS, fecal production increased by 5%. Not only was manure production increased, but the concentration of phosphorus in the manure also increased. The degermed DGS contained less phosphorus than the more traditional distiller's grains, which led to numerically less fecal excretion of phosphorus.

In this study, carcass characteristics and quality (Table 4) were not altered when a diet of 13% DGS was fed.

Implications

Feeding DGS to feedlot cattle yielded growth performance and carcass characteristics comparable to grain-based diets, but increased manure production by 5%. Degermed DGS have feed value similar to the more traditional distiller's grains.

Table 1. Experimental Diets

Item	Control	DDGS[a]	DEGERM[b]
Ingredient			
Steam-flaked corn	80.9	71.2	71.9
DGS	0.0	13.0	13.0
Concentrated separator byproduct	5.0	5.0	5.0
Alfalfa hay	6.0	6.0	6.0
Soybean meal	2.9	0.0	0.0
Urea	1.2	0.7	0.0
Supplement[c]	1.8	1.9	1.9
Nutrient, %			
Dry matter	82.1	82.8	82.8
Crude protein	14.0	14.0	14.0
Fat	3.8	4.8	3.9
Calcium	0.7	0.7	0.7
Phosphorus	0.29	0.38	0.31

[a]DDGS = Corn dried distiller's grains with solubles.
[b]DEGERM = Partially degermed corn dried distiller's grains with solubles.
[c]Formulated to provide 300 mg/day Rumensin, 90 mg/day Tylan, and 0.5 mg/day MGA.

Table 2. Animal Performance and Efficiency of Yearling Heifers Fed Finishing Diets Based on Steam-flaked Corn

Item	CONTROL	DDGS[a]	DEGERM[b]	SEM
No. of head	203	204	203	-
No. of pens	8	8	8	-
Days on feed	118	118	118	-
Initial weight, lb	765	765	765	10.0
Final weight, lb	1066	1073	1054	14.8
Dry matter intake, lb/day	20.1[xy]	20.7[x]	19.7[y]	0.35
Average daily gain, lb/day	2.55	2.61	2.44	0.07
Feed:gain	7.89	7.93	8.08	0.002

[a]DDGS = Corn dry distiller's grains with solubles.
[b]DEGERM = Partially degermed corn dry distiller's grains with solubles.
[xy]Means within a row without common superscripts are different ($P<0.05$).

Table 3. Apparent Total Tract Digestibility by Yearling Heifers Fed Finishing Diets Based on Steam-flaked Corn

Item	CONTROL	DDGS[a]	DEGERM[b]	SEM
No. of head	203	204	203	-
No. of pens	8	8	8	-
Intake				
Dry matter, lb	17.95	18.14	17.31	0.13
Organic matter, lb	17.11	17.17	16.45	0.13
Phosphorus, g	23.61[x]	31.28[y]	24.34[x]	0.43
Fecal excretion				
Dry matter, lb	4.32[x]	5.03[y]	4.81[y]	0.08
Organic matter, lb	3.40[x]	4.10[y]	3.81[y]	0.07
Phosphorus, g	11.98	14.08	12.16	0.64
Apparent total tract digestibility, %				
Dry matter	75.9[x]	72.3[y]	72.2[y]	0.92
Organic matter	80.1[x]	76.1[y]	76.8[y]	0.85
Phosphorus	49.5	55.0	50.2	1.9

[a]DDGS = Corn dried distiller's grains with solubles.
[b]DEGERM = Partially degermed corn dried distiller's grains with solubles.
[xy]Means within a row without common superscripts are different (P<0.05).

Table 4. Carcass Characteristics of Yearling Heifers Fed Finishing Diets Based on Steam-flaked Corn

Item	CONTROL	DDGS[a]	DEGERM[b]	SEM
Hot carcass weight, lb	677	681	669	9.39
Dressing percentage	63.5	63.2	62.8	0.27
Longissimus muscle area, sq inches	13.86	13.52	13.53	0.13
Kidney, pelvic, and heart fat, %	2.24	2.24	2.20	0.08
12th rib fat, inches	0.32	0.35	0.32	0.02
USDA yield grade				
Yield grade 1, %	41.1	32.6	38.9	4.91
Yield grade 2, %	39.8	47.5	41.8	3.10
Yield grade 3, %	18.6	18.9	19.3	3.65
Yield grade 4, %	0.5	1.0	0.0	0.47
Yield grade 5, %	0.0	0.0	0.0	-
Average yield grade, %	1.78	1.88	1.80	0.08
USDA quality grade				
Prime, %	1.0	0.5	0.5	0.54
Choice, %	40.2	46.9	43.4	5.48
Select, %	52.9	49.2	50.7	5.29
No Roll, %	5.9	3.4	5.4	1.15
Marbling score[c]	385	392	397	8.5
Liver abscess, %	4.9	4.9	3.9	1.7

[a]DDGS = Corn dried distiller's grains with solubles.
[b]DEGERM = Partially degermed corn dried distiller's grains with solubles.
[c]A+ = one or more large, or multiple small, active abscesses, with or without adhesions; A = two to four small, well-organized abscesses; and A- = one or two small abscesses or scars.

EFFICACY OF FEED GRADE ANTIBIOTICS IN FINISHING DIETS CONTAINING DISTILLER' GRAINS WITH SOLUBLES (DGS)

B. E. Depenbusch, J. S. Drouillard, E. R. Loe, and M. J. Quinn

Introduction

Rumensin[1] and Tylan[1], both marketed by Elanco Products Company, have proved to be valuable feed additives when fed to finishing feedlot cattle. Rumensin was approved in the mid-1970s to improve feed efficiency and average daily gain. Rumensin frequently is used to manage digestive disturbances associated with otherwise erratic intakes of high grain diets. Tylan is fed as a preventative for liver abscesses. Rumen disorders such as acidosis and rumenitis are predisposing factors for liver abscesses. Erratic intakes of high grain diets along with poor bunk management are important factors that predispose cattle to ruminal disorders. Abscessed livers can have deleterious affects on animal performance, and in extreme situations lead to excess carcass trim and reduced carcass yields.

Distiller's grains with solubles (DGS) typically contain the protein, bran, and germ portions of the grain used in the fermentation process. In studies previously conducted at Kansas State University, corn germ fed at levels as low as 5% (dry basis) significantly reduced the incidence of liver abscesses. Since DGS also contain the corn germ, we hypothesized that a similar effect could be achieved by substituting DGS for corn. The objective of this study was to evaluate the efficacy of Rumensin and Tylan on growth performance, carcass characteristics, and carcass quality of yearling heifers fed diets based on steam-flaked corn with and without 25% corn wet DGS.

Experimental Procedures

Three hundred and seventy-one crossbred-yearling heifers (660 ± 19 lbs) were obtained from a common source and used in a finishing study. Heifers were fed finishing diets based on steam-flaked corn with and without 25% of diet dry matter as corn wet DGS. Within each diet, heifers were fed no antibiotics (NONE), Rumensin only (RUMENSIN), or Rumensin plus Tylan (RUM+TYL). Rumensin was fed at 300 mg/heifer daily and Tylan at 90 mg/heifer daily. Diets are described in Table 1.

Heifers were housed in 54 concrete-surfaced pens (392 ft^2) with overhead shade covering the bunk and half of the pen. Pens included automatic water fountains and 10.5 linear feet of bunk space. Pen weight of animals was determined on days 33, 61, 89, and 122 using a pen scale. Pen weights also were measured just prior to shipping to a commercial abattoir.

Cattle were harvested on day 150 at a commercial abattoir in Emporia, KS, at which time carcass data were collected. Hot carcass

[1]Rumensin and Tylan are registered trademarks of Elanco Animal Health, Indianaplis, IN.

weight and liver abscess scores were obtained at the time of harvest. Measurements taken following a 24-hour chill were ribeye area; subcutaneous fat thickness over 12th rib; kidney, pelvic, and heart fat; marbling score; USDA quality grades; and USDA yield grades. Final body weight was calculated by dividing hot carcass weight by a common dressing percentage of 63.5.

Results and Discussion

Yearling heifers fed the steam-flaked corn based diet with 25% corn-wet DGS gained 8% less weight and were less efficient than heifers fed no DGS. Addition of RUMENSIN and RUM+TYL did not significantly affect animal growth performance. Dry matter intake and feed to gain ratio were numerically lower for RUMENSIN and RUM+TYL, but this difference was not significant. Average daily gain and final body weights were similar among heifers fed NONE, RUMENSIN, and RUM+TYL.

Carcass weight and ribeye area were both less for the heifers fed 25% corn wet DGS. In addition, these heifers also had a lower dress yield. Percent liver abscess was not significantly altered with the inclusion of 25% corn wet DGS. Marbling score and carcasses grading USDA Choice or better were both significantly lower for heifers fed DGS. Carcass data from these heifers suggest that feeding 25% corn wet DGS resulted in similar 12th rib fat thickness and kidney, pelvic, and heart fat, but with less lean muscle (i.e., ribeye area) and a smaller carcass. The net result from feeding 25% corn-wet DGS was a lower valued carcass.

Addition of RUMENSIN and RUM+TYL to finishing diets based on steam-flaked corn with and without DGS resulted in no significant differences in carcass merit or quality. We did observe some numerical decreases in liver abscess with the addition of RUM+TYL, but only in diets without DGS. In the steam-flaked corn diets, RUM+TYL reduced liver abscess by 66%. However, in the diets containing DGS, we observed no differences in liver abscess rates. Results from this study suggest that Tylan yields a reduction in liver abscesses when added to traditional steam-flaked corn diets, but it may lack efficacy in finishing diets containing DGS.

Implications

Twenty-five percent corn wet DGS in steam-flaked corn diets reduced animal performance and carcass value. Rumensin did not result in any improvements in growth performance or carcass quality. Efficacy of Tylan in diets containing DGS appears to be less than in more traditional steam-flaked corn diets.

Table 1. Composition of Finishing Diets Based on Steam-flaked Corn With and Without 25% Corn Wet DGS Fed to Yearling Heifers

Ingredient, % (dry basis)	Steam-Flaked Corn	Steam-Flaked Corn with WDGS[b]
Steam-flaked corn	83.9	64.9
Corn wet DGS	-	25.0
Steep	5.0	-
Alfalfa hay	6.0	6.0
Limestone	1.3	1.3
Urea	1.0	-
Supplement[a]	2.8	2.8
Nutrient %, calculated		
Dry matter	78.8	61.0
Crude protein	14.0	14.8
Fat	3.3	5.4
Calcium	0.70	0.70
Phosphorus	0.30	0.36

[a]Supplement provided one of 3 different feed additive combinations:
NONE = Formulated to provide 0.5 mg MGA per heifer daily,
RUMENSIN = Formulated to provide 0.5 mg MGA and 300 mg Rumensin per heifer daily,
RUM+TYL = Formulated to provide 0.5 mg MGA, 300 mg Rumensin, and 90 mg Tylan per heifer daily.
[b]WDGS = Corn wet DGS was added to the diet at 25% (dry basis).

Table 2. Growth Performance of Yearling Heifers Fed Diets Containing Either Steam-flaked Corn or a Combination of Steam-flaked Corn and Corn Wet DGS With Different Feed Additives (NONE[a], RUMENSIN[b], and RUM+TYL[c])

	Steam-Flaked Corn			Steam-Flaked Corn and WDGS[d]				*P* value		
Item	NONE	RUMENSIN	RUM+TYL	NONE	RUMENSIN	RUM+TYL	SEM	Diet	Additive	Diet × Additive
No. of head	63	62	62	62	63	59	-	-	-	-
No. of pens	9	9	9	9	9	9	-	-	-	-
Days on feed	150	150	150	150	150	150	-	-	-	-
Initial weight, lb	660	660	660	660	660	660	19.3	0.56	0.41	0.84
Final weight, lb[e]	1,096	1,079	1,093	1,059	1,049	1,054	24.4	0.01	0.39	0.90
Dry matter intake, lb/day	17.6	17.4	17.1	17.4	17.1	17.0	0.41	0.34	0.33	0.93
Average daily gain, lb/day	2.91	2.80	2.89	2.66	2.59	2.63	0.07	0.01	0.36	0.91
Feed:gain	6.05	6.20	5.91	6.51	6.61	6.42	0.13	0.01	0.20	0.87

[a]NONE = Formulated to provide 0.5 mg MGA per heifer daily.
[b]RUMENSIN = Formulated to provide 0.5 mg MGA and 300 mg Rumensin per heifer daily.
[c]RUM+TYL = Formulated to provide 0.5 mg MGA, 300 mg Rumensin, and 90 mg Tylan per heifer daily.
[d]WDGS = Corn wet DGS was added to the diet at 25% (dry basis).
[e]Carcass adjusted final weight calculated by dividing carcass weight by a common dress yield of 63.5%.

Table 3. Carcass Characteristics of Yearling Heifers Fed Diets Containing Either Steam-flaked Corn or a Combination of Steam-flaked Corn and Corn Wet DGS With Different Feed Additives (NONE[a], RUMENSIN[b], and RUM+TYL[c])

	Steam-Flaked Corn			Steam-Flaked Corn and WDGS[d]				*P* value		
Item	NONE	RUMENSIN	RUM+TYL	NONE	RUMENSIN	RUM+TYL	SEM	Diet	Additive	Diet × Additive
Hot carcass weight, lb	696	685	694	673	666	669	15.5	0.01	0.37	0.93
Dress yield, %	62.3	61.6	61.7	61.3	61.1	61.4	0.24	0.01	0.90	0.30
Ribeye area, inches^2	12.77	11.97	12.41	12.16	11.74	12.09	0.26	0.05	0.04	0.71
Kidney, pelvic, and heart fat, %	2.65	2.62	2.68	2.68	2.64	2.66	0.05	0.73	0.55	0.79
12th –rib fat, inches	0.47	0.46	0.48	0.47	0.48	0.47	0.03	0.80	0.96	0.79
Liver abscess, %	24	22	8	15	16	16	5.1	0.53	0.27	0.24
A+[e]	16	12	3	8	6	10	3.5	0.48	0.30	0.09
A[f]	2	3	2	0	0	2	1.5	0.17	0.79	0.50
A-[g]	6	7	3	6	10	4	3.2	0.35	0.35	0.87

[a]NONE = Formulated to provide 0.5 mg MGA per heifer daily.
[b]RUMENSIN = Formulated to provide 0.5 mg MGA and 300 mg Rumensin per heifer daily.
[c]RUM+TYL = Formulated to provide 0.5 mg MGA, 300 mg Rumensin, and 90 mg Tylan per heifer daily.
[d]WDGS = Corn wet DGS was added to the diet at 25% (dry basis).
[e]A+ = One or more large or multiple, small, active abscesses with or without adhesions.
[f]A = Two to four small, well-organized abscesses.
[g]A- = One or two small abscesses or scars.

Table 4. USDA Yield and Quality Grade of Yearling Heifers Fed Diets Containing Either Steam-flaked Corn or a Combination of Steam-flaked Corn and Corn Wet DGS With Different Feed Additives (NONE[a], RUMENSIN[b], and RUM+TYL[c])

	Steam-Flaked Corn			Steam-Flaked Corn and WDGS[d]				*P* value		
Item	NONE	RUMENSIN	RUM+TYL	NONE	RUMENSIN	RUM+TYL	SEM	Diet	Additive	Diet × Additive
USDA yield grade, %	2.67	2.73	2.65	2.58	2.71	2.70	0.10	0.81	0.54	0.74
YG 1	6	6	2	7	5	5	2.73	0.78	0.46	0.68
YG 2	33	31	46	43	37	34	5.25	0.77	0.40	0.06
YG 3	48	47	39	37	41	48	6.54	0.63	0.95	0.31
YG 4	13	16	11	11	17	13	5.34	0.84	0.62	0.93
YG 5	0	0	2	2	0	0	1.00	0.91	0.61	0.24
USDA quality grade, %										
Choice or better	75	80	74	62	70	65	6.52	0.02	0.44	0.95
Prime	2	0	1	0	2	0	1.25	0.55	1.00	0.24
Choice	73	80	73	62	68	65	6.78	0.04	0.48	0.93
Select	22	20	24	37	27	35	6.21	0.02	0.45	0.81
Standard	3	0	2	2	2	0	1.85	0.95	0.73	0.31
Marbling score	464	444	448	428	439	428	12.64	0.03	0.77	0.38

[a]NONE = Formulated to provide 0.5 mg MGA per heifer daily.
[b]RUMENSIN = Formulated to provide 0.5 mg MGA and 320 mg Rumensin per heifer daily.
[c]RUM+TYL = Formulated to provide 0.5 mg MGA, 320 mg Rumensin, and 90 mg Tylan per heifer daily.
[d]WDGS = Corn wet DGS was added to the diet at 25% (dry basis).
[e]300 to 399 = Select, 400 to 499 = Choice, 500 to 599 = Prime

SUPPLEMENTATION WITH DEGRADABLE INTAKE PROTEIN INCREASES LOW-QUALITY FORAGE UTILIZATION AND MICROBIAL USE OF RECYCLED UREA

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Introduction

A common production practice throughout the United States is to supplement protein to cattle consuming low-quality forage (forage with a crude protein content of less than 7%) in order to improve animal performance (i.e., maintain body condition score and body weight) during the winter. Protein supplementation increases forage utilization (intake and digestion) and cow performance by supplying ruminal microbes with protein that is essential for microbial growth. Increased microbial activity in turn provides sources of both protein and energy to the cow. In addition to the protein that is fed and degraded in the rumen, ruminants have the ability to recycle urea—the same compound found in fertilizer and cattle feed—to the rumen, where microbes can use the urea to fulfill a portion of their nitrogen requirement. Although nutritionists know that recycling occurs, we have inadequate data to describe this process and, subsequently, the contribution from recycled urea is not adequately included in our present cattle feeding systems. Previous research at Kansas State University has clearly demonstrated that the greatest response to supplemental protein occurs when the supplemental protein is highly degraded within the rumen, as the degradable fraction of protein is directly available to ruminal microbes. The current project's objective was to measure how much recycled urea is used to meet the microbial nitrogen requirement when increasing amounts of degradable intake protein were provided to steers consuming low-quality forage. Researchers hoped to generate data useful in refining supplementation recommendations for cattle consuming low-quality forage.

Experimental Procedures

Five duodenally and ruminally fistulated Angus × Hereford steers (average initial body weight 613 pounds) were used to evaluate the effect of increasing amounts of supplemental degradable intake protein on forage utilization and recycled urea use by ruminal microbes in cattle consuming low-quality forage. All steers were given *ad libitum* access to prairie hay (4.9% crude protein and 72.3% NDF). Four levels of supplement were provided (0, 0.22, 0.44, 0.66 pounds per day) as casein, a source of pure protein that is highly degradable in the rumen. By using casein, researchers were able to study just the effects of supplemental degradable intake protein. The casein was placed directly into the rumen at the beginning of each day. On a protein equivalent basis, treatments provided the same amount of protein as 0, 0.42, 0.84, and 1.26 pounds of soybean meal per day. Previous research at Kansas State University had demonstrated that the highest level of supplementation was close to the degradable intake protein requirement for maximum forage utilization.

Calculations of intake, digestion, and nitrogen balance were made using observations of hay intake and total collection of feces and urine. Duodenal samples were used to determine microbial growth in the rumen. Additionally, we infused labeled urea intravenously, allowing measurement of urea

metabolism by the animal and the contribution of urea recycling to meeting microbial nitrogen requirements in the rumen.

Results and Discussion

Provision of supplemental, degradable intake protein increased forage intake and intake of total digestible organic matter (Table 1). This is in accordance with previous observations in which supplemental degradable intake protein increased forage utilization. It has been clearly demonstrated that the most efficient supplements for increasing intake and digestion of low-quality forage are supplements that are high in degradable intake protein, because this fraction of the protein directly addresses the ruminal nitrogen deficiency that occurs when low-quality forages are fed. In this study there were modest increases in digestibilities of organic matter and neutral detergent fiber with increasing degradable intake protein supplementation.

Urea production increased with increasing degradable intake protein, as did the amount of urea entering the gut. Urea production increased as degradable intake protein was supplemented because the metabolism of the nitrogen contained in the supplemental protein resulted in the formation of urea by the animal. Gut entry (recycling) of urea also increased with protein supplementation, because almost all of the urea was recycled by the nitrogen-deficient steers (i.e., recycling was greater than 95% of production). Urea can either be excreted in the urine and lost, or it can be recycled to the gut.

The amount of recycled urea incorporated into microbial nitrogen increased with increasing degradable intake protein; however, the proportion of microbial nitrogen from recycled urea was relatively constant (28%) across the treatments.

These data are valuable because they provide information about how ruminal nitrogen requirements are being met. This is important because recycled urea can be an important contributor of nitrogen to the rumen, and this should be accounted when estimating ruminal nitrogen requirements and, subsequently, the amount of protein to supplement. Recycling of nitrogen provides the cow with a greater supply of protein and energy due to increased microbial activity.

Implications

Degradable intake protein supplementation increased forage intake and digestion. Urea recycling played a significant role in meeting ruminal nitrogen requirements, and it should be considered as a source of nitrogen available to meet the needs of rumen microbes.

Table 1. Effects of Degradable Intake Protein Supplementation on Intake, Digestion, Urea Metabolism and Microbial Flow in Steers Fed Low-quality Forage

	Degradable Intake Protein, pounds/day			
Item	0	0.37	0.74	1.11
Organic matter intake, pounds/day				
Forage[a]	9.9	12.0	13.6	15.2
Total[a]	9.9	12.2	14.0	15.9
Digestible[a]	4.9	6.3	7.8	9.1
Total tract digestibility, %				
Organic matter[a]	49.8	52.0	55.0	56.9
Neutral detergent fiber[a]	47.0	49.6	52.8	54.3
Urea kinetics, g nitrogen/d				
Production[a]	19.9	24.8	42.9	50.9
Gut entry (recycled) [a]	19.8	24.5	42.4	48.6
Duodenal flows, g nitrogen/d				
Total[a]	67.5	90.9	113.3	153.3
Microbial nitrogen[a]	40.3	61.3	81.4	108.8
Undegradable intake protein[a]	27.2	29.6	31.9	44.5
Recycled urea nitrogen in microbes				
Nitrogen, g/d[a]	12.3	15.6	23.9	28.9
% of total microbial nitrogen	32.3	25.0	30.0	24.8
% of urea production	60.6	63.2	55.2	59.1

[a]Linear effect of degradable intake protein ($P<0.05$).

MICROBIAL USE OF RECYCLED UREA IS DEPENDENT ON THE LEVEL AND FREQUENCY OF DEGRADABLE INTAKE PROTEIN SUPPLEMENTATION

T. A. Wickersham, E. C. Titgemeyer, R. C. Cochran, E. E. Wickersham, and E. S. Moore

Introduction

Protein supplementation increases utilization (intake and digestion) of low-quality forage and ultimately animal performance. Despite its effectiveness, protein supplementation is often expensive. One strategy to reduce the cost of supplementation is to supplement less frequently than daily, generally every other day or every third day. By reducing the frequency of supplementation, the cost of delivering the supplement is reduced. Reducing the frequency of supplementation is an effective strategy for reducing cost, and it only minimally impacts animal performance, with less frequent supplementation resulting in slightly greater losses of body condition score and body weight during the winter supplementation period.

Urea recycling, the transfer of urea from the animal's body to the gastrointestinal tract, has been suggested as a mechanism that allows infrequently supplemented cattle to perform similarly to cattle supplemented daily. However, little data is available to substantiate this claim, and such data would be useful in helping nutritionists better understand nitrogen metabolism in infrequently supplemented ruminants. Our objective was determine the role of urea recycling in meeting ruminal nitrogen requirements in infrequently supplemented cattle fed low-quality forage.

Experimental Procedures

Five duodenally and ruminally fistulated Angus × Hereford steers (average initial body weight 807 pounds) were used to evaluate the effect of increasing amounts of supplemental degradable intake protein on forage utilization and recycled urea use by ruminal microbes in cattle consuming low-quality forage. All cattle were given *ad libitum* access to prairie hay (4.7% crude protein and 73% NDF). Two levels of supplemental protein were provided daily: 0.31 pounds (low) and 0.93 pounds (high), and two levels were provided every third day: 0.93 pounds (low) or 2.79 pounds (high) per supplementation event. Steers supplemented with the low amount of protein, either daily or every third day, received the same amount of supplement per week; the frequency of delivery was the only difference. Similarly, steers supplemented with the high amount of protein, either daily or every third day, received the same amount of supplement per week, with frequency being the only difference. Supplemental protein was provided as casein pulse-dosed into the rumen. Casein was used because it is a protein source that is highly available to ruminal microbes and it has a high protein content, which allowed researchers to study only the effects of supplemental protein.

Calculations of intake, digestion, and nitrogen balance were made using observations of hay intake and total collections of feces and urine. Duodenal samples were used to determine microbial flow from the rumen and ruminal digestion. Additionally, labeled urea was infused intravenously, allowing measurement of urea metabolism by the animal and the contribution of urea recycling to meeting microbial nitrogen requirements in the rumen.

Results and Discussion

Frequency of supplementation had no impact on forage intake, and only modest increases in forage intake were observed as the amount of supplemental protein increased from low to high (Table 1). At the low level of supplementation, less frequent supplementation resulted in greater total tract digestion.

Urea production and gut entry (recycling) of urea were greater for steers supplemented every third day as compared to those supplemented daily at the high level. Additionally, the contribution of urea recycling to meeting the nitrogen requirements of ruminal microbes was greater for infrequently supplemented steers at the high level of supplementation. This greater dependency on urea recycling in infrequently supplemented animals is in contrast to the effects on urea recycling to the gut and the contribution of urea recycling to ruminal microbes when steers were on the low level of supplementation. In the latter case, less frequent supplementation resulted in a numeric reduction in both gut entry and microbial incorporation of recycled urea nitrogen. When the high level of supplementation was provided infrequently, the amount of nitrogen in the rumen exceeded what the ruminal microbes could use and excess nitrogen was absorbed from the rumen as ammonia. Ammonia is not useful to the animal and is detoxified to urea, which can then be recycled to the gut and used by the ruminal microbes. In contrast, at the low level of supplementation, infrequent provision of supplemental protein provided a small enough amount of nitrogen at each feeding that the ruminal microbes were able to capture most of the nitrogen and utilize it directly for the synthesis of microbial protein. There was not an excessive amount of nitrogen lost from the rumen when the steers were supplemented at a low level every third day. Urea recycling was not needed under those conditions to capture most of the benefits from the supplemental protein.

Implications

At levels of protein supplementation near the requirement for degradable intake protein (the high treatment in this study), animals supplemented infrequently were more dependent on urea recycling as a means of capturing benefit from supplemental protein than animals supplemented more frequently or supplemented a lesser amount at the same frequency.

Table 1. Effects of Frequency and Level of Degradable Intake Protein Supplementation on Intake, Digestion, Urea Metabolism and Microbial Flow in Steers Fed Low-quality Forage

	Level of Supplementation			
	Low		High	
	Frequency of Supplementation			
Item	Daily	Every 3rd day	Daily	Every 3rd day
Organic matter intake, pounds/day				
Forage	14.1	16.1	16.7	16.7
Total	14.3	16.3	17.6	17.8
Digestible	7.9	10.1	10.1	10.1
Total tract digestibility, %				
Organic matter	54.8	61.4	57.6	54.8
Neutral detergent fiber	55.1[c]	61.7[d]	58.1	54.2
Urea kinetics, g nitrogen/d				
Production	58.3	45.5	86.6[c]	126.5[d]
Gut entry (recycled)	57.3	47.7	68.1[c]	106.1[d]
Duodenal flows, g nitrogen/d				
Total	135.5	130.4	165.0	148.4
Microbial nitrogen	96.4	95.8	133.3[c]	114.7[d]
Undegradable intake protein	39.1	34.7	31.7	33.9
Recycled urea nitrogen in microbes				
Nitrogen, g/d	35.2	31.8	30.8[a]	47.4[b]
% of total microbial nitrogen	34.1	33.2	22.8[a]	42.1[b]
% of urea production	65.7	67.5	35.2	38.5

[a,b]Means in the same row and same level of supplementation with different superscripts differ ($P<0.05$).
[c,d]Means in the same row and same level of supplementation with different superscripts differ ($P<0.10$).

SUPPLEMENTATION WITH UNDEGRADABLE INTAKE PROTEIN INCREASES UTILIZATION OF LOW-QUALITY FORAGE AND MICROBIAL USE OF RECYCLED UREA

T. A. Wickersham, E. C. Titgemeyer, R. C. Cochran, and E. E. Wickersham

Introduction

Low-quality forage utilization (intake and digestion) is improved by protein supplementation. Typically, the recommendation is to select supplements that are high in degradable intake protein because this fraction of the protein directly addresses the ruminal nitrogen deficiency that exists when low-quality forages are fed. However, the low cost of by-products (e.g., distiller's grains) that are high in undegradable intake protein makes them an attractive source of supplemental protein even though the response per unit of supplemental protein is less for undegradable protein than for degradable protein. One of the primary barriers to utilizing highly undegradable protein sources as supplements is the lack of information regarding their ability to provide nitrogen to ruminal microbes and, ultimately, their effectiveness as protein supplements to cattle fed low-quality forage. Because the protein is not ruminally degraded, the use of undegradable protein supplements to meet ruminal nitrogen requirements depends on the ability to recycle nitrogen to the rumen in the form of urea. Subsequently, the urea is utilized as a nitrogen source by ruminal microbes.

Our objective was to measure how much nitrogen is recycled as urea and how much recycled nitrogen is used to meet microbial growth requirements when increasing amounts of undegradable intake protein were provided to steers consuming prairie hay. This data will be useful in developing supplementation strategies for cattle consuming low-quality forage.

Experimental Procedures

Four duodenally and ruminally fistulated Angus × Hereford steers (average initial body weight 694 pounds) were used to evaluate the effect of increasing amounts of supplemental undegradable intake protein on forage utilization and recycled urea use by ruminal microbes in cattle consuming low-quality forage. All steers were given *ad libitum* access to prairie hay (4.7% crude protein and 73% NDF). Four levels of supplement were provided (0, 0.27, 0.54, and 0.81 pounds per day) as casein, a source of pure protein that is highly digestible. The casein was continuously infused into the abomasum, so the protein physically bypassed the rumen and was made directly available for absorption by the animal. By using casein, researchers were able to determine the effects of only supplemental undegradable intake protein on forage utilization and urea recycling. On a protein equivalent basis, treatments provided the same amount of protein as 0, 0.51, 1.02, and 1.53 pounds of soybean meal per day.

Calculations of intake, digestion, and nitrogen balance were made using observations of hay intake and total collections of feces and urine. Duodenal samples were used to determine microbial flow from the rumen and ruminal digestion. Additionally, labeled urea was infused intravenously, allowing meas-

urement of urea metabolism by the animal and the contribution of urea recycling to meeting microbial nitrogen requirements in the rumen.

Results and Discussion

Provision of supplemental undegradable intake protein increased forage intake and intake of total digestible organic matter (Table 1). This is in accordance with previous observations in which supplemental undegradable intake protein increased forage utilization. The magnitude of the increase in response to undegradable intake protein was less than if the same amount of protein had been provided as degradable intake protein. This supports the observations that the primary barrier to low-quality forage utilization is a ruminal nitrogen deficiency and that degradable intake protein is more effective than undegradable protein at increasing utilization of low-quality forages. There were no increases in digestibility of either organic matter or neutral detergent fiber with supplemental undegradable intake protein.

Urea production increased with increasing undegradable intake protein, as did the amount of urea entering the gut (recycled). Urea production increased because the cattle did not require all of the absorbed protein for growth, so excess protein was catabolized by the animal and converted to urea. More than 89% of the urea that was produced was recycled to the gut, so increases in urea production were linked to increases in recycling.

Urea produced by cattle can be excreted in the urine (and lost) or it can be recycled to the gut. The urea that enters the rumen can be utilized by ruminal microbes to meet some of their nitrogen requirement for growth. Because of urea recycling, a portion of the nitrogen contained in undegradable protein is ultimately available to ruminal microbes. In other words, the urea recycling mechanism allows the animal to conserve and utilize nitrogen from protein that is not directly available in the rumen. Microbial protein production, measured as microbial nitrogen flow, increased with supplementation of undegradable intake protein. Correspondingly, the amount of microbial nitrogen coming from recycled urea increased with increasing amounts of undegradable intake protein, indicating a dependence on urea recycling when a supplement high in undegradable intake protein was fed. The contribution of recycled urea nitrogen to microbial protein as a percent of total microbial flow increased from 31% for 0 to 58% for 0.54 pounds of undegradable intake protein, underscoring the fact that a portion of the response to supplemental undegradable intake protein can be attributed to nitrogen recycling.

Implications

Undegradable intake protein can make substantial contributions to meeting ruminal nitrogen demands in cattle consuming low-quality forage. Supplements high in undegradable intake protein are viable alternatives to highly degradable protein supplements.

Table 1. Effects of Undegradable Intake Protein Supplementation on Intake, Digestion, Urea Metabolism and Microbial Flow in Steers Fed Low-quality Forage

	Undegradable Intake Protein, pounds/day			
Item	0	0.27	0.54	0.81
Organic matter intake, pounds/day				
Forage[b]	13.4	15.2	17.4	16.1
Total[b]	13.4	15.4	17.9	17.0
Digestible[a]	8.1	9.0	10.6	10.1
Total tract digestibility, %				
Organic matter	60.4	58.7	58.1	59.5
Neutral detergent fiber	59.0	55.9	54.3	56.7
Urea kinetics, g nitrogen/d				
Production[a]	27.1	49.9	82.2	85.8
Gut entry (recycled)[a]	26.3	48.7	77.2	76.6
Duodenal flows, g nitrogen/d				
Total [a]	80.8	113.8	161.2	161.1
Microbial nitrogen [a]	45.7	65.3	81.2	75.7
Undegradable intake protein[a]	35.1	48.5	79.1	85.5
Recycled urea nitrogen in microbes				
Nitrogen, g/d[b]	13.9	28.3	47.7	33.9
% of total microbial nitrogen[b]	31.4	42.5	58.0	44.2
% of urea production	52.6	57.0	57.5	41.0

[a]Linear effect of degradable intake protein ($P \leq 0.05$).
[b]Quadratic effect of degradable intake protein ($P \leq 0.05$).

OPTAFLEXX[1] AFFECTS RUMEN FERMENTATION

C. E. Walker, J. S. Drouillard, and T. G. Nagaraja

Summary

Three experiments were conducted to determine effects of ractopamine-HCl, sold under the trade name Optaflexx, on rumen fermentation. In experiment 1, fermentative gas production was measured *in vitro* to determine the impact of increasing amounts of ractopamine-HCl added to rumen fluid. Ractopamine-HCl increased gas production when added to rumen fluid up to 10 times the assumed physiological dosage of 200 mg per head/day, but depressed gas production at 100 times the physiological dose. Experiment 2 and 3 evaluated the effects of ractopamine-HCl on production of volatile fatty acids (VFAs) by ruminal microbes. *In vitro* experiments revealed no effect of ractopamine on volatile fatty acid production, but VFA levels in rumen fluid of cattle 23 hours after feeding were lower for cattle fed Optaflexx then for controls (P = 0.01). Results of these studies indicate that ractopamine-HCl has a direct influence on fermentation by rumen microflora.

Introduction

Ractopamine-HCl is a beta-agonist similar in structure to catecholamines and is marketed commercially under the trade name Optaflexx. Feeding Optaflexx accelerates gain and improves efficiency when administered to cattle during the final 4 to 6 weeks of feedlot finishing. Naturally occurring catecholamines have been noted to affect certain types of microorganisms. Consequently, researchers were interested in determining if ractopamine-HCl could impact ruminal microorganisms in a similar manner.

Materials and Methods

Experiment 1. Concentrations of ractopamine-HCl were 0, 0.0339, 0.3339, 3.339, or 33.39 mg RAC per gram of corn dry matter were compared in an *in vitro* experiment with rumen microorganisms. Ground corn was added to each flask as a source of substrate for the microorganisms. Rumen fluid was mixed with McDougall's artificial saliva to a final ratio of 2:1 and added to the culture flasks. Flasks were incubated at body temperature, and gas production was measured at hourly intervals for 6 hours.

Experiment 2. *In vitro* VFA profiles were determined with five concentrations of ractopamine-HCl (0, 0.0339, 0.3339, 3.339, or 33.39 mg RAC per gram of corn dry matter) added to flasks. Flasks were incubated 6 hours, and VFA concentrations were determined using gas chromatography.

Experiment 3. Rumen fluid samples used to determine *in vivo* VFA profiles were obtained from 60 cross-bred heifers fed a 94% concentrate ration formulated to provide 0 or 200 mg/day Optaflexx. Samples were taken 23 hours after feeding. Heifers were sampled on two separate occasions. Samples were analyzed for VFA concentrations.

[1]Optaflexx is a registered trademark of Elanco Animal Health, Indianapolis, IN.

Results and Discussion

Experiment 1. Optaflexx concentration had a quadratic effect on in vitro gas production. Gas production increased significantly from the control with addition of Optaflexx at the concentration of .3339 mg of RAC per gram of corn dry matter and 3.339 mg RAC per gram of corn dry matter ($P<0.05$). The highest concentration resulted in the lowest gas production. The increase in gas production in response to increased concentration of ractopamine-HCl provides evidence that changes are occurring in the rumen of cattle fed Optaflexx. The decline in gas production at 33.39 mg RAC per gram of corn dry matter indicates that the rumen can be exhausted by an excessive amount of ractopamine-HCl, negatively impacting the rumen microflora.

Experiment 2 and 3. The VFA profiles from *in vitro* fermentations are not different among increasing levels of Optaflexx (Table 1). Optaflexx decreased total VFA production *in vivo* ($P = 0.014$, Table 2). The contradiction between *in vitro* and *in vivo* VFA profiles may be a result of the sampling technique. The *in vitro* samples were obtained sis hours after the substrate was added to the batch fermentation system. Heifers were sampled 23 hours after feeding for the *in vivo* analysis. The decline in total VFA production may be a result of more extensive digestion of the ration rather than from a decline in VFA production. Sampling rumen fluid from cattle ruminally cannulated at several time points after feeding of Optaflexx may better illustrate the effects on fermentation and the rumen.

Conclusion/ Implication

Supplementing cattle with Optaflexx changes the rumen environment. Developing a greater understanding of these changes may make it possible to further improve responses to Optaflexx supplementation.

Table 1. Effects of Ractopamine-HCl on *In Vitro* VFA Profiles

	Volatile Fatty Acid Concentration, mM						
	Acetate	Propionate	Butyrate	Isobutyrate	Isovalerate	Valerate	Total
Control	28.41	13.21	7.07	0.63	1.62	1.04	51.96
Ractopamine-HCL	28.85	13.12	7.49	0.65	1.68	1.08	52.86

Control and ractopamine are not different, $P>0.50$

Table 2. Effects of Optaflexx Supplementation on *In Vivo* VFA Profiles

	Volatile Fatty Acid Concentration, mM						
	Acetate[a]	Propionate[a]	Butyrate[b]	Isobutyrate[b]	Isovalerate	Valerate[a]	Total[a]
Control	27.65	31.08	6.48	0.34	0.65	2.48	68.62
Optaflexx	25.33	28.37	5.7	0.37	0.68	2.08	62.52

[a]Control and Optaflexx groups are different, $P<0.05$.
[b]Control and Optaflexx groups are different, $P<0.10$.

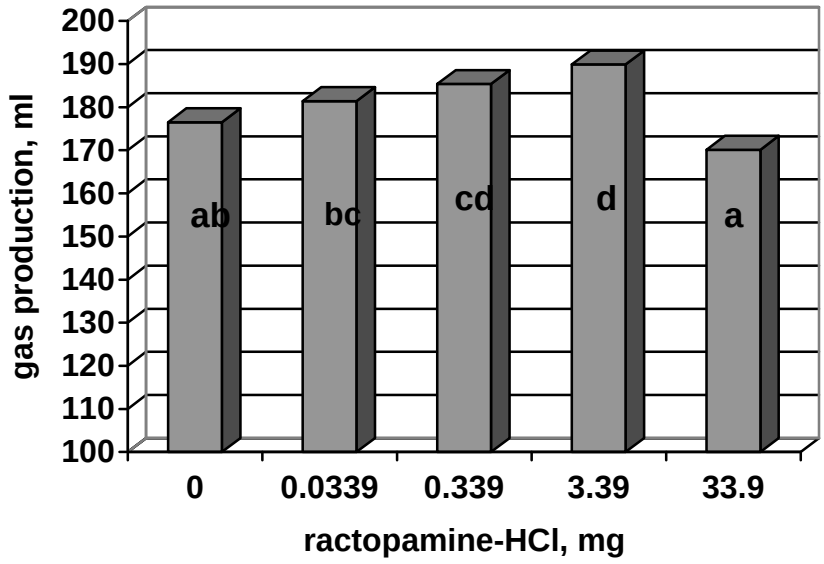

Figure 1. The Amount of Fermentative Gas Produced by Rumen Microbes During a 6 Hour *In Vitro* Fermentation with 5 Concentrations of Ractopamine-HCl. Gas production was measured as ml of water displaced during the six hour fermentation. [a,b,c,d]Means without a common superscript are different ($P<0.10$).

THE EFFECTS OF RACTOPAMINE-HCL (OPTAFLEXX[1]) ON FINISHING FEEDLOT HEIFERS

M. J. Quinn, J .S. Drouillard, E. R. Loe, B. E. Depenbusch, and M. E. Corrigan

Introduction

Whether occurring naturally or synthetically, beta-agonists are classified as phenethanolamines based on their chemical structure. Other specificities of structure determine the exact behavior of the compound in animals. Beta-agonists bind to specific receptors on the cell membranes of skeletal muscle, adipose, and other tissues. Upon binding, these agents alter metabolic pathways, ultimately causing a repartitioning of nutrients to increase muscle and decrease fat accretion. In cattle, beta-agonists such as cimaterol and clenbuterol improve feed efficiency, average daily gain, and longissimus muscle area. The proposed effects of ractopamine HCl are similar to those of other beta-agonists. The purpose of this study was to examine the effects of ractopamine-HCl on live performance, carcass characteristics, and meat quality of finishing beef heifers.

Experimental Procedures

Three hundred and two crossbred heifers (890±3 lbs) were purchased from salebarns and transported to Kansas State University Beef Cattle Research Center in Manhattan. All cattle were offered *ad libitum* access to hay and water prior to processing. Body weight was determined and the animals were given an internal/external parasiticide. Heifers were implanted with Revalor[2]-H (140 mg TBA, 14 mg estradiol) and gradually adapted to a diet containing 94% concentrate and 6% alfalfa hay. At the end of the adaptation phase, the heifers were blocked by initial weight and allotted to dirt-surfaced feeding pens containing 12 to 13 animals each. Treatments were with Optaflexx and a control treatment. Cattle receiving the Optaflexx treatment were fed 200 mg/day of ractopamine-HCl, beginning 28 days prior to slaughter. Pens of cattle were weighed using a platform scale on day 0, at approximately 28-day intervals thereafter, prior to the Optaflexx period, and immediately before being transported to a commercial abattoir for slaughter.

All cattle were allowed *ad libitum* access to a common finishing diet. The entire daily ration was delivered at approximately 1:00 p.m. At the end of the experiment, heifers were shipped to a commercial abattoir in Emporia, Kansas. Slaughter data, including hot carcass weight, incidence and severity of liver abscess, and dress yield, were obtained on the day of slaughter. Following a 24-hour chill, carcasses were evaluated for subcutaneous fat thickness; kidney, pelvic, and heart fat; longissimus muscle area; marbling score; and USDA yield and quality grades.

Following fabrication, loins were obtained from three animals randomly selected from each pen. The loins were aged for 14 days in

[1]Optaflexx is a registered trademark of Elanco Animal Health, Indianapolis, IN.
[2]Revalor is a registered trademark of Intervet, Inc.

cryovac packages at 32±2 F. After aging, loin steaks were removed and vacuum packaged for sampling. Loin steak samples were analyzed for fatty acid composition, purge loss measurements from a seven-day display period, and Warner-Bratzler shear force. Loin steak samples were cooked using to an internal temperature of 160° F. Samples were then refrigerated at 38 F for 24 hours. Following the 24-hour refrigeration period, six to eight half-inch cores were removed parallel to the fiber orientation of the steaks for shear force analysis.

Results and Discussion

Over the entire 75-day feeding period, dry matter intake, average daily gain, and efficiency of gain were not different between heifers that received 0 or 200 mg/day of ractopamine-HCl (P>0.17). However, Optaflexx-fed cattle had improved feed efficiency for the 28-day Optaflexx period (P = 0.056). Similar measurements (P>0.19) were obtained for the two treatments for dressing percent; hot carcass weight; marbling score; fat thickness; ribeye area; kidney, pelvic and heart fat; and USDA yield and quality grades. There was also no difference in Warner-Bratzler shear force between the two treatments (P>0.40). Purge loss during the seven day commercial display period and loss during cooking also were not different between treatments (P>0.50).

Table 1. Ingredients and Nutrient Composition of Finishing Diets

Item, % dry basis	Diet
Steam-flaked corn	79.55
Ground alfalfa hay	6.00
Corn-steep liquor	6.23
Vitamin/mineral supplement	6.01
Feed additive premix[a]	2.21[a]
Nutrient	
Dry matter	80.0
Crude protein	14.00
Fat	3.70
Calcium	0.75
Phosphorus	0.39

[a]Formulated to provide 300 mg monensin, 90 mg Tylosin, 0.5 mg MGA, and 0 or 200 mg ractopamine-HCl daily in a ground corn carrier.

Implications

Optaflexx added to the diets of finishing beef heifer improved gain efficiency during the 28-day feeding period with no effect on carcass quality or meat characteristics.

Table 2. Live Performance of Heifers Fed 0 or 200 mg Ractopamine-HCl for 28 Days Prior to Finishing

Item	Control	Optaflexx	SEM	P-Value
Number of heifers	150	152	-	-
Days fed Optaflexx	0	28	-	-
Initial weight, lb	1055	1054	6	0.91
Daily dry matter intake, lb	22.2	21.7	0.25	0.19
Average daily gain, lb	3.72	3.95	0.12	0.17
Feed:gain	5.98	5.46	0.005	0.06
Final weight[a], lb	1159	1164	7	0.59

[a]Final body weight based on carcass adjusted weight (carcass weight divided by 63.5% dress).

Table 3. Carcass Characteristics of Heifers Fed Either 0 or 200 mg/day of Ractopamine HCl

Characteristic	Control	Optaflexx	SEM[2]	P-Value
Carcass weight, lb	736	739	5	0.59
Ribeye area, square inches	13.38	13.67	0.2	0.31
Fat thickness (12th rib), inches	0.31	0.30	0.01	0.47
Kidney, pelvic, heart fat, %	2.24	2.23	0.03	0.85
Marbling[1]	380	373	7	0.48
Average yield grade	1.99	2.01	0.07	0.85
USDA Choice, %	36.2	40.7	5.1	0.55
USDA Select, %	57.8	56.0	5.4	0.81
USDA Standard, %	6.0	3.4	2.0	0.37
USDA YG1, %	26.4	21.2	4.4	0.41
USDA YG2, %	51.6	58.3	4.2	0.28
USDA YG3, %	17.2	19.2	3.1	0.65
USDA YG4, %	4.1	1.3	1.5	0.19

[1]Traces=200-299; Slight=300-399; Small=400-499.
[2]SEM=Standard Error of the Mean.

Table 4. Meat Quality Characteristics of Control and Optaflexx Fed Heifers

Item	Control	Optaflexx	SEM	P-Value
Warner-Bratzler shear force, lbs	10.1	10.4	1.1	0.41
Purge loss from retail display, %	3.2	3.3	0.7	0.58
Purge loss from cooking, %	25	25	14	0.51
L*	42.4	41.5	5	0.11
a*	31.0	30.0	5	0.40
b*	24.1	23.7	2	0.17

THE EFFECTS OF RACTOPAMINE-HCL (OPTAFLEXX[1]) ON PERFORMANCE, CARCASS CHARACTERISTICS, AND MEAT QUALITY OF FINISHING FEEDLOT HEIFERS

M. J. Quinn, J. S. Drouillard, C. D. Reinhardt, B. E. Depenbusch, and M. L. May

Introduction

Beta-adrenergic agonists are commonly used in livestock production to accelerate growth by enhancing lean tissue gain. These compounds repartition nutrients away from fat deposition and toward protein accretion. Generally, increased growth is associated with ractopamine feeding, which improves feed conversion and increases body weight gain. However, little data exists on the effects of ractopamine-HCl on live performance or carcass characteristics of beef heifers. Data released from Elanco Animal Health indicate that differences between gender may exist in response to ractopamine, and therefore appropriate strategies for the administration of this compound must be defined for heifers independent of those for steers. The objective of this study was to determine the effects of Optaflexx, when fed for different dosages over different durations, on finishing heifer performance.

Procedures

Non-implanted crossbred heifers (n= 281, 1,049 lb initial body weight) were fed diets based on steam-flaked corn and individually weighed on day 0. The animals were blocked by body weight into 10 weight blocks. Within each weight block, heifers were randomly allocated to 50 partially-covered, concrete-surfaced pens (five to six animals/pen, 10 pens/treatment). Pens were then randomly assigned to five dietary treatments: no ractopamine (Control); 200 mg of ractopamine per heifer daily for 28 days prior to slaughter (200×28); 200 mg of ractopamine per heifer daily for 42 days prior to slaughter (200×42); 300 mg of ractopamine per heifer daily for 28 days prior to slaughter (300×28); and 100 mg for 14 days, 200 mg for 14 days, and 300 mg of ractopamine per heifer daily for the 14 days prior to slaughter (Step-up).

Pens of cattle were weighed using a platform scale on day 0 and immediately before being transported to a commercial abattoir for slaughter. All cattle were allowed *ad libitum* access to a common finishing diet. The entire daily ration was delivered at approximately 1:00 p.m. Dry matter intake, rate of gain, and feed efficiency were determined for each pen of cattle. Initial carcass weights were used for performance calculations and were estimated by multiplying initial live weight by an assumed dressing percentage of 62%. The dose and duration of Optaflexx feeding is summarized in Table 2. All values represented in tables were calculated based on the entire 42-day period.

[1]Optaflexx is a registered trademark of Elanco Animal Health, Indianapolis, IN.

Table 1. Experimental Diet and Nutrient Composition

Item, % dry basis	Diet
Steam-flaked corn	82.9
Ground alfalfa hay	7.0
Corn steep liquor	5.0
Vitamin/mineral supplement[a]	2.9
Feed-additive premix[b]	2.2
Nutrient	
Dry matter	79.3
Crude protein	14.0
NEm, mcal/lb	1.00
NEg, mcal/lb	0.70
Calcium	0.70
Phosphorus	0.36

[a]Formulated to provide 0.13 ppm Co, 10 ppm Cu, 0.63 ppm I, 60 ppm Mn, 0.25 ppm Se, 60 ppm Zn, 91 ppm Fe, 0.67% K, 2,640 IU/kg vitamin A, 110 IU/kg vitamin D, and 32.2 IU/kg vitamin E.

[b]Formulated to provide 300 mg monensin, 90 mg tylosin, 0.5 mg melengestrol acetate and 0, 100, 200, or 300 mg ractopamine-HCl per head daily in a ground corn carrier.

Results and Discussion

Dry matter intake was lower for heifers fed the high dose of Optaflexx. In addition, carcass average daily gain and gain efficiency were improved in all animals fed Optaflexx when compared to the control treatment ($P<0.05$). Carcass gain efficiency was similar for those heifers fed Optaflexx at 200 and 300 mg/heifer daily.

Table 2. Amount and Duration of Optaflexx Feeding

	Days of Experiment		
Treatment[1]	0 to 14	15 to 28	29 to 42
CON	0	0	0
200×28	0	200	200
300×28	0	300	300
200×42	200	200	200
Step-Up	100	200	300

[1]Numbers displayed as mg per head daily of ractopamine-HCl.

No differences among treatments existed for hot carcass weight; dressing percent; yield grade; marbling score; loin eye area; kidney, pelvic, and heart fat; incidence of liver abscess; or quality grade ($P>0.19$).

Duration of feeding Optaflexx appeared to have a greater impact than the dosage level. There was no advantage in feeding an escalating dose of Optaflexx when compared to continuous feeding of 200 mg/day.

Implications

In general, feeding Optaflexx to finishing feedlot heifers increased performance, and had relatively little impact on carcass characteristics.

Table 3. Performance of Heifers Fed 100, 200, or 300 mg/day Optaflexx for 28 or 42 Days

Item	CON	200×28	300×28	200×42	STEP-UP	Contrast[1]
Number of heifers	57	56	57	55	56	-
Days on feed	42	42	42	42	42	-
Days on Optaflexx	0	28	28	42	42	-
Initial carcass weight[1], lb	616	614	612	616	614	-
Hot carcass weight, lb	671	679	676	688	684	+
Dry matter intake, lb/day	18.0[a]	18.0[a]	16.9[b]	18.0[a]	17.4[ab]	**
Carcass gain, lb/day	1.28	1.47	1.50	1.67	1.63	*
Feed:carcass gain	14.1	12.0	11.1	10.5	10.4	+

[1]Contrasts: Control vs. Optaflexx = *; 200 mg vs. 300 mg = **; (P≤ 0.05), Contrasts: Control vs. Optaflexx = +; (P≤ 0.10).
[abc]Superscripts with uncommon letters differ (P≤ 0.05).

Table 4. Carcass Characteristics of Heifers Fed Optaflexx at 100, 200, or 300 mg/heifer Daily for 28 or 42 Days

Item	CON	200×28	300×28	200×42	STEP-UP	Contrast[2]
Dressing, %	63.8	63.9	64.5	65.2	64.7	-
Yield grade	2.09	2.12	2.12	2.31	2.36	-
Marbling[1]	438	431	411	427	409	-
Backfat, inches	0.34	0.39	0.40	0.43	0.41	+
Loin eye area, inches[2]	13.0	12.90	12.90	13.01	12.81	-
Kidney, pelvic, and heart fat, %	2.69	2.56	2.57	2.66	2.61	-
Liver abscess, %	1.68	2.00	6.68	3.34	7.00	-
USDA Choice, %	60.7	70.7	55.3	61.8	59.3	-
USDA Select, %	39.3	27.7	44.7	38.2	40.7	-
USDA Standard, %	0	1.7	0	0	0	-

[1]Marbling scores were obtained by a commercial abattoir; slight = 300 to 399, small = 400 to 499, modest = 500 to 599.
[2]Contrasts: Control vs. Optaflexx = +; (P≤ 0.10).

EFFECTS OF SRP VACCINE IN REDUCING *E. COLI* O157:H7 IN CATTLE

A.B. Thornton[1], D.U. Thomson[1], J.T. Fox[1], G.H. Loneragan[2], D. Burkhardt[3], and T. G. Nagaraja[1]

Introduction

Cattle are the main reservoir of *Escherichia coli* O157:H7, which is a foodborne pathogen that causes bloody diarrhea in adults and kidney damage in children . *E. coli* O157 is shed in the feces of cattle, which can be a contamination source of water, ground beef, fresh vegetables, and unpasterized milk and fruit juices. In 2003, shiga-toxin producing *E. coli* O157:H7 caused 73,000 illnesses, which resulted in over 2,000 hospitalizations and 60 deaths in the United States. The estimated annual cost of this illness was $405 million, which included $370 million for premature deaths, $30 million for medical care, and $5 million for lost productivity. Strategies to reduce this food borne illness must be further investigated.

A new vaccine technology targeting *E. coli* O157:H7 in hopes of reducing the colonization of this pathogen in beef cattle has been developed (Epitopix, LLC, Wilmar, MN). This vaccine was designed to block the transport of iron into the bacterial cell, which is an essential nutrient needed for the survival of this microorganism. Previous trials showed that this vaccine elicited an immune response and reduced fecal shedding of the pathogen in five-month old Holstein steers. The purpose of this experiment was to further evaluate the efficacy of this new siderophore receptor/porin protein (SRP) technology by analyzing fecal shedding and immune responses of mixed-breed calves orally inoculated with *E. coli* O157:H7.

Experimental Procedures

Thirty beef calves (3 to 4 months old) that were pre-tested and shown to be free of *E. coli* O157:H7, were processed and allowed to acclimatize as a herd at a local Manhattan, Kansas farm. Calves were treated with One Shot Ultra 7, Bovi-Shield Gold 5, Micotil 300, and Dectomax. Calves were fed a starter ration at approximately 7 lbs per head per day and had *ad libitum* access to water and brome grass hay.

Approximately one month after arrival, calves were placed into one of two treatment groups and administered either the SRP vaccine or the placebo on day 0 of the trial. Twenty-one days after the first injection was administered, the calves were revaccinated and transported to a BL-2 facility where they were confined to individual pens and allowed to acclimatize for one

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[3]Epitopix LLC, Wilmar, MN.

week. On day 36, calves from both treatment groups were orally inoculated with a mixture of five strains of *E. coli* O157:H7, which were made resistant to nalidixic acid.

Cattle fecal samples and rectoanal mucosal swab (RAMS) samples were collected once a day for five consecutive days after oral challenge and then sampled three times a week for the following five weeks. Blood samples were collected on day 1, just prior to vaccination, and at weekly intervals to monitor antibody response to SRP vaccination in calves. At the end of the study, calves were euthanized and samples were taken from the rumen, omasum, abomasum, cecum, colon, and rectum, along with tissue samples from the gall bladder mucosa and the rectoanal mucosa, to determine the presence and concentration of *E. coli* O157:H7. Detection of this microorganism was performed by transferring each sample to a selective enrichment broth, by making serial 10-fold dilutions to allow for quantification of the microorganism, and by transferring each dilution to a selective agar containing nalidixic acid to simplify detection of the challenge organism. Further antigenic testing was performed to confirm proper identification of the microorganism, and concentration of the bacteria from each sample was calculated.

Results and Discussion

The presence and concentration of *E. coli* O157:H7 in the two treatment groups are illustrated in Figures 1-5. From day 11 to day 35 post challenge, there was a decrease ($P<0.04$) in fecal shedding of *E. coli* O157:H7 over time when the "SRP" treatment group was compared to the control group. There was no significant difference between the two treatment groups when evaluating the concentration of the bacteria using the RAMS (rectoanal mucosal swab) sampling technique. There was a difference ($P<0.05$), however, when the prevalence in both the fecal and RAMS samples were combined (Figure 3), showing that there were twice as many positive samples in the control group when compared to the "SRP" treatment group by day 32 post challenge.

The necropsy data also illustrated the efficacy of this vaccine showing the mean proportion of samples testing positive in the SRP treatment group were less ($P<0.01$) than those found positive in the non-vaccinate control group. The SRP vaccinate group had higher ($P<0.01$) concentrations of anti SRP antibodies compared to the control group.

Implications

Overall, vaccination of calves with the SRP vaccine reduced the prevalence of *E. coli* O157:H7 in cattle. This not only defines a new potential strategy to reducing food borne illness, but also increases the consumer's confidence when purchasing quality meat.

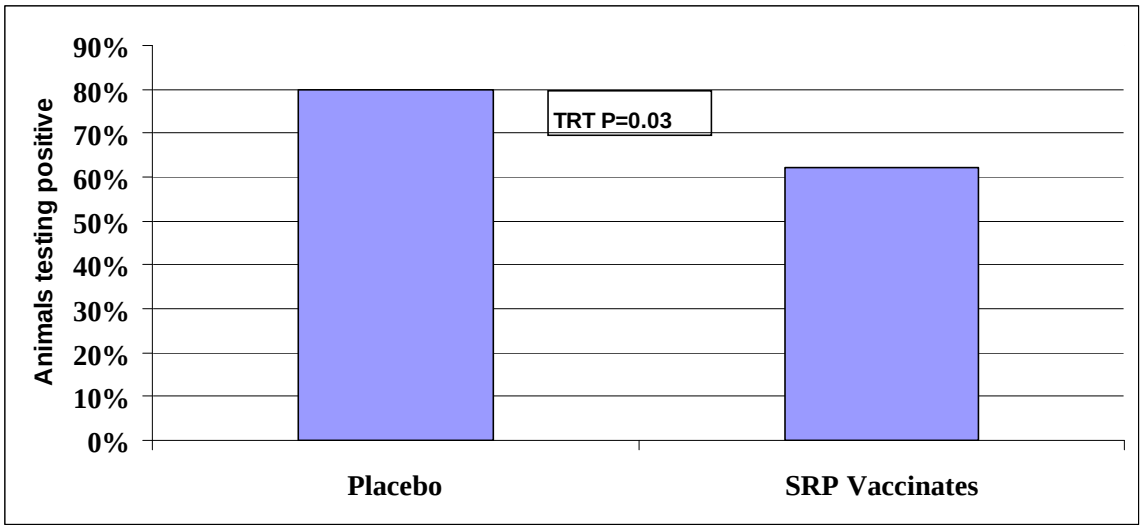

Figure 1 Average Percent of Animals Positive with Nal^R *E. coli* O157:H7 from Day 11 Post Challenge to the Day of Necropsy.

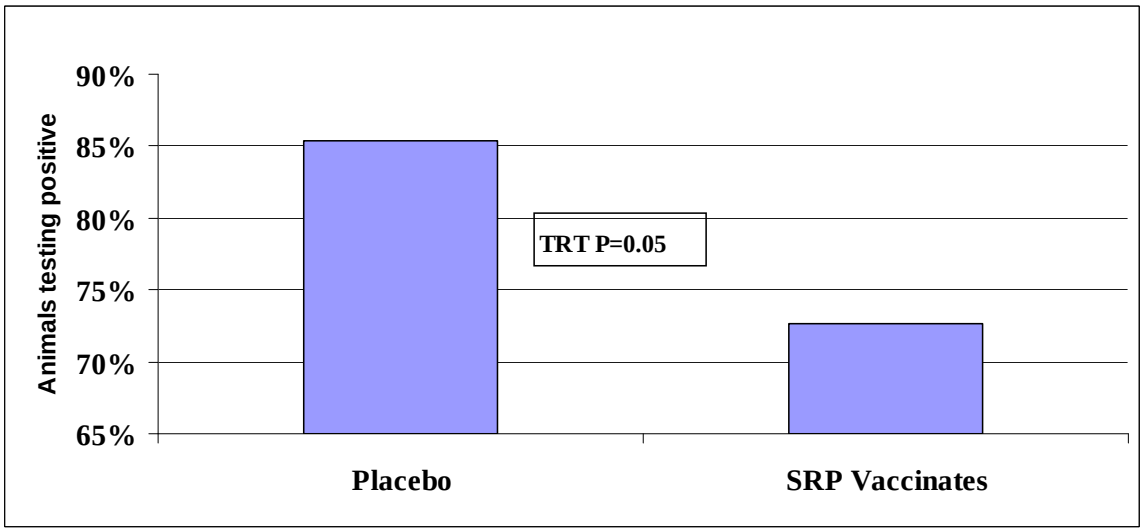

Figure 2 Nal^R *E. coli* O157:H7 Positive Cattle in Either the Fecal or Rectoanal Mucosal Swabs Samples from Day 11 Post Challenge to the Day of Necropsy

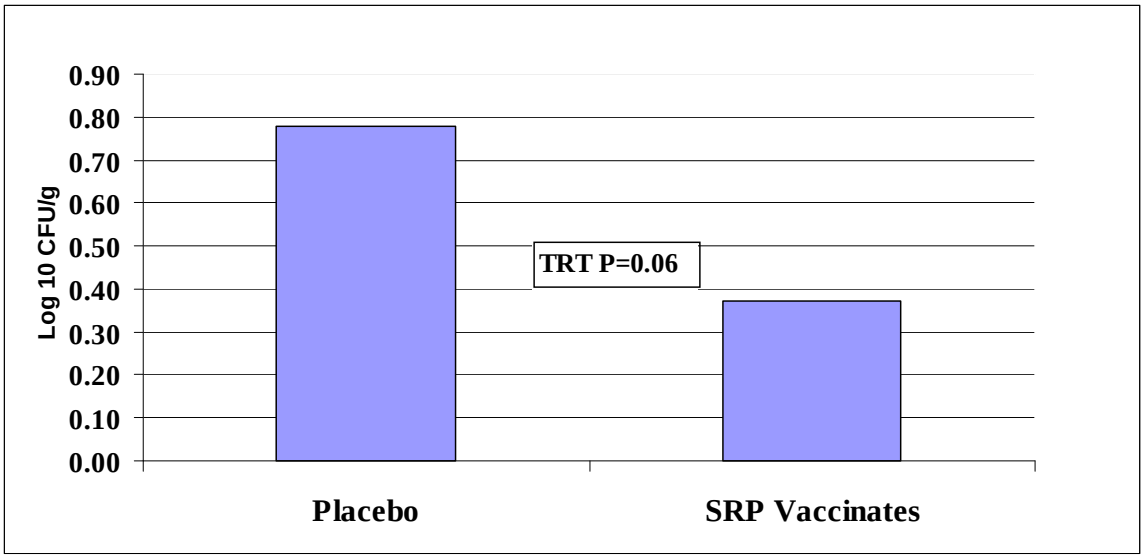

Figure 3 Average Fecal Concentration of Nal^R *E. coli* O157:H7 in Cattle from the Day of Challenge to the Day of Necropsy

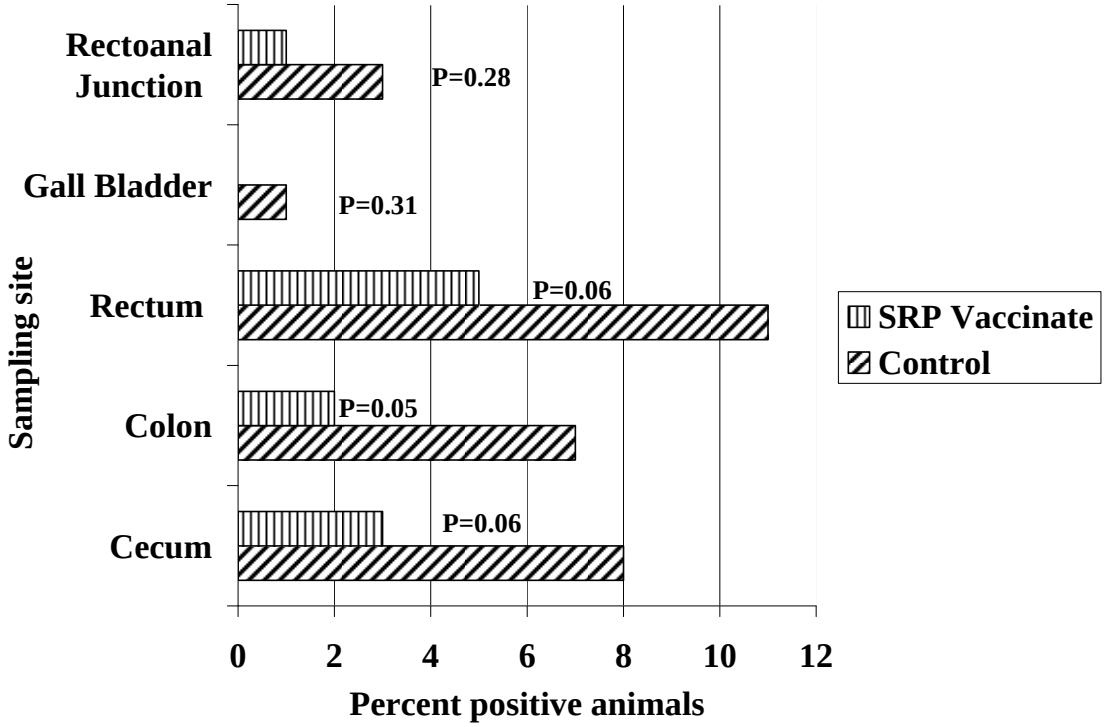

Figure 4 The Number of Animals from Each Treatment Group that had Nal^R *E. coli* O157:H7 Present in the Selected Sampling Site

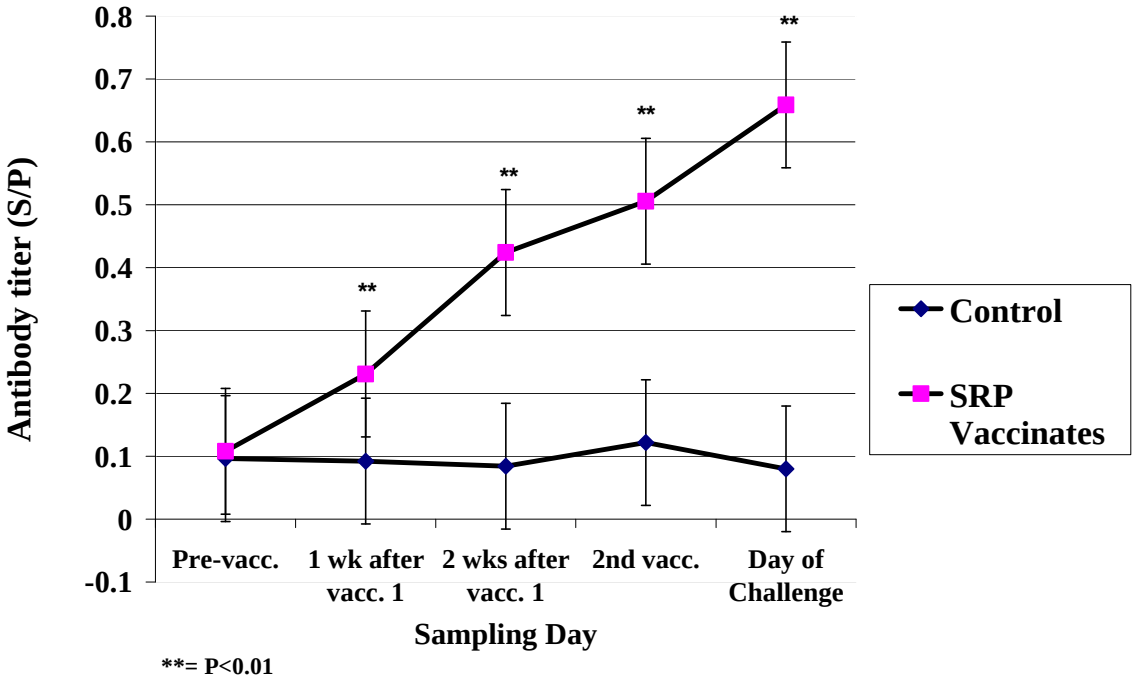

Figure 5 Calves' Immunological Responses from the Day the First Vaccination was Administered to the Day of Challenge.

VACCINE IMPACTS *E. COLI* O157 IN FEEDLOT CATTLE

J. T. Fox, D. U. Thomson, J. S. Drouillard, A. B. Thornton, M. E. Jacob, and T. G. Nagaraja[1]

Introduction

Many human foodborne illnesses are caused by pathogens commonly harbored by food animals. *Escherichia coli* O157 is one of these pathogens commonly isolated from beef cattle feces and can enter the food chain at harvest. In addition to the human health concerns, this pathogen has important economic implications. Costly recalls of beef products and loss of consumer confidence associated with outbreaks of foodborne illness can affect profitability on many levels of production. In the past 10 years, *E. coli* O157 has cost the beef industry an estimated $2.67 billion. A portion of this expense is allocated to government and industry research. Methods to intervene and reduce the opportunity of these pathogens to enter the food chain have been tested and implemented both pre- and post-harvest. The focus of this experiment was to evaluate the effectiveness of a novel vaccine technology to reduce *E. coli* O157 shedding in feeder cattle prior to harvest.

A relatively new vaccine technology developed by Epitopix (Wilmar, MN) targets pathogenic bacteria based on their inherent requirement for iron. Vaccines developed with this technology target siderophore receptor and porin proteins (SRP) of specific bacteria and disrupt their iron transport systems, which ultimately causes death of the organisms. Preliminary experiments have shown that SRP vaccines reduce fecal shedding of *Salmonella* Newport and *E. coli* O157 in experimentally infected mice. In two experiments involving experimentally infected cattle, an SRP vaccine for *E. coli* O157 reduced fecal shedding of the experimental strain of *E. coli* O157. Given the success of this vaccine in cattle challenged with *E. coli* O157, the objective of the current experiment was to test the efficacy of the *E. coli* O157 SRP vaccine in feedlot cattle naturally infected with *E. coli* O157.

Experimental Procedures

A population consisting of approximately 600 feedlot heifers was screened for the presence of *E. coli* O157 in the feces. Cattle positive for fecal shedding of *E. coli* O157 were re-sampled to confirm shedding. At re-sampling, an additional procedure was included to identify animals that were shedding the organism at abnormally high levels (super-shedders). Sixty cattle were selected from the original population for use in this study. Fifty of these 60 animals were fecal positive for *E. coli* O157 on two occasions and the remaining 10 animals were fecal positive on one occasion. Cattle were stratified based on results of fecal shedding of *E. coli* O157 in screening samples and randomly allotted, within strata,

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to one of three treatment groups (20 animals/treatment): 1) control, 2) vaccinated on day 0 and 21 with 2 cc with SRP *E. coli* vaccine, or 3) vaccinated on day 0 and 21 with 3 cc of SRP *E. coli* O157 vaccine. Cattle were housed in one of three barns containing 20 individual feeding pens. Animals were allocated to pens in treatment blocks within each barn to eliminate sharing of waterers across treatments and reduce animal-to-animal contact across treatments. Waterers were cleaned three times weekly to reduce the potential of these as a transmission vector. Cattle were fed a standard feedlot receiving diet (Table 1) once daily.

Table 1. Ingredient Composition and Nutrient Content of the Experimental Diet

Ingredients:	Percent of Diet (DM basis)
Steam-flaked corn	50.3%
Alfalfa hay	40.0%
Corn steep liquor	4.0%
Premix	5.7%
Nutrients:	
NEm	0.83 Mcal/lb
NEg	0.55 Mcal/lb
CP	14.5%
Ca	0.70%
P	0.33%
Ca:P	2.1:1

Fecal samples and rectoanal mucosal swab samples were collected two or three times a week for 8 weeks to monitor shedding of *E. coli* O157. Precautions were taken to reduce the potential for sample contamination chute side. Detection of *E. coli* O157 was by selective enrichment, immunomagnetic separation, and plating on selective agar. Biochemical and antigenic tests were also used for further confirmation. Procedures to identify super-shedders were also performed on fecal samples. Briefly, pre-enriched samples were streaked onto selective agar in triplicate and if two or three of these plates had confirmed *E. coli* O157 colonies present, the animal of sample origin was considered a super-shedder.

Results and Discussion

Overall, average *E. coli* O157 prevalence across all sampling days in the feedlot heifers was 9.3% as detected by rectoanal mucosal swab (RAMS) culture, 10.9% as detected by fecal culture, and 15.8% as detected by either RAMS or fecal culture. A previous study performed one year earlier with similar type cattle in the same facility with similar procedures found an average prevalence of 50%. Because prevalence was lower than expected, data were analyzed as repeated measures on animals over weeks instead of sampling days to increase prevalence, and barn was included as a random effect. Overall prevalence of *E. coli* O157 in cattle receiving placebo, 2 ml vaccine, and 3 ml vaccine was 33.7%, 29.1%, and 17.7% (Figure 1). Treatment also reduced the number of days that animals were found positive for *E. coli* O157, with a significant difference in pair-wise comparison of placebo vs 3 ml vaccine treatments (P = 0.08; Figure 2).

Modeling efforts by other researchers revealed that 80% of natural transmission of *E. coli* O157 in a cattle population is attributed to 20% of infections in which animals are shedding the organism at abnormally high levels. Reducing the number of animals shedding at high levels would be an important outcome of pre-harvest intervention strategies. In the current experiment, the number of animals identified as super-shedders on one or more sampling days was reduced by vaccine treatment (P = 0.08; Figure 3). Again, pair-wise com-

parison of placebo and 3 ml vaccine treatments revealed that the vaccine was efficacious in reducing the percentage of *E. coli* super-shedders in feeder cattle. These differences may give insight into proper dosage of the vaccine for efficacy in naturally infected cattle.

Implications

The *E. coli* O157 SRP vaccine reduced prevalence and the number of days that cattle shed *E. coli* O157 and there is evidence that the vaccine decreases the number of cattle shedding high levels of the organism.

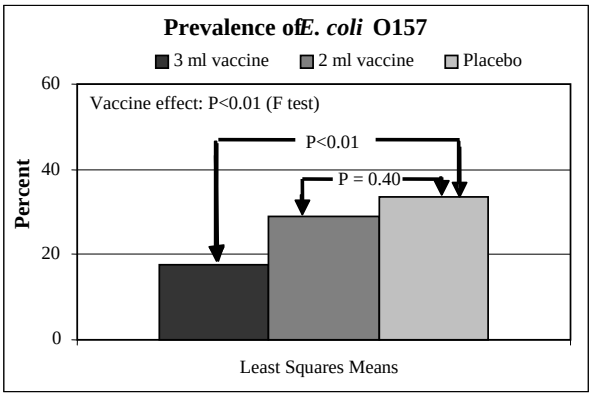

Figure 1. Percent of Animals Testing Postitive for *E. coli* O157 on Sampling Weeks by Treatment Group.

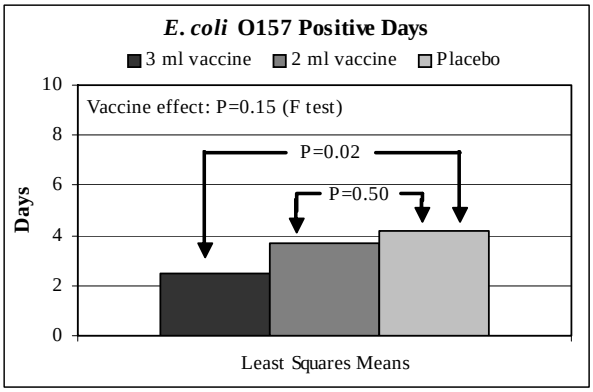

Figure 2. Least Squares Means of the Number of Days Animals were Found Positive for *E. coli* O157 by Treatment. Data were analyzed with a general linear model.

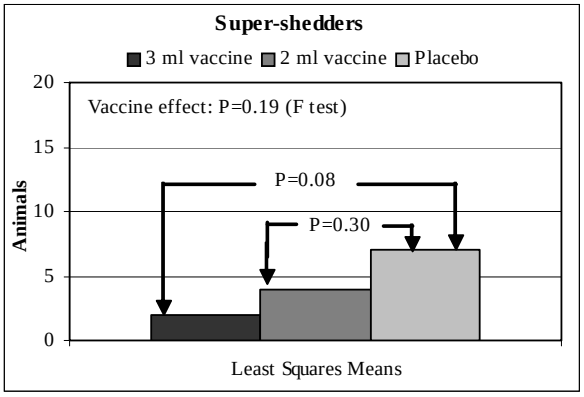

Figure 3. Least Squares Means by Treatment of the Number of Animals Detected as Super-shedders on One or More Sampling Days. Data were analyzed with a general linear model.

GRAIN PROCESSING REDUCES *E. COLI* O157 IN FEEDLOT CATTLE

J. T. Fox, J. S. Drouillard, M. E. Jacob, S. L. Reinstein, and T. G. Nagaraja[1]

Introduction

Escherichia coli O157 is an important food-borne pathogen for which the gastrointestinal tract of cattle is the major reservoir. Fecal shedding of *E. coli* O157 in cattle reflects the ability of the organism to persist in or colonize the gastrointestinal tract. Evidence suggests that the site of persistence or colonization is in the hindgut and not the rumen. Although the reasons are not known, it is likely that the ecosystem of the hindgut is more hospitable than the rumen. Therefore, we hypothesize that dietary factors that promote supply of substrates (starch, fiber, protein, or lipids) to the hindgut will have a significant effect on the ability of *E. coli* O157 to survive and colonize, and influence shedding in feces.

Our objective was to use processed grains to alter hindgut fermentation in ways detrimental to the survival, growth, and colonization of *E. coli* O157. Grains that are less extensively digested within the rumen produce more starch for the hindgut, increasing fermentation activity and acid production in the hindgut. Steam-flaking of grains has been shown to enhance ruminal starch digestion compared to dry-rolling, effectively reducing the amount of starch reaching the hindgut. The objective of this study was to evaluate the effects of grain type (sorghum or wheat) and grain processing (dry-rolled or steam-flaked) in finishing diets on prevalence of *E. coli* O157 in cattle.

Experimental Procedures

Heifers (n = 347) were screened for the presence of *E. coli* O157. Heifers positive for fecal shedding of *E. coli* O157 were retested within a week, and 40 heifers (initial body weight = 630 lbs) were selected for use in the study. Heifers were assigned to one of four treatments consisting of a 2 × 2 factorial arrangement with factor 1 being grain type (sorghum- or wheat-based diets) and factor 2 being the method of grain processing (steam-flaking or dry-rolling). A series of transition diets were used to adapt animals to high-concentrate finishing diets consisting of 81.4% (dry-matter basis) dry-rolled or steam-flaked sorghum, or 52.0% (dry-matter basis) dry-rolled or steam-flaked wheat (Table 1). Steam-flaked corn was added to wheat diets to achieve a similar concentrate to forage ratio among all diets. Each transition diet was fed for four days to achieve the final diet on day 16 of the study. Once daily, heifers were fed amounts sufficient to result in only traces of feed remaining on the following day. Animals were housed in one of two barns containing 20 individual pens.

Fecal and rectal swab samples were collected from each heifer three times a week for a month. Detection of *E. coli* O157 was by

[1]Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine.

selective enrichment, immunomagnetic separation, and plating on selective agar. Biochemical and antigenic tests were also used for further confirmation. Fecal pH was measured in samples once a week.

Results and Discussion

Sorghum and wheat grains were chosen for this study because their ruminal digestibilities differ substantially, resulting in different amounts of starch reaching the hindgut. Steam-flaked or dry-rolled wheat diets in our study contained only 52.0% wheat, because wheat has one of the fastest rates of ruminal starch digestion with increased propensity to induce metabolic disorders. Grain processing impacted (P = 0.026) dry matter intake, but grain type did not (P>0.10; Figure 1). One study demonstrated intake differences of diets containing different grain processing methods are likely a combination of differences in metabolizable energy and ruminal degradation of starch, which yielded differences in ruminal acid concentrations.

Fecal pH was measured on days 9, 16, 23 and 30 as a potential indicator of hindgut fermentation activity. Grain processing had no effect on fecal pH (Figure 1); however, grain type × sampling day interaction (P = 0.01) affected fecal pH. On day 9 of the study when animals were fed the third transition diet, fecal pH was lower (P = 0.01) in cattle fed sorghum diets (6.38) compared to cattle fed wheat diets (6.56), but this difference was not apparent on any other sampling day. A previous study had reported that increased availability of substrate in the hindgut increases the accumulation of organic acids (VFA) and reduces pH. Short-chain fatty acids (acetic, propionic, butyric) have been shown to suppress and inhibit growth of *E. coli* O157 at pH values of 6.0 and 5.5, respectively. In our study, differences in fecal pH were not consistently detected among dietary treatments. It is possible that fecal pH may not truly reflect the pH of the cecum or colon.

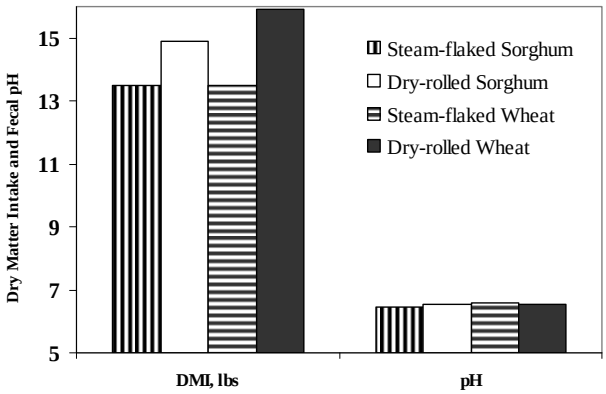

Figure 1. Average Dry Matter Intake and Fecal pH in Heifers Fed Steam-flaked Sorghum, Dry-rolled Sorghum, Steam-flaked Wheat or Dry-rolled Wheat Diets.

Mean prevalence of *E. coli* O157 in all heifers across all sampling days was 50.0%. Analysis of prevalence data began on day 9, when animals were on the third transition diet. Mean prevalence of *E. coli* O157 from day 9 in heifers fed the steam-flaked sorghum, dry-rolled sorghum, steam-flaked wheat, and dry-rolled wheat diets were 73%, 30%, 58%, and 29%, respectively. Grain type did not impact prevalence of *E. coli* O157, but grain processing method did (P<0.001). Mean prevalence in heifers fed dry-rolled grain diets (29.5%) was lower than prevalence in heifers fed steam-flaked grain diets (64.7%; Figure 2). Previous studies have shown that cattle diets containing grains with lower ruminal-starch degradation are associated with lower prevalence of *E. coli* O157. Dry-rolled grains are known to have lower ruminal-starch degradation compared to steam-flaked grains, thus presenting more starch to the hindgut and possibly increasing fecal starch. Previous dietary intervention strategies for *E. coli* O157 resulted in lower fecal pH and lower prevalence of the organism in cattle fed corn as compared to cattle fed barley. Because barley is more digestible than corn in the rumen, corn diets would present more starch to the hindgut and increase organic acid production, thus reduc-

ing pH and potentially reducing survivability of *E. coli* O157.

Implications

Grains processed by dry rolling, which are known to increase the amount of starch reaching the hindgut and enhance fermentation, may be useful in reducing *E. coli* O157 in cattle when fed prior to slaughter.

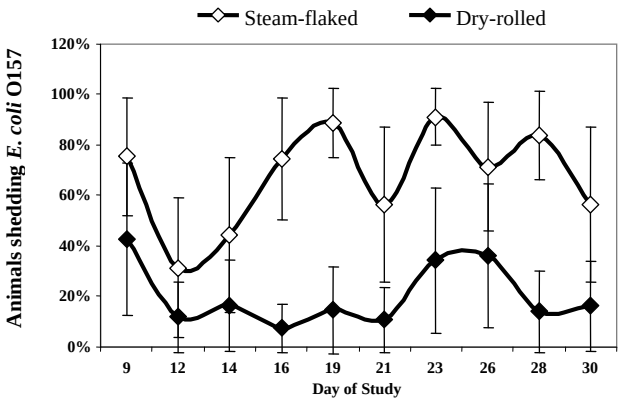

Figure 2. Least Squares Means and Standard Errors (bars) for Prevalence of *E. coli* O157 in Heifers Fed Diets with Dry-rolled or Steam-flaked Grains.

Table 1. Ingredient Composition of Experimental Diets (% dry matter basis) and Days Diets were Fed

Diet	Transition 1	Transition 2	Transition 3	Transition 4	Final Diet
Days fed	0-3	4-7	8-11	12-15	16-30
Sorghum diets					
Sorghum[1]	48.4	56.6	64.9	73.1	81.4
Alfalfa hay	40.0	31.8	23.5	15.3	7.0
Corn steep liquor	5.5	5.5	5.5	5.5	5.5
Soybean meal	1.8	1.8	1.8	1.8	1.8
Premix[2]	4.3	4.3	4.3	4.3	4.3
Wheat diets					
Wheat[1]	31.4	36.5	41.7	46.8	52.0
Steam-flaked corn	18.8	21.9	25.0	28.1	31.2
Alfalfa hay	40.0	31.8	23.5	15.3	7.0
Corn steep liquor	5.5	5.5	5.5	5.5	5.5
Premix[2]	4.3	4.3	4.3	4.3	4.3

[1]Steam-flaked or dry-rolled as appropriate for treatments.
[2]Formulated to provide 0.7% calcium, 0.7% potassium, 0.3% salt, 0.1 mg / kg cobalt, 10 mg / kg copper, 0.5 mg/kg iodine, 60 mg/kg manganese, 0.3 mg/kg selenium, 60 mg/kg zinc, 0.05 g/ton melengestrol acetate, 30 g/ton monensin, and 9 g/ton tylosin in the final diet (dry-matter basis).

EYE LENS WEIGHT AND NITROGEN CONTENT PREDICT BEEF ANIMAL AGE[1]

C. R. Raines. M. E. Dikeman, J. A. Unruh, M. C. Hunt, J. J. Higgins[2], and J. L. Marsden

Introduction

With the emergence of Bovine spongiform encephalopathy (BSE) and the necessity to guarantee cattle ages to meet export requirements of some countries, the need to accurately determine age is paramount to the worldwide beef industry. The United States Department of Agriculture (USDA) estimates that only approximately 5% of U.S. beef cattle have documented chronological ages. Several methods for determining or predicting cattle age exist, including vertebra ossification, lean color, and dentition. Current systems can be criticized due to their subjectivity and subsequent inherent variability. Because concerns exist about current methods of determining cattle age, we investigated the use of the bovine eye lens to determine cattle age. Researchers have found that the eye lens grows continually throughout life, and that all animals exhibit a similar lens growth pattern. Lens properties, specifically weight and nitrogen content, are highly related to age of kangaroos, and are also minimally affected by diet and environment for swine. We hypothesized that eye lens weight and nitrogen content, alone or in combination, would more accurately predict the chronological age of cattle than dentition or carcass maturity.

Experimental Procedures

Eyes, dentition scores, and USDA overall maturity scores were obtained from cattle (n = 386) representing 15 feedyards in Kansas, Missouri, Nebraska, and Oklahoma, and were slaughtered at six different commercial beef processing plants. Fed steers, bullocks, heifers, heiferettes, and non-fed young cull cows, from 370 to 1,115 days of age, were used in this study. Eyes from a different group of 18 cows ranging from three to 12 years of age were collected to evaluate the lens as a predictor of age in much older cattle. For these 18 cows, a USDA grader was not present to determine overall maturity score. Data were supplemented with two randomly selected one- and two-year-old cattle from the larger group, for a total of 20 cattle, ranging from one to 12 years old.

Dentition was recorded immediately after slaughter; trained individuals were given a diagram and instructed to circle the image most similar to the mouth of the subject (Figure 1). If cattle had more than two sets of permanent incisors (indicating age of >30 months), data recorders documented the number of permanent incisors present. A USDA grader determined the USDA overall maturity score to the nearest 10 degrees at commercial-line speed. Overall maturity scores were transformed to numeric scores where A^{00} = 100, B^{00} = 200, and C^{00} = 300. The degree within each age range was added to the maturity range score. For example, A^{70} overall maturity was transformed to 170.

[1]The authors thank the Kansas Beef Council for funding this project.
[2]Department of Statistics.

Eyes were dissected and lenses removed, weighed, and stored at 35.6°F in an airtight container for nitrogen analysis. Total nitrogen was measured with a LECO Nitrogen Analyzer (Model FP-2000; LECO Corporation, St. Joseph, MI; AOAC Method 990.03) and converted to milligrams of nitrogen. In some cases, one viable lens remained, and thus only one lens was used to determine predictive ability. Statistical analyses were conducted to determine correlations with age, and to determine an age prediction equation.

Results and Discussion

Correlations for each independent age determinant and age in days for the slaughter-age group were: Lens weight (r = 0.77); dentition (r = 0.74); Lens nitrogen (r = 0.71); and USDA maturity (r = 0.64). Lens weight and age in years (r^2 = 0.91) and lens nitrogen content and age in years (r^2 = 0.92) were highly correlated in the cull group. Correlations obtained from the group of 20 cull cattle were clearly higher than those obtained from the group of 386 slaughter-age cattle. The slaughter-age cattle used in our study represented a very narrow age range (15 to 35 months) and, thus, the correlations of age predictors were somewhat lower. As indicated by the data including subjects of a much wider age range, however, both lens nitrogen and lens weight are good indicators of animal age.

From the larger slaughter-age group, an age prediction equation was developed (R^2=0.67): *Age (months)* = -21.79 + 17.23(*lens weight*) + 0.038(*dentition score*). To evaluate the application of this equation at the less than equal to 20-month threshold, the age prediction equation that we developed was used to predict ages of cattle up to 25 months old. The youngest and oldest ages predicted for cattle at each actual age in months (as determined by the equation) are listed in Table 1. The youngest age predicted with the equation using only lens weight and dentition score was 8.89 months, but the animal was actually 15 months old. The oldest age predicted was 30.47 months, but the animal was actually only 24 months old. No cattle greater than 20 months old had a predicted age less than 17.08 months. Among the 218 cattle less than or equal to 20 months old, 83 cattle, or 38.07%, had a predicted age less than 17.08 months (Table 1). The very young predicted ages for younger cattle are likely attributed to very young dentition scores (i.e., 100) because the equation includes dentition, but intermediate scores between 100 and 200 were not assessed. Figure 2 indicates the correct, grouping of cattle as less than or equal to 20 months old and greater than or equal to 20 months old. Those cattle in the shaded region of Figure 2 are correctly grouped by their predicted age as less than or equal to or greater than 20 months old. Those points in the non-shaded quadrants can be considered incorrectly grouped.

Table 1. The Youngest and Oldest Predicted Ages for 356 Slaughter Cattle Aged 25 Months or Less Using the Age Prediction Model

Actual Age (months)	Predicted Age	
	Youngest	Oldest
13	15.06	17.77
14	11.22	19.34
15	8.89	20.25
16	10.90	22.33
17	12.82	21.93
18	17.45	22.30
19	15.73	20.69
20	17.37	27.77
21	18.58	24.41
22	*17.08*	24.93
23	18.78	27.50
24	17.33	30.47
25	21.62	25.63

Implications

Lens recovery involves eye removal and dissection, as well as the use of an analytical balance. Eye removal can be accomplished at line-speed, but requires additional personnel for lens recovery. To successfully achieve the 20- versus 21-month age break, we recommend screening cattle based on dentition, because cattle without visible space between teeth (equivalent score of 100) were all less than or equal to 20 months old, and evaluating dentition is a very simple procedure. We do not recommend lens analysis for every beef animal to verify age. But this is a feasible procedure for pens or groups of cattle that are likely less than or equal to 20 months old, and a verifiable objective method is needed to document that cattle are less than or equal to 20 months.

With the re-establishment of overseas beef trade with some countries, use of the age-prediction equation developed in our study would effectively qualify nearly four times the number of cattle eligible for export trade than would currently qualify by using the USDA maturity limit.

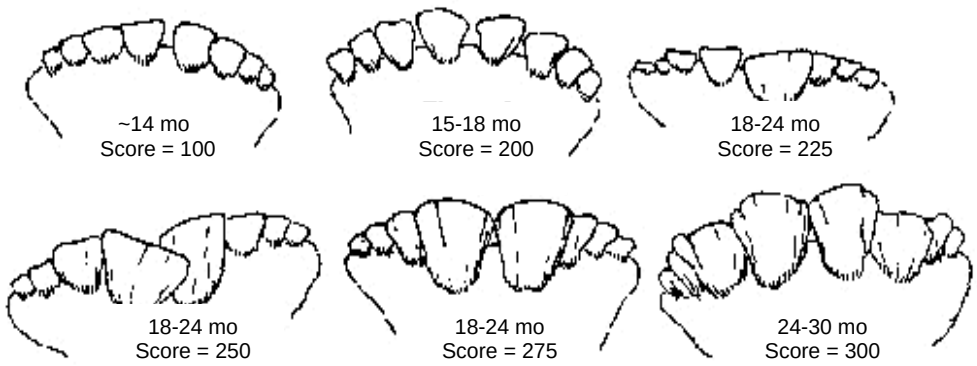

Figure 1. Changes in Dentition of Cattle Up to 30 Months of Age and Associated Numeric Dentition Score (adapted from Manitoba Agriculture, Food and Rural Initiatives).

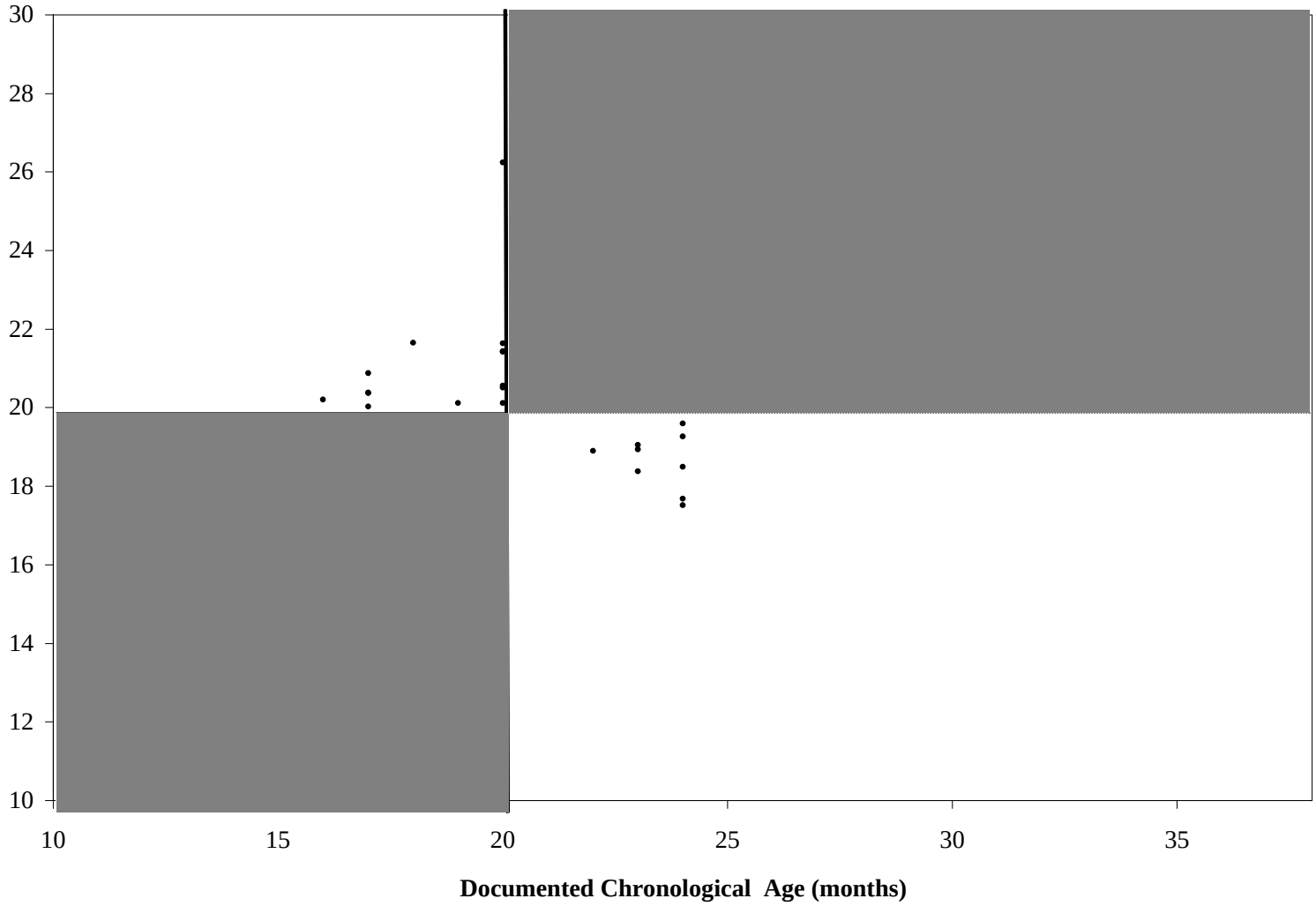

Figure 2. Documented Chronological Age versus Predicted Age at a 20-month Cut-off. Correctly grouped cattle are in the shaded quadrants.

AGING, BLADE TENDERIZATION, AND INJECTION IMPACTS TENDERNESS OF MUSCLES FROM FED STEERS

S. Hutchison, J. A. Unruh, M. C. Hunt, and T. T. Marston

Introduction

Enhancement of steer and heifer meat has become a common practice, especially for some large retailers in the United States, because it increases the weight of salable product and decreases variability in tenderness and juiciness. Enhancement also may reduce the aging period for some muscles. Muscles for this research were identified by National Cattlemen's Beef Association (NCBA) as possible muscles in which value could be added with some type of postmortem tenderization treatment. If muscles are enhanced, aging may become less important, thus allowing more efficient and faster processing of those cuts. Therefore, the objective of this research was to determine the influence of aging period on tenderness of enhanced muscles from three intermediate-priced steaks.

Experimental Procedures

Muscles from 24 steers were used in this study. The round tip (knuckle), top sirloin (*gluteus medius*), and top blade (*infraspinatus*/flat iron) steaks from the right and left sides were removed and randomly assigned to seven or 28 days of vacuum aging. Following aging, the muscles were frozen for further processing. Muscles were subsequently thawed ed for 36 hours, and then all muscles were blade-tenderized and injection-pumped at 10% of their weight with a solution containing 0.35% phosphate and 0.5% salt. Freeze-thaw losses were calculated from the initial weights after seven and 28 days of aging. After pumping, muscles were allowed five minutes to drip before they were repackaged and frozen to facilitate cutting (band saw) into three 1-inch thick steaks. One steak was randomly assigned to Warner Bratzler shear force (WBSF) testing; the other two steaks were used for further lab analysis. Steaks for WBSF were thawed at 36°F overnight. Steaks were then weighed in the package, removed from the package and re-weighed to determine package loss percentages. The steaks were cooked to an internal temperature of 104°F, turned, and cooked to a final internal temperature of 158°F. Following a 30-minute cooling period, steaks were reweighed to determine percentage of cooking loss. Cooked steaks were chilled at 32°F overnight and six 0.5-inch cores were removed parallel to the muscle fiber direction. Each core was sheared once perpendicular to the direction of the muscle fibers using the WBSF attachment to the Instron Universal Testing Machine with a 50-kg compression load cell and a cross head speed of 250 mm/min. Treatments were arranged as a split-plot with the whole plot a randomized complete-block design.

Results and Discussion

Freeze thaw loss after seven days of aging was 6.2%, 7.8%, and 5% for the round tip, top sirloin, and top blade, respectively. After 28 days of aging, freeze thaw loss for these same cuts was 6.8%, 8.2%, and 4.2%, respectively. Tenderness, cooking losses, and package losses of round tip steaks were not significantly different due to aging time. However, tenderness of the *rectus femoris* was more ($P<0.01$) tender than the *vastas lateralis*. The

rectus femoris portion of the knuckle could be cut into steaks and sold for a higher price. Aging of this muscle for 7 vs 28 d was not necessary to improve tenderness.

Table 1. Effects of Days of Aging and Muscle (*vastus lateralis, rectus femoris*) on Tenderness and Moisture Loss of Steaks From the Knuckle

	Days of Aging	
Item:	7	28
Vacuum Package Loss, %	2.3	2.3
Cook Loss, %	31.7	32.0
Warner Bratzler shear force, lb		
Round Tip	6.8	6.6
Rectus femoris[a]	5.9[b]	6.3[b]
Vastas lateralis[a]	7.7[c]	6.9[c]

[a]Denotes both muscles sampled within the knuckle. Means for muscle with a different superscript letter are different (P<0.01).
[b,c]Differing superscripts within a column are different (P<0.01).

Tenderness and package losses of top sirloin steaks were not affected by postmortem aging. Steaks that were aged for 28 days had greater (P<0.05) cooking losses than those that were only aged for seven days. The greater cooking losses could have been due to a reduction in water holding capacity of aged meat.

Top blade steaks that were aged for 28 days were more (P<0.05) tender than those aged for seven days. Cooking and package losses were not different due to days of aging. These steaks have become very common in the marketplace. It may be important to see if an intermediate number of aging days would increase tenderness to the same extent as 28 days of aging.

Table 2. Effects of Days of Aging on Tenderness and Moisture Loss of Top Sirloin and Top Blade Steaks (*gluteus medius* and *infraspinatus* muscles, respectively)

	Days of Aging	
Item:	7	28
Top Sirloin		
Package Loss, %	2.6	2.5
Cook Loss, %	31.3[a]	33.8[b]
Warner Bratzler shear force, lb	6.3	5.7
Top blade		
Package Loss, %	3.9	3.9
Cook Loss, %	23.3	24.7
Warner Bratzler shear force, lb	4.6[a]	4.1[b]

[a,b]Differing superscripts within a row are different (P<0.01).

Implications

Top blade steaks of steer carcasses will benefit from aging for 28 days, whereas seven days aging of round tip and top sirloin steaks were sufficient for tenderness.

AGING, BLADE TENDERIZATION, AND ENZYME INJECTION IMPACTS TENDERNESS OF MUSCLES FROM FED CULL COWS OF KNOWN AGE

S. Hutchison, J. A. Unruh, T. T. Marston, and M. C. Hunt

Introduction

Approximately 16% of the 31 million head of cattle harvested in the United States in 2005 were aged cows. Cow meat is known to be tougher than meat from young steers and heifers, and it typically has a less desirable, darker color. It is generally assumed that cow meat needs to be ground or have some form of post-mortem tenderization applied to be merchandized as a whole muscle product. The knuckle, top sirloin, and top blade muscles have been identified as muscles that potentially can be upgraded to medium-priced steaks. Most cow steaks are fabricated by food-service providers for their customers with different specifications for aging and post-mortem tenderization application. Aging, blade tenderization, and injection enhancement are commonly used on cow meat to increase tenderness. It is unknown if extended aging is needed in addition to the other two methods to improve tenderness. If shorter aging periods can be used without compromising an improvement in tenderness, then aging costs would be greatly reduced. Our objective was to determine the effects of days of aging on tenderness of cow steaks from the knuckle, top sirloin, and top blade that were blade tenderized and injected with an enhancement solution containing an enzyme tenderizer.

Experimental Procedures

Muscles from 31 cull cows that were fed a high concentrate diet for 60 days were used in this study. The round tip (knuckle), top sirloin (*gluteus medius*), and top blade (*infraspinatus*/flat iron) steaks from the right and left sides were removed and randomly assigned to seven or 28 days of vacuum aging. After aging, the muscles were frozen for further processing. Muscles were subsequently thawed for 36 hours and freeze-thaw loss calculated. They were then blade-tenderized using 1 pass and injected at 10% by weight with a solution containing 0.35% phosphate, 0.5% salt, and 0.023% bromelin. After pumping, muscles were allowed five minutes to drip before they were repackaged (vacuum packaged) and frozen to facilitate band-saw cutting into three 1-inch thick steaks from each muscle. One steak was randomly assigned for Warner Bratzler shear force (WBSF) testing; the other two steaks were used for further lab analysis. Frozen steaks for WBSF were thawed at 36°F, weighed, removed from the package, then reweighed to determine package loss percentages. The steaks were cooked to an internal temperature of 104°F, turned, and cooked to a final internal temperature of 158°F. Following a 30-minute cooling period, steaks were reweighed to determine cooking loss percentages. Steaks were chilled at 32°F overnight and six 0.5-inch cores were removed parallel to the muscle fiber direction. Each core was sheared once perpendicular to the direction of the muscle fibers using the WBSF attachment to the Instron Universal Testing Machine with a 50-kg compression load cell and a cross head speed of 250 mm/min.

Treatments were arranged as a split plot with the whole plot a randomized-complete-block design. The PROC MIXED procedure of SAS (2005) was used to determine if there

were any differences among treatments and least square means were separated using the PDIFF option. Age was used as a covariate; if it was determined to be significantly ($P<0.05$) different, PROC GLM was used to determine regression values.

Results and Discussion

Neither cow age nor days of aging had an effect on tenderness of round tip steaks (Table 1). However, when the *rectus femoris* and *vastus lateralis* were separated, the *rectus femoris* was more ($P<0.01$) tender than the *vastus lateralis*. There were no differences in cooking losses or package losses of round tip steaks due to days of aging. These results suggest that the *rectus femoris* could be used alone as a steak and provide acceptable tenderness and potentially higher value than the whole knuckle.

Top sirloin steak tenderness was not different due to cow age (Table 2). Steaks aged 28 days were more ($P<0.01$) tender than those that were aged for only seven days. Cooking losses and package losses were not different due to aging time or cow age.

Top-blade steak tenderness was not different due to aging days (Table 2). As cow age increased, Warner-Bratzler shear force increased (less tender, $P<0.02$) for the top-blade steaks. We speculate that this may be due to the increase in connective tissue maturation. As animals age, they have more collagen cross-linking, which can increase the toughness of the meat. Cooking loss and package losses in top-blade steaks were not different due to days of aging. Cooking loss was not different due to cow age; however, package loss increased ($P<0.05$) as cow age increased.

Implications

These results provide evidence for not aging the round tip and flat iron steaks for more than seven days when the combination of blade tenderization and injection enhancement with enzyme is applied to these muscles. This would allow food service providers to distribute this product faster and free needed storage space.

Table 1. Effects of Days of Aging, Cow Age, and Muscle (*vastus lateralis, rectus femoris*) on Tenderness and Moisture Loss of Steaks from the Knuckle

	Days of Aging		
Item:	7	28	Cow Age
Freeze-thaw loss, %	4.1	4.5	
Vacuum package loss, %	2.5	2.5	NS[a]
Cook loss, %	34.1	32.8	NS
Warner Bratzler Shear, lb			
Whole Knuckle	6.5	6.3	NS
Rectus femoris[b]	5.8[c]	5.6[c]	NS
Vastas lateralis[b]	7.1[d]	6.9[d]	NS

[a]NS = not significant.
[b]Denotes both muscles sampled within the knuckle. Means for muscle with a different superscript letter are different.
[c,d]Means for muscles in a column with different superscript letters are different (P<0.01).

Table 2. Effects of Days of Aging and Cow Age on Tenderness and Moisture Loss of Top Sirloin and Top Blade Steaks (*gluteus medius* and *infraspinatus* muscles, respectively)

	Days of Aging		
Item:	7	28	Cow Age
Top Sirloin			
Freeze-thaw loss, %	6.0	7.4	
Vacuum package loss, %	2.5	2.5	NS[a]
Cook loss, %	32.0	31.8	NS
Warner Bratzler Shear, lb	4.7[b]	3.3[c]	NS
Top Blade			
Freeze-thaw loss, %	3.7	5.0	
Vacuum package loss, %	3.6	3.7	<0.02
Cook loss, %	27.6	25.4	NS
Warner Bratzler Shear, lb	3.6	3.7	<0.01

[a]NS = not significant.
[b,c]Differing superscripts within a row are different (P<0.01).

ANTIOXIDANTS MAY REDUCE HETEROCYCLIC AMINES IN COMMERCIALLY MARINATED BEEF STEAKS

F. Ameri and J. S. Smith

Introduction

Heterocyclic amines (HCAs) are carcinogenic and mutagenic compounds found at a level of parts per billion in grilled fish and meats. Since the connection between consumption of dietary carcinogens and risk of different cancers in humans has been established, it is necessary to explore effective inhibitors that can prevent or reduce the formation of HCAs in cooked meats. Cooking meat with natural antioxidants decreases or eliminates HCAs in meat. Our objective was to study the inhibition of five HCAs in beef steaks marinated using commercial ingredients that are natural antioxidants.

Experimental Procedures

Three marinades were used. Marinade 1 contained rosemary, thyme, and chives as the main antioxidant-containing spices. Marinade 2 contained oregano, thyme, garlic, and onion. Marinade 3 contained garlic and onion. Fresh eye of round steaks were marinated with each of the marinades for one hour, then grilled at 400ºF for five minutes on each side. Control steaks were simply those without any marination and blank steaks were marinated with a commercial product containing vegetable oil, vinegar, and water.

Since HCA formation is a surface phenomenon, only the browned exterior surface was trimmed from grilled steaks for analysis. Samples were ground, then homogenized in sodium hydroxide. Adsorbed polar and non-polar amines were eluted using methanol concentrated, ammonium-hydroxide solution, concentrated under nitrogen, and then dissolved in methanol. The amount of five known HCAs (MeIQ, MeIQx, harman, norharman, and PhIP) were measured by solid-phase extraction followed by high performance liquid chromatography (HPLC). The antioxidant level of each marinade was evaluated using ethanol and a water bath extraction method followed by HPLC.

Results and Discussion

The levels of three potent antioxidants (rosemarinic acid, carnosol, and carnosic acid) found in each of the marinades are shown in Figure 1. Compared with controls, HCAs decreased by greater than 87% ($P<0.05$) in marinated steak samples (Figure 2). Marinade 1, which had the highest reduction effects on HCA formation, contained the highest amount of rosmarinic acid, carnosol and carnosic acid compare to marinades 2 and 3.

Implications

Treatment of steaks with marinades containing antioxidants one hour before grilling resulted in a significant reduction of HCA formation. Using antioxidants rich in phenolic compounds, such as rosmarinic acid, carnosol and carnosic acid, present in commercial marinades, is suggested as a useful approach for HCA inhibition.

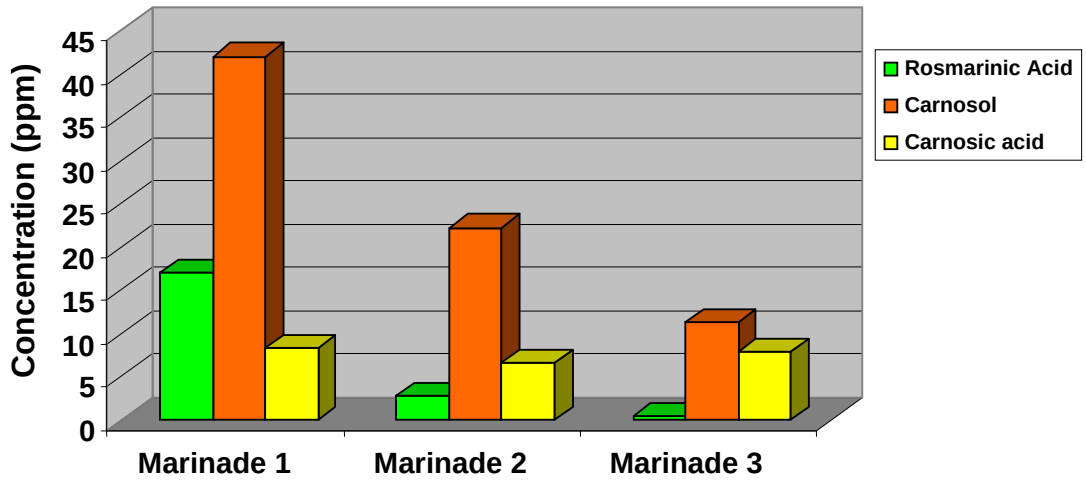

Figure 1. Level of Antioxidants in Different Marinades.

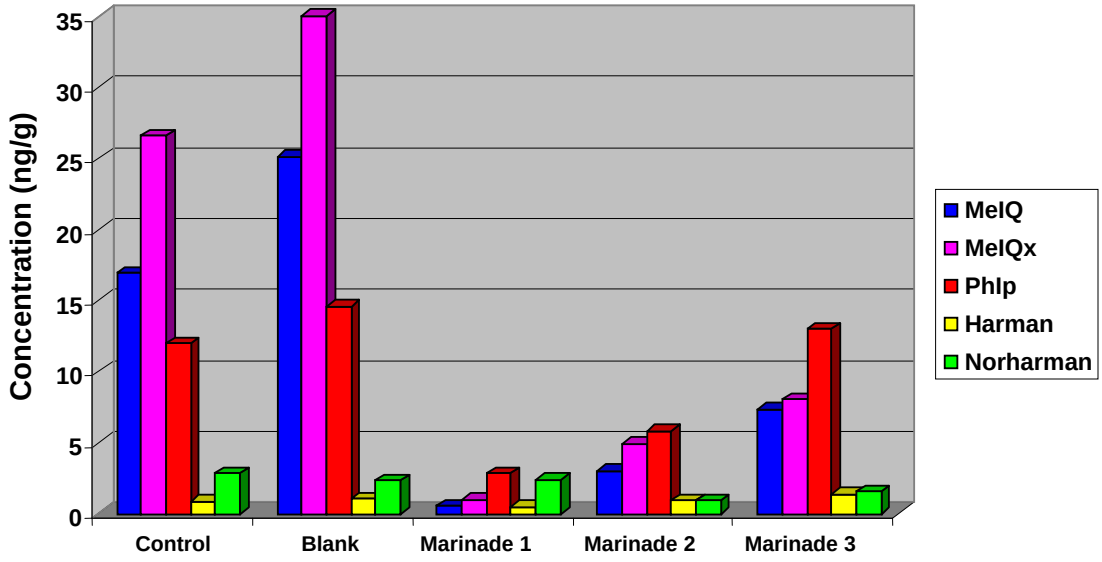

Figure 2. Level of HCAs in Control and Marinated Steaks.

FORMATION AND SAFETY OF 2-DODECYLCYCLOBUTANONE, A UNIQUE RADIOLYTIC PRODUCT IN IRRADIATED BEEF

P. Gadgil and J. S. Smith

Introduction

Treating food with ionizing radiation improves product safety and helps maintain quality. The main selling point of irradiated foods is that it is microbially safe. Beginning in October 2002, companies could petition the FDA for permission to use terms like "electronic pasteurization" on the labeling for irradiated foods. Consumers are already familiar with pasteurization and they associate the term with a safe product. There needs to be a protocol in place to test for irradiation to verify that products meet regulatory requirements. Being able to differentiate between irradiated and non-irradiated food will aid in proving the authenticity and safety of irradiated products and in detecting mislabeled products. In November 2003, Excel Corporation (Dodge City, KS) voluntarily recalled 26,000 pounds of ground beef that was mislabeled as irradiated. The incident appears to be the first case of its kind, and it emphasizes the need for a method that can reliably distinguish between irradiated and non-irradiated foods.

At the doses currently approved for food irradiation, the only unique radiolytic products that have been identified are alkylcyclobutanones (2-ACBs). These are cyclic compounds formed by rearrangement of fatty acids when exposed to irradiation. They are found in a wide variety of lipid-containing foods and have been universally accepted as indicators of irradiation exposure.

Recent studies have raised the possibility of 2-ACBs being weak genotoxins or cancer promoters when tested at high concentrations. Numerous long-term and short-term toxicity tests have demonstrated the safety of irradiated foods. In spite of these reports, some claim that irradiated foods are unsafe and have used the previous studies as proof that alkylcyclobutanones are carcinogenic. Therefore, more studies evaluating the toxicity of these chemicals at high and low concentrations are needed to conclusively prove their safety. Accordingly, the objectives of this research were to evaluate the formation of 2-dodecylcyclobutanone (2-DCB), the alkylcyclobutanone formed from palmitic acid, in irradiated ground beef, and to assess its toxicity.

Experimental Procedures

Formation of 2-DCB in Irradiated Beef. Quarter-pound ground beef patties with 15% or 25% fat were made and irradiated at an electron beam facility at 4 doses: 1, 2, 3 and 4.5 kGy. The data obtained from these samples were used to construct the dose response curves in Figure 1.

One lb chubs of commercially irradiated ground beef were obtained from two sources. Two samples of Brand X (ground round with 7% fat and ground chuck with 20% fat) and two samples of Brand Y (ground round with 10% fat and ground chuck with 20% fat) were evaluated. The 2-DCB was extracted by supercritical fluid extraction and analyzed by gas chromatography-mass spectrometry.

Toxicity and Mutagenicity. The Ames assay uses special strains of *Salmonella* to detect chemical substances that lead to gene mutations. Incubating these strains with a

mutagenic chemical will cause an increase in the number of bacterial colonies compared to the same strains incubated without the mutagen. The number of colonies usually increases with an increase in concentration of the mutagen. Some chemicals are transformed into mutagens by the body's metabolic processes. Therefore, a liver enzyme extract was used in this assay to check for this possibility. We evaluated five *Salmonella* test strains with and without liver enzyme activation, as well as four concentrations of 2-DCB.

The Microtox system is a screening tool used for a variety of toxicity testing applications. The assay utilizes *Vibrio fischeri*, a marine bioluminescent bacterium. The inhibition of light production by *V. fischeri* in the presence of toxins forms the basis of this assay. Acute toxicity of 2-DCB was evaluated by the Microtox acute toxicity system and compared with cyclohexanone and 2-nonenal (both GRAS additives).

Results and Discussion

Formation of 2-DCB in Irradiated Beef. 2-DCB was detected in all the irradiated samples and its concentration increased linearly with dose, as illustrated in the response curve shown in Figure 1. There was no significant difference in the amount formed between the two fat levels. There might be an upper threshold beyond which the amount of fat does not effect 2-DCB formation. This indicates that the amount of fat may not be a factor affecting 2-DCB formation, at least at these fat levels. Thus, the absorbed dose can be estimated for commercial samples with a wide range of fat levels. In a commercial setting where there is considerable variation in product composition, this would be an advantage.

The 2-DCB was detected in all the commercial samples and the absorbed doses were calculated from the dose response curves. The estimated doses applied to the commercial samples ranged between 1.38 kGy and 1.55 kGy—values consistent with doses normally used in the industry (1.0 to 2.0 kGy)

Lab samples were irradiated at a SureBeam facility that also irradiates ground beef for retail sale. The samples were processed in much the same way as commercial samples would be and were suitable for estimating applied dose. It should be noted that the absorbed dose values are estimates. There were no true controls for the commercial samples and there was no information about when the samples were irradiated. Therefore, the effect of storage conditions and/or time, if any, was unknown. However, these values are within the range of 1.0 to 2.0 kGy normally used in the industry indicating that this method was able to approximate the dose applied.

Mutagenicity and Toxicity: The 2-DCB did not increase the number of colonies compared to controls with or without S9 addition. Therefore, 2-DCB was non mutagenic in the Ames assay and was not activated by liver enzymes, indicating that it was not biotransformed into mutagenic by-products.

The Microtox assay measures the relative toxicity of each chemical by calculating concentration of a chemical that reduces the light production of the microorganism *V. fischeri* by 50% (EC_{50}). The lower the EC_{50} value is, the higher the toxicity. The dose-response curves for the three compounds tested are shown in Figure 2. As the EC_{50} value for 2-DCB was between that of nonenal and cylohexanone, 2-DCB would not represent a greater risk compared to nonenal, a Generally Recognized as Safe additive.

The maximum number of cells of *V. fischeri* affected by 2-DCB was 65 ± 4 %, while it reached 90-100% for the other two compounds. When comparing toxicity of chemicals, two parameters can be examined; potency and efficacy. Potency is the range of doses over which toxicity is observed and ef-

ficacy is the elicited by the chemical. Compared to the other chemicals, 2-DCB had the lowest maximum toxic effect.

The amount of 2-DCB found in commercial ground beef patties ranged from 0.03 to 0.05 µg/g of ground beef. For a patty weight of about 4 oz (115g), this amounts to about 3.5 to 5.8 µg per patty. The total exposure to 2-DCB by eating one of these irradiated patties would be 0.08 µg/kg body weight for a 154 lb adult. Thus, the amount consumed would be so small that any potential risk of 2-DCB would be minimal.

Implications

The amount of 2-DCB formed in irradiated beef can be used to monitor the irradiation dose and is too low to pose a significant health risk. Therefore, irradiation is a safe method to ensure quality and safety of ground beef.

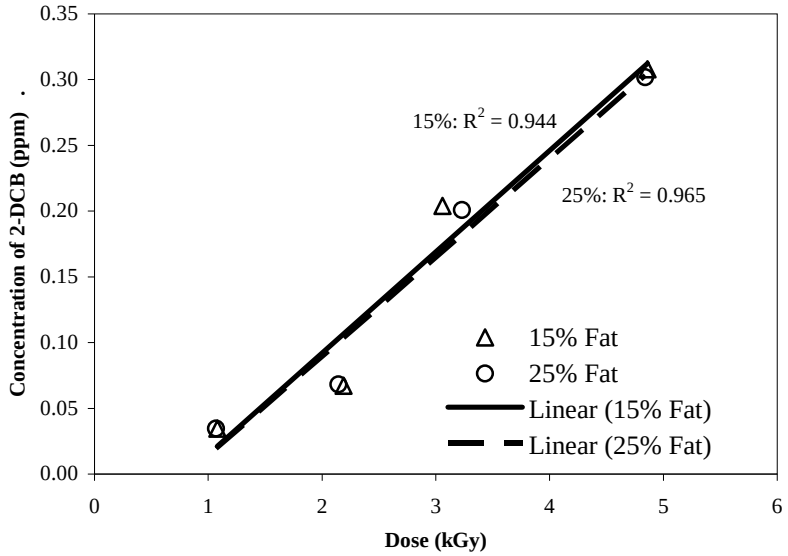

Figure 1: Response of 2-DCB (µg/g of beef) with Increasing Irradiation Dose.

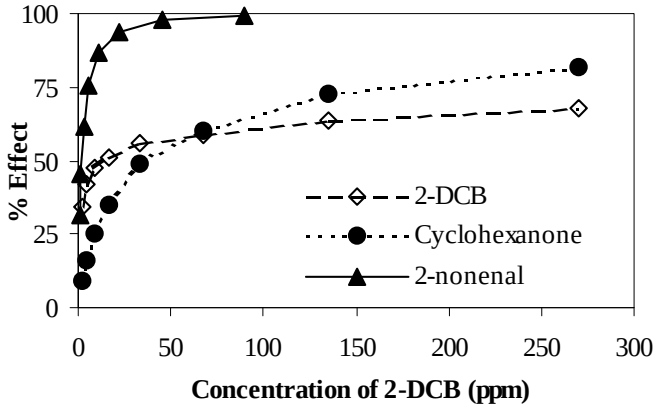

Figure 2: Effect of Concentration of 2-DCB, Cyclohexanone, and 2-nonenal on Light Emission by *V. fischeri*. Concentrations tested were between 90 ppm to 270 ppm for 2-DCB and cyclohexanone, and 90 ppm for 2-nonenal.

THERMAL PROCESS FOR JERKY PROVIDES PROPER LETHALITY FOR CONTROLLING PATHOGENS

M. N. Roberts, K.J.K. Getty, and E.A.E. Boyle

Introduction

In 2003, the New Mexico Department of Health linked an outbreak of Salmonellosis with consumption of beef jerky. Due to the increasing commonality of foodborne illness associated with dried meats, in 2004 USDA/FSIS published the Compliance Guideline for Meat and Poultry Jerky Produced by Small and Very Small Plants, which addresses the issues of how to obtain adequate lethality and verify adequate drying. Small meat businesses that produce jerky products must validate that their processes achieve a 5-log reduction of *E. coli* O157:H7 and a $\geq$ 6.5-log reduction of *Salmonella*. The objective of this study was to determine the effects of thermal processing temperatures and times on reducing *E. coli* O157:H7 and *Salmonella* in chopped and formed beef jerky.

Experimental Procedures

Meat Batter Preparation and Inoculation. Fresh chopped and formed all-beef jerky batter was obtained from a commercial processor. The product was separated into three 4-lb batches. Two treatments, consisting of an *E. coli* O157:H7-inoculated batch and a *Salmonella*-inoculated batch, were prepared by adding an *E. coli* O157:H7 five-strain inoculum or *Salmonella* five-strain inoculum and thoroughly mixing into the jerky batter. A control batch was prepared by adding sterile deionized water into the meat batter.

Batter was extruded using a manual jerky gun with a 1/4-inch by 1-inch nozzle onto polyscreen sheets and then thermally processed in a commercial smokehouse (Table 1). A replication consisted of both inoculated batches and a control batch placed in the smokehouse simultaneously. Three replications were conducted.

***E. coli* O157:H7 and *Salmonella* Enumeration**. Raw inoculated samples were taken from the inoculated jerky batter. Heat-treated samples were taken at six different times (end of stages 6, 7, 8, 10; 1.5 hours into stage 12; and at the end of the stage 12; Table 1). Population levels of *E. coli* O157:H7 and *Salmonella* were determined for both raw and heat-treated samples. In addition, heat-treated samples with counts below the detection limit were tested for a positive or negative level of either *E. coli* O157:H7 or *Salmonella*.

Water Activity (a_w), pH, Proximate Analysis, and Salt. Water activity and pH levels were determined on control samples. Samples for proximate analysis (moisture, fat, and protein) and salt content were taken from the non-inoculated raw control batch 1.5 hours into stage 12 and at the end of stage 12 (final).

Results and Discussion

For all *E. coli* O157:H7- and *Salmonella*-inoculated jerky strips, initial raw batter populations ranged from 7.3 to 7.4 log cfu/g and 7.1 to 7.5 log cfu/g, respectively. When the product reached stages 6, 7, 8, and 10, *E. coli* O157:H7 populations ranged from less than 1.48 (detection limit) to 2.68 log cfu/g and *Salmonella* counts ranged from less than 1.5 to 2.1 log cfu/g. By 1.5 hours into stage 12, counts were consistently less than 1.5 log

cfu/g on all media. End-product *E. coli* O157:H7 and *Salmonella* populations were consistently <0.5 log cfu/g.

There was ≥ 5.0 log cfu/g reduction of *E. coli* O157:H7 at all sampling times as required by USDA/FSIS, with the most consistent reductions being after stage 7. A ≥ 6.5 log cfu/g reduction of *Salmonella*, as mandated by USDA/FSIS, was seen in stage 12 and at the end of the cycle (Figure 1). End product populations for both *E. coli* O157:H7 and *Salmonella* show reductions well above those mandated by USDA/FSIS.

Samples from 1.5 hours into stage 12 and end-product samples showed negative populations for both *E. coli* O157:H7 and *Salmonella* for all samples tested, confirming the likelihood that pathogens are dead as opposed to heat-injured.

Moisture content ranged from 52.4 to 56.0% for raw product and 15.1 to 19.8% for the final product. Protein content ranged from 15.9 to 17.0% for raw product and 34.2 to 37.7% for the final product. Salt contents for raw products ranged from 2.2 to 2.3% and from 4.2 to 5.2% for final product. The moisture-to-protein ratio ranged from 0.4 to 0.6 for the final product. This ratio is in compliance with the requirement of an MPR less than 0.75:1 needed for the product to be labeled as "jerky".

Raw batter pH values ranged from 6.0 to 6.2. The final pH range for all products was 5.1 to 5.3. It should be noted that a lowered pH was not a determining factor for the reduction of *E. coli* O157:H7 or *Salmonella* populations.

Water activity range for all final products was 0.570 to 0.625. According to the USDA/FSIS Jerky Compliance Guidelines, water activity for jerky products should be ≤ 0.80 to ensure lack of microbial growth.

Implications

A thermal process for producing chopped and formed jerky provided proper lethality to control pathogens such as *E. coli* O157:H7 and *Salmonella* and provides a process that will produce safe jerky for consumers.

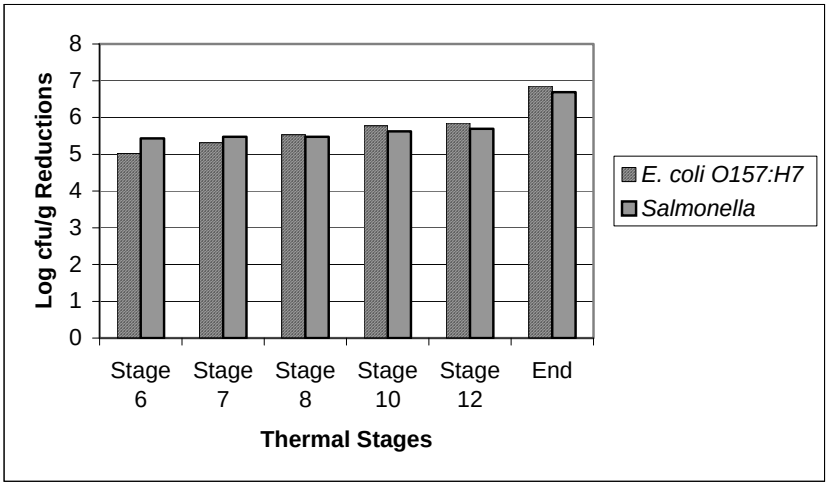

Figure 1. *E. coli* O157:H7 log CFU/g Reductions and *Salmonella* Reductions at Six Thermal Stages[a] during Production of Chopped and Formed Beef Jerky.

[a]Times and dry bulb smokehouse temperatures for thermal stages: stage 6 – 44 min at 132ºF and 46 min at 172ºF, stage 7 – 44 min at 132ºF and 1 hour at 172ºF, Stage 8 – 44 min at 132ºF and 1 hour 16 min at 172ºF, stage 10 – 44 min at 132ºF and 1 hour 46 min at 172ºF, stage 12 – 44 min at 132ºF and 3 hours 30 min at 172ºF, End – 44 min at 132ºF and 7 hours at 172ºF.

Table 1. Thermal Processing Schedule[a] and Sampling Times for Chopped and Formed Beef Jerky

Stage	Dry Bulb (D.B.) (ºF)[a]	Time	Blower Speed	Sampling Time	Cumulative Times and Temperatures at Each Sampling Time
1	132	14 min	Medium		
2	132	16 min	Medium		
3	132	14 min	Medium		
4	172	16 min	Medium		
5	172	14 min	Medium		
6	172	16 min	Medium	End of stage	44 min at 132ºF and 46 min at 172ºF
7	172	14 min	Fast	End of stage	44 min at 5132ºF and 1 h at 172ºF
8	172	16 min	Fast	End of stage	44 min at 132ºF and 1 h 16 min at 172ºF
9	172	14 min	Fast		
10	172	16 min	Fast	End of stage	44 min at 132ºF and 1 h 46 min at 172ºF
11	172	14 min	Fast		
12	172	5 h	Fast	1.5 h into stage	44 min at 132ºF and 3 h 30 min at 172ºF
End				End of stage 12	44 min at 132ºF and 7 h at 172ºF

[a]The smokehouse has an automated damper system and the ability to inject steam as needed to control humidity and the exhaust fan was running during the whole process. Percent relative humidity remained at less than 10% throughout the entire smokehouse cycle. Blower speed: Medium=788.8 ± 52.7 ft/min and fast speed = 1141.5 ± 111.9 ft/min.

AMMONIA ION SELECTIVE ELECTRODE AND INDOPHENOL METHODS CAN BE USED SUCCESSFULLY TO EVALUATE MEAT CONTAMINATED BY AMMONIA

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Introduction

Anhydrous ammonia is used as a refrigerant in large warehouses for cooling meats, fruits, vegetables, milk, and other products. Ammonia offers several advantages over other refrigerants; it does not harm the ozone layer and is a very efficient heat transfer agent. However, cold storage facilities sometimes have ammonia leaks. When this happens, products are held for an indeterminate period or are condemned because there is no official method to evaluate the degree of product contamination. In one case, a warehouse owner discarded a product because he could not prove that it was safe. His insurance company would not compensate him because he failed to prove that the product was not safe for human consumption. Over the last several years, many owners of refrigeration warehouses have experienced this problem.

Foodborne illness outbreaks caused by ammonia have been reported twice in the United States. On October 30, 1985, a foodborne outbreak was reported in two elementary school children in Wisconsin. The children suffered from burning of the mouth and throat, as well as nausea, within one hour of drinking milk packaged in half-pint containers. Analysis of the remaining containers revealed that the milk was contaminated with ammonia at levels ranging from 530 ppm to 1,524 ppm. The pH levels of the contaminated milk ranged from 9.1 to 10.0, while normal milk pH ranges from 6.7-6.9. This was the first reported incident of acute ammonia poisoning by the Centers for Disease Control and Prevention. On November 25, 2002, another outbreak was reported in several dozen school children in Illinois. The children suffered from stomachache, nausea, and headache within one hour of eating chicken tenders. A laboratory investigation by the U.S. Department of Agriculture's Food Safety Inspection Service (FSIS) showed that the chicken tenders were contaminated with ammonia at levels ranging from 552 ppm to 2,468 ppm. Assessment of ammonia damage to determine whether food is fit for human consumption is based on tentative methods because published information is limited. According to the Food and Drug Administration (FDA), at least three different measurement methods should be used to assess contaminated products: ammoniacal nitrogen, sensory test, and pH measurement. The objective of this study was to evaluate assays for ammonia detection so that they could be used for rapid in-plant testing of meat contaminated by ammonia refrigerant leaks and to determine the ammonia background of different meat products using the ammonia ion selective electrode (ISE).

Experimental Procedures

Evaluations of ammonia ion selective electrode, indophenol, salicylate, and Reflectoquant[1]

[1]Reflectoquant is a registered trademark of Gallade Chemical Co., Santa Ana, CA.

test strip methods were done using ground eye of round beef spiked with ammonium chloride as standard. Beef samples were spiked with 25, 50, 100, or 200 ppm ammonia as nitrogen (N) and the amounts recovered were background corrected, depending on the background determined on the day of analysis. The ammonia-electrode assay was performed on aqueous homogenate and on a perchloric supernate. Meat protein was precipitated using perchloric acid, trichloroacetic acid, or tungstic acid and an aliquot of the filtrate was tested with indophenol, salicylate, or Reflectoquant test strips. To determine ammonia concentration in perchloric acid supernate from beef by ion selective electrode, meat protein was precipitated with perchloric acid. Ammonia liberated in the supernate upon alkalization was then measured with the ion selective electrode.

After evaluation of various ammonia assays, beef, pork, and chicken products were obtained from local stores and analyzed with the ion selective electrode to determine the normal ammonia background in these products. The ion selective electrode was chosen because it is fast, sensitive, and has a broad dynamic range.

Results and Discussion

The precision of the Reflectoquant test strips was evaluated by measuring a known ammonium chloride standard. The coefficient of variation was 11.6%, which means that this method is not precise (data are not shown in this paper). The recovery of ammonia from spiked beef samples by the Reflectoquant method ranged from 77.4% to 96.9% and the standard deviation (SD) was higher than 14% at all spiked levels (Table 1). The reaction of salicylate with ground eye of round beef was slow due to the interference of protein fragments. The recovery of ammonia from spiked beef samples by the salicylate methods was low (Table 2 and 3) when samples were spiked with low ammonia levels (25 and 50 ppm ammonia as nitrogen).

Recovery of the indophenol method was better than that of the salicylate and the Reflectoquant test strips, especially when perchloric acid was used to precipitate meat protein. Recovery of ammonia by indophenol method ranged from 95.4% to 113% and the SD was lower than 8.3% (Table 2).

The recovery of ammonia from the spiked beef filtrate by ion selective electrode ranged from 98.3% to 100% and the SD was less than 2%, while the recovery of ammonia from spiked beef samples by ion selective electrode-perchloric acid method, developed in our lab, ranged from 90% to110% and the SD was less than 7.6% (Table 3). This new method offers many advantages. It decreases the response time of the membrane, prevents any drift in the electrode potential, increases the useable life of the membrane, and gives excellent recovery.

The ammonia backgrounds of different meat products, analyzed with ammonia-ion selective electrode by direct homogenization, are shown in Table 3. These backgrounds are important because the FDA recommends analysis of similar foods that have not been exposed to ammonia to determine the normal ammonia background. According to the FDA, the product can be released if its ammonia content does not exceed the normal value by 1%. Our values (Table3) are lower than those obtained using the official ammoniacal nitrogen method.

Implication

Both ammonia-ion selective electrode and indophenol methods are precise and accurate. Rapid methods that can be used for in-plant testing of muscle food products potentially contaminated by ammonia refrigerant leaks.

Table 1. Summary of the Average Percent Recoveries of Ammonia Spikes in Ground Eye of Round Beef

Spiked Level	Indophenol	Salicylate	Reflectoquant Test Strips	Ion Selective Electrode	Number of Samples
Background ppm ammonia as (N)	78.4 ± 3.1	103.7 ± 10.1	93.3 ± 15.5	74.8 ± 1.4	10
25 ppm ammonia as (N)	78.0 ± 25.3	63.3 ± 32.2	96.9 ± 34.4	100 ± 1.8	10
50 ppm ammonia as (N)	85.8 ± 11.4	81.5 ± 11.1	81.0 ± 32.7	99.6 ±1.6	10
100 ppm ammonia as (N)	79.9 ± 5.4	98.0 ± 16	92.2 ± 14.2	99.2 ± 1.1	10
200 ppm ammonia as (N)	82.5 ± 5.0	99.3 ± 13.4	77.4 ± 15.0	98.3 ± 0.9	10

*Meat protein was precipitated with 10% sodium tungstate and 1 N sulfuric acid in the indophenol, salicylate, and Reflectoquant methods. Ammonia was extracted using distilled water in the ion selective electrode method, and the sample extract was spiked after recording the background reading.

Table 2. Summary of the Average Percent Recoveries of Ammonia Spikes in Ground Eye of Round Beef using 0.3 M Perchloric Acid as a Deproteinizing Agent

Spiked Level	Indophenol	Salicylate	Ion Selective Electrode	Numnber of Samples
Background ppm ammonia as (N)	93.9 ± 4.0	109 ± 6.5	103 ± 1.5	5
25 ppm ammonia as (N)	113 ± 8.3	34.7 ± 21.6	89.9 ± 6.1	5
50 ppm ammonia as (N)	109 ± 3.6	44.5 ± 11.3	93.5 ± 7.6	5
100 ppm ammonia as (N)	98.6 ± 5.8	118 ± 9.7	110 ± 3.1	5
200 ppm ammonia as (N)	95.4 ± 4.4	100 ± 3.0	102 ± 1.0	5

Table 3.Ammonia Background in Different Commercial Meat Products Analyzed by Direct Homogenization Using the Ion Selective Electrode

Type of Product	Ammonia Background (ppm)	Number of Samples	SD
Ground Chuck (80:20)	99.8	6	4.2
Beef eye of round (90:10)	134	6	5.3
Top loin beef	120	6	6.7
Turkey thigh	149	5	18
Chicken breast	166	6	10.6
Chicken thigh	150	6	21.1
Top loin pork	136	6	13.5
Pork leg (steak)	141	6	10.4
Breakfast sausage (turkey)	113	6	11.8
Chicken nuggets	87.2	6	8.6
Turkey franks	87.0	6	9.6

BIOLOGICAL VARIABILITY AND STATISTICAL EVALUATION OF DATA

The variability among individual animals in an experiment leads to problems in interpreting the results. Animals on treatment X may have a higher average daily gain than those on treatment Y, but variability within the groups may indicate that the difference between X and Y is not the result of the treatment alone. You can never be totally sure that the difference you observe is due to the treatment, but statistical analysis lets researchers calculate the probability that such differences are from chance rather than from the treatment.

In some articles, you will see the notation "$P<0.05$." That means the probability that the observed difference was due to chance is less than 5%. If two averages are said to be "significantly different," the probability is less than 5% that the difference is due to chance, and the probability exceeds 95% that the difference is true and was caused by the treatment.

Some papers report correlations: measures of the relationship between traits. The relationship may be positive (both traits tend to get larger or smaller together) or negative (as one gets larger, the other gets smaller). A perfect correlation is either +1 or -1. If there is no relationship at all, the correlation is zero.

You may see an average given as 2.5 ± 0.1. The 2.5 is the average; 0.1 is the "standard error." That means there is a 68% probability that the "true" mean (based on an unlimited number of animals) will be between 2.4 and 2.6. "Standard deviation" is a measure of variability in a set of data. One standard deviation on each side of the mean is expected to contain 68% of the observations.

Many animals per treatment, replicating treatments several times, and using uniform animals all increase the probability of finding real differences when they actually exist. Statistical analysis allows more valid interpretation of the results, regardless of the number of animals in an experiment. In the research reported herein, statistical analyses are included to increase the confidence you can place in the results.

In most experiments, the statistical analysis is too complex to present in the space available. Contact the authors if you need further statistical information.

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