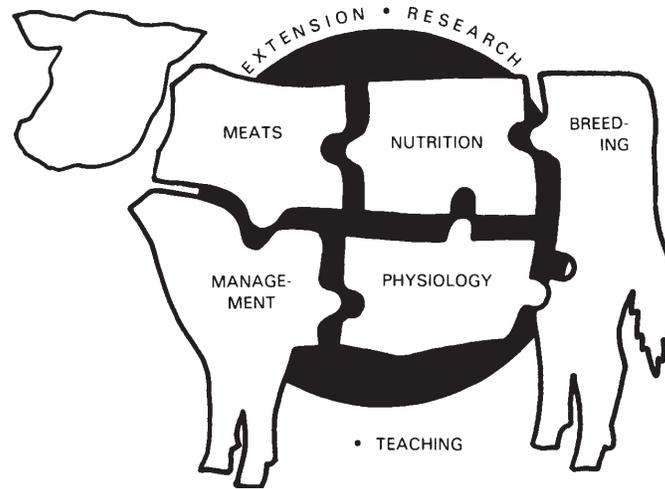


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2010 Beef Cattle Report



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Effect of Calving Season and Wintering System on Cow Performance

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Procedure

Cow Management

Data were collected over four years from 218 cows (5/8 Red Angus, 3/8 Continental) per year. Cows were located at the Gudmundsen Sandhills Laboratory (Whitman, Neb.). Cows were assigned to one of five treatments: 1) spring calving cows (SP) wintered on native range (n = 44); 2) SP wintered on cornstalks (n = 44); 3) summer calving cows (SUM) wintered on native range (n = 37); 4) SUM wintered on cornstalks (n = 37); or 5) fall calving cows (FA) wintered on cornstalks (n = 55). Average calving dates were March 24, June 15, and August 5 for SP, SUM, and FA, respectively.

SP wintered on native range (treatment 1) were allowed to graze native Sandhills range from mid-May until the end of February, then were fed meadow hay from the beginning of March until mid-May. SP wintered on cornstalks (treatment 2) were allowed to graze native Sandhills range from mid-May until mid-October when cows were transported to cornstalks in the Platte River valley; at the end of February, they were returned to the ranch and fed meadow hay until mid-May. From late winter to early spring, both groups (SP wintered on range and SP wintered on cornstalks) were supplemented 1 lb/head daily with a 28% crude protein (CP) dried distillers grain cube (Table 1).

SUM wintered on native range (treatment 3) were allowed to graze native Sandhills range for the entire year. SUM wintered on cornstalks (treatment 4) were allowed to graze native Sandhills range from April until the beginning of October, transported to cornstalks in mid-October, and returned to the ranch at the beginning of April. FA wintered on cornstalks (treatment 5) also were transported to cornstalks in mid-October and returned to the ranch

Table 1. Composition of 28% CP distillers grain cube¹.

Item, %	DM basis
DDGS	62
Wheat midds	11
Cottonseed meal	9
Corn gluten feed	5
Molasses	5
Urea	2
Calcium carbonate	3
Binder	3

¹Formulated to provide 10,000 IU/lb of vitamin A and 16 mg/lb of Rumensin (Elanco Animal Health, Greenfield, Ind.).

at the beginning of April. During late winter to early spring, SUM and FA were not fed hay; however, SUM calving cows wintered on range (treatment 3) were supplemented 2.5 lb/head daily of 28% CP dried distillers grain cube to meet protein requirements. Additionally, SUM wintered on cornstalks (treatment 4) and FA (treatment 5) were supplemented 1.0 lb/head daily.

At calving, cows were assigned a calving difficulty score from 1 to 5 (1 = no assistance; 2 = minor assistance; 3 = difficult assistance; 4 = caesarean section; 5 = abnormal presentation) and a calf vigor score from 1 to 5 (1 = nursed unassisted; 3 = nursed with assistance; and 5 = dead at birth). Calves from SP cows were weaned on October 31 (220 days of age). Calves from SUM and FA were weaned on April 11, at 298 and 247 days of age, respectively. April 11 also was the date SUM and FA cows grazing cornstalks during the winter were returned to the ranch.

For each system, cow BW and BCS were recorded at three different periods during the year: at 21 days before calving (pre-calving), at 59 days post calving (pre-breeding), and at weaning. Calf BW was recorded at birth, dam pre-breeding, and weaning.

(Continued on next page)

Summary

Four years of data from three different calving seasons and two different cow wintering systems were evaluated utilizing 218 cows/year. Cows calved in spring, summer, or fall and were wintered on native Sandhills range or cornstalks. Calving season affected cow body weight (BW) and body condition score (BCS) throughout the production year; calving in the fall reduced number of calves weaned per cow. No differences were observed between cows wintered on Sandhills range and those wintered on cornstalks.

Introduction

The amount of feed required to maintain cows in the Sandhills can be affected by calving date (Adams et al., 1996 *Rangelands* 18:57). To meet cow nutrient requirements, producers feed hay and purchased feeds that can increase costs (Stockton et al., 2007 *Prof. Anim. Sci.* 23:500). Changing calving date could decrease the use of harvested forages and purchased feeds by matching the cow's requirements with the nutrient supply of the forage. The use of corn residue can be advantageous in beef production systems. As corn price increases, there is potential for increased corn acres leading to increased cornstalk availability. Cornstalks offer producers an inexpensive feed and help minimize the use of harvested forages and purchased feeds. Therefore, the objective of this study was to determine the effect of calving season and wintering system on cow BW change and breeding performance.

Data from this study were analyzed as a completely randomized design using the MIXED procedure of SAS. The experimental unit for this study was group of cows within treatment; therefore, the only replication in this study is year. To determine the effect of calving date, the model included calving season with year included as a random effect. Contrast statements were used to evaluate the differences between calving seasons (SP vs. SUM, SP vs. FA, and SUM vs. FA). To compare FA to SP and SUM, performance data from SP and SUM cows wintered on range and SP and SUM cows wintered on cornstalks were averaged and compared to FA (FA were wintered only on cornstalks). SP and SUM cows were used to determine the difference between wintering systems, since FA were wintered only on cornstalks. The model to test for differences between wintering system included wintering system with year included as a random effect. Data are presented as least square means with differences considered significant at $P < 0.05$.

Results

Calving Season

Calving difficulty was greatest for SP ($P = 0.05$; Table 2) compared to SUM and FA, which were not different from each other ($P = 0.70$). Calf vigor ($P = 0.78$) was not different among calving seasons. Pre-calving BW was greatest for FA ($P < 0.01$) and least for SUM ($P < 0.01$). BW at pre-breeding was greatest for FA when compared to SP ($P < 0.01$) and SUM ($P < 0.01$); BW for SUM was 199 lb heavier ($P < 0.01$) than for SP. Cow BW at weaning was lower for SP ($P = 0.04$) compared to SUM; however, SP and FA were not different ($P = 0.14$). In addition, for SUM and FA, BW at weaning was not different ($P = 0.64$).

Pre-calving BCS differed ($P < 0.03$) among calving seasons, with FA having the greatest BCS, followed by SUM and SP (Table 2). At pre-breeding, SP had

Table 2. The effect of calving season on cow performance.

Item	SP ¹	SUM ²	FA ³	SEM
n/yr	89	74	55	—
Calf vigor ⁴	1.01	1.01	1.01	0.01
Calving difficulty ⁵	1.03 ^x	1.01 ^y	1.00 ^y	0.01
Cow BW				
Pre-calving, lb	1172 ^y	1251 ^y	1384 ^x	23
Pre-breeding, lb	1055 ^z	1254 ^y	1296 ^x	12
Weaning, lb	1102 ^y	1154 ^x	1142 ^{xy}	25
Cow BCS				
Pre-calving	5.3 ^z	5.9 ^y	6.6 ^x	0.1
Pre-breeding	5.3 ^y	6.1 ^x	6.0 ^x	0.1
Weaning	5.1	5.1	5.0	0.1
Calf BW				
Birth BW, lb	81	83	84	2
Pre-breed BW, lb	203 ^y	231 ^x	226 ^x	4
Weaning BW, lb	523 ^y	558 ^x	514 ^y	9
Adj. weaning BW ⁶ , lb	491 ^x	410 ^z	441 ^y	7
Calf ADG ⁷ , lb/day	2.00 ^x	1.60 ^z	1.74 ^y	0.03
Calved ⁸ , %	98.4	97.1	94.4	2.7
Rebreeding ⁹ , %	93.6	93.2	90.0	3.3
Calves weaned per cow	96.2 ^x	94.5 ^{xy}	85.7 ^x	4.6

¹SP = spring calving cows (average calving date = March 24); reflects the combined performance measures for cows wintered on cornstalks and native range.

²SUM = summer calving cows (average calving date = June 15); reflects the combined performance measures for cows wintered on cornstalks and native range.

³FA = fall calving cows (average calving date = August 5); reflects cows wintered on cornstalks only.

⁴Calf vigor = 1 = nursed unassisted, 3 = nursed with assistance, and 5 = dead at birth.

⁵Calving difficulty = 1 = no assistance, 3 = hard assistance, and 5 = abnormal presentation.

⁶Adj. weaning BW = calf weaning weight adjusted to 205 days.

⁷Calf ADG = ADG for the calf from birth to weaning.

⁸Calved = percent of cows that calved in the production year.

⁹Rebreeding = percent of cows determined to be bred at weaning.

^{xyz}Means with unlike superscripts differ ($P < 0.05$).

Table 3. The effect of wintering system on cow performance.

Item	Cornstalks	Native Range	SEM	P-value
n	82	81	—	—
Calf vigor ¹	1.02	1.00	0.01	0.06
Calving difficulty ²	1.02	1.02	0.01	1.00
Cow BW				
Pre-calving, lb	1202	1220	26	0.57
Pre-breeding, lb	1160	1149	42	0.86
Weaning, lb	1135	1121	20	0.61
Cow BCS				
Pre-calving	5.5	5.6	0.2	0.61
Pre-breeding	5.6	5.7	0.2	0.70
Weaning	5.1	5.1	0.1	0.80
Calf BW				
Birth BW, lb	82	82	1	0.64
Pre-breed BW, lb	215	219	7	0.64
Weaning BW, lb	537	544	11	0.63
Adj. weaning BW ³ , lb	446	452	15	0.77
Calf ADG ⁴ , lb/day	1.77	1.81	0.09	0.72
Calved ⁵ , %	97.8	97.7	1.6	0.94
Rebreeding ⁶ , %	92.3	88.3	0.8	0.04
Calves weaned per cow	94.8	95.8	2.8	0.65

¹Calf vigor = 1 = nursed unassisted, 3 = nursed with assistance, and 5 = dead at birth.

²Calving difficulty = 1 = no assistance, 3 = hard assistance, and 5 = abnormal presentation.

³Adj. weaning BW = calf weaning weight adjusted to 205 days.

⁴Calf ADG = ADG for the calf from birth to weaning.

⁵Calved = percent of cows that calved in the production year.

⁶Rebreeding = percent of cows determined to be bred at weaning.

the lowest BCS ($P < 0.01$) compared to SUM and FA, which were not different ($P = 0.82$). There were no differences ($P = 0.22$) in BCS at weaning among calving seasons.

There was no difference in birth BW for the different calving seasons ($P = 0.26$; Table 2). Spring calves were 28 and 23 lb lighter at pre-breeding than SUM ($P < 0.01$) and FA ($P < 0.01$) calves, respectively. Calf weaning BW was similar ($P = 0.36$) for SP and FA calves; however, because of increased days of age, SUM calves were 44 and 35 lb heavier than FA ($P < 0.01$) and SP ($P < 0.01$) calves, respectively. Calf ADG from birth to weaning was 0.40 and 0.26 lb/day greater for SP calves compared to SUM ($P < 0.01$) and FA ($P = 0.03$) calves, respectively. Adjusted 205-day weaning BW for calves was greatest for SP calves ($P < 0.01$) compared to SUM and FA calves. Adjusted weaning weights for FA calves were 31 lb greater than for SUM calves ($P < 0.01$).

Percentage of cows to calve was not different when comparing calving seasons ($P = 0.16$; Table 2). In addi-

tion, rebreeding rates were similar for SP, SUM, and FA (93.6 vs. 93.2 vs. 90.0; $P = 0.29$). Calves weaned per cow was not different for SP and SUM (0.962 vs. 0.945; $P = 0.67$); however, FA weaned fewer calves per cow than SP (0.857 vs. 0.962; $P = 0.05$) and tended to wean fewer calves per cow than SUM (0.857 vs. 0.945; $P = 0.08$).

Wintering System

Calf vigor scores tended to be greater for cows wintered on cornstalks compared to those wintered on Sandhills range ($P = 0.06$; Table 3); however, calving difficulty ($P = 1.00$) was not different between cows wintered on Sandhills range and those wintered on cornstalks. In this study cows wintered on cornstalks received 1.5 lb/day more supplement than cows wintered on Sandhills range. However, cow BW and BCS at pre-calving ($P > 0.57$), pre-breeding ($P > 0.70$), and weaning ($P > 0.61$) were not different between wintering systems.

Wintering system did not influence calf BW at birth ($P = 0.64$), at start of

the breeding season ($P = 0.64$), or at weaning ($P = 0.63$). Additionally, calf ADG ($P = 0.72$) from birth to weaning and adjusted 205-day weaning BW ($P = 0.77$) were not different between wintering systems. Neither percentage of cows to calve, rebreeding rate, or calves weaned per cow were influenced ($P > 0.65$) by wintering system.

Results from this study indicate that calving season can affect cow BW and BCS throughout the production year. However, calving season does not impact rebreeding rate but can impact the number of calves weaned per cow. In terms of wintering system, cows can be wintered on Sandhills range or cornstalks without affecting breeding performance or cow BW and BCS.

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Extending Grazing in Heifer Development Systems Decreases Cost Without Compromising Production

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Summary

Three experiments compared heifer development in the dry lot, grazing either dormant winter range or corn crop residue. Grazing corn residue may reduce pre-breeding gain and in doing so increase age at puberty. Compared to dry lot development, grazing corn residue reduced AI pregnancy rate, but final pregnancy rate was similar for both development systems. Calf production and rebreeding efficiency were not affected by the development system. However, grazing corn residue during heifer development reduced cost compared to development in the dry lot. Developing heifers by grazing dormant forage does not affect final pregnancy rate and reduces cost, improving the sustainability of beef production.

Introduction

Current recommendations indicate a heifer should reach approximately 65% of her mature body weight by the first insemination for successful reproduction (Patterson et al., 1992, *Journal of Animal Science*, 70:4018–4035). Prompted by rising input costs, there is increasing interest in alternative heifer development systems minimizing the use of harvested feedstuffs in favor of grazing. However, dormant forages are lower in available nutrients and may result in poorer animal performance, leading to lower BW at breeding. Recent data indicate heifers reaching less than 58% of mature BW by breeding have similar reproductive ability as their heavier counterparts (Funston and Deutscher, 2004, *Journal of Animal Science*, 82:3094–3099; Martin et al., 2008, *Journal of Animal Science*, 86:451–459). Moving heifer development out of the dry lot (DL) in

favor of grazing standing forage may be cost effective. Corn residue (CR) and winter range (WR) are abundant sources of standing winter forage in Nebraska. These studies evaluated the effect of grazing CR or WR compared to DL on first service conception, pregnancy rate, and first calf production.

Procedure

The University of Nebraska–Lincoln Institutional Animal Care and Use Committee approved the procedures and facilities used in these experiments.

Experiment 1

Two hundred ninety-nine cross-bred nulliparous heifers (558 ± 4 lb initial BW) from 3 production years were utilized to compare traditional post-weaning DL development to grazing CR during the same period. After a receiving period at the University of Nebraska West Central Research and Extension Center, heifers were blocked by initial BW and randomly assigned to graze CR or consume a diet in a DL for approximately 145 days. The CR heifers were offered 1.0 lb/day of a 28% crude protein (DM basis) supplement. Subsequently, heifers were placed in the DL and offered a common diet for 42 days each year. Heifers assigned to the DL treatment were offered a common diet for 187 days each year, formulated to produce an ADG that would allow heifers to reach approximately 65% of mature BW (1,250 lb) prior to AI.

In year 1, estrus was synchronized using MGA/PGF, followed by timed AI (TAI). In years 2 and 3, estrus was synchronized using MGA/PGF, followed by estrous detection and AI. After AI, heifers were exposed to fertile bulls for 45 days. Approximately 45 days after AI, AI conception was determined, and final pregnancy rate

was determined 45 days after bulls were removed. During the subsequent winter, all pregnant heifers grazed CR and were offered the equivalent of 1.0 lb/day of a 28% CP (DM basis) supplement. After calving, heifers consumed a common diet through AI breeding. Approximately 60 days after calving, estrus was synchronized using CIDR/PGF, followed by timed AI. All cows were exposed to fertile bulls for a period not less than 45 days. Approximately 45 days after TAI, first service conception was assessed, and at weaning, final pregnancy rate was determined and calf BW was collected. The data were analyzed using the MIXED and GLIMMIX procedures of SAS.

Experiment 2

Experiment 2 was conducted using heifers from the Gudmundsen Sandhills Laboratory (GSL) near Whitman, Neb. Composite Red Angus x Simmental weaned heifer calves ($n = 270$) were assigned randomly by initial BW (495 ± 5 lb) to graze either CR or WR during post weaning development. Heifers either grazed WR pastures at GSL or were transported to CR fields and grazed for approximately 100 days each year. A daily supplement was offered (1.0 lb/head; 28% CP) while grazing. Subsequently, all heifers grazed WR for 100 days prior to breeding with a daily supplement (1.0 lb/head; 28% CP) until breeding. Estrus was synchronized with a single i.m. injection of PGF_{2α} administered 108 hours after bulls were turned in with the heifers; bulls remained in for 45 days. Pregnancy diagnosis was performed approximately 45 days following completion of the breeding season. During the breeding season and until pregnancy diagnosis, heifers grazed upland summer Sandhills range. Between pregnancy diagnosis and calving, pregnant heifers grazed upland Sandhills range until mid-November and then grazed CR during

Table 1. Effect of winter system on gain and reproduction in heifers, experiments 1, 2 and 3.

Item	Treatment									P-values		
	Exp. 1 ¹			Exp. 2 ²			Exp. 3 ³					
	DL	CR	SEM	WR	CR	SEM	WR	CR	SEM	Exp.1	Exp.2	Exp.3
n	150	149		136	134		90	90				
Pre-breeding BW, lb	853	740	6	656	622	5	808	813	7	< 0.001	< 0.001	0.62
Percentage of mature BW	65	56	1	55	52	5	63	62	1	< 0.001	< 0.001	0.62
Pregnancy diagnosis BW, lb	978	917	6	792	769	592	6	917	8	< 0.001	0.003	0.44
ADG during grazing, lb/day ⁴	1.27	0.42	0.02	0.54	0.30	0.02	0.94	0.82	0.03	< 0.001	< 0.001	0.002
Pre-breeding ADG, lb/day ⁵	1.49	0.92	0.02	0.84	0.64	0.02	1.20	1.22	0.02	< 0.001	< 0.001	0.66
ADG from breeding to pregnancy diagnosis, lb/day	1.04	1.47	0.03	1.48	1.61	0.02	1.02	0.91	0.04	< 0.001	< 0.001	0.05
Pubertal by AI, %	88	46	4	—	—	—	57	63	5	< 0.001	—	0.36
Year 1	—	—	—	73	33	7	—	—	—	—	< 0.001	—
Year 2	—	—	—	77	61	8	—	—	—	—	< 0.001	—
Year 3	—	—	—	49	58	7	—	—	—	—	0.003	—
Pregnant to AI, %	64	54	8	—	—	—	43	44	5	0.08	—	0.89
Yearling pregnancy, %	94	92	5	85	84	3	83	89	4	0.37	0.85	0.27
n	88	75		72	75		24	26				
Pre-calving BW, lb	983	945	11	981	969	8	926	1016	9	0.01	0.33	0.16
AI pregnant, 2-year old, %	62	66	6	—	—	—	61	56	10	0.61	—	0.75
Pregnant, 2-year old, %	87	81	5	85	77	7	92	100	6	0.39	0.37	0.98

¹DL = developed in the dry lot; CR = developed on corn residue (145 days) and fed in the dry lot (42 days) before AI.

²WR = developed on winter range; CR = developed grazing corn residue (100 days) and grazed winter range (100 days) before breeding.

³WR = developed on winter range; CR = developed grazing corn residue (120 days) and grazed winter range (100 days) before AI.

⁴ADG during the winter grazing period.

⁵ADG after the winter grazing period prior to breeding.

the winter with a supplement (1.0 lb/day, 28% CP) until calving. The data were analyzed using the MIXED and GLIMMIX procedures of SAS.

Experiment 3

Experiment 3 was conducted at the Agricultural Research and Development Center near Mead, Neb. Composite MARC III x Red Angus weaned heifer calves (n = 180) were assigned randomly by initial BW (578 + 6 lb) to graze either CR or WR between weaning and breeding. Heifers grazed WR or CR for 119 days each year. A daily supplement was offered (1.0 – 2.0 lb/day; 29% CP) while winter grazing. Subsequently, all heifers grazed WR for 100 days prior to breeding with a daily supplement (1.0 lb/head; 28% CP). Estrus was synchronized using 2 i.m. injections of PGF_{2α} administered 16 and 2 days prior to AI breeding. Following the second PGF_{2α} injection, estrus was detected for at least 5 days. After AI, bulls were turned in with the heifers for 45 days. Pregnancy to AI was determined approximately 45 days after AI, and final pregnancy rate was determined 45 days after bulls were removed. Following pregnancy diagnosis, pregnant heifers grazed CR with a daily

supplement (3.0 lb/day; 10.5% CP). Data were analyzed using the MIXED and GLIMMIX procedures of SAS.

Results

Heifer gain and reproduction data for Exp. 1, 2, and 3 are summarized in Table 1. In Exp. 1, heifers grazing CR gained 0.86 lb/day less ($P < 0.001$) than DL heifers. In Exp. 2, CR heifers gained 0.14 lb/day less ($P < 0.001$) than heifers grazing WR during the winter grazing period. Heifers grazing CR in Exp. 3 gained 0.13 lb/day less ($P = 0.002$) than heifers grazing WR.

In Exp. 1 and 2, heifers grazed with minimal hay supplementation; however, snow cover necessitated more extensive hay feeding in Exp. 3. Pre-breeding BW was related to pre-breeding ADG, with heifers grazing CR being lighter ($P < 0.001$) prior to breeding compared to heifers in the DL (Exp. 1) or grazing WR (Exp. 2). However, pre-breeding BW of both groups was similar ($P = 0.62$) in Exp. 3. The CR heifers in Exp. 1 were 56% of mature BW and DL heifers 65% of mature BW before breeding. In Exp. 2, CR-developed heifers were 52% of mature BW, and WR heifers were 55% of mature BW at breeding.

In Exp. 3, CR and WR heifers were approximately 62-63% of mature BW at breeding.

Likely due to decreased pre-breeding BW, fewer ($P < 0.001$) heifers grazing CR were pubertal before breeding, compared to DL heifers in Exp. 1 and compared to WR heifers in years 1 and 2 of Exp. 2. However, a similar ($P = 0.36$) percentage of heifers from each treatment were pubertal at AI in Exp. 3. In Exp. 1, AI pregnancy rate was 10% lower ($P = 0.08$) in CR heifers compared to DL heifers, possibly due to pubertal differences. However, AI pregnancy rates in both treatment groups were similar ($P = 0.89$) in Exp. 3. Regardless of the percentage of pubertal heifers, final pregnancy rates were similar ($P \geq 0.27$) in Exp. 1, 2, and 3.

Prior to calving, the CR heifers were still lighter ($P = 0.01$; Exp. 1) than DL heifers, although pre-calving BW was not different ($P \geq 0.16$) in Exp. 2 and 3. The percentage of heifers that calved in the first 21 days of the season was not different ($P \geq 0.18$) between CR and DL in years 1 or 3 (Exp. 1) or between CR and WR (Exp. 2 and 3; Table 2). However, in year 2 of Exp. 1, 22% more ($P = 0.02$) DL heifers calved in the first

(Continued on next page)

Table 2. Effect of winter system on calf production, experiments 1, 2 and 3.

Item	Treatment									P-values		
	Exp. 1 ¹			Exp. 2 ²			Exp. 3 ³					
	DL	CR	SEM	WR	CR	SEM	WR	CR	SEM	Exp.1	Exp.2	Exp.3
n	136	127		111	109		49	52				
Calved in 1 st 21 days, %				81	78	4	65	64	7		0.57	0.99
Year 1	75	83	5							0.41		
Year 2	91	69	7							0.02		
Year 3	77	64	7							0.18		
Calf birth date, Julian day	70	74	1	68	69	1	77	77	2	0.06	0.85	0.84
Calf birth BW, lb	75	74	1	70	71	1	75	79	1	0.46	0.55	0.05
Assisted births, %	20	25	4	23	29	4	7	29	7	0.29	0.33	0.009
Sex, % male	47	48	5	52	51	5	59	69	7	0.92	0.85	0.30
Calf weaning BW, lb	425	435	10	393	399	8	485	498	12	0.49	0.59	0.44
Calf 205 day BW, lb	397	410	9	429	434	7	474	483	10	0.31	0.59	0.51

¹ DL = developed in the dry lot; CR = developed grazing corn residue (145 days) and fed in the dry lot (42 days) before AI.

² WR = developed on winter range; CR = developed grazing corn residue (100 days) and grazed winter range (100 days) before breeding.

³ WR = developed on winter range; CR = developed grazing corn residue (120 days) and grazed winter range (100 days) before AI.

21 days. Similarly, average calf birth date also was not different ($P \geq 0.84$) in Exp. 2 and 3; however, in Exp. 1, CR heifers tended to give birth 4 days later ($P = 0.06$) than DL heifers. Both calf birth BW ($P \geq 0.46$) and the percentage of male calves ($P \geq 0.85$) were similar in Exp. 1 and 2. Although the percentage of male calves was similar ($P = 0.30$) for CR and WR heifers in Exp. 3, CR heifers gave birth to heavier ($P = 0.05$) calves. A primary concern associated with this system is an increase in calving difficulty because heifers are lighter at calving. The percentage of heifers requiring calving assistance was not different ($P \geq 0.29$) in Exp. 1 and 2. However, in Exp. 3, 22% more ($P = 0.009$) CR-developed heifers than WR-developed heifers required calving assistance.

Pregnancy rates to AI in the second breeding season were similar ($P \geq 0.61$) in Exp. 1 and Exp. 3 (Table 1). Final pregnancy rates after the second breeding season also were similar ($P \geq 0.37$) among treatment groups in all three experiments. Neither calf weaning BW ($P \geq 0.44$) nor calf adjusted 205-day BW ($P \geq 0.31$) were different among treatments in Exp. 1, 2 or 3. These data agree with previous research conducted by Funston and Deutscher (2004, *Journal of Animal Science*, 82:3094–3099) and Martin et al. (2008, *Journal of Animal Science*, 86:451-459), indicating that although heifers developed to 50% of mature BW at breeding are lighter through the third breeding, long term reproduction and calf pro-

Table 3. Effect of winter system on heifer development cost, experiments 1, 2 and 3.

Item	Treatment								
	Exp. 1 ¹			Exp. 2 ²			Exp. 3 ³		
	DL	CR	Diff	WR	CR	Diff	WR	CR	Diff
n	150	149		136	134		90	90	
Feeding cost, \$/heifer	237	195	-42	124	123	-1	128	121	-8
Total development cost, \$/heifer	982	941	-41	832	838	6	853	848	-5
Cull heifer value, \$/heifer exposed	53	77	-24	131	135	4	160	104	-56
Net cost of 1 pregnant heifer, \$	985	940	-45	821	832	11	831	835	4

¹DL = developed in the dry lot; CR = developed grazing corn residue (145 days) and fed in the dry lot (42 days) before AI.

²WR = developed on winter range; CR = developed grazing corn residue (100 days) and grazed winter range (100 days) before breeding.

³WR = developed on winter range; CR = developed grazing corn residue (120 days) and grazed winter range (100 days) before AI.

duction are not impacted.

Non-pregnant heifers developed by grazing standing forage are lighter at pregnancy diagnosis than traditionally developed heifers and may be better suited for a long-yearling feedlot program. Cull heifers were considered an additional source of revenue in this system. Developing heifers by grazing CR reduced winter feed cost by \$42/heifer compared to development in the dry lot (Table 3). In addition, slightly more CR heifers were not pregnant after breeding, increasing the value of culled heifers. After considering feeding cost and cull value difference, CR development reduced the net cost of developing one pregnant heifer by \$45 compared to DL development. However, as WR and CR were charged to the development system at a similar cost and pregnancy rates were similar, there was little difference in the cost of developing a pregnant heifer on either CR or WR.

Implications

Winter development using corn residue is a suitable alternative to development on a winter range or a dry lot. The reduction in the percentage of pubertal heifers developed grazing corn residue may reduce AI conception rate, but final pregnancy rate is similar. The factors that mediate these effects are complex; however, developing heifers using corn residue does not negatively influence long-term production. Developing heifers by grazing dormant forage reduces cost compared to dry lot feeding, improving sustainability.

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Post Weaning Management of Heifer Calves Impacts ADG and Feed Efficiency as Pregnant Heifers

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Summary

Replacement heifers were developed on cornstalks (Exp. 1, 2, and 3), dry lot (Exp. 1 and 2), or winter range (Exp. 3). In Exp. 1, pregnant heifers were individually fed during mid to late gestation. Heifers developed on cornstalks were more feed efficient than heifers developed in a dry lot. In Exp. 2 and 3, pregnant heifers grazed cornstalks during mid to late gestation. Heifers developed on cornstalks gained more and were more efficient, especially compared to heifers developed in a dry lot. These data provide evidence of an adaptive response to grazing low quality forages and may be beneficial in the critical period leading up to the first calving season.

Introduction

Current recommendations indicate a heifer should reach approximately 65% of mature body weight (BW) by the first insemination for successful reproduction. However, recent data demonstrate heifers reaching less than 58% of mature BW by breeding do not display impaired reproductive performance (2008 Nebraska Beef Report, pp. 5-7). Heifers developed on an excessively high plane of nutrition have impaired milk production, which reduces productivity (Ferrell et al., *Journal of Animal Science*, 1976, 42:1477). Heifers developed on grazing corn residue (CR) gain less during winter grazing but compensate during the summer, yet are lighter prior to first calving (2008 Nebraska Beef Report, pp. 8-10). These findings suggest cows developed grazing CR are more efficient. Lighter cows may have smaller liver mass (Jenkins et al.,

Animal Production, 1986, 43:245), and a smaller liver mass is associated with improved feed efficiency (DiCostanzo et al., *Journal of Animal Science*, 1991, 69:1337). There also is anecdotal evidence of a learning curve associated with grazing CR. It may be cows grazing CR as virgin heifers are better adapted to graze CR prior to calving.

The objective of the current experiments was to evaluate the effect of replacement heifer development system on subsequent gain and efficiency of pregnant heifers.

Procedure

The University of Nebraska–Lincoln Institutional Animal Care and Use Committee approved the procedures and facilities used in these experiments.

Experiment 1

The effect of heifer development system on ADG and G:F during gestation was evaluated. Following weaning, predominately Angus-based heifers were transported to the West Central Research and Extension Center (WCREC), North Platte, Neb. After a receiving period, heifers were blocked by initial BW and randomly assigned to graze CR (n = 50) or consume a diet in a dry lot (DL; n = 50). The CR heifers grazed for approximately 88 days and were offered 1 lb/day of a 28% crude protein (CP; DM basis) supplement daily. Following CR grazing, heifers grazed dormant mixed grass upland range with 1 lb/day of a 28% CP (DM basis) supplement daily for 60 days. Heifers then entered the DL and were offered a common diet for 47 days until completion of artificial insemination (AI). Following weaning, heifers assigned to the DL grazed mixed upland winter range and were offered 1 lb/day of a 28% CP (DM basis) supplement daily for 45 days. Heifers then entered the

DL and were offered a common diet for 128 days until completion of AI. The DL diet was formulated to achieve an ADG that would allow heifers to reach approximately 65% of mature BW (1,320 lb) prior to AI (NRC, 1996). Estrus was synchronized using MGA/PGF followed by estrous detection and AI. After AI, heifers were exposed to fertile bulls for 60 days. Approximately 45 days after AI, first service conception was determined; final pregnancy rate was determined 45 days after bulls were removed. During the breeding season and until individual feeding began in October, heifers grazed mixed grass upland summer range in a single group.

Primiparous heifers pregnant by AI (n = 40) were blocked by previous development system and BW. Only heifers pregnant by AI were used to remove variation due to period of gestation. Heifers were originally developed grazing CR (930 ± 11 lb; n = 20) or fed in a DL (983 ± 11 lb; n = 20) prior to first breeding. Heifers were individually fed once daily. Body weight was measured for three consecutive days at the beginning and end of the study to compute an average. The pregnant heifers consumed a diet composed of 90% grass hay (11.7% CP; DM basis) and 10% wet distillers grains plus solubles/straw mixture (21.8% CP; DM basis) during late gestation. Individual feed offered was recorded daily and individual feed refusal was recorded weekly. Data were analyzed using the MIXED procedure of SAS with development system as the fixed effect and pen as random effect.

Experiment 2

Pregnant heifers grazed CR prior to calving with a supplement (1 lb/day; 28% CP) to evaluate effect of heifer development system prior to first breeding on gain during late gestation.

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Heifers utilized in Exp. 2 were from the same herd as heifers in Exp. 1 and were developed following the same protocols through pregnancy diagnosis. However, heifers used in Exp. 2 were pregnant as a result of a combination of either AI or natural mating. Pregnant heifers (n = 55) were blocked by BW and mating type and sorted into three groups. The treatment groups included: heifers developed prior to breeding in a DL (981 ± 18 lb; n = 18); heifers developed prior to breeding grazing CR (963 ± 18 lb; n = 18); and a mixture of the two development systems (MIX; 959 ± 18 lb; n = 19). Heifers were transported to CR Dec. 1 and returned to WCREC Feb. 18, grazing CR for 80 days. While grazing CR during late gestation, heifers were offered the equivalent of 1 lb/day of a 28% CP (DM basis) supplement provided three times per week.

Experiment 3

The effect of development system prior to breeding on gain during late gestation while grazing CR was evaluated. Composite Red Angus x Simmental heifer calves (n = 90) from the Gudmundsen Sandhills Laboratory (GSL) near Whitman, Neb., were assigned randomly by initial BW (496 ± 4 lb) to graze CR or winter range (WR) between weaning and the breeding season. Grazing treatments were initiated approximately 30 days after weaning, beginning in mid-November, and continuing through mid-May. Heifers either grazed WR pastures at GSL or were transported to CR fields and grazed for 88 days. A daily supplement was offered (1 lb/day; 28% CP) while grazing. Subsequently, all heifers grazed WR for 100 days until breeding with a daily supplement (1 lb/day; 28% CP). Estrus was synchronized with a single i.m. injection of PGF_{2α} administered 108 hours after bulls were turned in with the heifers. Heifers were exposed to fertile bulls (1 bull to 25 heifers) for 45 days. Pregnancy diagnosis was performed approximately 45 days following completion of the breeding season. During the breeding

Table 1. Effect of heifer development system on ADG and feed efficiency of pregnant heifers, Exp. 1.

	Treatment ¹			P-value
	DL	CR	SEM	
n	20	20		
Initial BW, lb	984	930	11	0.002
Final BW, lb	1103	1059	14	0.03
DMI, lb	25.7	24.4	0.6	0.04
ADG, lb	1.66	1.79	0.09	0.29
G:F	0.065	0.073	0.0	0.08

¹DL = heifers developed in a dry lot; CR = heifers developed on corn residue.

Table 2. Effect of heifer development system on ADG of pregnant heifers grazing CR, Exp. 2.

	Treatment ¹			SEM	P-value
	DL	CR	MIX		
n	18	18	19		
Initial BW, lb	980	964	960	18	0.71
Final BW, lb	1028	1072	1033	20	0.27
ADG, lb	0.69 ^x	1.28 ^y	0.98 ^{xy}	0.15	0.04
BCS	5.14	5.47	5.47	0.14	0.08

¹DL = heifers developed in a dry lot; CR = heifers developed on corn residue; MIX = mixture of heifers from DL and CR treatments.

^{xy}Means without a common superscript differ (P < 0.05).

Table 3. Effect of heifer development system on ADG of pregnant heifers grazing CR, Exp. 3.

	Treatment ¹			SEM	P-value
	WR	CR	MIX		
n	17	17	15		
Initial BW, lb	883	873	872	17	0.86
Final BW, lb	956	974	946	18	0.54
ADG, lb	0.9 ^x	1.33 ^y	0.95 ^x	0.11	0.02
BCS	5.2	5.27	5.18	0.10	0.81

¹WR = heifers developed on winter range; CR = heifers developed on corn residue; MIX = mixture of heifers from WR and CR treatments.

^{xy}Means without a common superscript differ (P < 0.05).

season and until grazing CR, heifers grazed upland Sandhills range. A subset of the pregnant heifers (n = 49) was blocked by BW and sorted into three groups: heifers developed prior to breeding grazing WR (884 ± 15 lb; n = 17); heifers developed prior to breeding grazing CR (873 ± 15 lb; n = 17); and a mixture of the two development systems (MIX; 873 ± 18 lb; n = 15). Pregnant heifers grazed CR during late gestation with a supplement (1 lb/day; 28% CP) provided three times per week in late gestation. Heifers were transported to CR fields Dec. 1 and returned to GSL Feb. 18, grazing CR for 80 days. Heifer BW was measured at days 1, 51, and 80. In addition, heifer body condition score (BCS) was assessed at day 80.

Statistical Analysis (Exp. 2 and 3)

The corn residue fields were of differing acreage and corn yield. According to the 2004 *Nebraska Beef Report* (pp.13-15), corn yield influences the carrying capacity of a corn residue field. The relationship between yield and carrying capacity is mass of leaf and husk per acre = ([bushels/acre corn yield x 38.2] + 429) x 0.39. Assuming corn residue mass (88% DM) to support 1 AUM was equal to 686 lb of biomass and a 50% utilization rate, the carrying capacity of a corn residue field was calculated. The number of AU represented by each individual heifer and the number of AUM supported by the acreage of the field was utilized to adjust the gain data. Subsequently, data were ana-

lyzed with the MIXED procedure of SAS. The model included the fixed effects of previous winter development treatment and AUM per field per animal.

Results

Heifer gain data for Exp. 1 are summarized in Table 1. In Exp. 1, pregnant heifers developed prior to breeding in the DL had a greater ($P = 0.04$) dry matter intake (DMI) than heifers developed grazing CR; however ADG was not different ($P = 0.29$). Thus, pregnant heifers developed in the DL had a lower ($P = 0.08$) G:F than heifers developed grazing CR. Previous data indicated that heifers developed to a greater weight prior to breeding had a greater liver mass at 72 months of age (Arnett et al., *Journal of Animal Science*, 1971, 33:1129). Cows with a greater liver mass consume more DM and are less efficient than cows with less liver mass (DiCostanzo et al., *Journal of Animal Science*, 1991, 69:1337). Heifers developed grazing CR were lighter prior to calving than heifers developed in the DL (2008 *Nebraska Beef Report*, pp. 8-10). Perhaps these lower BW heifers were more efficient due to differences in metabolism. The CR-developed heifers also may have experienced compensatory gain linked to alterations in metabolic hormones such as IGF-1 and T3/T4 (Yambayamba et al., *Journal of Animal Science*, 1996, 74:57).

Heifer gain data for Exp. 2 are summarized in Table 2. Pregnant heifers grazing CR during late gestation that also grazed CR during development gained more ($P = 0.04$), and tended to maintain a greater ($P = 0.08$) body condition score (BCS) prior to calving, than heifers devel-

oped in the DL. The mixture of CR- and DL-developed pregnant heifers had an intermediate ADG but were not different from heifers developed grazing CR or in the DL. Heifer gain data for Exp. 3 are summarized in Table 3. In Exp. 3, pregnant heifers grazing CR during late gestation that also grazed CR during development gained more ($P = 0.02$) than heifers grazing WR or the combination of WR- or CR-developed heifers. Heifer BCS prior to calving was similar ($P = 0.81$) in Exp. 3.

Heifers that previously grazed CR were more efficient (DiCostanzo et al., *Journal of Animal Science*, 1991, 69:1337) or experienced more compensatory gain (Yambayamba et al., 1996) than heifers developed in the DL. Heifers developed grazing CR also gained more than heifers developed grazing WR, although precalving BW was not different (2008 *Nebraska Beef Report*, pp. 8-10). It seems likely a mechanism other than a change in efficiency is partially responsible for the difference in gain.

Previous data (1989 *Nebraska Beef Report*, pp. 11-15; 1990 *Nebraska Beef Report*, pp. 51-53) have suggested cattle require an acclimation period to grazing corn residue. Other research (Fernandez-Rivera et al., *Journal of Animal Science*, 1989, 67:574; Fernandez-Rivera and Klopfenstein, *Journal of Animal Science*, 1989, 67:590) has determined that naïve cattle require a learning period when grazing corn residue. Dietary starch content indicated younger cattle consumed less starch in the first 3 weeks of grazing compared to older, experienced cattle (Fernandez-Rivera and Klopfenstein, 1989). Thus, naïve cattle gained less weight early in the grazing season and may lose

weight early in the grazing season (Fernandez-Rivera and Klopfenstein, 1989). Possibly, heifers originally grazing CR during development were better prepared to graze as pregnant heifers, leading to selection of higher quality nutrients and greater gain. Moreover, heifers developed in the DL grazing CR during the first pregnancy, combined with heifers developed grazing CR, gained more than DL-developed heifers grazing separately. Although heifers developed grazing CR had a greater BCS prior to calving than heifers developed in the DL, there was no pre-calving BCS difference between WR- and CR-developed heifers. Thus, it appears exposing heifers to low quality forage during development better prepares them for grazing CR during the first pregnancy.

Implications

These data provide evidence of an adaptive response to grazing low quality forages and may be beneficial in the critical period leading up to the first calving season. Not only does grazing CR during development improve feed efficiency, it also prepares heifers for grazing CR during pregnancy. Grazing low quality forage during development may produce a heifer better adapted to a lifelong grazing system.

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Estrous Synchronization Increases Early Calving Frequency, Which Enhances Steer Progeny Value

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Summary

Calving records collected between 2000 and 2008 at the Gudmundsen Sandhills Laboratory, Whitman, Neb., were used to determine the effect of estrous synchronization on calving distribution and the impact of time of calving on carcass characteristics. More synchronized cows calved during the first 21 days compared to non-synchronized cows, and calves born to synchronized dams were heavier at weaning. Calves born in the first 21 days of the calving season had greater carcass weights, marbling scores, and yield grades than later born calves. In addition, the percentage of steers grading premium choice or greater and the total carcass value declined as time of calving increased. Estrous synchronization with natural breeding resulted in cows giving birth earlier, and calves born earlier in the season were heavier at weaning and produced a heavier, more valuable carcass.

Introduction

Estrous synchronization is potentially beneficial to cattle producers using natural mating. Prostaglandin F_{2α} (PGF) causes lysis of the corpus luteum (CL) when administered at least 96 hours after ovulation; however, the corpus luteum is not responsive to PGF prior to this time. Standing estrus will occur between 48 and 96 hours after PGF in cyclic females. Whittier et al. (1991, *Journal of Animal Science*, 69:4670-4677) demonstrated a single PGF injection administered 96 hours after bull turn-in increased the percentage of cows calving in the first 50 days of the calving season. However, they did not detect a difference in the percentage calving in the first

21 days, nor did they measure weaning BW or carcass characteristics of the resulting calf crop. Data from our group indicate more heifers given PGF 96 hours after bull turn-in calve in the first 21 days of the calving season. Further research is needed to evaluate the effect of this system in mature, lactating cows. Thus, data from eight production years were summarized to determine the effect of estrous synchronization on time of calving and subsequent effects of time of calving on carcass characteristics.

Procedure

The University of Nebraska–Lincoln Institutional Animal Care and Use Committee approved the procedures and facilities used in this experiment.

Breeding, calving, weaning, and carcass data were collected from the research herd at the Gudmundsen Sandhills Laboratory (GSL) near Whitman, Neb. The data for the spring calving herd, collected between 2000 and 2008, were used for the purposes of this analysis. Calves born between 2000 and 2006 resulted from non-synchronized 60-day breeding seasons between 1999 and 2005 (n = 2,075). Calves born in 2007 and 2008 resulted from estrous synchronized 45-day breeding seasons in 2006 and 2007 (n = 521). The exception was a subset of cows used in a nutritional experiment exposed to bulls for 60 days during the estrous synchronized spring breeding season in 2007 (118 cows). The breeding season began on approximately June 15. Estrus was synchronized using a single injection of PGF administered 108 hours after fertile, mixed age bulls were turned in with the cowherd. The bull to cow ratio was not greater than 1:25 in all years. Pregnancy was diagnosed via rectal palpation approximately 45 days following bull removal. As varying nutritional and breeding treatments were applied to the yearling

heifers during breeding, two year-old cows were removed from this analysis to avoid confounding the results. Weaning data were analyzed for the 2007 and 2008 weaned calves (408 individual records) and compared to calves weaned between 2000 and 2006 (1,790 individual records).

Weaned steers (n = 659) in each year were transported to the West Central Research and Extension Center in North Platte, Neb. The data from these steers were used to determine the effect of early calving frequency on feedlot performance and carcass quality. Steers were fed a common diet in the feedlot within each year for approximately 218 days. Steers were slaughtered at a commercial abattoir when 12th rib fat cover was visually assessed to be approximately .5 in. Routine carcass data were collected after slaughter. Carcass characteristics were evaluated by period of calf birth defined as the first, second, or third 21-day period of the calving season. The continuous data were analyzed using the MIXED procedure of SAS; binomial data were analyzed with the GLIMMIX procedure of SAS. The model included the fixed effects of estrous synchronization and the age of the dam. The model also included the random effects of year and any treatments imposed on each particular herd within each year.

Results

The data demonstrating effects of estrous synchronization on reproduction and calf production are displayed in Table 1.

Calf birth date was similar ($P = 0.23$) for estrous synchronized and non-synchronized cows; however, calf birth BW ($P < 0.001$) and the incidence of dystocia ($P < 0.001$) were lower in calves from synchronized dams. The percentage of male calves was unaffected ($P = 0.62$) by estrous synchronization. Estrous synchroniza-

Table 1. Effect of estrous synchronization in a natural mating system on reproduction and calf production.

Item	Estrous synchronized		SEM	P
	No	Yes		
n	2075	521		
Calf birth date, Julian day	86	85	1	0.23
Calf birth BW, lb	84	82	2	< 0.001
Assisted births, %	4.4	1.7	5	< 0.001
Calved in 1 st 21 days, %	61	73	2	< 0.001
Calved in 2 nd 21 days, %	33	23	2	< 0.001
Calf sex, % male	51	52	2	0.62
n	1790	408		
Calf weaning BW, lb	483	503	7	< 0.001
Cow BW at weaning, lb	1113	1107	9	0.16
Cow BCS at weaning	5.2	5.2	0.1	0.25
Pregnant, % ¹	95	94	1	0.48

¹ Pregnancy rate after an estrous synchronized or unsynchronized natural mating season.

Table 2. Effect of calving period on feedlot performance and carcass characteristics of steer progeny.

Item	Calving period ¹			SEM	P
	1	2	3		
n	347	259	53		
Calf birth BW, lb	81	83	82	1	0.47
Calf weaning BW, lb	515 ^a	483 ^b	435 ^c	12	< 0.001
Pre-weaning ADG, lb	2.12	2.12	2.13	0.05	0.92
Feedlot ADG, lb	3.61	3.62	3.63	0.12	0.90
HCW, lb	816 ^a	800 ^b	771 ^c	11	< 0.001
Marbling score ²	574 ^a	554 ^b	527 ^c	15	< 0.001
Empty body fat, %	30.4 ^a	29.9 ^b	29.0 ^c	0.4	< 0.001
Yield grade	3.0 ^a	2.8 ^b	2.6 ^c	0.2	< 0.001
Choice or greater, %	84	83	73	8	0.17
Average Choice or greater, %	30 ^a	17 ^b	12 ^b	5	0.001
Carcass value, \$	1102 ^a	1079 ^b	1025 ^c	45	< 0.001

¹ 1 = calved in the first 21 days; 2 = calved in the second 21 days; 3 = calved in the third 21 days.

² 500 = small⁰.

^{abc} Means without a common superscript differ ($P \leq 0.05$).

tion increased ($P < 0.001$) the percentage of cows giving birth in the first 21 days by 12% (73 vs. 61%, estrous synchronized vs. non-synchronized, respectively). This may partially explain the reduction in birth BW. Cows at GSL were calved in a common group and consumed a higher quality diet during calving than during late gestation. Thus, cows calving later were on a higher plane of nutrition during late gestation than earlier calving cows, perhaps leading to heavier calves at birth.

The mechanism underlying this estrous synchronization system relies on the observation that the CL is unresponsive to PGF within 96 hours after ovulation. Thus, bulls were allowed to inseminate cows at natural estrus for approximately 5 days; cows

inseminated during this period will not respond to PGF. On day 5, PGF was administered to all cows and the bulls inseminated cows at synchronized estrus following PGF. It was imperative to administer PGF at the correct interval to avoid destroying the CL in cows inseminated on the day of bull turn-in. Calf birth date was unaffected, which may seem counterintuitive. Most likely, cows that failed to conceive at the synchronized estrus were inseminated 21 days later, and thus average calving date was unaffected. As further evidence, 96 and 94% of the 94-95% of cows that became pregnant (estrous synchronized and non-synchronized, respectively), calved within the first 42 days of the season. Regardless, more calves were born early in the season

with estrous synchronization.

As more calves were born earlier in the season, one may expect unadjusted weaning BW to be increased. Accordingly, calves from estrous synchronized dams were 20 lb heavier ($P < 0.001$) than calves from non-synchronized dams. This likely made calves from estrous synchronized dams more valuable at weaning, improving profitability.

Although the natural breeding season was shortened when estrous synchronization began, pregnancy rate was unaffected ($P = 0.48$) by synchronization. Perhaps this indicates a more efficient use of bull resources during the breeding season. At pregnancy diagnosis, both cow BW and BCS were similar ($P \geq 0.16$) for estrous-synchronized and non-synchronized cows.

Estrous synchronization increased the percentage of cows calving in the first 21 days of the breeding season (Table 2). This indicates more cows were mated by natural service early in the breeding season. Estrous synchronization increased calf weaning BW and potential value. In addition, the breeding season was shortened from 60 to 45 days between non-synchronized and estrous synchronized seasons, respectively, without negatively affecting pregnancy rate.

When evaluating only steer progeny, male calves born earlier in the season did not have a lighter ($P = 0.47$) birth BW than those born later. As the time of calving became more advanced, steer weaning BW was lower ($P < 0.001$) with each successive interval, likely related to calf age. Neither preweaning ($P = 0.92$) nor feedlot ADG ($P = 0.90$) were affected by time of calving.

Similar to weaning BW, hot carcass weight (HCW) increased ($P < 0.001$) with early calving frequency. Perhaps more interesting, marbling score and the percentage of steers achieving a USDA quality grade of modest or greater were greater ($P = 0.001$) in steers born earlier than those born later. It was, and perhaps still is, a

(Continued on next page)

common paradigm that intramuscular fat is a late developing trait. These data would support the hypothesis steers born earlier in the calving season are older at harvest. The increase in marbling score cannot be separated from a difference in caloric intake, as DMI was not measured. However, older steers also are fatter, as evidenced by an increase ($P < 0.001$) in yield grade of earlier born steers. As time of calving became more advanced, the percentage of empty body fat ($P < 0.001$) decreased. Thus, it appears as time of calving advanced, carcass fat content in all depots, including intramuscular, decreases. Although

later born steers had a slightly lower yield grade, the reduction in marbling score made their carcasses less valuable ($P < 0.001$). The difference in carcass value also was related to the increased HCW of steers born earlier in the calving season. Therefore, carcasses of earlier born steers were more valuable on a weight basis and received a greater premium on a carcass basis than later born steers.

Implications

Estrous synchronization with a single injection of PGF can increase the percentage of cows naturally

mated early in the breeding season. This improvement occurs even in a shorter breeding season. Moreover, most cows not mated at the first estrus become pregnant at the second. Steer calves born earlier in the calving season have greater weaning BW, HCW, and marbling scores. Improving early calving frequency may increase progeny value at weaning and enhance carcass value of the steers.

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Reproductive Aging Influences Ovarian Function in Beef Cows

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Summary

Anti-Müllerian Hormone (AMH) has been associated with follicle number and age of the ovary. Therefore, our hypothesis was that AMH was a biomarker for both follicle number and ovarian function in the beef cow. Ovaries were collected by flank laparotomy. The number of follicles increased as cows aged from 1.5 to 6 years and began to decrease thereafter; however, the size of the ovary continued to increase with advanced age. Expression of the AMH gene increased with increasing follicle number in 2-year-old beef cows. These results suggest that heifers with larger ovaries will have greater numbers of follicles and greater productivity, allowing them to stay in the production herd longer. AMH could be used to identify heifers of high reproductive potential at a very young age.

Introduction

Fertility declines in mammalian females as they age, mainly due to depletion of the number of follicles in the ovary. Early studies demonstrated that Hereford heifers were born with approximately 100,000 follicles in their combined ovaries, but there was a great deal of variation among heifers in the number of follicles in their ovaries at birth. Low follicle number is associated with decreased heifer pregnancy rate, poor oocyte quality, decreased superovulatory response, impaired corpus luteum

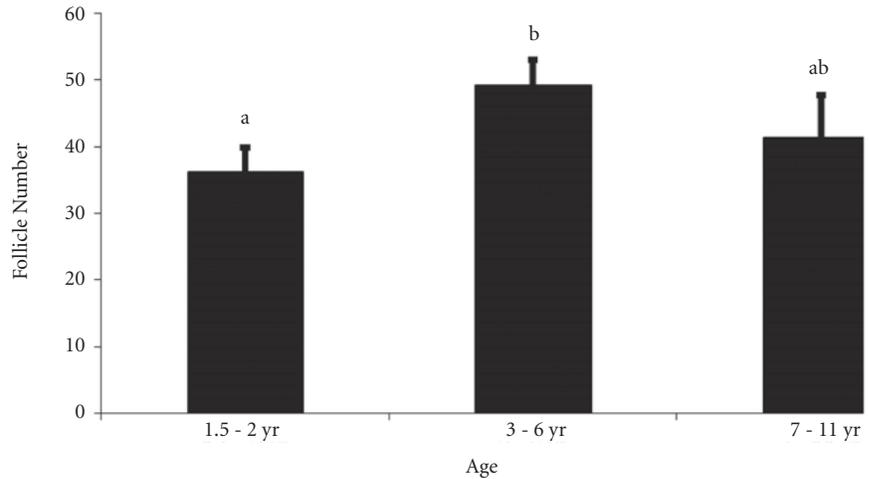


Figure 1. Influence of age on surface follicle numbers in the bovine ovary. Follicle numbers were greater in mature cows than in heifers, and began to decrease in cows of advanced age ($P = 0.04$).

Table 1. Influence of age on ovarian traits in beef cows.

Trait	Age			P-value
	1.5 - 2 yr	3 - 6 yr	7 - 11 yr	
No. of cows	25	248		
Ovarian weight (g) ¹	11.8 ± 0.9 ⁴	17.2 ± 1.0 ⁵	22.5 ± 1.6 ⁶	0.0001
Ovarian length (mm) ²	28.1 ± 0.9 ⁴	31.2 ± 0.9 ⁵	33.0 ± 1.5 ⁶	0.008
Ovarian height (mm) ³	19.6 ± 0.6 ⁴	21.3 ± 0.6 ⁵	24.0 ± 1.0 ⁶	0.001

¹Sum of the weight of the combined ovaries.

²Average length of the left and right ovary within a cow.

³Average height of the left and right ovary within a cow.

^{4,5,6}Within a row, means with different superscripts are different.

function, and increased ovulation failure in beef cows. Anti-Müllerian Hormone is a growth factor that has been demonstrated to be both a biological and genetic marker of ovarian function and follicle numbers in other mammalian females. Therefore, we hypothesized that AMH could act as a biomarker and genetic marker of follicle number in beef cows.

Procedure

All procedures were approved by the Animal Care and Use Committee (IACUC) at the University of Nebraska–Lincoln. Beef cows ($n = 37$) ranging in age from 1.5 to 11 years were injected with Lutalyse, and ovaries were removed by flank laparotomy (incision in the flank through

the side to excise the ovaries) 36 hours later to obtain dominant follicles prior to ovulation. Ovaries were weighed, measured for length and height, and all visible surface follicles were counted. The outer cortical region of the ovary that contains the follicles was dissected and a representative piece was frozen for genomic analysis.

Results

The number of follicles was greater in mature cows than in cows less than 3 years of age; however, beyond 6 years of age, follicle numbers declined (Figure 1). Interestingly, although follicle numbers declined, ovarian size continued to increase in cows of advanced age (Table 1). In general, larger ovaries were associated with

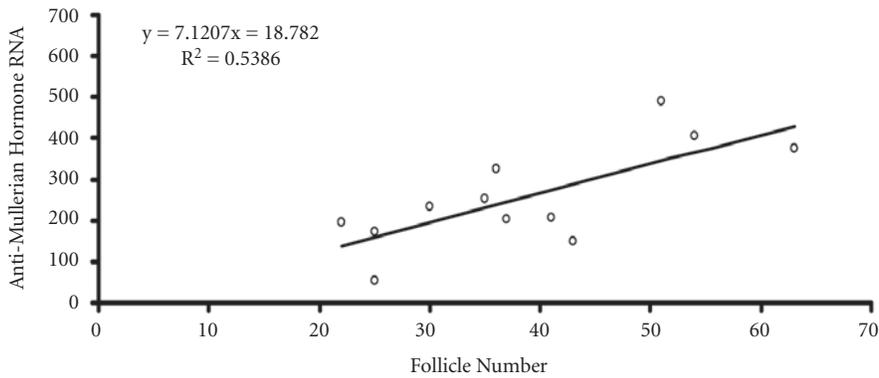


Figure 2. Relationship between relative level of AMH gene expression and follicle numbers in the ovarian cortex of the 2-year-old beef cow. As the number of follicles increased, the amount of AMH RNA increased ($P = 0.01$).

increased follicle numbers in heifers.

These results suggest that cows that are productive to an advanced age have larger ovaries and larger numbers of follicles than do heifers. This would explain why ovarian size appears to be increasing as follicle number is beginning to decrease.

Within the ovarian cortex of 2-year-old cows, AMH gene expression increased as follicle numbers increased (Figure 2). Similar results have been observed in rodents, primates, and women. Additionally, polymorphisms in the human AMH gene have been associated with follicle

numbers and ovarian dysfunction. The results of the present study suggest AMH may be a genetic marker of follicle number and ovarian function in the beef cow as well, and DNA sequencing efforts have begun. Genetic markers would be useful for identifying heifers of high reproductive potential at a young age, before ultrasonography is viable. This would allow culling decisions to be made before time and resources were wasted on heifers with low reproductive potential.

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Comparison of Feeding Wet Distillers Grains in a Bunk or on the Ground to Cattle Grazing Native Sandhills Winter Range

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Summary

Two experiments determined the effects of feeding wet distillers grains with solubles (WDGS), either on the ground or in a bunk, to cattle grazing native Sandhills winter range. In Exp. 1, frequency of supplementation had no effect on cow body weight (BW) or body condition score (BCS). BCS and BW of cows fed in a bunk were improved compared to cows fed on the ground. In Exp. 2, steers fed in a bunk had greater average daily gain than steers fed on the ground. Feeding WDGS on the ground resulted in 13-20% waste and cost between \$0.03 and \$0.045 per day.

Introduction

Growth of the ethanol industry in Nebraska and surrounding states has increased the availability of distillers co-products for livestock feed. Distillers grains plus solubles are high in protein, energy, and phosphorous, making them an excellent supplement in many grazing situations (2008 Nebraska Beef Report, pp. 25-27). In a summary of 14 grazing trials, supplementation of dried distillers grains with solubles (DDGS) increased final BW and ADG (2009 Nebraska Beef Report, pp. 37-39).

Wet distillers grains with solubles (WDGS) have not been widely used in grazing applications. This is due, in part, to potential inefficiencies in delivery of WDGS to grazing cattle. Feeding WDGS on the ground may result in higher waste levels when compared to feeding it in a bunk, but may increase its use in practical grazing situations and increase

profitability compared to bunk feeding. Therefore, the objective of this study was to compare feeding WDGS to grazing cattle in a bunk or on the ground.

Procedure

Two experiments were conducted at the University of Nebraska Gudmundsen Sandhills Laboratory (GSL) near Whitman, Neb. Cattle grazed native upland Sandhills winter range. For both experiments, wet distillers grains were obtained from an ethanol production facility (Standard Ethanol, LLC, Madrid, Neb.) and transported about 111 miles to GSL. The distillers grains were purchased in September each year and stored in a bunker fashioned from large round bales of meadow hay arranged in a "U" shape and covered with plastic until initiation of the experiment.

In Exp. 1, 120 March-calving cows (1182 ± 118 lb BW) were stratified by age and assigned randomly to one of eight pastures. Pastures were then assigned randomly to treatment. Treatments were arranged as a 2 X 2 factorial in a completely randomized design as follows: WDGS fed on the ground, either three or six days/week; or WDGS fed in a bunk either three or six days/week. The experiment was conducted for 90 days from Dec. 1, 2007, to March 1, 2008. Cows were supplemented with the daily equivalent of 1.0 lb/cow (DM basis) WDGS, delivered on Monday, Wednesday, and Friday to cattle in the three days/week treatment and on Monday through Saturday to cattle in the six days/week treatment. Cattle continuously grazed the same pasture throughout the experiment. Cow BW and BCS were measured upon initiation and completion of the 60-day feeding period. Weights were taken on a single day and cows were not limit fed prior

to weighing.

In Exp. 2, 63 March-born steer calves (443 ± 60 lb BW) were assigned to one of two feeding treatments: WDGS fed in a bunk or on the ground. There were four pastures, and pasture served as the experimental unit. Steers in Exp. 2 were supplemented with the daily equivalent of 2.25 lb/steer (DM basis) delivered five days/week. The experiment was conducted for 62 days from Oct. 14, 2008, to Dec. 15, 2008. Steers continuously grazed the same pasture throughout the experiment. Steer BW was recorded on two consecutive days at the initiation and completion of the feeding period. Calves were not limit fed prior to weighing.

Results

In Exp. 1, there were no frequency-by-method interactions ($P > 0.10$). Frequency had no effect on cow BW ($P = 0.55$) or BCS ($P = 0.27$). Body condition score of cows fed in a bunk increased, while that of cows fed on the ground did not change (0.4 vs. 0.0; $P = 0.01$; Table 1). Cows fed in a bunk lost less BW than cows fed on the ground (20.0 vs. 63.9 lb; $P = 0.07$; Table 1). Previous research at GSL has demonstrated 0.30 lb/day of supplemental crude protein to be sufficient to maintain BCS of spring-calving cows during the winter (Hollingsworth-Jenkins et al., 1996 Nebraska Beef Report, pp. 14-16). In this experiment, feeding WDGS in a bunk at an equivalent CP level resulted in a slight increase in BCS. This may have been a result of the energy content of WDGS. While better performance was achieved by feeding in a bunk, this experiment demonstrated WDGS is a viable supplement for cows grazing winter range.

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In Exp. 2, steers fed in a bunk had higher ADG than steers fed on the ground (0.63 vs. 0.44; $P = 0.04$; Table 2). The NRC (1996) was used to retrospectively calculate the WDGS intake difference between treatments. For steers fed in a bunk, a reduction in WDGS intake between 0.31 and 0.45 lb/day would have resulted in a 0.20 lb reduction in ADG. This is the equivalent of 13-20% waste. At \$200 (DM basis) per ton for wet distillers grain, the cost of the wasted distillers grains was between \$0.03 and \$0.045 per day. Because steers in this experiment were gaining BW at a relatively modest rate, even a slight reduction in WDGS intake resulted in a relatively large decrease in ADG. If the steers were being fed to achieve relatively rapid BW increases and waste of WDGS remained constant, then the relative difference in ADG between cattle fed in a bunk versus on the ground would be expected to be less than what was observed in this study.

An economic analysis was conducted on Exp. 2. This analysis was based on the value of the average difference in weight gained between

Table 1. Change in body weight (BW) and body condition score (BCS) of cows fed WDGS on the ground or in a bunk (Exp 1).

	Bunk	Ground	SEM	<i>P</i> -value
BCS change	0.4	0.0	0.1	0.01
Body weight change (lb)	-20	-64	12	0.07

Table 2. Performance of steers fed WDGS on the ground or in a bunk (Exp 2).

	Bunk	Ground	SEM	<i>P</i> -value
Initial weight (lb)	440	447	11	0.67
Final weight (lb)	481	475	11	0.71
ADG	0.36	0.44	0.07	0.04

steers fed WDGS in a bunk or on the ground. Calf sale value would have to be less than \$0.81/lb to justify not feeding in a bunk, based on bunk feeding cost of about \$0.16/day. The cost of \$0.16/day was derived from the cost of purchasing a commercial (Werk Weld Inc., Armour, S.D.) feed bunk, assuming full capacity of 40 head. Bunk cost of \$973.65 included a one-time delivery charge with a three-year payback period and 60 days of use per year at an interest rate of about 9.5%. Bunk cost for individual producers will vary as will calf value necessary to justify bunk feeding.

In conclusion, frequency of delivery of WDGS did not affect animal performance. An advantage in animal performance to feeding WDGS in a bunk versus on the ground was seen in the current studies.

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Supplementing Wet Distillers Grains Mixed with Low Quality Forage to Grazing Cow/Calf Pairs

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Procedure

Experiment 1

In 2007, 3-year old, non-gestating, lactating beef cows with spring born calves at side (n=24) grazed their assigned paddocks for 56 days during the summer. Paddocks were 2.47 acres and were assigned randomly to one of three treatments that consisted of: 1) the recommended stocking rate of 0.6 AUM/acre with no supplementation (CON1); 2) double the recommended stocking rate (1.2 AUM/acre) and supplemented 14.6 lb/head daily (50% of estimated DMI) of 55% grass hay and 45% WDGS (DM) (SUP); and 3) double the recommended stocking rate (1.2 AUM/acre) with no supplementation (2X). Stocking rate was increased by dividing the assigned paddock into halves and allowing the cattle access to only one of the halves during a grazing period of the rotation. Cattle were rotated through seven paddocks, and the days of grazing for each paddock were adjusted prior to initiation of the trial to account for stage of plant growth.

Experiment 2

In 2008, a second study of similar design was conducted in the same paddocks to compare different mixtures of WDGS and wheat straw. Wheat straw was selected to serve as a source of lower quality forage containing more NDF than the grass hay used in the previous year. Wheat straw was mixed with WDGS at three different levels consisting of 50:50, 40:60, and 30:70 WDGS:wheat straw on a DM basis. The mixtures of WDGS and wheat straw were stored in silo bags thirty days prior to initiation of the trial. Water was added to the two lower levels of WDGS during mixing until the moisture content was equal to that of the high level of WDGS (about 50%).

Twenty paddocks were arranged by the previous year's usage and graz-

ing order, and then assigned to one of four treatments: 1) the recommended stocking rate (0.6 AUM/acre) with no supplementation (CON2); 2) 50:50 WDGS:wheat straw supplement (HIGH); 3) 40:60 WDGS:wheat straw supplement (MED); or 4) 30:70 WDGS:wheat straw supplement (LOW). The paddocks assigned to treatments 2, 3, and 4 were grazed at double the recommended stocking rate (1.2 AUM/acre). Cattle received 12.6 lbs (DM) of WDGS and wheat straw mixture daily (50% of estimated daily intake). These paddocks were divided in half to increase stocking rate, and cattle were allowed to graze one of the halves during the grazing period. Two-year old lactating cows with spring born calves at side (n = 40) were utilized and assigned to a specific paddock rotation. Cattle within a block grazed each assigned paddock for seven days. When cattle were not grazing the experimental pasture, they were moved to a pasture of similar forage species composition and managed separately. They continued to be supplemented with the mix to measure differences in animal performance.

For both years, the experiment was conducted at the University of Nebraska's Gudmundsen Sandhills Laboratory located near Whitman, Neb. These studies were replicated over two blocks based on botanical composition and topography. Standing crop and forage utilization were determined by clipping 20 1-m² quadrats both pre- and post-grazing; quadrats were sorted by live grass, forbs, standing dead, and litter, then dried and weighed to determine forage availability. Cow/calf pairs were limit fed meadow hay at 2% of BW for five days prior to and at the conclusion of the grazing period to eliminate variation due to gut fill. The final three days of each limit feeding period, cows and calves were individually weighed, and the average of the weights was used

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Summary

Two studies were conducted over two years during the summer grazing season to determine the effect of grass intake when grazing cow/calf pairs were supplemented wet distillers grains (WDGS) with low quality forage. In 2007, a mixture of 45% WDGS and 55% grass hay was fed. In 2008, three blends of 50:50, 60:40, and 70:30 WDGS and wheat straw were fed. Supplemented cows and calves outgained non-supplemented groups in 2007. There were no differences in animal performance during 2008. Grazed forage intake was reduced by supplementing WDGS mixed with wheat straw without negatively affecting animal performance.

Introduction

Storing wet distillers grains with solubles (WDGS) for extended lengths of time can be beneficial to cow/calf producers. Mixing WDGS with low-quality forage increases the palatability of the forage, and the additional bulk from the forage can potentially reduce grazed forage intake by supplying fill. Two consecutive summer grazing studies were conducted to determine the effect of supplementing cows with wet distillers grains (WDGS) that had previously been mixed and stored with low quality forage on 1) grazed forage intake and 2) cow and calf performance.

as the initial and ending BW. Cattle that were offered supplement received the mixture at 50% of their estimated daily intake. The supplement was fed in feed bunks located in alleys contiguous to the paddocks to eliminate trampling of forage around the feeding site.

Results

Experiment 1

Initial BW (Table 1) was not different across treatments for individual cows or individual calves ($P > 0.89$); neither was final BW ($P > 0.13$). However, ADG for cows and calves receiving the WDGS and grass hay supplement (SUP) was numerically higher when compared to cows and calves that received no supplement, regardless of stocking rate. Cows receiving supplementation outgained CON1 and 2X cows by 1.54 lb and 1.70 lb per day ($P < 0.01$), respectively. Calves receiving supplementation outgained CON1 and 2X calves by 0.55 lb and 0.71 lb per day ($P < 0.01$), respectively. The extra gain observed for the calves receiving supplement can be a result of either a) increased milk production from the dam's consumption of a higher quality diet than the non-supplemented cows, b) the observed consumption of the WDGS and wheat straw mixture by the calves, or c) a combination of the two. The calves were at the bunk and appeared to be eating each day; however, it is not possible to determine the actual amount of mixture that the calves consumed.

The amount of forage that disappeared during the grazing period was determined by pre- and post-grazing clipping samples. These measurements were used to determine the percentage utilization of the available forage and the amount of grazed forage intake that was replaced by the WDGS and wheat straw mixture.

Percentage forage utilization was determined by dividing the amount of forage that disappeared during the grazing period by the amount of available forage prior to grazing. Percentage utilization was similar for the

Table 1. Exp. 1 animal performance and grazing results.

	Treatment			SEM	P-value
	CON1 ¹	SUP ²	2X ³		
Initial, lb					
Cow	1016	1016	1012	24	0.99
Calf	254	247	247	9	0.89
ADG, lb					
Cow	-0.99 ^a	0.55 ^b	-0.11 ^a	0.07	< 0.01
Calf	1.8 ^a	2.36 ^b	1.65 ^a	0.02	< 0.01
% Utilization	33.1 ^a	52.0 ^b	57.8 ^b	0.1	< 0.01
DMI lb/day					
Grazed intake ⁴	27.8	24.5	25.6		
Supplement	—	14.8	—		

^{a,b} Means with different superscripts differ (P -value < 0.05).

¹ Cattle grazed at recommended stocking rate and received no supplementation.

² Cattle grazed at double the recommended stocking rate and received 50% of estimated daily intake of 45:55 WDGS:wheat straw mixture.

³ Cattle grazed at double the recommended stocking rate and received no supplementation.

⁴ Calculated by dividing total amount of grazed forage disappearance by number of cow/calf pairs and number of grazing days.

Table 2. Exp. 2 animal performance and grazing results.

	Treatment				SEM	P-value
	CON2 ¹	LOW ^{2,3}	MED ^{2,4}	HIGH ^{2,5}		
Initial, lb						
Cow	880	882	893	893	20	0.63
Calf	276	280	267	267	15	0.53
ADG, lb/d						
Cow	-0.07	0.29	0.24	0.93	0.31	0.06
Calf	1.96	1.98	1.96	2.18	0.20	0.46
% Utilization	34.4 ^a	38.4 ^{ab}	44.3 ^b	46.0 ^b	0.3	0.01
DMI, lb/day						
Grazed intake ⁶	25.4 ^a	13.5 ^b	16.5 ^b	16.3 ^b	1.32	< 0.01
Supplement	— ^a	12.8 ^b	12.6 ^b	12.4 ^b	0.2	< 0.01

^{a,b} Means with different superscripts differ (P -value < 0.05).

¹ Cattle grazed at the recommended stocking rate.

² Cattle grazed at double the recommended stocking rate, and received 50% supplement of estimated daily intake.

³ Cattle were supplemented with 70:30 wheat straw:WDGS mixture.

⁴ Cattle were supplemented with 60:40 wheat straw:WDGS mixture.

⁵ Cattle were supplemented with 50:50 wheat straw:WDGS mixture.

⁶ Calculated by dividing total amount of grazed forage disappearance by number of cow/calf pairs and number of grazing days.

double-stocked treatments SUP and 2X (52.0 and 57.8%, respectively; $P < 0.15$). However, CON1 had significantly less percentage utilization of the available forage compared to SUP and 2X (18.9 and 24.7% less, respectively).

The amount of forage that disappeared from each paddock during the grazing period was divided by the number of cow/calf pairs and the number of days each paddock was grazed. There were no differences among CON1, SUP, or 2X (27.8, 24.5, and 25.6 lb, respectively; $P = 0.44$) in

the amount of forage that disappeared per cow/calf pair on a daily basis. In addition to this, the cattle receiving supplement also consumed 14.8 lb/day of WDGS and wheat straw. Therefore, 1 lb of WDGS and grass hay mixture replaced 0.22 lb of grazed forage.

Experiment 2

Initial BW (Table 2) was not different among treatments in 2008 ($P > 0.27$). Ending BW was affected by supplementation ($P = 0.04$). Cattle assigned to HIGH treatment were

heavier at the conclusion of the study compared to CON2, LOW, and MED (944, 875, 899, and 906 lb, respectively), and cattle on MED treatment tended ($P = 0.09$) to be heavier than CON2 at the end of the study. Cow ADG tended ($P = 0.06$) to be different among treatments and was numerically higher for HIGH. Calf ending BW ($P = 0.63$) and ADG ($P = 0.46$) were not different among treatments.

CON2 cattle had significantly less percentage utilization of available forage than HIGH and MED (34.4, 46.0, and 44.3%, respectively; $P = 0.02$). However, CON2 and LOW did not differ (34.4 and 38.4%, respectively; $P = 0.27$) in percent utilization of available forage. Cattle on CON2 had greater DMI of grazed forage than those on supplemented treatments ($P < 0.01$), but there was no difference for grazed forage disappearance among HIGH, MED, and LOW treatments ($P > 0.11$). The total amount of grazed forage and WDGS/wheat straw supplement consumed daily in the double stock

treatments was similar to the daily amount of forage that disappeared for CON2 ($P = 0.12$). This suggests that the supplemented cattle and CON2 had similar total daily DMI. The LOW and CON2 treatments had similar percentage utilization of available forage and total DMI, suggesting that the 12.8 lb of WDGS/wheat straw supplement consumed daily by the LOW treatment replaced 11.9 lb of grazed forage intake. Cattle in the MED and HIGH treatments consumed more WDGS and less wheat straw than those in the LOW treatment; as a result, both grazed forage intake and total intake increased. The combined amount of neutral detergent fiber (NDF) consumed daily from the grazed forage intake and the WDGS and wheat straw supplement for the LOW treatment was similar to the NDF intake of CON2 (15.7 and 15.4 lb NDF/day; $P = 0.89$). This suggests the fibrous nature of the diet limited DMI.

The lower quality wheat straw used in 2008 replaced a larger proportion

of grazed forage intake than the grass hay used in 2007. The higher fiber content of the wheat straw and lower digestibility are the most likely reasons for this greater replacement rate. The 70:30 wheat straw:WDGS blend nearly replaced grazed forage intake on a 1:1 basis. The replacement rate of grazed forage was reduced as the quality of the supplement increased; that is, fiber content decreased. Cow and calf performance was greatest when grass hay was mixed with WDGS, but the replacement rate was the lowest. The quality and ratio of the forage used will determine the grazed forage replacement rate and the animal response.

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Evaluation of Storage Covers When Wet Distillers Byproducts Are Mixed and Stored with Forages

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mixed with forage and covered in different ways.

Procedure

Storage

To replicate a bunker storage environment, a combination of 70% WDGS and 30% ground cornstalks (DM basis) was mixed and packed in 55 gallon steel barrels at the University of Nebraska Research Feedlot near Mead, Neb. Stalks were ground using a tub grinder with a 5-inch screen. Each barrel was filled with approximately the same weight of mix and packed to a similar height. Weights (as-is) were recorded for each barrel and samples were collected for DM determination. The height by barrel also was recorded. Table 1 provides the composition of mixes tested and corresponding barrel cover treatments

for the three experiments. Within each experiment, cover treatments were assigned randomly to each barrel. Barrels contained approximately 300 lb of as-is mix with 3.14 ft² of surface area exposed.

Cover Treatments

In Exp. 1, three covers were evaluated: an open, uncovered treatment (Control; Figure 1); a plastic cover (6 mil thickness) weighted with sand to mimic tires that would be used in commercial sized bunkers; and salt added as a cover at the rate of 1 lb per ft² of surface area (Figure 2). Barrels were housed indoors in temperature-controlled rooms and undisturbed for 57 days.

In Exp. 2, three cover treatments with two different mixes were evaluated. One of three cover treatments was assigned randomly to barrels

Summary

Wet corn co-products were mixed with forage and stored in 55 gallon barrels with different covers mimicking bunker storage methods to determine shrink losses and spoilage. Three mix combinations and seven cover treatments were used to compare spoilage levels of covered co-product mixes vs. uncovered mixes. Spoilage and losses of the mix were effectively reduced with all covers, with losses reduced from 8 to 9% when uncovered, to 1 to 5% when different cover treatments were used.

Introduction

Wet distillers grains plus solubles (WDGS) have a relatively short shelf life and spoilage can occur within a few days depending on the extent of oxygen exposure and ambient air temperature. Also, WDGS is delivered in semi-truck load quantities, making it impractical for use on smaller livestock operations that cannot feed up large quantities within a few days. In addition, seasonality of feedlot cattle numbers affects the price of WDGS, thereby making it economical for both feedlots and cow-calf producers to purchase it in the summer and use it later in the year or in the winter. Previous research has focused on methods to “bulk” up WDGS or solubles for storage in either silo bags or bunkers. When bunker storage is used (likely the most predominant storage method), losses or shrink are important and likely minimized depending on how the bunker is covered. Therefore, the objective of the current study was to evaluate different covers for bunkers by determining spoilage and losses when distillers byproducts are

Table 1. Mixture composition (%DM basis) and corresponding cover treatments for three experiments in 55-gallon barrels to mimic storage bunkers.

Exp. 1			
WDGS	Corn Stalks		Cover
70	30		Open ¹
70	30		Plastic with sand ²
70	30		Salt ³
Exp. 2			
WDGS	Solubles	Straw	Cover
70	—	30	Open ¹
70	—	30	Solubles ⁴
70	—	30	Solubles with salt ⁵
—	70	30	Open ¹
—	70	30	Solubles ⁴
Exp. 3			
WDGS		Straw	Cover
70		30	Open ¹
70		30	Open with H ₂ O ⁶
70		30	Open (outside) ⁷
70		30	Solubles with salt ⁵
70		30	Solubles with salt and with H ₂ O ^{5,6}

¹Open barrel has no cover and is considered control.

²Plastic with 6-mil thickness used as a cover and sealed on outside of the barrel with tape and weighted down with sand.

³Salt was added at a rate of 1.0 lb/ft².

⁴Solubles were added to simulate a 3-in cover equivalent, 45 lb (as-is); 16 lb of DM required in the barrel to provide 3 in.

⁵Salt was added to solubles at rate of 1.0 lb/ft².

⁶Water was applied to an uncovered barrel by hand 1 time per week equivalent to .6 in of rain.

⁷Barrels were stored outdoors uncovered and subjected to all environmental factors.



Figure 1. Picture of Control (uncovered) barrels depicting spoilage layer, fresh layer, and markings for determining the height of spoilage.



Figure 2. Salt cover illustrating amount of salt (1 lb/ft²) added and change in height.

that contained a 70:30 ratio (DM basis) of WDGS:straw. Another mix containing a 70:30 ratio of distillers solubles and straw was used to evaluate only two cover treatments. The three cover treatments evaluated with WDGS:straw mixtures included no cover (Control), solubles added directly to the top as a cover (Solubles; Figure 3), and addition of solubles combined with salt (Sol+Salt). Solubles were added in quantity to provide a 3-inch thick cover which

equated to 45 lb (as-is) or 16 lb of DM. For the Sol+Salt treatment, the same quantity (45 lb) of solubles was added; however, salt was mixed with solubles at the same rate of 1 lb per ft² of surface area (3.14 lb of salt). The two cover treatments evaluated with the solubles:straw mixture were a Control (no cover) and the Solubles cover treatment. The same sampling and process was used as for Exp. 1. Barrels were housed indoors in temperature controlled rooms and were undis-

turbed for 62 days.

In Exp. 3, five cover treatments were evaluated with a mixture ratio of 70% WDGS and 30% straw. The cover treatments included: a Control (no cover) and Sol+Salt cover (similar to that in Exp. 2), both stored indoors in temperature controlled rooms; an open barrel stored outdoors where temperature and moisture would fluctuate; an open barrel housed indoors with simulated rainfall of 0.6 in. of water once weekly; and a Sol+Salt treatment housed indoors, with simulated rainfall of 0.6 in. of water once weekly. Barrels were stored for 56 days from March 15 to May 15, 2009.

When each barrel within the three treatments was opened, total barrel weight and mix height measurements were taken to determine DM loss of the product. Surface spoilage content was measured for depth, removed, and weighed. On treatments with distillers solubles as a cover, depth measurements were taken, and the solubles were removed and weighed. The unspoiled portion of the mix also was measured for depth, then removed and weighed. Representative samples of spoiled material, unspoiled or "normal" material, and solubles (if present for that treatment) were taken from within each individual barrel to be used for analysis. Spoilage was based on visual appraisal (Figure 1).

Samples either were frozen or a subset was dried in a 60° C forced air oven for 48 hours to obtain DM. Frozen samples were freeze dried for subsequent quality analysis. Freeze-dried samples were ground through a Wiley Mill (1 mm screen) and analyzed for *in vitro* DM digestibility, determined by a 30-hour incubation of 0.3 g substrate in a 1:1 mixture of McDougall's buffer (1g Urea/L) and rumen fluid collected from steers fed a forage-based diet. Tubes were stoppered, flushed with CO₂, incubated at 39°C, and swirled every 12 hours. After 30 hours, 6 mL of 20% HCl solution and 2 mL of 5% pepsin solution were added to each tube. Tubes were then incubated at 39°C for 24 hours. Residue from the tubes was filtered and

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dried in a 60°C forced air oven for 24 hours.

The goal of this research was to evaluate covers for bunker storage using a barrel as a model and to allow for replication that is not possible with large, commercial size bunkers. Data were calculated for amount of spoilage and amount of DM that was not recovered for a barrel approximately 27 inches in height. A key assumption was that all spoilage and losses would occur from the top where stored material was exposed to oxygen. Therefore, the amount of DM that was spoiled or not accounted for (loss) was extrapolated to a barrel that was 10 ft in height to mimic a 10-ft bunker storage facility. Data are presented as both a barrel and a bunker; a bunker is defined as a 10-ft height that would contain the same density of weight extrapolated to that height. Data were analyzed as completely randomized design experiments in SAS (SAS Institute, Cary, N.C.) with barrel as the experimental unit. Data were analyzed separately by experiment and separately based on the mix of distillers solubles with straw or WDGS with straw in Exp. 2.

Results

In Exp. 1, approximately 124 lb of DM were added to barrels, and cover treatment affected ($P < 0.01$) spoilage and loss (Table 2). Barrels covered in plastic had the least amount ($P < 0.05$) of spoilage and loss compared to either Control or Salt covers. Salt was intermediate ($P < 0.05$) to Control and Plastic covers. Depth of surface spoilage of barrels was consistent among treatments and across experiments, ranging from about 8 to 10 in on average. When spoilage loss was calculated for a 10-ft bunker situation, DM losses ranged from 1.2 to 3.8% loss and were affected ($P < 0.01$) by cover treatment with the same statistics as the barrel measurements. Spoilage also was affected ($P < 0.01$), with only 0.6% spoilage in the Plastic cover treatment for a 10-ft bunker compared to 3.7% spoilage when the bunker was left

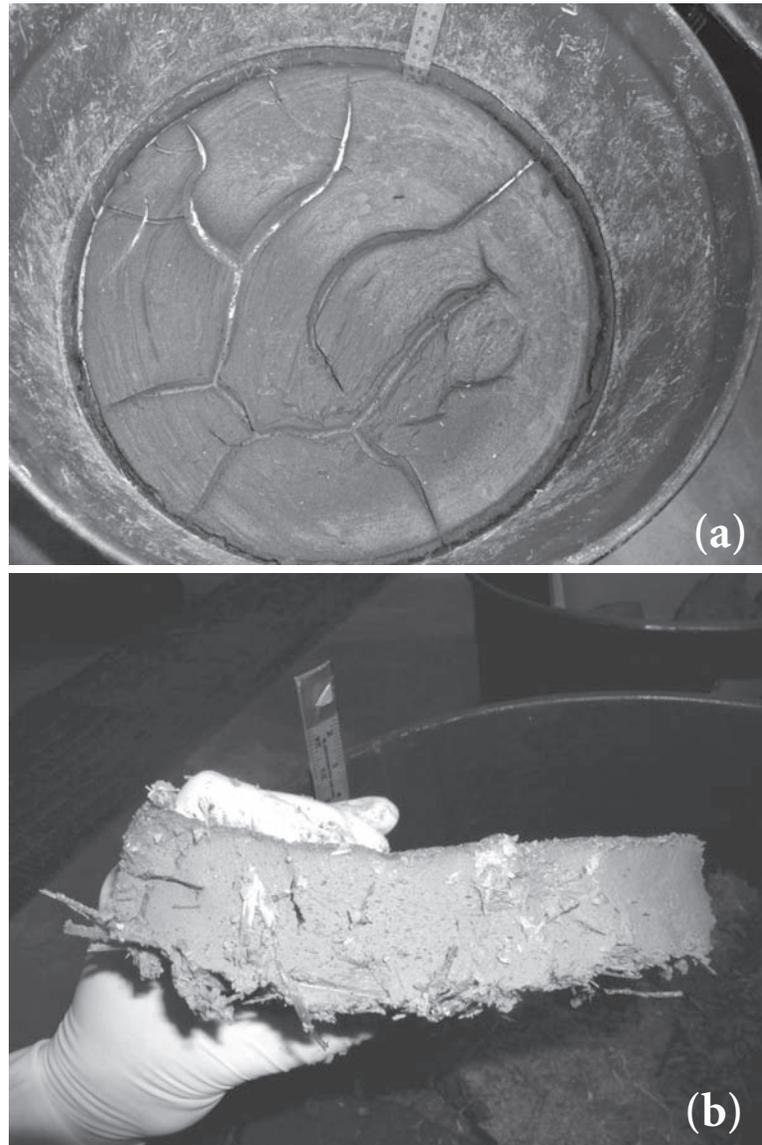


Figure 3. (a) Solubles as a cover and (b) solubles layer following approximately 60 days of storage illustrating loss of moisture and DM over time from the solubles as a cover.

Table 2. Effect of storage covers for storing 70% WDGS with 30% ground corn stalks on DM loss and spoilage in Exp. 1.

	Control	Plastic	Salt	F-test
<i>Barrel</i>				
DM added, lb	115.4	115.13	114.8	0.95
DM spoilage, lb	20.2 ^a	3.1 ^b	19.8 ^a	< 0.01
DM loss, lb	17.6 ^a	0.0 ^c	4.2 ^b	< 0.01
<i>10 ft. Bunker¹</i>				
% DM loss ²	3.4 ^a	0.0 ^c	.82 ^b	< 0.01
% Spoilage ³	3.9 ^a	0.61 ^b	3.8 ^a	< 0.01
% DM spoilage & loss	7.4 ^a	.57 ^c	4.7 ^b	< 0.01

¹Losses and spoilage extrapolated to a bunker storage facility with 10 ft height assuming all losses are from the surface and therefore the same whether a 27-in barrel or 10-ft bunker.

²% DM loss calculated based on the amount of loss as a percent of the total stored in a 10-ft tall bunker. The weight in a 10-ft bunker with 3 ft² surface area is calculated from DM density added to barrels.

³% Spoilage calculated similar to method for calculating % DM loss but with amount of spoilage DM. a,b,c Means with different superscripts differ ($P < 0.05$).

Table 3. Effect of storage covers for storing 70% WDGS with 30% straw on DM loss and spoilage in Exp. 2.

	Control	Solubles ¹	Sol+Salt ^{1,2}	F-test
<i>Barrel</i>				
DM in, lb	94.9 ^a	90.9 ^{ab}	87.8 ^b	0.04
DM spoilage, lb	22.1 ^a	8.6 ^c	11.6 ^b	< 0.01
DM loss, lb	13.3 ^a	.35 ^b	1.55 ^b	0.02
<i>10-ft. Bunker³</i>				
% DM loss ⁴	2.9 ^a	.07 ^b	.37 ^b	0.02
% Spoilage ⁵	4.9 ^a	2.0 ^b	2.7 ^b	< 0.01
% DM spoilage/loss	7.9 ^a	2.1 ^b	3.1 ^b	< 0.01
<i>Barrel – Solubles as Cover</i>				
Solubles DM in		16.0	16.0	—
Solubles DM recovered ⁶		8.1	10.3	< 0.01
Solubles DM loss % ⁷		49.6	35.2	< 0.01

¹Solubles were added to simulate a 3-in cover equivalent, 45 lb (as-is); 16 lb of DM required in the barrel to provide 3 in.

²Salt was added to soluble at rate of 1.0 lb/ft².

³Losses and spoilage extrapolated to a bunker storage facility with 10 ft height, assuming all losses are from the surface and therefore the same whether a 27-in barrel or 10-ft bunker.

⁴% DM loss calculated based on the amount of loss as a percent of the total stored in a bunker that is 10 ft tall. The weight in a 10-ft bunker with 3 ft² surface area is calculated from DM density added to barrels.

⁵% Spoilage calculated similar to method for calculating % DM loss but with amount of spoilage DM.

⁶lb of DM measured in solubles left after storage.

⁷Loss of DM from solubles expressed as a % of solubles added as a cover.

^{a,b,c}Means with different superscripts differ ($P < 0.05$)

Table 4. Effect of storage covers for storing 70% WDGS with 30% straw on DM loss and spoilage in Exp. 3.

	Control ¹	Control ²	Control ³	SOL+Salt ⁴	SOL+Salt ^{2,4}	F-test
<i>Barrel</i>						
DM in, lb	94.6	96.3	100.2	101.4	99.6	0.43
DM spoilage, lb	21.0 ^a	16.9 ^a	20.5 ^a	9.4 ^b	6.6 ^b	< 0.01
DM loss, lb	11.7 ^b	8.04 ^b	20.2 ^a	0.0 ^c	0.0 ^c	< 0.01
<i>10-ft Bunker⁵</i>						
% DM loss ⁶	2.7 ^b	1.8 ^b	4.4 ^a	0.0 ^c	0.0 ^c	< 0.01
% Spoilage ⁷	4.9 ^a	3.9 ^a	4.5 ^a	2.1 ^b	1.5 ^b	< 0.01
% DM spoilage/loss	7.7 ^{ab}	5.7 ^b	8.9 ^a	1.4 ^c	0.0 ^c	< 0.01
<i>Barrel – Solubles as Cover</i>						
Solubles DM in				16.0	16.0	
Solubles DM recovered ⁸			11.5	11.3	0.71	
Solubles DM loss % ⁹				27.9	29.4	0.71

¹Open barrel has no cover and is considered control.

²Water was applied to barrel by hand 1 time per week equivalent to .6 in of rain.

³Barrels were stored outdoors uncovered and subjected to all environmental factors.

⁴Solubles were added to simulate a 3-in. cover equivalent, 45 lb (as-is); 16 lb of DM required in the barrel to provide 3 in; in addition, salt was added at a rate of 1 lb/ft² of surface area.

⁵Losses and spoilage extrapolated to a bunker storage facility with 10 ft height assuming all losses are from the surface and therefore the same whether a 27-in barrel or 10-ft bunker.

⁶% DM loss calculated based on the amount of loss as a percent of the total stored in a bunker that is 10 ft tall. The weight in a 10-ft bunker with 3 ft² surface area is calculated from DM density added to barrels.

⁷% Spoilage calculated similar to method for calculating % DM loss but with amount of spoilage DM.

⁸lb of DM measured in solubles left after storage.

⁹loss of DM from solubles expressed as a % of solubles added as a cover.

^{a,b,c}Means with different superscripts differ ($P < 0.05$)

uncovered. It is unclear whether spoilage and losses should be combined. Most producers would likely feed the spoiled material; however, when spoiled and lost amounts were added, there was 1.8% spoilage/loss from Plastic cover treatments compared to a 7.5% loss from uncovered treatments (Control), with Salt covering being intermediate.

In Exp. 2, cover treatment affected both spoilage ($P < 0.01$) and loss ($P = 0.02$), with Solubles or Sol+Salt covers resulting in less spoilage and loss ($P < 0.05$) compared to uncovered barrels (Control; Table 3). The same trend was observed for bunker storage with total spoilage and loss cut in half for Solubles or Sol+Salt (4.6 or 5.4%) compared to Control (uncovered) bunkers (9.3%). However, when solubles were used as a cover, it was necessary to account for the amount of solubles lost. Approximately 50% of the solubles' DM was lost when added as a 3-in cover; this loss was reduced ($P < 0.01$) to 35% when 1 lb/ft² of salt was mixed with solubles prior to covering. Therefore, not all of the solubles were retained when used as a cover treatment for bunkers.

In Exp. 3, when water was added by simulating a 0.6 in rainfall once a week, spoilage and losses were not decreased in barrels, but they were decreased when data were extrapolated to a bunker situation (Table 4). When barrels were stored outside and exposed to both precipitation and temperature fluctuations, then DM losses were greater in a bunker situation than when water was added to barrels stored indoors with no fluctuation in temperature. It is unclear why temperature fluctuation may increase losses. Within the same experiment, adding solubles and salt, either with simulated rainfall (0.6 in per week) or without added water, dramatically decreased ($P < 0.05$) spoilage and losses in the barrels and when extrapolated to a bunker. Similar to Exp. 2, 28 to 29% of the solubles' DM was lost when used as a cover, but appeared to be effective at reducing spoilage and losses of the stored WDGS:straw mix.

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In Exp. 2, a mix of 70% distillers solubles and 30% straw also was tested. The Control treatment showed a loss of 2.3% in a 10-ft bunker, but this loss was numerically reduced when solubles alone were added as a cover (Table 5). However, no difference was observed between the Control or solubles coverings for distillers solubles mixed with straw for total spoilage and losses in a bunker. Again, 36.8% of the 3-in covering of solubles was lost.

Results from the *in vitro* DM disappearance suggest little difference between spoiled material and non-spoiled material (data not shown; Exp. 1 and Exp. 2 only). The *in vitro* DM digestibility averaged 51.8% for spoiled material and 51.5% for non-spoiled material. Solubles used as a cover averaged 62.3% digestible; however, this is not compared to fresh solubles. Clearly, it is expected that spoiled and non-spoiled material would have different feeding value. These data suggest that the spoiled material is not markedly different

Table 5. Effect of storage covers for storing 70% distillers solubles with 30% straw on DM loss and spoilage in Exp. 2.

	Control	Solubles	F-test
<i>Barrel</i>			
DM in, lb	96.9	87.2	0.02
DM spoilage, lb	12.1	11.6	.33
DM loss, lb	10.3	1.55	< 0.01
<i>10-ft Bunker</i>			
% DM loss	1.6	.36	< 0.01
% Spoilage	1.9	2.7	< 0.01
% DM spoilage & loss	3.5	3.1	0.22
<i>Barrel – Solubles as Cover</i>			
Solubles DM in		16.0	
Solubles DM recovered		10.1	
Solubles DM loss %		36.8	

when compared to the non-spoiled material and therefore could be fed to livestock.

Based on barrel storage, leaving a mix of WDGS and forage (70:30 ratio, DM basis) uncovered results in DM losses ranging from 3.5 to 5.0% in a 10-ft bunker. If spoilage is included as a loss, then the percentages range from 7.5 to 9.3% of DM. Plastic appears to be the most effective cover for reducing losses and spoilage, followed

by solubles, salt, or combinations of the two. If solubles are used as a cover, one should expect that 25 to 50% of the solubles themselves will be lost as they dry during storage.

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Genetic Analysis of Mature Size in American Angus Cattle

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Summary

Genetic parameters for weights and heights of mature cows were estimated using a repeatability model from field data provided by the American Angus Association. The results showed that the heritabilities of both traits were large, and correlations between them were positive and strong. Selection on either trait should easily produce a response, and changing one should lead to a correlated response in the other. Genetic trend was generally for increasing cow weight over the last 25 years.

Introduction

Cow weights and heights affect efficiency, maintenance requirements, cow-calf profitability, reproduction, and cull cow value. Mature size impacts the profitability of beef enterprises and thus should be considered in selection programs. Previous estimates of direct heritability have been generally moderate to high.

The objective of this study was to estimate genetic parameters and (co) variance components for mature weight and mature height of Angus cows using a repeatability model and to estimate genetic trends for both traits.

Procedure

The data and pedigree files used for the analysis were supplied by the American Angus Association (AAA). Two samples were obtained from the complete data file based on the last digit of the herd code. The first sample contained 23,658 mature weight (MWT) and 13,012 mature height (MHT) records (Table 1). The second sample contained 23,698 MWT and 13,310 MHT records. All weights were corrected for body condition score.

Table 1. Summary of data for analyses of mature cow weight (MWT, lb) and mature cow height (MHT, in) for two samples of Angus cows.

	Sample 1		Sample 2	
	MWT1	MHT1	MWT2	MHT2
No. records	23,658	13,012	23,698	13,310
No. cows	14,056	8,131	15,038	8,439
No. cont. groups	1,180	581	1,227	692
No. pedigree	43,105	43,105	44,141	44,141
Means	1315.3	53.4	1296.9	52.8

Table 2. Estimates of genetic parameters (SE) for mature cow weight (MWT, lb) and mature cow height (MHT, in) for two samples of Angus cows (single trait analyses).

Estimates	Sample 1		Sample 2	
	MWT1	MHT1	MWT2	MHT2
Heritability ^a	0.45 (0.012)	0.64 (0.018)	0.48 (0.011)	0.62 (0.018)
Repeatability ^a	0.64	0.77	0.66	0.70
Cont. group ^b	0.50	0.52	0.52	0.46
Phenotypic variance	24363	5.62	25929	5.12

^aFraction of phenotypic variance not including contemporary group variance.

^bFraction of phenotypic variance including contemporary group variance.

Table 3. Estimates of genetic parameters for mature cow weight (MWT, lb) and mature cow height (MHT, in) for two samples of Angus cows (two trait analyses).

Estimates	Sample 1		Sample 2	
	MWT1	MHT1	MWT2	MHT2
Heritability ^a	0.44	0.62	0.47	0.62
Repeatability ^a	0.64	0.76	0.66	0.70
Cont. group ^b	0.50	0.53	0.52	0.46
Phenotypic variance	24346	5.59	25689	5.06

^aFraction of phenotypic variance not including contemporary group variance.

^bFraction of phenotypic variance including contemporary group variance.

The four-generation pedigree files included 43,105 and 44,141 animals for samples 1 and 2, respectively (Table 1). The records were from cows born between 1983 and 2006. The range in ages when cows were weighed was 2 to 11 years, with the majority (80%) of records for cows between 2 and 6 years of age. Cows on average had 1.7 records for MWT. Univariate and bivariate analyses were used to estimate genetic parameters for MWT and MHT. Estimates were obtained using the MTDFREML programs. The animal model included age as fixed factor; random factors were contemporary group, permanent environmental effect of the cow, additive genetic value of the cow, and residual. Contemporary group was formed by herd and year of measurement.

Results

Estimates of variance and covariance components, heritability and repeatability for samples 1 and 2 are reported in Tables 2 and 3. Estimates of heritability for MWT were similar to those from previous studies. Previous estimates of heritability for mature weight and height have ranged from moderately to highly heritable. The results for MWT from the current study agree with previous work using data from the AAA. The estimates obtained from the current study have smaller standard errors. For MHT, estimates from the current study are less than estimates previously reported from AAA field data. Estimates of repeatability for samples 1 and 2 were

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Table 4. Estimates of correlations between mature cow weight (MWT) and mature cow height (MHT).

	Sample 1			Sample 2		
	Genetic	PE	Residual	Genetic	PE	Residual
Correlations	0.80	0.75	0.15	0.83	0.69	0.18

PE: Permanent environmental effect.

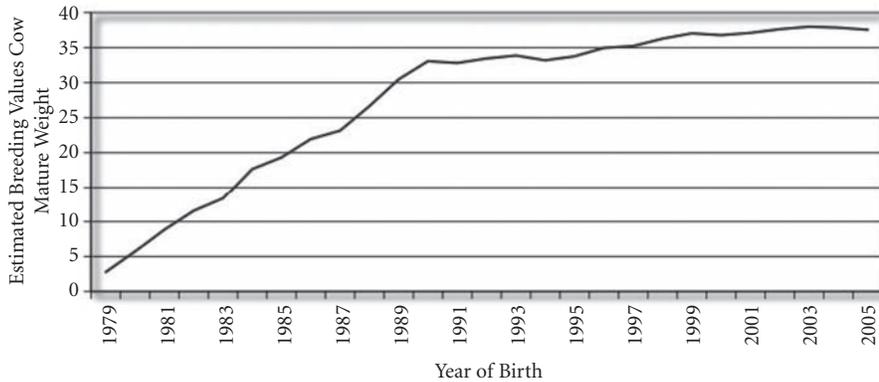


Figure 1. Genetic trend for cow weight (MWT).

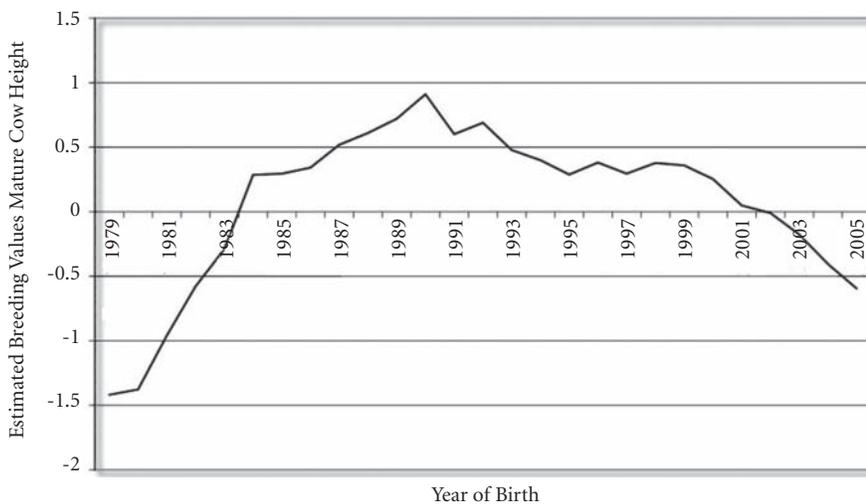


Figure 2. Genetic trend for cow height (MHT).

0.64 and 0.65 for MWT and 0.77 and 0.70 for MHT. Contemporary groups accounted for approximately 50% of phenotypic variance for both MWT and MHT.

Estimates of the genetic correlation between weight and height were strong and positive, ranging from 0.80

to 0.83. The permanent environmental correlations also were high, ranging from 0.69 to 0.75 (Table 4).

Changes in estimated breeding values (EBVs) by year of birth from the whole data file (about 238,000 records of 138,000 cows with a pedigree file of 308,000 animals) for

mature weight and mature height are represented graphically in Figures 1 and 2. An EBV is equal to twice the animal's expected progeny difference (EPD). Birth years of cows with EBVs for MWT and MHT ranged from 1979 to 2006. Cows born prior to 1983 did not have a record themselves, but genetic merit was estimated using pedigree relationships and the performance of progeny. The MWT trend suggests that MWT has been increasing and recently has begun to plateau. During the ascending time (first 11 years), the regression coefficient for EBV/year was 5.54 lb/year, and after the apparent plateau, was 0.64 lb/year. For MHT, there was a positive trend throughout the first 13 years of the data and then a decline for the rest of the years represented in the analysis. The regression coefficient for the positive trend during the first 13 years was 0.082 in/year, and during the decline was -0.035 in/year.

Implications

Results from the current study, as expected, show that both MWT and MHT would respond favorably to selection and that changing one would lead to correlated response in the other. Selection would be more accurate for MHT than for MWT because heritability is greater and less variation is due to permanent environmental effects. The repeatability model used gave us more accurate results because permanent environmental effects were considered in the model. Ignoring permanent environmental effects in the case of repeated records can lead to overestimates of genetic parameters.

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Factors Associated with Feed Intake of Angus Steers

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 L. Dale Van Vleck¹

Summary

Estimates of variance components and heritability of average daily feed intake (AFI) and residual feed intake (RFI) were obtained using an animal model. Data were from 475 Angus steers raised and fed at the Circle A Ranch (Iberia, Mo.). Pedigree files were provided by the American Angus Association. Estimates of heritability after adjustment for average daily gain (ADG) were 0.56 and 0.60 for AFI and RFI. Selection for feed intake (FI) should be effective if FI records are available. Feed intake needs to be adjusted for age and weight on test. Carcass measurements (fat thickness and rib eye muscle area) were significantly associated with AFI and RFI, whether measured by ultrasound at mid-test or by direct measurement at harvest. With carcass measurements held constant, estimates of heritability for AFI were reduced from 0.35 to 0.21 (harvest) and to 0.26 (ultrasound), with the change due to a reduction in the estimate of genetic variance with little change in residual variation. For RFI, the estimate was reduced from 0.60 to 0.37 (harvest) and 0.40 (ultrasound) due to a reduction in estimates of genetic variance and an increase in estimates of residual variation. These results indicate estimated breeding values (EBV) or expected progeny differences (EPD) for fat depth and rib eye area of the carcass, as well for AFI and RFI and other economically important traits, should be weighted by their economic values and included in an economic index for selection.

Introduction

Feed cost for maintenance represents 60 to 65% of the total feed requirements for the cow herd and is the most important determinant of

Table 1. Estimates of variance components and heritability after adjustment for factors affecting average feed intake (AFI, lb).

Factors	Heritability	Variation	
		Genetic	Residual
Held Constant			
None	0.31	1.12	2.43
A, W on test ¹	0.35	1.07	2.00
A, W, Carcass (end of test) ²	0.21	0.54	2.09
A, W, Ultrasound (mid-test) ³	0.26	0.73	2.09
A, W, ADG	0.56	0.97	0.78
A, W, ADG, Carcass	0.32	0.54	1.12
A, W, ADG, Ultrasound	0.34	0.54	1.07

¹A = age on test; W = weight on test.

²Carcass traits measured at harvest: fat depth, rib eye area, marbling score.

³Ultrasound carcass traits measured at mid-test: fat depth, rib eye area, intramuscular fat.

feedlot costs. Variation in feed intake, however, exists among individual animals independent of their body size. The objective of this study was to estimate (co)variance components and heritability of AFI and RFI using data from Angus steers. A second objective was to determine the association of AFI and RFI with carcass traits measured by ultrasound at mid-test or directly at harvest.

Procedure

Data were collected on 4,105 steers raised and fed at the Circle A Ranch (Iberia, Mo.). The pedigree files for sires of these steers were obtained from the American Angus Association (St Joseph, Mo.). Variance components were estimated using the MTDFREML programs (Boldman et al., 1995) from a sample of 475 Angus steers for AFI (lb/day) and RFI (lb/day). Residual feed intake was calculated from AFI for all days on test adjusted to constant ADG and metabolic body weight at mid-test (average of 44 days before end of an average 114-day test period). AFI and RFI were analyzed separately. Covariates in six different models included ADG; age (A, average of 332 days) and weight (W, average of 830 lb) on test; and harvest (S) and ultrasound (U) carcass measures at mid-test (fat thickness, rib eye area, and intra-muscular fat %). All models included contemporary groups (days on feed – pen number – year) and A and W as covariates (usual model)

except for the model with no covariates.

Results

Estimates of heritability and genetic and residual variances for AFI are in Table 1. Adjusting for carcass traits reduced estimates of genetic variation by about one-half with a small increase in estimates of residual variation. The result was smaller estimates of heritability. Correction for more fixed factors usually reduces residual variation and increases heritability. The carcass covariates, however, contain both genetic and residual components. Adjustment for such covariates removes the effects of genes affecting both the carcass traits and feed intake. Only other genes affecting FI but not the carcass traits contribute to genetic variation of FI after adjustment for the carcass traits.

The pattern was the same for carcass traits measured at harvest and by ultrasound at mid-test. These results mean that either traditional measures at harvest or ultrasound measures can be used to adjust AFI, with ultrasound measurements being easier and less expensive to obtain.

Adjusting for ADG reduced estimates of residual variation by about two-thirds with little effect on the estimate of genetic variation, resulting in a larger estimate of heritability. This result implies adjustment was

(Continued on next page)

mainly for the residual component of ADG and not the genetic component, because for this data set the estimate of heritability for ADG was near zero (usually not so small). Adjusting for ADG and carcass traits reduced estimates of both genetic and residual variation by about 50%. This result combines the effects of adjusting separately for ADG and for carcass traits.

Usually adding more fixed factors, such as age or sex, to a model reduces residual variation, but ADG and the carcass measures all have genetic and residual components. The genetic and residual correlations with AFI and RFI probably explain reductions (or lack of) in estimates of genetic and residual variation for AFI and RFI. That explanation has not been tested. If the necessary records are available, instead of adjusting feed intake to constant ADG, fat depth, rib eye area and marbling, a more satisfactory approach to obtain an economic EBV or EPD would be to use multiple trait analyses (adjusting for contemporary groups and age and weight on test) to obtain EPD for the 5 (or more) traits and weight them by their net economic values.

Estimates of heritability and genetic and residual variances for RFI are in Table 2. All models included effects of pen. Adjusting for either harvest or ultrasound carcass measures reduced estimates of genetic variation by about 40%, and increased estimates of residual variation by about 50%. The result was a much reduced estimate of heritability. With AFI, the genetic variation decreased but the residual variation did not change. The patterns for AFI and RFI may be different because RFI was adjusted for ADG for the test period using a standard adjustment factor. Further adjusting for ADG from the test data had little effect on estimates of variance components and heritability. Adjusting for ADG and carcass measurements resulted in the same estimates as did adjusting for carcass measurements while ignoring ADG. Heritability for RFI is not much different from the estimate of heritability for AFI when

Table 2. Estimates of variance components and heritability after adjustment for factors affecting residual feed intake (RFI, lb).

Factors	Variation			
	Held Constant	Heritability	Genetic	Residual
None		0.61	1.07	0.67
A, W on test ¹		0.60	1.03	0.69
A, W, Carcass (end of test) ²		0.37	0.59	1.01
A, W, Ultrasound (mid-test) ³		0.40	0.64	0.97
A, W, ADG		0.60	1.04	0.68
A, W, ADG, Carcass measures		0.37	0.59	1.01
A, W, ADG, Ultrasound measures		0.40	0.64	0.97

¹A = age on test; W = weight on test.

²Carcass traits measured at harvest: fat depth, rib eye area, marbling score.

³Ultrasound carcass traits measured at mid-test: fat depth, rib eye area, intramuscular fat.

Table 3. Regression coefficients* to adjust average feed intake (AFI, lb) to constant age (days) and weight (lb) on test, average daily gain (lb), carcass measurements at slaughter (fat depth, in; rib eye area, in²; and marbling score), and carcass measurements by ultrasound (fat depth, rib eye area, intramuscular fat score) at mid-test.

Model	Age	Weight	ADG	S-fat ^a	S-rea ^b	S-mar ^c	U-fat ^d	U-rea ^e	U-imf ^f
1	-0.015*	0.012*	—	—	—	—	—	—	—
2	-0.018*	0.008*	—	2.162*	0.004*	0.157	—	—	—
3	-0.018*	0.009*	—	—	—	—	3.330*	0.001	0.077
4	-0.004	0.011*	2.272*	—	—	—	—	—	—
5	-0.007	0.010*	2.231*	0.831*	-0.002	0.121	—	—	—
6	-0.009	0.010*	2.230*	—	—	—	1.717*	-0.002*	0.104

^aS-fat = carcass fat depth.

^bS-rea = carcass ribeye area.

^cS-mar = carcass marbling score.

^dU-fat = fat thickness measured by ultrasound.

^eU-rea = ribeye area measured by ultrasound.

^fU-imf = intramuscular fat measured by ultrasound.

*Significant ($P < 0.05$)

Table 4. Regression coefficients* to adjust residual feed intake (RFI, lb) to constant age (days) and weight on test (lb), average daily gain (lb), carcass measurements at slaughter (fat depth, in; rib eye area, in²; and marbling score), and carcass measurements by ultrasound (fat depth, rib eye area, intramuscular fat score) at mid-test.

Model	Age	Weight	ADG	S-fat ^a	S-rea ^b	S-mar ^c	U-fat ^d	U-rea ^e	U-imf ^f
1	-0.004	0.003*	—	—	—	—	—	—	—
2	-0.007	0.002	—	0.699*	-0.002*	0.132	—	—	—
3	-0.009	0.002	—	—	—	—	0.132*	-0.023*	0.097
4	-0.004	0.003*	-0.038	—	—	—	—	—	—
5	-0.007	0.002	-0.068	0.737*	-0.002	0.132	—	—	—
6	-0.009	0.002	-0.063	—	—	—	0.143*	-0.003*	0.097

^aS-fat = carcass fat depth.

^bS-rea = carcass ribeye area.

^cS-mar = carcass marbling score.

^dU-fat = fat thickness measured by ultrasound.

^eU-rea = ribeye area measured by ultrasound.

^fU-imf = intramuscular fat measured by ultrasound.

* Significant ($P < 0.05$)

records are adjusted to a constant ADG. The large estimates of heritability for AFI and RFI while holding ADG constant indicate selection on EPD for AFI or RFI would be effective if FI records were available.

Table 3 contains coefficients for the regression of AFI on covariates such as age on test; for example, a change of one inch in fat depth at harvest is expected to increase AFI by about two pounds. The most important factor associated with AFI was ADG. A one lb increase in ADG is expected to increase AFI by about 2.25 lb. As expected, age and weight on test had significant effects on AFI; younger animals have lower average intakes and heavier animals have greater average

intakes. Fat depth had a significant association with feed intake – more fat requires more feed. The expected increase in AFI from a one-inch change in fat depth at harvest (2.16 lb) was less than that expected from a one-inch change in ultrasound fat depth (3.33 lb). The difference may be due to the ultrasound measurements being taken an average of 44 days earlier. Marbling score and intramuscular fat were not significantly associated with AFI, although the regression coefficients suggested that increases in marbling or IMF might be associated with increased AFI.

Table 4 contains coefficients for the regression of RFI on the same covariates used in models for AFI. Fat depth

and rib eye area (either at harvest or by ultrasound prior to harvest) were significantly associated with RFI. As with AFI, rather than adjusting RFI to a constant basis for fat depth and rib eye area, EPD (or EBV) for fat depth and rib eye area should be included in an economic EPD along with EPD for RFI and ADG and other economically important traits.

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Genetic and Phenotypic Parameter Estimates for Feed Intake and Other Traits in Growing Beef Cattle

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Summary

The goal of this study was to estimate genetic and phenotypic parameters for growth, feed intake, feed efficiency, and temperament traits in a mixed-breed composite population of growing beef cattle. Intake and gain:feed (G:F) were moderately heritable; however, residual feed intake (RFI) was more heritable than other measures of feed efficiency. Adjusting RFI and G:F for carcass fatness had little effect on heritability and correlations with remaining traits. Flight speed was moderately heritable and highly repeatable. Flight speed was not highly correlated with measures of intake or feed efficiency. Some small breed effects were observed. High heritability estimates indicate that selection for or against specific intake and feed efficiency traits may be successful. Flight speed may be useful in selection as an indicator of temperament, but does not appear to be a useful indicator of feed efficiency.

Introduction

Approximately two-thirds of the cost of beef cattle production is attributed to the cost of feed; however, less than 20 percent of nutrients consumed are converted into usable product. Thus, the genetic component of feed utilization in beef cattle has been an area of interest.

Traits that support efficient use of grazed forages may be biologically different from those that support efficient use of harvested feeds. Therefore, biological efficiency of beef production is separated into two very distinct systems: a cow-calf system and post-weaning calf growth system.

Better understanding of the genetic variation of feed requirements may enable selection of more efficient animals.

In conjunction with studying feed intake and efficiency of feed utilization, emphasis also has been placed on the study of cattle temperament. Research indicates temperament may be useful in genetic evaluations as an indicator trait for economically relevant traits, such as feed efficiency, or it may have direct economic value. The objectives of this research were to estimate genetic and phenotypic parameters for growth, feed intake, feed efficiency, and temperament traits in a mixed-breed composite population of growing beef cattle.

Procedure

Steers (n = 998) were born from 2003 to 2006 at the U.S. Meat Animal Research Center, Clay Center, Neb., and were produced by randomly mating F1-cross sires to straight-bred and F1 females. Seven breeds were represented in various percentages, and these breed percentages varied across animals. Breeds represented were: Hereford, Angus, Simmental, Charolais, Limousin, Gelbvieh, Red Angus, and MARC III (¼ Hereford, ¼ Angus, ¼ Pinzgauer, ¼ Red Poll). Either Hereford or Angus or both were a fraction of each steer. Spring-born steers were weaned at an average age of 165 days, received a series of lower energy diets through the fall, were assigned randomly to pen in December of each year, and then relocated to the feeding facility where individual feed intake measurements of calves in a pen environment were taken using the Calan Broadbent Feeding System. Daily feed provided to each animal was recorded. Feed was delivered to the steers each morning at 0800 hr and feed refusals were collected once per week.

Table 1. Composition of finishing diet.

Ingredient	% Diet (DM)
DRC	82.668
Alfalfa	10.602
SBM	5.663
Limestone	0.574
Urea	0.401
Salt	0.062
Rumensin	0.015
Vitamin A, D, E supp	0.008
Trace mineral supp	0.007

Steers were on feed for an average of 140 days. Weights were collected two consecutive days at the beginning and end of the experiment each year, with interim weights taken every four weeks. Each year steers were serially slaughtered in four groups. Because steers varied in time on feed and data collection, final body weight, cumulative feed intake, backfat, and marbling were adjusted to the average time on feed. The composition of the finishing diet is given in Table 1.

Performance traits analyzed were ADG, DMI, mid-period body weight (MBW), residual feed intake (RFI, determined from DMI adjusted for MBW and ADG), adjusted residual feed intake (RFI_{adj}, adjusted for carcass fatness), gain:feed (G:F), and adjusted gain:feed (G:F_{adj}, adjusted for carcass fatness; G:F is a common measure of feed efficiency [output/input]). Flight speed (FS) data were collected at least twice (separated by ~60 days) as an indicator trait for temperament. Each steer was released from a scale and traveled around a working chute before crossing the first set of electric eyes. The second set of electric eyes was placed 14.2 feet from the first set of electric eyes. Breaking the light beam at each set of electric eyes initiated the start and then the end of the time measurement, and 14.2 feet divided by time provided flight speed in ft/sec. Table 2 provides descriptive statistics for traits measured.

Restricted Maximum Likelihood

Table 2. Descriptive statistics for traits¹.

Variable	Mean	SD	CV
ADG, lb	3.48	0.51	15
MBW, lb	1,036	109	11
DMI, total lb	2,781	353	13
RFI, lb	0.48	206	7 ²
G:F	0.18	0.05	12
FS, ft/s	8.63	3.12	36

¹MBW = mid-period body weight; RFI = residual feed intake; G:F = gain:feed; FS = flight speed.

²Relative to the mean for DMI.

Table 3. Estimates of heritabilities¹ and genetic² and phenotypic³ correlations for traits⁴.

	ADG	MBW	DMI	RFI	GF	FS
ADG	0.22 (0.08)	0.50 (0.17)	0.51 (0.16)	-0.16 (0.20)	0.48 (0.18)	0.09 (0.09)
MBW	0.45 (0.03)	0.48 (0.10)	0.69 (0.10)	-0.18 (0.17)	-0.33 (0.18)	-0.33 (0.16)
DMI	0.66 (0.02)	0.74 (0.02)	0.32 (0.09)	0.52 (0.13)	-0.53 (0.18)	-0.22 (0.18)
RFI	0.00 (0.04)	0.04 (0.04)	0.59 (0.02)	0.46 (0.10)	-0.70 (0.11)	-0.13 (0.17)
G:F	0.55 (0.02)	-0.22 (0.04)	-0.25 (0.03)	-0.63 (0.02)	0.36 (0.10)	0.3 (0.18)
FS	-0.06 (0.03)	-0.35 (0.03)	-0.05 (0.01)	-0.00 (0.00)	0.00 (0.00)	0.30 (0.07)

¹Heritability estimates are on the diagonal (\pm standard error, below).

²Genetic correlation coefficients are above the diagonal (\pm standard error, below).

³Phenotypic correlation coefficients are below the diagonal (\pm standard error, below).

⁴See Table 2 for trait definitions.

methods were used in univariate and bivariate models that accounted for the fixed effects of year, season (FS only), pen size (some pens held 4 steers and others held 8), age at weaning, breed heterozygosity (expected to be proportional to expressed heterosis), and fraction of each breed; random effects were animal genetic, pen nested within pen size, permanent environmental (FS only), and residual.

Results

Adjusting for carcass fatness had little effect on the heritability estimates of RFI and G:F, as well as phenotypic and genotypic correlations with remaining traits; therefore, only the non-adjusted trait is presented and discussed. Table 3 provides heritability and correlation estimates for all traits. Average daily gain was lowly heritable (0.22); whereas MBW was more highly heritable (0.48), with DMI being intermediate (0.32).

As expected, strong positive genetic (r_g) and phenotypic (r_p) correlations between ADG and MBW were found ($r_g = 0.50$ and $r_p = 0.45$). Furthermore, strong positive correlations were found between ADG and DMI ($r_g = 0.51$ and $r_p = 0.66$). Mid-period body weight also was highly correlated with DMI ($r_g = 0.69$ and $r_p = 0.74$).

As expected, no phenotypic correlation between RFI and ADG was found ($r_p = 0.0$). Likewise, RFI was phenotypically independent of MBW ($r_p = 0.04$). Feed intake was highly correlated with RFI ($r_g = 0.52$ and $r_p = 0.59$), also as expected. Conversely, G:F was highly correlated with component trait ADG ($r_g = 0.48$ and $r_p = 0.55$). Low to moderate negative correlations between G:F and MBW, as well as G:F and DMI, were found ($r_g = -0.33$ and $r_p = -0.22$; $r_g = -0.53$ and $r_p = -0.25$, respectively). Flight speed was moderately heritable (0.30) and highly repeatable (0.63), which indicates that taking multiple mea-

surements may not be necessary, and one measurement midtest may be adequate. Despite this, FS was not highly correlated with measures of feed intake and efficiency.

In general, breed differences were small; still, some breed effects were observed. A steer with a greater fraction of a specific breed will exhibit a greater “breed effect” for that specified breed. The Limousin breed effect was greater than average for ADG ($P < 0.05$), and also gave higher G:F ($P < 0.01$), indicating this breed was more efficient than others included in the evaluation. The Simmental breed effect produced steers that were heavier ($P < 0.05$) at mid-test and had a lower G:F ($P < 0.01$). The Angus breed effect influenced steers to consume more ($P < 0.1$) throughout the trial, and Angus had higher RFI ($P < 0.1$). This suggests that the Angus breed effect contributes to less efficient feed utilization than other breeds evaluated. Finally, the Hereford effect on steers was to produce slower FS ($P < 0.01$), suggesting a docile temperament. Breed heterozygosity, and thus heterosis, was not an important source of variation for any of the body weight and gain measures or any of the feed intake and efficiency measures, as expected due to the moderate heritability estimates for these traits.

Heritability estimates obtained from these data are greater than some found in previous literature, likely due in part to the larger range of genetic variation of the breeds included in this population of cattle and the many breed combinations. Higher heritability estimates indicate that selection for or against specific intake and feed efficiency traits would be successful in production of more efficient animals. Flight speed is not recommended as a selection tool for intake or feed efficiency traits, but it may be a useful indicator of temperament.

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Plant and Animal Responses to Grazing Systems in the Nebraska Sandhills

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Summary

Short duration grazing (SDG) and deferred rotation (DR) were compared in a 10-year study conducted on upland native pastures in the northern Nebraska Sandhills. Herbage production of cool-season grasses and sedges was less on the SDG pastures, although total herbage production (including warm and cool season herbage) did not differ consistently between the two grazing systems. The decline in diet quality (CP and IVOMD) through the 5-month grazing season did not differ consistently between the two systems, and ADG of spayed heifers was similar. The lack of increased forage production and animal performance responses to SDG indicate that the higher input costs associated with SDG are not justified in the Nebraska Sandhills.

Introduction

Two common grazing systems used in the Nebraska Sandhills are short duration grazing (SDG) and deferred rotation (DR). Claims have been made that SDG systems can enhance range condition and livestock diet quality, distribution, and performance compared to less intensive forms of grazing systems. A DR system is less intensive and was developed to enhance range condition through increased plant vigor and reproduction by deferring grazing in one pasture of a multiple-pasture system until the dormant season. The objective of this study was to compare herbage standing crop, diet quality, and weight gain of grazing cattle in these two systems in order to determine if the implementation of a more intensive grazing

system is beneficial to producers in the region.

Procedure

The study was conducted on upland range at the University of Nebraska Barta Brothers Ranch in the northeastern Nebraska Sandhills near Ainsworth, Neb. The study was initiated in 1999 with establishment of 2 replications of an 8-pasture SDG system and a 4-pasture DR system. Each system was grazed annually (1999 through 2008) by cow-calf pairs from 15 May to 15 October. Average pasture size was 115 acres. Stocking rates were adjusted each year based on precipitation and herbage availability, but stocking rate remained similar throughout the study on all systems at about 0.73 AUM/acre. The SDG systems were grazed in 3 cycles with 2-day occupations in the first cycle and 6- to 11-day occupations in the second and third cycles. Each pasture in the DR system was grazed only once during the growing season, and the pasture grazed last in the grazing sequence was deferred until September 1. Grazing periods lasted for 30 to 45 days. Timing of grazing changed annually for each pasture in the two grazing systems. A pasture was grazed one or two grazing periods earlier with each successive year, except for a pasture in the first grazing period that was moved to the last grazing period in the next year.

Standing crop was estimated by clipping in 240 grazing exclosures (16 ft²) distributed through six pastures of each treatment. The exclosures were moved to a new location in May of each year. All standing vegetation was clipped to ground level in a 2.8 ft² quadrat placed in each of the exclosures in mid-June and mid-August of each year. The mid-June and mid-August harvests represent peak standing crop of cool-season grasses and sedges and warm-season

grasses, respectively.

Esophageally fistulated cows were used to collect diet samples throughout the grazing seasons of 2005 and 2006. Collection sites of about 5 acres were selected in each of the 14 pastures that were sampled. All DR pastures were sampled and three pastures in each SDG replication were sampled each year. Diet samples were collected at the mid-point of each grazing period in each DR pasture. Samples were collected 1 to 2 days before and after each grazing period in the second and third cycle of each designated SDG pasture. Diet samples were frozen immediately following collection, freeze-dried, and ground through a Wiley Mill using a 1 mm screen. Samples were composited by pasture and analyzed for NDF, CP, and *in vitro* organic matter digestibility (IVOMD).

Twenty spayed heifers replaced 10 pairs in each of the four herds in 2006, 2007, and 2008. Individual body weights of the spayed heifers were recorded at the beginning and end of each grazing season.

Experimental unit was the individual grazing system. For diet quality data (IVOMD, CP, NDF), the PROC REG procedure of SAS was used to evaluate linear and quadratic relationships between quality characteristics and collection dates. This analysis was conducted within year and grazing system. The PROC MIXED and PROC REG procedures of SAS were then used to test year and grazing system effects on regression coefficients, and to test for year and grazing system effects for grazing period.

Results

Standing crop of cool-season grasses and sedges was 12 to 19% lower on SDG pastures than DR pastures in mid-June and mid-August (Table 1). Yields of the other live portions of the standing crop did not differ between the two grazing systems. In mid-June,

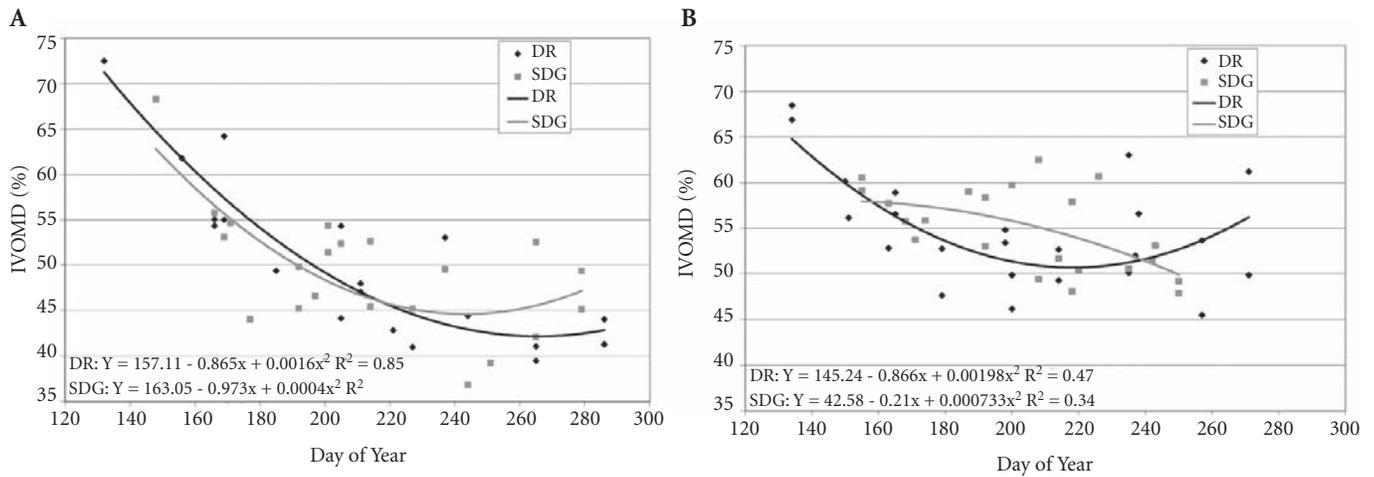


Figure 1. IVOMD of diet samples from DR (deferred rotation) and SDG (short duration grazing) pastures in 2005 (A) and 2006 (B).

Table 1. Mean herbage yields (lb/acre; SE) in June and August from 2000-2008.

Grazing System	Warm-Season Grasses	Cool-Season Graminoids	Forbs	Shrubs	Cactus	Litter and Standing Dead	Total Live
June							
DR ¹	286 (13)	590 (36) ^a	126 (15)	129 (15)	22 (8)	613 (42)	1154 (39) ^a
SDG ²	284 (8)	517 (23) ^b	112 (10)	123 (10)	24 (5)	612 (28)	1061 (26) ^b
August							
DR	629 (31)	619 (39) ^a	240 (24)	152 (20)	22 (5)	474 (32) ^b	1664 (63)
SDG	642 (21)	503 (26) ^b	238 (16)	162 (12)	22 (4)	551 (21) ^a	1570 (41)

^{a,b}Herbage means within column and month with a different superscript differ ($P < 0.1$).

¹DR = deferred rotation.

²SDG = short duration grazing.

total live standing crop of SDG pastures was 8% lower than that of DR, but there was no difference in mid-August. All SDG pastures were grazed in the first cycle during the last half of May of each year, while only one of the four DR pastures was grazed in late May and early June. The annual grazing of SDG pastures in May might have been the cause of the relatively low yields of cool-season graminoids.

Crude protein content of diets declined through the growing season of

both years but did not differ between SDG and DR. The IVOMD of diets declined at similar rates for the two systems in 2005, but rate of decline was greater for DR in 2006 (Figure 1). Weight gain of spayed heifers did not differ between the two treatments. Average daily gain (ADG) over treatments and years was 1.88 lb/head/day. The ADG varied by year ($P < 0.1$), with the highest average ADG (2.04 lb/head/day) in 2007.

When compared to DR, SDG has

been hypothesized to provide a more consistent supply of high quality forage through the growing season, resulting in greater animal performance. The assumption has been that the increased stocking density and multiple rotations through the pastures associated with SDG will result in more even use of forage and will maintain the pasture forage in a more palatable and productive state. Short duration grazing can require more fencing and livestock water development and can be more labor and management intensive. Overall, the lack of increased forage production and animal performance responses to SDG in this study indicate that the higher input costs associated with SDG are not justified in the Nebraska Sandhills.

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Supplementing Modified Wet Distillers Grains with Solubles to Long Yearling Steers Grazing Native Range

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Summary

Modified wet distillers grains with solubles (MDGS) was supplemented on the ground to yearling steers with access to native range during summer grazing. Supplemented steers had greater ADG than non-supplemented steers and were heavier entering the feedlot. NRC energy equations determined that 1.0 lb supplementation of MDGS replaced 0.74 lb forage during summer grazing. Additionally, these data suggest response to MDGS may exceed response to dried distillers grains with solubles (DDGS) for gain during grazing, based on previous experiments.

Introduction

Efficiency of gain has traditionally favored the calf-fed system over the yearling production system (2009 Nebraska Beef Report, pp. 37-39). Co-products of the corn dry milling industry fit well into forage production systems, because distillers grains provide a highly fermentable fiber source that does not negatively impact forage digestion (2004 Nebraska Beef Report, pp. 22-24), and they supply additional undegraded intake protein (UIP) to meet metabolizable protein deficiencies common to young cattle grazing forage.

The yearling system capitalizes on use of the animal to harvest forage, as opposed to the calf-fed system that requires additional harvesting costs associated with any forages utilized. The yearling production system is further segregated into short or long yearlings. Short yearlings are received in the fall, backgrounded during the

winter, then returned to the feedlot in the spring; long yearlings are received in the fall and backgrounded through the following fall, at which time they re-enter the feedlot. The objective of the current research was to determine effects of supplementing modified wet distillers grains with solubles (MDGS) on the ground to long yearling steers grazing native Sandhills range.

Procedure

In 2008, 240 long yearling steers (BW = 504 ± 35 lb) were backgrounded on cornstalk residue from late fall to mid-spring (144 days). While grazing cornstalks, calves were supplemented 5.0 lb/steer daily of wet corn gluten feed. Following backgrounding, steers were allowed to graze smooth brome grass pastures for 21 days. After grazing smooth brome grass, calves were weighed, stratified by BW, assigned randomly to summer grazing treatments, and relocated to graze Sandhills range at the University of Nebraska Barta Brothers Ranch. Summer grazing treatments included grazing native range with no supplementation (CON) and grazing native range with MDGS supplementation at 0.6% BW (SUPP). Weights were projected for summer grazing treatment assignment to account for weight gain. MDGS was fed daily on the ground with a tractor and feed wagon, allowing for steers to be distributed to different locations within each pasture at

the time of feeding. Steers grazed Sandhills range for 135 days before entering the feedlot on Sept. 24. Steers were limit fed at 1.8% BW (DM basis) for 5 days; initial and final BW for summer were the means of weights taken on 2 consecutive days.

Data were analyzed using the MIXED Procedure of SAS (SAS Inst. Inc.) as a completely randomized design; feedlot pen was the experimental unit. Summer grazing treatment was considered a fixed effect, with animal nested within summer grazing treatment and residual as random effects. Because there were different numbers of cattle in each treatment, the weight option was used.

Results

Table 1 provides descriptive statistics for the current experiment. At the time of summer treatment assignment, BW was not different between SUPP and CON steers ($P = 0.47$); however SUPP steers had 0.84 lb greater ($P < 0.01$) ADG during summer grazing than CON steers. Consequently, SUPP steers were 116 lb heavier ($P < 0.01$) than CON steers at feedlot entry. Using these summer performance data, *in vitro* dry matter digestibility (IVDMD) of the native Sandhills range from the two previous years, and NRC energy equations, it was determined that 0.74 lb grass was saved for every 1.0 lb MDGS fed (DM basis). Also, based on visual appraisal,

Table 1. Effect of supplementing modified wet distillers grains during summer grazing on performance of long yearling steers.

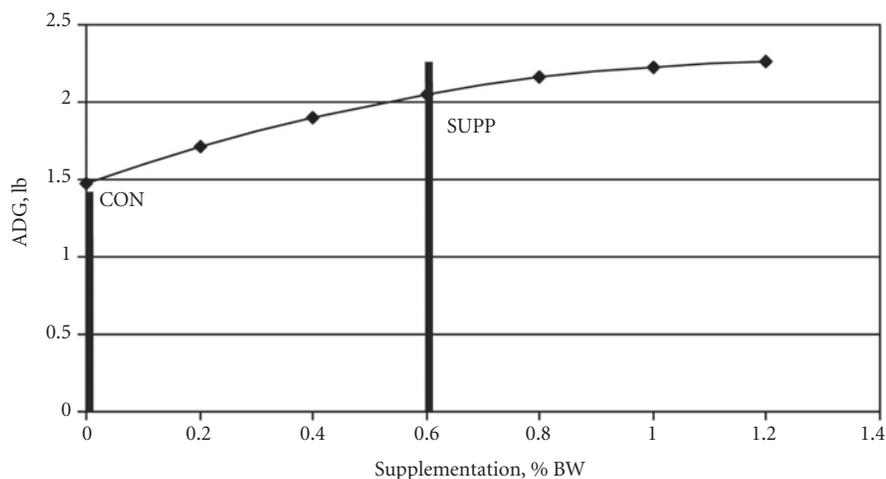
Item	CON	SUPP	P-value
Initial BW ¹ , lb	506	504	0.801
Spring BW ² , lb	730	735	0.539
Feedlot BW ³ , lb	915	1030	<0.001
Summer ADG ⁴ , lb	1.36	2.20	<0.001

¹Initial BW = weight taken during first fall.

²Spring BW = weight taken after grazing corn stalks.

³Feedlot BW = weight taken after grazing summer pastures.

⁴Summer ADG = gain attained when grazing summer pastures.



¹ — = response to gain from current trial with MDGS.
² —◆ = quadratic response to gain from previous research with DDGS.

Figure 1. Effect of supplementing modified wet distillers grains during summer grazing¹ on ADG compared to meta-analysis².

feeding MDGS on the ground did not have a negative impact on native range.

Additionally, a meta-analysis of 12 pasture grazing experiments (2009 *Nebraska Beef Report*, pp. 37-39), in which dried distillers grains with solubles (DDGS) was fed in a bunk, found a quadratic response to DDGS

for ADG ($y = -0.0124x^2 + 0.1866x + 1.507$; Linear < 0.01; Quadratic = 0.17). Figure 1 shows the meta-analysis quadratic response to DDGS for gain with the ADG for CON and SUPP steers from the current experiment, to illustrate the relative difference between the two trials. These data suggest response to MDGS may

exceed response to DDGS for ADG during grazing.

It is important to note these results are based on one year of data; however, the experiment will be replicated over the next two years to provide additional power. It can be concluded after one year, however, that supplementing MDGS on the ground at 0.6% BW (DM basis) to long yearling steers grazing native range increased ADG during summer grazing.

A simple economic analysis was conducted on data from cattle performance. The MDGS was priced at \$0.07/lb of dry matter and \$0.10/animal was charged daily for feeding the MDGS (above routine animal care). The grass saved (0.74 lb/lb MDGS) was priced at \$0.04/lb (\$27/AUM). Based on these prices, the cost of gain for the additional 116 lb gained by supplementing MDGS was \$0.35/lb.

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Supplementing Dried Distillers Grains to Steers Grazing Cool Season Meadow

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Summary

Two experiments evaluated the performance response of supplementing dried distillers grains plus solubles (DDGS) to steers grazing cool season meadow. Steers were supplemented 0.0 or 0.6% of BW in Exp. 1, and 0.0, 0.6, or 1.2% of BW in Exp. 2. In Exp. 1, supplemented steers had 0.13 lb/day greater ADG. In Exp. 2, there was a linear response to supplementation level, with steers supplemented 1.2% of BW having greatest ADG. Diet samples indicate the differences were due to increased energy and not increased protein intake.

Introduction

Supplementation with dried distillers grains plus solubles (DDGS) has been well studied in grazing programs using native warm season pastures and cool season monocultures. DDGS is high in protein (30 to 33% CP), undegradable protein (65 to 70% of the CP), and energy. Supplementation of protein and energy in grazing programs has led to a cost effective increase in ADG leading to heavier cattle after the grazing season. The objectives of these two studies were to determine 1) the effect of supplementing DDGS to steers grazing cool season-dominated Sandhills meadow and 2) whether or not the response is due to increased metabolizable protein or energy intake.

Procedure

Experiment 1

Twenty-eight spring-born steer calves (640 ± 48 lb) located at the Gudmundsen Sandhills Laboratory (Whitman, Neb.) were used in a grazing study to determine effects of supplemental DDGS while grazing sub-irrigated meadow dominated by cool season grasses. Prior to trial initiation, steers were limit fed meadow hay at 2% of BW for 5 days and weighed on 3 consecutive days to determine initial BW. Steers were stratified by initial BW and assigned randomly to 1 of 2 treatments: unsupplemented or supplemented 0.6% of BW during the summer grazing season. Steers were allowed to graze 92 days and were managed as one group during the summer grazing period. The amount of DDGS supplemented per steer was determined by multiplying the initial BW by 0.6% (range = 3.2 to 4.4 lb of DDGS/steer). Supplementation was offered to each steer 6 days/week. Steers receiving DDGS were individually penned each morning (0700 hr) and not turned out until DDGS was consumed (approximately 1 hour). Each day of supplementation, unsupplemented steers were penned as a group and not allowed to graze until supplemented steers had consumed all of their DDGS. At the end of the grazing period, steers were limit fed meadow hay 5 days at 2% of BW. After limit feeding, steer BWs were collected on 3 consecutive days to determine final grazing BW.

Experiment 2

Forty-eight spring-born steer calves (617 ± 48 lb) located at the Gudmundsen Sandhills Laboratory were used in a grazing study to determine the effect of supplemental DDGS at two different levels while grazing sub-irrigated meadow domi-

nated by cool season grasses. Prior to trial initiation, steers were limit fed meadow hay at 2% of BW for 5 days and weighed on 3 consecutive days to determine initial BW. Steers were stratified by initial BW and assigned randomly to 1 of 3 treatments: unsupplemented, low supplementation level (0.6% of BW), or high level of supplementation (1.2% of BW). Steers were allowed to graze 91 days, and during the summer grazing period steers were managed as one group. Amount of DDGS supplemented per steer was determined by multiplying the initial BW by 0.6% (range = 3.0 to 4.5 lb of DDGS/steer) or 1.2% (range = 6.1 to 8.5 lb of DDGS/steer) and delivered to each steer 6 days/week. Steers receiving DDGS were individually penned each morning (0700 hr) and not turned out until DDGS was consumed. Each day of supplementation, unsupplemented steers were penned as a group and not allowed to graze until supplemented steers had consumed all of their DDGS. At the end of the grazing period steers were limit fed meadow hay 5 days at 2% of BW. After limit feeding, steer BWs were collected on 3 consecutive days to determine final grazing BW.

In both experiments, steers were shipped to North Platte, Neb. (West Central Research and Extension Center) and finished in the feedlot. Final BW for steers at harvest was calculated using a carcass weight divided by a 63% dressing percentage.

During the grazing period, diet samples were collected weekly using 4 esophageally cannulated cows. Diet samples were analyzed for TDN (IVDMD), NDF (Ankom fiber analyzer), CP (Leco nitrogen analyzer), and undegradable protein (*in situ*) (Table 1). These data, along with average steer BW for the grazing period and measured steer performance, were used to determine animal intake and metabolizable protein balance using the 1996 NRC model.

Table 1. Nutrient analysis for cool season dominated meadow¹.

Item	Exp. 1 ²	Exp. 2 ³
TDN, %	63.1	58.7
CP, %	13.0	11.6
Undegradable protein, % of CP	11.1	10.3
NDF, %	64.6	65.8

¹Nutrient profile for both experiments is the average of each variable for the entire grazing season.

²Reported nutrient value is the average of 62 samples taken over 14 weeks.

³Reported nutrient value is the average of 50 samples taken over 13 weeks.

Table 2. Results from experiment 1.

Item	Control	Supplemented ¹	SEM	P-value
Grazing Performance				
Initial BW, lb	639	640	13	0.94
Final grazing BW, lb	818	831	14	0.52
Grazing ADG, lb/day	1.94	2.07	0.06	0.16
Feedlot Performance				
Final BW, lb	1423	1420	26	0.94
Feedlot ADG, lb/day	3.96	3.85	0.12	0.53
Carcass Characteristics				
Carcass weight, lb	897	895	17	0.94
Marbling score ²	596	576	20	0.47
Calculated YG ³	3.12	3.20	0.14	0.69
Fat thickness, in	0.54	0.51	0.04	0.61
Rib eye area, in ²	14.21	13.64	0.21	0.06

¹Calves supplemented at 0.6% of initial BW.

²Marbling score = 500 = small⁰⁰, 600 = modest⁰⁰, etc.

³USDA YG (yield grade) = 2.5 + (2.5*12th rib fat thickness, in) - (0.32*rib eye area, in²) + (0.2*2.5 KPH,%) + (0.0038*carcass weight, lb).

Table 3. Results from experiment 2.

Item	Control	Supplemented ¹		SEM	P-value	
		0.6%	1.2%		Linear	Quadratic
Grazing Performance						
Initial BW, lb	616	622	615	20	0.93	0.67
Final grazing BW, lb	794	828	852	14	< 0.01	0.79
Grazing ADG, lb/day	1.96	2.27	2.61	0.09	< 0.01	0.85
Feedlot Performance						
Final BW, lb	1422	1461	1521	21	0.02	0.79
Feedlot ADG, lb/day	4.08	4.11	4.34	0.16	0.19	0.60
Carcass Characteristics						
Carcass weight, lb	896	920	958	21	0.02	0.79
Marbling score ²	655	685	667	22	0.66	0.35
Calculated YG ³	2.67	2.89	2.88	0.17	0.32	0.58
Fat thickness, in	0.43	0.51	0.46	0.04	0.48	0.12
Rib eye area, in ²	14.68	14.97	15.01	0.40	0.51	0.80

¹Calves supplemented as a % of initial BW.

²Marbling score = 500 = small⁰⁰, 600 = modest⁰⁰, etc.

³Calculated YG (yield grade) = 2.5 + (2.5*12th rib fat thickness, in) - (0.32*rib eye area, in²) + (0.2*2.5 KPH,%) + (0.0038*carcass weight, lb).

Both experiments were analyzed using the MIXED procedure of SAS with animal as the experimental unit. Treatment was included in the model statement and significance was deter-

mined when $P \leq 0.05$. Data from Exp. 2 also were analyzed using orthogonal contrasts to determine linear and quadratic effects of supplementation level.

Results

Experiment 1

Initial BW for both treatments was not different ($P = 0.94$; Table 2). Steer ADG was numerically 0.13 lb/day greater ($P = 0.16$) for the summer grazing period; however, BW at the end of the grazing period was not significantly different ($P = 0.52$), even though supplemented steers were 13 lb heavier than unsupplemented steers. When comparing feedlot performance for supplemented and unsupplemented steers, there were no differences in carcass weight, marbling score, calculated yield grade, or fat thickness.

Results from the 1996 NRC model suggest unsupplemented steers consumed 17.9 lb (DM-basis) of forage daily and were 43 g/day (7.7% of the total requirement) deficient in metabolizable protein. However, steers supplemented DDGS consumed excess metabolizable protein (287 g/day) due to supplementation and forage intake.

Experiment 2

Initial BW was not different across the three treatments ($P = 0.91$; Table 3). Steer BW at the end of the grazing period increased linearly ($P < 0.01$) with increasing level of supplementation because of a linear increase in ADG with increased level of supplementation ($P < 0.01$). When comparing feedlot performance for the supplemented and unsupplemented steers, final BW was increased with increased level of supplementation ($P = 0.02$). Interestingly, the increase in final BW observed after finishing was greater than the increase in BW observed after the summer grazing period. After the grazing period, supplemented steers were 34 and 58 lb heavier for low and high DDGS supplementation, respectively, compared to unsupplemented steers. At the end of the finishing period, low and high DDGS-supplemented steers were 39 and 99 lb heavier, respectively, when compared to unsupplemented steers

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because of a linear increase in carcass weight with supplementation level ($P = 0.02$). These results suggest that unsupplemented steers did not exhibit any compensatory gain during the finishing period. When comparing feedlot performance and carcass characteristics, there were no differences in marbling score, calculated yield grade, fat thickness, or rib eye area.

Results from the 1996 NRC model suggest that unsupplemented steers consumed 20.2 lb (DM-basis) of forage daily and were 22 g/day (3.9% of the total requirement) deficient in metabolizable protein when not supplemented. However, steers sup-

plemented DDGS consumed excess metabolizable protein due to supplementation (low = 308 g/day and high = 638 g/day) and forage intake.

Results from both experiments suggest that added gain from supplementation was a result of increased energy intake and not because the diet was meeting a protein deficiency. This is supported by the lack of a significant response to DDGS supplementation in Exp. 1, and because the response in Exp. 2 was linear and not quadratic. In addition, metabolizable protein deficiency calculated by the 1996 NRC model was very small for both experiments and probably

too small to measure. Therefore, results from this study indicate that steers grazing cool season dominated meadow during the summer are not deficient in metabolizable protein.

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Supplementing Dried Distillers Grains to Growing Calves on Smooth Bromegrass Pastures

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Summary

Steers supplemented daily with dried distillers grains with solubles (DDGS) on non-fertilized smooth bromegrass pastures gained 1.9 lb/day compared to 1.46 lb/day for cattle on both fertilized and non-fertilized pastures. The fertilized and supplemented treatments were stocked at equal densities, and the non-fertilized pastures were stocked at 69% the density of the other two treatments. At a lower stocking rate, the non-fertilized pastures showed poorer forage production, but equal cattle performance compared to the fertilized pastures. The supplemented pastures showed slightly decreased forage production compared to the fertilized pastures, but at the same time showed increased cattle performance. Each lb of DDGS replaced about 1 lb of forage. DDGS improved steer and pasture performance when supplemented daily on smooth bromegrass pastures.

Introduction

Dried distillers grains with solubles (DDGS) increased weight gains and decreased forage intake by cattle (2007 Nebraska Beef Report, pp. 10-11). Previous research has estimated DDGS will replace 0.27 to 0.79 lb of forage for every lb supplemented (2007 Nebraska Beef Report, pp. 12-14). Also, grazing cattle supplemented with DDGS will have excess nitrogen in their diet, which will be excreted on the pastures in the form of urea and may replace N fertilizer. The objective of the current experiment was

to measure both cattle and pasture production under different grazing and cattle/pasture supplementation strategies.

Procedure

Forty-five yearling steers (686 ±33 lb) were used in a randomized complete block design to evaluate cattle gain and pasture production with different supplementation and management strategies on smooth bromegrass pastures. Yearling steers were stocked at 4 AUM/acre on pastures fertilized with 80 lb N/acre (FERT) and on non-fertilized pastures supplemented with 0.6% of body weight DDGS (DM) fed daily (SUPP). Non-fertilized pastures (CONT) were stocked at 69% of the FERT and SUPP pastures, or 2.76 AUM/acre. Pasture was the experimental unit and was replicated 3 times. Pastures were grazed from April 24 to Sept. 26, 2008. Through the duration of each cycle and within pasture (block) and treatment, cattle were rotated through 6 paddocks. In cycles 1 and 5, cattle occupancy time was 4 days/paddock. Cattle were moved every 6 days in cycles 2, 3, and 4. Cattle were weighed after each cycle and limit fed for 5 days before initial and final body weights were taken. Weights after each cycle were based on a 4% pencil shrink to account for rumen fill. Diet samples were col-

lected in one paddock/treatment at the mid-point of each cycle utilizing six ruminally fistulated steers. Forage dry matter (DM), crude protein (CP), and *in vitro* dry matter digestibility (IVDMD) were then evaluated. Following the pasture trial, cattle were moved into the feedlot and exposed to a diet of 50% high-moisture corn (HMC), 40% wet corn gluten feed (WCGF), 5% wheat straw, and 5% meal supplement (DM).

Results

Steers on SUPP pastures gained 1.9 lb/day over the entire grazing season, more than either the FERT or CONT cattle ($P < 0.01$; Table 1). FERT cattle gained 1.48 lb/day and CONT cattle gained 1.44 lb/day ($P = 0.6$). Increases in BW for SUPP cattle were probably due to the energy from fat and undegradable intake protein content of the DDGS (2006 Nebraska Beef Report, pp. 27-29). A quadratic response in ADG over time was measured, with the lowest gains in cycle 3 corresponding to lower digestibility of the bromegrass (Figure 1); however, IVDMD did not differ among treatments ($P = 0.25$). Crude protein was highest for FERT pastures in cycle 1 at 23.2%. Crude protein then decreased to 11.8% by cycle 5 for all treatments ($P < 0.01$). Forage production showed a quadratic

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Table 1. Pasture and feedlot performance of steers grazing smooth bromegrass.

	CONT	FERT	SUPP	SEM	P-Value
<i>Pasture Performance</i>					
Days	156	156	156		
Initial BW, lb	69	693	671	8.8	0.07
Final BW, lb	915	924	966	5.8	0.01
ADG, lb	1.44	1.48	1.9	0.07	0.01
<i>Feedlot Performance</i>					
Days	116	116	116		
Final wt, lb	1401	1383	1377	8.6	.65
Marbling	569	571	631	14.6	.04

response for all treatments with peak production reached in cycle 2. The FERT pastures had the greatest forage production per acre overall, while CONT pastures had the least growth, and SUPP pastures were of intermediate production. Because the CONT cattle had 45% more area, forage availability per animal was similar to that of FERT cattle. Based on the NRC model, it was estimated the cattle were consuming 18 lb of DM/day. All pastures were grazed at a similar pressure or to the same height of forage standing crop by the end of the season. Some substitution of forage by the DDGS was evidenced by data showing the SUPP pastures producing less total forage than the FERT pastures while being subjected to the same stocking rate. The SUPP cattle received about 5 lb DDGS (DM) daily. The NRC model estimated that the SUPP cattle replaced about 1 lb of forage intake for every 1 lb of DDGS supplemented. However, measuring or predicting cattle intakes on pastures is difficult.

There were no differences in BW of cattle coming out of the feedlot, although SUPP cattle had higher marbling scores than FERT or CONT cattle ($P = 0.04$; Table 1). Dried distillers grains increased steer and pasture performance when fed daily on smooth bromegrass pastures.

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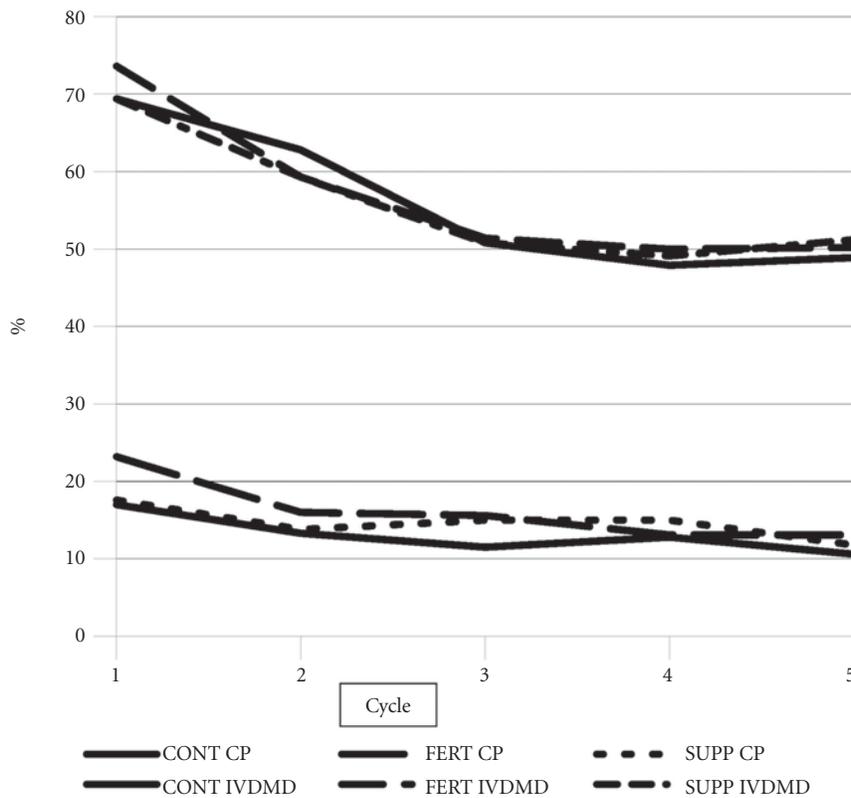


Figure 1. *In vitro* dry matter digestibility (IVDMD) and crude protein (CP) content of smooth bromegrass over time.

Forage Quality and Grazing Performance of Beef Cattle Grazing Brown Midrib Grain Sorghum Residue

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Summary

Two hybrids of grain sorghum, the AWheatland x RTx430 hybrid (CON) and its near isogenic brown midrib counterpart (BMR), were used in a 65-day residue grazing experiment. Grain sorghum was planted in 4 replications for each treatment within the same field, and grazed with 6 steers/replication. Samples of the sorghum residue were collected on days 1, 31, and 60 for neutral detergent fiber (NDF) and *in vitro* NDF digestibility analysis. Steers grazing the BMR treatment gained 1.55 lb/day while the steers grazing the CON treatment gained 1.32 lb/day ($P = 0.14$). The BMR and CON were similar in NDF (73.5%), but *in vitro* NDF digestibility increased by 9.9 percentage units in the leaf portion.

Introduction

The brown midrib (BMR) trait has been successfully incorporated into a number of crop species, including corn, pearl millet, and sudangrass. A crop residue with the BMR trait is more digestible due to the lower lignin content, thus improving cattle performance. Until recently, the BMR trait was not available in grain sorghum; however, it has now been developed. Research conducted at the University of Nebraska (Oliver, et al., 2005 *Crop Science*) indicated grain sorghum with the BMR-12 gene was no different in grain yield and residue neutral detergent fiber (NDF) content than

the common grain sorghum hybrid AWheatland x RTx430, but the BMR trait improved *in vitro* NDF digestibility. A study was designed across two years to determine the impact of the BMR trait on gain of cattle grazing grain sorghum residue, as well as the NDF content and digestibility of residue. Year 1 results already have been reported (2008 *Nebraska Beef Report*, pp. 31-33). Year 2 results and performance for both years are reported here.

Procedure

In year 2, 48 steers (492 ± 50 lb) were stratified by BW and assigned randomly to 5.75-acre paddocks with six steers in each paddock. Four paddocks contained a conventional grain sorghum hybrid, AWheatland x RTx430 (CON), and four contained its near-isogenic BMR counterpart containing the BMR-12 gene. For 5 days, the steers were limit fed at 2% of BW a diet of 25% alfalfa, 25% grass hay, and 50% wet corn gluten feed to minimize variation in gut fill. Following grazing, steers were limit fed the same diet at a projected 2% of BW to equalize gut fill, as well. Steers were weighed for two consecutive days and those weights averaged for both initial and ending BW. Steers grazed for 65 days from Dec. 2, 2008 until Feb. 5, 2009. Throughout the grazing period, the steers were supplemented daily with 2.5 lb of a distillers grain-based supplement containing 93.8% dry distillers grains, 4.7% limestone, 0.8% tallow, 0.1% Rumensin-80 premix, 0.3% beef trace mineral, 0.2% selenium, and 0.1% vitamin premix.

Residue samples were collected on day 1 (Dec. 2, 2008), day 31 (Jan. 4, 2009), and day 60 (Feb. 4, 2009). Samples were taken from one row (3 ft.) in the grazed portions of each paddock and from one row (3 ft.) in

6x4-ft. grazing enclosures in each paddock for comparison of forage quality between grazed and ungrazed residue over time. The enclosures provided a standard for comparison of residue quality change as the residue was grazed.

Residue samples were separated into stem and leaf portions and dried in a 60°C forced air oven. Samples were ground through a 1-mm screen and analyzed for NDF content and *in vitro* NDF digestibility (IVNDFD). The NDF content was determined by refluxing 0.5 g of each sample in NDF solution for 1 hour (0.5 g of sodium sulfite was added to aid in protein removal). The samples were then filtered and dried for 24 hours. IVNDFD was determined using a 30-hour incubation of 0.3 g of sample in a 1:1 mixture of McDougal's buffer (1 g/L urea) and rumen fluid collected from ruminally fistulated steers. Samples were incubated in a water bath at 39°C and swirled every 12 hours. After incubation, the same reflux technique used to determine NDF content was used to determine the remaining NDF, but only 0.3 g of sodium sulfite was used.

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Cary, N.C.) with paddock as the experimental unit. Performance data also were combined across two years with data from the 2008 *Nebraska Beef Report* (pp. 31-33); the interaction between year and treatment was tested, and years were combined when no interaction was observed. Fiber and digestibility data of residue were analyzed as repeated measures with an auto-regressive (AR-1) covariance structure, with paddock as the experimental unit. Samples were analyzed for the effects of treatment, plant part (i.e., leaves and stems), day of grazing, grazed vs. non-grazed, and their interactions.

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Table 1. Effect of grain sorghum hybrid on steer performance grazing grain sorghum residue for 65 days (Year 2).

	CON ¹	BMR ²	SEM	P-value
Initial BW, lb	495	489	2	0.06
Ending BW, lb	575	584	5	0.30
ADG, lb	1.32	1.55	0.10	0.14

¹CON = treatment in which steers grazed conventional grain sorghum hybrid AWheatland x RTx430.

²BMR = treatment in which steers grazed grain sorghum containing the brown midrib gene.

Table 2. Effect of grain sorghum hybrid on steer performance grazing grain sorghum residue across two years for an average of 69 days.¹

	CON ²	BMR ³	SEM	P-value		
				Interaction ⁴	Year ⁵	Hybrid ⁶
Initial BW, lb	530	526	2	0.35	< 0.01	0.19
Ending BW, lb	597	618	4	0.07	< 0.01	< 0.01
ADG, lb	1.03	1.39	0.06	0.20	< 0.01	< 0.01

¹Data from year 1 are presented in 2008 Nebraska Beef Report, pp. 31-33.

²CON = treatment in which steers grazed conventional grain sorghum hybrid AWheatland x RTx430.

³BMR = treatment in which steers grazed grain sorghum containing the brown midrib gene.

⁴P-value for year x hybrid interaction.

⁵P-value for the main effect of year.

⁶P-value for the main effect of sorghum type.

Table 3. Effect of grain sorghum hybrid on leaf and stem quality averaged during grazing (Year 2).

	Leaves			Stems			Interaction
	CON ¹	BMR ²	P-value	CON ¹	BMR ²	P-value	
NDF ³ , %	73.2	73.8	0.56	76.3	77.2	0.37	0.82
IVNDFD ⁴ , %	48.8	58.7	< 0.01	44.8	58.7	< 0.01	< 0.01

¹CON = conventional grain sorghum hybrid AWheatland x RTx430.

²BMR = grain sorghum containing the brown midrib gene.

³NDF = neutral detergent fiber represented as percent of the sample.

⁴IVNDFD = *in vitro* neutral detergent fiber digestibility.

Table 4. Effect of day of grazing on leaf and stem quality averaged across hybrid (Year 2).

Day	1	31	60	SEM	Linear	Quadratic
NDF ¹ , %	73.5	76.1	75.7	0.6	< 0.01	0.04
IVNDFD ² , %	52.6	54.4	51.2	0.9	0.27	0.03

¹NDF = neutral detergent fiber represented as percent of the sample.

²IVNDFD = *in vitro* neutral detergent fiber digestibility.

Results

Steer performance is presented in Table 1. Daily gain tended ($P = 0.14$) to be greater for steers grazing BMR compared to CON. When the data from both years were combined, steers grazing BMR gained more ($P < 0.01$) than steers grazing CON, and no interaction between year and treatment was ob-

served for ADG $P = 0.20$; Table 2).

When the data from both years are combined, final BW was greater ($P < 0.01$) for steers grazing BMR compared to steers grazing CON.

In year 2, the BMR gene caused no significant difference in NDF content of either the leaf or stem portion of the sorghum plant as compared to the CON (Table 3). The NDF content was

73.8% and 73.2% for the BMR and CON leaf portions, respectively, while the stem portions contained 77.2% NDF for the BMR and 76.3% for the CON. There was no significant difference in % NDF between grazed residue and residue in the enclosures.

In year 2, there was no significant difference between grazed residue and residue in the enclosures. *In vitro* NDF digestibility of both stems and leaves was impacted by treatment. Leaves from BMR paddocks were 9.9 percentage units more digestible ($P < 0.01$) than CON paddocks, regardless of whether from grazed or ungrazed areas. Stems from BMR paddocks were approximately 13.9% units greater ($P < 0.01$) in IVNDFD compared to CON paddocks. An interesting observation was that the BMR stems and leaves had the same IVNDFD of 58.7%, suggesting that if stems were palatable, cattle would receive a similar amount of energy from either stems or leaves in BMR grain sorghum residue.

In year 2, a quadratic effect of time was observed for the day of sampling with regard to % NDF and IVNDFD for both BMR and CON groups (Table 4). The values for both NDF and IVNDFD were greater at day 31 than at day 1 or day 60. This could have been due to a combination of weather conditions and selective grazing. However, these changes were relatively small in both NDF and *in vitro* NDF digestibility.

This experiment indicates residue from BMR grain sorghum has greater digestibility of NDF compared to conventional hybrids. This increase in digestibility translates into better ADG when calves graze BMR grain sorghum residue following grain harvest.

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Comparing Ensiled or Fresh Mixed Wet Distillers Grains with Solubles with Straw at Two Inclusions in Growing Calf Diets

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Summary

This study evaluated feeding ensiled or freshly mixed wet distillers grains with solubles (WDGS) with straw at 2 blends and the effect of an inoculum with the ensiled mixture on steer calf performance. Treatments included 30 or 45% WDGS (DM basis) mixed with straw and fed either as a fresh mix or ensiled with and without a microbial inoculum. No significant interactions were observed between type and level of mix. Steers fed the ensiled mixes had higher ADG and lower F:G compared to those fed the fresh mix.

Introduction

Greater DMI and ADG with lower F:G resulted from feeding increased levels of WDGS in straw mixes from ensiled silo bags (2009 Nebraska Beef Report, pp. 30-32). However, these trials could not attribute the improved ADG and F:G to the mixes being ensiled due to differences in DMI. Ensiling with microbial inoculum may improve feed digestibility. The objectives of this experiment were to 1) determine differences in weight gain and feed conversion for feeding WDGS and straw as a fresh mixture or an ensiled mixture; and 2) determine if inoculating the ensiled mixture would enhance performance.

Procedure

A growing trial used 60 individually fed, crossbred steer calves (510 ± 40.1 lb) in a completely random-

ized design. Steers were weighed on 3 consecutive days (day -1, 0, 1) to obtain an initial BW after a 5-day limit feeding period of a 50% ground alfalfa hay and 50% wet corn gluten feed diet at 2.0% of BW. The averaged weights obtained from days -1 and 0 were used to stratify the steers by BW and assign them randomly to treatments.

A 2 x 3 factorial arrangement of dietary treatments was used, including two mixtures of WDGS and straw and three storage types. Ratios were either 30% WDGS with 70% straw or 45% WDGS with 55% straw (DM basis). Three storage types of each mixture were evaluated: mixed fresh every other day, ensiled and stored without microbial inoculum, or ensiled and stored with microbial inoculum. The same source of WDGS was used in the fresh mix and the ensiled mixes. The WDGS used in the fresh mix was put in a bag at the time of ensiling. Therefore, no WDGS composition differences should be due to WDGS storage. The inoculum was applied to provide 500,000 colony forming units (CFU) of *Lactobacillus buchneri* strain 40788 (Lallemand Animal Nutrition North American, Milwaukee, Wis.) per gram of as-is mixture. The ensiled mixtures were stored for 70 days prior to trial initiation and were used throughout the experiment. All of these mixtures were fed at 97.5% of diet DM; 2.5% of the diet DM included a dry supplement formulated to supply steers with 200 mg/steer daily of Rumensin (Elanco Animal Health, Indianapolis, Ind.). Diets were formulated to meet or exceed NRC (1996) requirements for metabolizable protein, degradable intake protein, Ca, and P.

Steers were individually fed using the Calan gate system. Steers were fed *ad libitum* at 0700 hr. Steers

assigned to the ensiled treatments were matched by similar BW to steers fed the fresh mixtures and were fed the same DMI. The respective diets were fed for 84 days. At the end of the experiment, steers were limit fed the same common diet they received at the beginning of the trial for 5 days at 2.0% of BW to limit gut fill effects. Ending BW was obtained on 3 consecutive days.

Feed samples were collected weekly and analyzed for DM at 60°C for 48 hours. Data were analyzed using the MIXED procedures of SAS as a completely randomized design, with steer as the experimental unit.

Results

No interactions ($P \geq 0.10$, Table 1) were observed between ratio of WDGS to straw nor whether the mixes were fed fresh, ensiled without inoculum, or ensiled with inoculum; therefore, only main effects are presented. The higher inclusion of WDGS relative to straw resulted in greater ending BW ($P < 0.01$), ADG, and DMI ($P = 0.05$). By design, DMI was not affected by storage type ($P = 0.99$). Although DMI was kept constant for steers fed mixes with different storage types, increased ($P = 0.02$) ADG and decreased ($P < 0.01$) F:G was observed for ensiling the mixes compared to feeding them fresh. A 4.4% numerical improvement in F:G was observed when the mixes were ensiled with the inoculants; however, this was not a significant difference ($P = 0.46$).

There should not have been any changes in fermentation, because the WDGS fed as a fresh mix with straw was bagged, as was the WDGS in the ensiled mixes. Therefore, improvements in ADG and F:G

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Table 1. Steer performance for WDGS and straw mixes fed fresh or ensiled with or without inoculum.

Performance	WDGS: Straw Mix ¹			Storage Type ²				P-value Inter ³
	30:70	45:55	P-value	Fresh	Ensil-No	Inoc	Ensil-W/Inoc	
Initial BW, lb	509	510	0.97	510	508	511	0.96	0.99
Ending BW, lb	578	613	<0.01	585 ^a	597 ^b	604 ^b	0.43	0.71
DMI, lb/day	9.2	9.7	0.05	9.4	9.5	9.4	0.99	1.0
ADG, lb	0.82	1.22	< 0.01	0.89 ^a	1.07 ^b	1.11 ^b	0.02	0.16
F:G	11.3	8.0	< 0.01	10.7 ^a	9.0 ^b	8.6 ^b	< 0.01	0.10

¹Main effects for WDGS and straw mixtures.

²Main effects for the storage type of mixture fed.

³Interaction for mixture and type.

^{a,b}Means within type of mix effect and the same row without a common superscript differ ($P \leq 0.05$).

suggest changes in composition and/or a digestibility improvement of the straw portion of the mixes. However, an *in vitro* run was conducted to evaluate the digestibility of fresh or ensiled mixes, and no change was observed. The improved cattle performance suggests improved rate

or extent of fiber digestion, perhaps by ensiling of the straw fiber. Feeding ensiled mixes previously showed an improvement in palatability by increased DMI compared to the mixes fed fresh (2009 Nebraska Beef Report, pp. 30-32). These data suggest not only that palatability increases, but

digestion does as well, which increases ADG and decreases F:G.

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Comparing the Energy Value of Wet Distillers Grains to Dry Rolled Corn in High Forage Diets

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Procedure

Sixty crossbred calves (509 ± 30 lb) were utilized in a completely randomized design to compare the energy value of WDGS to DRC in forage-based diets. Treatments were arranged in a 2x3 factorial design: energy source (WDGS and DRC) fed at three levels (LOW, MEDIUM, and HIGH). Calves were stratified by BW, then assigned randomly to treatment. All treatments contained 30% sorghum silage and various levels of grass hay depending on the inclusion level of WDGS or DRC (Table 1). Levels of WDGS were included at 15.0, 25.0, or 35.0% of the diet DM for diets containing WDGS. A feeding value of 130% the energy value of DRC established by Nuttelman et al. (2009) for WDGS in high forage diets was used to determine the inclusion level of DRC so the diets would be isocaloric. Therefore, DRC was included at 22.0, 41.0, or 60.0% of the diet DM for treatments containing DRC. Calves were matched with a calf of similar initial BW within the same level (LOW, MEDIUM, or HIGH) of energy sources to keep intakes identical for DRC and WDGS treatments. Average daily gain was allowed to vary among animals. Soyypass[®] was included in the low and intermediate levels of DRC treatments to meet

or exceed the metabolizable protein (MP) requirements, and urea was included in all diets to meet or exceed the degraded intake protein (DIP) requirements as determined by the NRC (1996) model, to prevent a protein response rather than an energy response between WDGS and DRC.

Steers were individually fed for 84 days using Calan electronic gates. Bunks were evaluated daily. Feed refusals were collected weekly and DM of refused feed was determined. Cattle were limit fed a mixture of 47.5% wet corn gluten feed, 47.5% alfalfa hay, and 5.0% supplement for 5 days prior to and following the feeding period to reduce variation due to gut fill. Calves were consecutively weighed on the final three days of each limit-feeding period, and the average of each three-day weight was used for initial and ending BW.

The NRC (1996) model uses feed intake and net energy content of the diet to predict animal performance. Therefore, if performance and feed intake are known, the energy content of the feed can be determined.

Data were analyzed using the MIXED procedure of SAS. Individual animal was the experimental unit (10/treatment). Interactions between energy source and level were tested.

(Continued on next page)

Summary

Sixty crossbred steers were used to compare the energy value of wet distillers grains (WDGS) to dry rolled corn (DRC) in high forage diets at three levels. DRC was included at 22.0, 41.0, and 60.0% of the diet (DM), and WDGS was included at 15.0, 25.0, and 35.0% of the diet (DM). Diets were formulated to meet degradable intake protein and metabolizable protein requirements. Cattle consuming WDGS gained more than DRC cattle. Average daily gain increased with increasing levels of DRC and WDGS. The energy value of WDGS was calculated using the National Research Council model (1996). In this study, the energy value of WDGS was calculated to be 146, 149, and 142% the energy value of DRC.

Introduction

Previous research indicates WDGS contains 130% the energy value of DRC when fed at 25% of the diet DM in high forage diets (Nuttelman et al., 2009 *Nebraska Beef Report*, p. 28). In light of the findings of Loy et al. (2008, *Journal of Animal Science*, 86:3504), who compared dried distillers grains (DDGS) to DRC, the 30% increased feeding value of WDGS is higher than expected. Nuttelman et al. (2009) reported a 46% improvement in feeding value compared to DDGS when WDGS is fed at 25% of the diet DM. The main objective of the present study was to compare the energy value of WDGS to DRC at increasing levels in forage-based diets.

Table 1. Diet composition, % DM.

Item	WDGS ¹			DRC ¹		
	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
WDGS	15	25.0	35.0	—	—	—
DRC	—	—	—	22.0	41.0	60.0
S.Silage ¹	30	30.0	30.0	30.0	30.0	30.0
Grass hay	52.8	42.8	32.8	42.5	24.6	6.8
Urea	0.8	0.8	0.8	1.0	1.3	1.6
Soyypass [®]	—	—	—	3.0	1.5	—
Supplement ²	1.4	1.4	1.4	1.5	1.6	1.6

¹ WDGS = Wet distillers grains plus solubles; DRC = dry rolled corn; S.Silage = sorghum silage.

² Supplements contained: limestone, urea, salt, trace minerals, and vitamins.

When interactions were not significant, main effects were reported.

Results

There were no type x level interactions ($P > 0.81$). Therefore, only the main effects of energy source and level are presented.

Type of Supplementation

There was no difference for initial or ending BW ($P > 0.13$; Table 2). By design, DMI was similar between treatments ($P = 1.00$). Cattle consuming diets containing WDGS gained 0.21 lb more per day than cattle consuming diets with DRC ($P < 0.01$). Gain efficiency also was improved for cattle consuming WDGS ($P < 0.01$) due to greater ADG and constant DMI.

Level of Supplementation

Initial BW was similar across level ($P = 0.93$; Table 3). Ending BW responded quadratically ($P < 0.01$) with increasing level of energy, with the LOW level being the lightest at the conclusion of the experiment. Dry matter intake was not different among levels ($P = 0.38$). There was a quadratic response for ADG with the MEDIUM and HIGH levels of DRC and WDGS, gaining 0.49 and 0.69 lb more per day, respectively, compared to LOW. Consequently, feed efficiency was improved with increased level of DRC and WDGS ($P < 0.01$).

The NRC (1996) model was used to determine the energy value of WDGS in relation to DRC in high forage diets. The percent TDN was set to 60% for sorghum silage and to 52% for grass hay. It was necessary to use the net energy (NE) adjusters in the NRC (1996) model to get actual cattle performance to determine the

Table 2. Main effects of energy source.

	DRC ^a	WDGS ^a	SEM	P-value
Initial BW, lb	510	508	6	0.82
Ending BW, lb	696	711	7	0.13
DMI, lb/day	15.8	15.8	0.24	1
ADG, lb	2.21	2.42	0.05	< 0.01
F:G	7.14	6.54	0.003	< 0.01

^aDRC = dry rolled corn; WDGS = wet distillers grains plus solubles.

Table 3. Main effects of level of energy source.

	Level ¹			SEM	P-value	Linear	Quadratic
	LOW	MEDIUM	HIGH				
Initial BW, lb	507	510	510	7	0.93		
Final BW, lb	668 ^a	715 ^b	728 ^b	8	< 0.01	0.28	< 0.01
DMI, lb/day	15.6	16.1	15.7	0.29	0.38	0.35	0.18
ADG, lb	1.91 ^a	2.40 ^b	2.60 ^b	0.06	< 0.01	0.10	< 0.01
F:G	8.13	6.23	6.06	0.004	< 0.01	0.02	< 0.01

¹LOW = 15% wet distillers grains plus solubles or 22% dry rolled corn; MEDIUM = 25% wet distillers grains plus solubles or 44% dry rolled corn; HIGH = 35% wet distillers grains plus solubles or 60% dry rolled corn.

^{a,b}Means with different superscripts differ ($P < 0.05$).

energy calculations in the study. The NE adjusters were set to 95.0, 92.5, and 90.4% for LOW, MEDIUM, and HIGH, respectively. The percent TDN for WDGS was increased until the observed ADG matched the NRC-predicted ADG. The resulting TDN value was divided by the TDN of the corn at the same level to determine the energy value of WDGS in relation to DRC. The feeding values of WDGS were 147, 149, and 142% the energy value of DRC when included in high forage diets at 15.0, 25.0, and 35.0% of the diet DM. This increased feeding value of WDGS in relation to DRC is attributed to the decreased negative associative effects on fiber digestion that are observed with increasing levels of starch, as well as the higher fat content of the WDGS. However, Loy et al. (2007, *Journal of Animal Science*, 85:2625) reported that fat level also can contribute to the quadratic response in animal performance observed with increasing levels of

WDGS, due to the subsequent effect on ruminal cellulolytic activity.

The feeding value of WDGS appears to be higher than that of DDGS in relation to DRC when compared to the findings of Loy et al. (2008). The reason for this potential difference is unknown, but could potentially be due in part to the drying process. However, without a direct comparison of WDGS to DDGS at increasing levels, we cannot conclude WDGS has more energy than DDGS in high forage diets. However, this trial suggests that WDGS contains a higher energy value than DRC with values ranging from 142% to 149%.

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Effects of Time of Transporting Prior to Sale Date on Selling Weight of Weaned Steer Calves

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Summary

An experiment was conducted using 88 weaned steer calves to evaluate shrink difference when shipped at differing times prior to sale date. Two groups of calves were transported 24 hours prior to sale date, with one group being withheld from water and feed 2 hours prior to sale while the other group was not restricted. Another group (control) was transported 2 hours prior to the sale. All cattle were transported 95 miles and co-mingled at the sale facility prior to processing. Percent shrink for +1-Adlib, +1-R, and Control was 1.8, 2.2, and 0.6%, respectively.

Introduction

Many factors such as diet, age, weaning status, and pen conditions can affect sale weight. The objective of this study was to evaluate effects of time of transporting prior to sale date on sale weight of weaned steer calves.

Procedure

Eighty-eight crossbred steers were held for 14 days at UNL's Dalbey-Halleck Research Unit near Virginia, Neb. Calves received 2.0 lb of dried distillers grains (DDGS) and free choice brome grass hay during the weaning phase. To initiate the study, steers were randomly assigned to one of three groups. Calves in groups one

Table 1. Effects of shipping time prior to sale.

Performance Characteristics	Treatment ¹			SEM	P-value
	+1-R	+1-Adlib	Control		
Initial BW, lb	565	554	531	23.7	0.07
Final BW, lb	550	541	527	23.5	0.33
Shrink, lb	15.4	13.2	4.0		
Shrink, %	2.2	1.8	0.6	0.02	0.80

¹Treatments: +1-R = transported 1 day prior to sale and restricted for 2 hours; +1-Adlib = transported 1 day prior to sale and allowed *ad libitum* access to feed and water; Control = transported the day of the sale.

²Shrink = (final BW – initial BW).

³% Shrink = 1 – (final BW / initial BW).

and two were weighed on day 1 and day 2 of the study. On day 2, groups one and two were transported 95 miles to the ARDC research feedlot near Mead, Neb. Calves in group three (Control) also were weighed on days 1 and 2, but remained at the Dalbey-Halleck unit until they were transported to ARDC on day 3. On day 3, one group of calves at the ARDC was removed from hay and water at 0800 hr (+1-R), while the other group was allowed access to hay and water (+1-Adlib). When group three calves (Control) arrived at ARDC on day 3, calves in the three groups were co-mingled and processed. All three treatments received free choice brome grass hay for the entire study. The weights recorded at processing were used as sale weights. Data were analyzed using the MIXED procedures of SAS.

Results

Initial BW did not differ ($P = 0.07$; Table 1) for +1-R, +1-Adlib, and Control. No differences were observed in final BW ($P = 0.33$; Table 1). Weight loss (shrink; $P = 0.80$) was 2.2%,

1.8%, and 0.6% for +1-R, +1-Adlib, and Control, respectively. Total weight losses from two days pre-mock sale date to the mock sale date were 15.4 lb, 13.2 lb, and 4.0 lb for +1-R, +1-Adlib and Control, respectively.

Shrink is a variable physiological process in which the contents of the digestive system are highly affected. In the present study the objective was to discover the amount of shrink recovered or lost in 24 hours at a new location for weaned calves that are preconditioned to eating hay and drinking water. We hypothesized that calves shipped one day prior to the sale would gain back the weight lost in the shipping process. However, in our data, calves shipped one day prior to the sale continued to shrink in the new environment. The +1-R calves shrunk more than +1-Adlib calves. The Control calves lost the least amount of weight.

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Determinants of Profit Variability in Calf-Fed and Yearling Production Systems

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Summary

Factors that were determinants of profit variability in calf-fed and yearling beef production systems were identified and ranked. The analysis indicated cattle prices have the greatest influence on profit variation for both systems and on all backgrounding and finishing phases of the yearling system. Prices of feed-stuffs (i.e., corn prices, wet corn gluten feed prices, and pasture and cornstalk rental rates) were the next most important factors explaining profit risk. Cattle performance variables and interest rates had the smallest impact on profit variation.

Introduction

An understanding of the relative impact of profit determinants can help producers identify which variables of production and financial risk to focus on managing. Based on cattle feeding budgets that use actual historical cash prices of inputs and outputs, as well as variation in cattle feeding performance based on research trials described by Griffen et al. (2007 *Nebraska Beef Report*, pp. 58-60), this research identifies the magnitude of year-to-year variability in profits in calf-fed and yearling production systems.

A large amount of research has evaluated the difference in cattle feeding profit variability based on profit determinants in calf-fed and yearling finishing systems. However, less research has been done to consider the impact of the backgrounding phases on the yearling system's total profitability and profit variation, driven by determinants unique to each particular backgrounding phase. The present study evaluated profit variability of

both systems and the corresponding profit variability of multiple phases in the yearling system. The objective was to identify determinants of profit variability and measure each determinant's relative impact on each system's profit risk.

Procedure

For the calf-fed system, the variables to explain the variation in profits included fed cattle sales price, feeder cattle purchase price, corn price, interest rate, ADG, and F:G. Fed cattle sales price was used in the model to represent revenue, while feeder cattle sales price was included as one of the main cost variables in the calf-fed system. Another main cost variable for this system was feed, measured here by corn price. Interest, or opportunity cost of money, was charged on variable costs associated with feeding cattle. All cattle prices and corn prices were market prices reported by USDA's Agricultural Marketing Service, and interest rates were reported by the Kansas City Federal Reserve Bank's Survey of Agricultural Credit Conditions. The impact of ADG and F:G on profits also was measured in the econometric model from experimental trials.

As discussed in Small et al. (2009 *Nebraska Beef Report*, pp. 40-42), the yearling production system incurs costs associated with backgrounding calves on crop residue in the winter and native grass pasture in the summer and finishing in the fall in a feedlot. Thus, explanatory variables in this study included fed cattle sales price, feeder cattle purchase price, average cornstalk and summer pasture rental rates, corn prices during feeding, average interest rates across the three phases, ADG for the three phases, and F:G in the feedyard finishing phase. Sources for these prices were the same as for the calf-finishing system, with the addition of cornstalk and pasture

rental prices from Nebraska Farm Real Estate Reports (Johnson), which are included because they represent the bulk of feed costs for the two backgrounding phases. Also, to better account for all phases in the yearling system, the entire system's ADG was calculated based on initial weight going onto cornstalks, final weight at marketing, and total days owned.

The yearling system's profit relationship also was divided into three production stages, and profits were calculated for each by valuing the feeder steer at the end of the winter grazing phase (start of the summer grazing phase) and the end of the summer grazing phase (start of the feedlot phase). The winter cornstalk grazing variables included feeder cattle price margin (difference in the price of the calf going onto cornstalks and the price of the calf coming off cornstalks); feeder cattle purchase price; the average cornstalk rental rate; the average price of wet corn gluten feed (WCGF) fed as a supplement during winter phase; interest rate; and ADG.

In order to rank the relative impact of variables on the summer pasture grazing profits, the following variables were included in the econometric model: the feeder cattle price margin (difference in the price of the calf going onto pasture and the price of the calf coming off pasture); feeder cattle purchase value at the beginning of the summer; the average pasture rent; interest rate during the summer phase; and ADG during the summer phase. The yearling system finishing phase profit variation model included the same variables as the calf-fed model, but measured only during the yearling steers' time in the feedyard.

The feeder cattle price margin for the winter and summer grazing phases was used in place of the feeder cattle sales price to lessen econometric problems associated with inclusion of both feeder cattle sales price and feed-

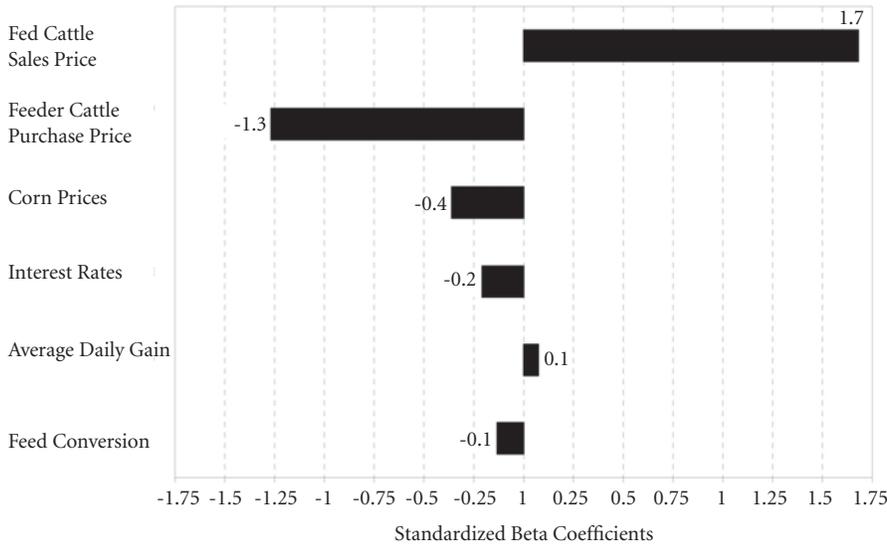


Figure 1. Calf-fed profit variation caused by prices and performance, 1996-2007¹.

¹Solid bars represent statistically significant coefficients, whereas striped bars are associated with coefficients that are not statistically different than zero.

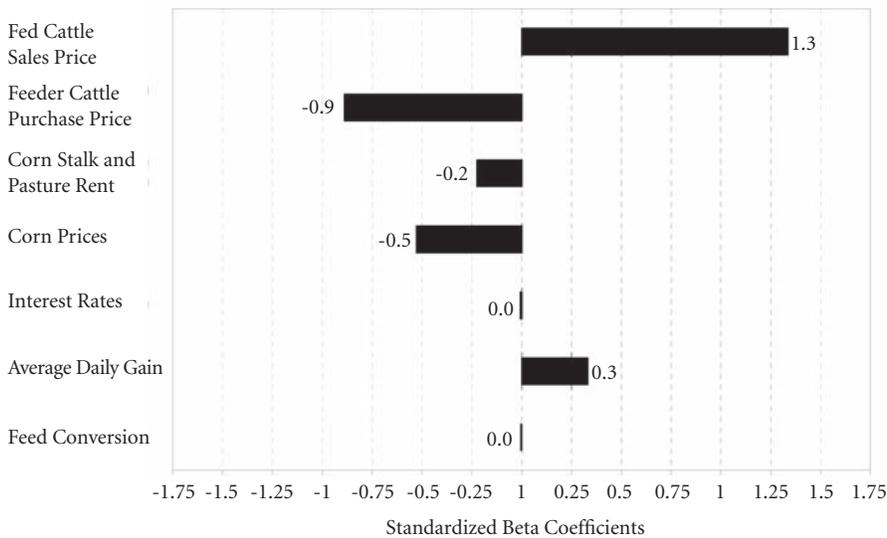


Figure 2. Yearlings (all phases) profit variation caused by prices and performance, 1996-2007¹.

¹Solid bars represent statistically significant coefficients whereas striped bars are associated with coefficients that are not statistically different than zero.

er cattle purchase price in the model. Thus, the feeder cattle purchase price measured overall input price levels, and the feeder cattle price margin quantified the price spread.

Standardized beta coefficients were used to rank the relative influence of profit determinants on profit risk. This method of analysis involved normalizing profit and the explanatory variables, resulting in a unit-less mea-

sure that allowed comparison of the influence of the explanatory variables on profits regardless of differing units of measure used to define each variable (e.g., dollars per bushel for corn price and dollars per hundredweight for feeder cattle price). Standardized beta coefficients have a special interpretation. Suppose that the explanatory variable *fed cattle sales price* has a standardized beta coefficient of 1.25.

This means that for a one standard deviation change in fed cattle sales price, profit changes from its mean by 1.25 standard deviations. Thus, the greater the standardized beta coefficient for a given variable, the greater the influence that variable has on profit variation.

Results

Figure 1 indicates the magnitude of the standardized beta coefficients of the variables that affected profits in calf-fed systems. The variables represented by bars on the right side of the graph have a positive relationship with profits (i.e., profits increase with increases in the given variable). The variables represented by bars on the left side of zero have a negative relationship with profits. Solid bars represent variables with coefficients that were statistically different than zero, whereas striped bars indicate that the variable's coefficient was not statistically significant. As shown in Figure 1, fed cattle sales price had the largest impact on profit variation, followed by feeder cattle purchase price. Corn price, interest rates, F:G, and ADG were the next most influential profit determinants.

These results are similar to those discussed in previous research and indicate the majority of the year-to-year profit risk from finishing calf-feds was due to cattle and corn prices. Even though animal performance was important in determining whether or not a profit resulted, ADG and F:G did not tend to explain a large proportion of the variation in profits across years (although they were statistically significant determinants of profit variability). In a relative sense, the variability of cattle performance was much smaller across the years of the study than the variability of cattle and corn prices, leading to the result that the more variable determinants like cattle and corn prices cause the most profit variability.

The magnitude and signs of the standardized beta coefficients for the entire yearling system are illustrated

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in Figure 2. Comparison of the bars in Figure 2 with those in Figure 1 demonstrates that the relative rank of a variable's importance in determining profits was somewhat different for yearlings (all phases) than for calf-feds. Similar to the profit determinants evaluated in the calf-fed system, fed cattle sale price, feeder cattle purchase price, and corn price had the largest influence on profits. Conversely, ADG was the next most important variable explaining profit variation for the yearling system, followed by the average cornstalk and pasture rental rates. Also note that the standardized beta coefficients for the sales price and purchase price were smaller in terms of absolute values for yearlings than for calf-feds. The total purchase price of the lighter steer at the beginning of the yearling system comprised less of the total cost of producing a finished steer, compared to the total purchase price of the heavier steer in the calf-fed system. Thus, it would be expected that the standardized beta coefficient associated with the feeder cattle purchase price for calf-feds would be greater than that of the yearling system.

It might also be assumed that corn prices for a yearling system would have a smaller impact on profit variation relative to a calf-fed system, since yearlings consumed corn for less time than calf-feds. However, yearlings were less efficient with the corn consumed (Griffin, 2007 *Nebraska Beef Report*, pp.58-60), which may be the cause of the larger standardized beta coefficient for corn in the yearling model than in the calf-fed model. Moreover, corn price was used to calculate the cost of WCGF, which also was fed to yearlings during the feedlot phase and supplemented during the winter cornstalk grazing phase. Therefore, the impact of corn price on profit variation may be partially attributed to the cost of WCGF if its impact was being captured by the corn price variable in the yearling system's model.

The model used to calculate standardized beta coefficients for the winter cornstalk grazing phase had

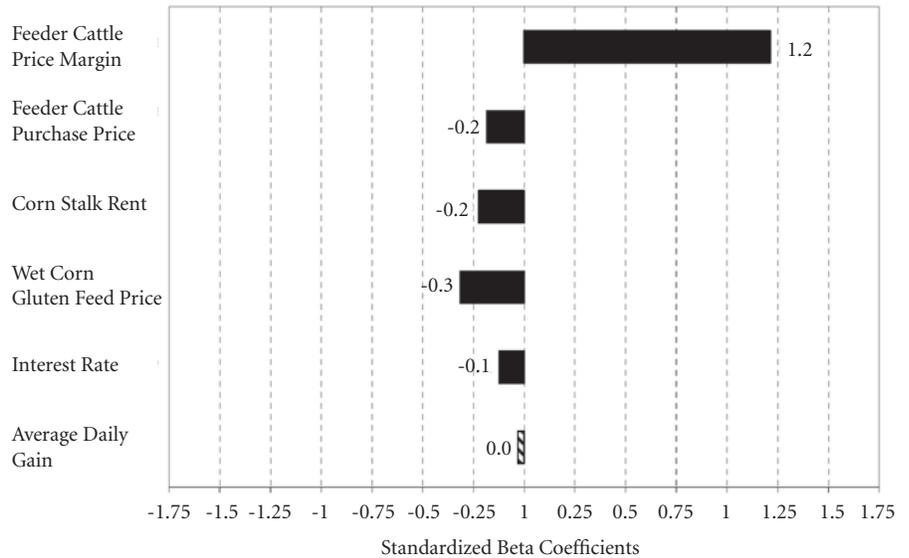


Figure 3. Yearlings (winter phase) profit variation caused by prices and performance, 1996-2007¹.

¹Solid bars represent statistically significant coefficients whereas striped bars are associated with coefficients that are not statistically different than zero.

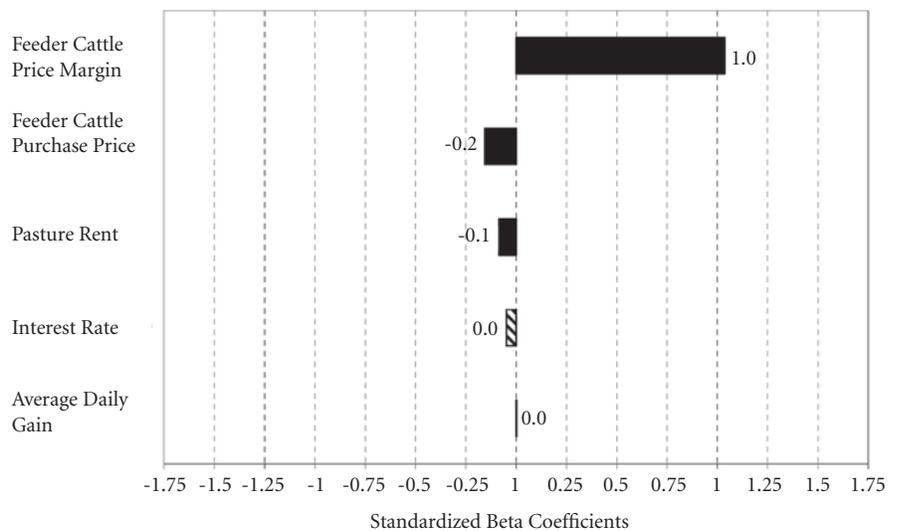


Figure 4. Yearlings (summer phase) profit variation caused by prices and performance, 1996-2007¹.

¹Solid bars represent statistically significant coefficients whereas striped bars are associated with coefficients that are not statistically different than zero.

all variables with their expected signs (positive for profit-increasing variables, like fed cattle price and cattle performance, and negative for costs that lower profits, like cornstalk grazing, interest, and feeder cattle purchase price) except winter phase ADG, which also was not statistically significant (Figure 3). The feeder cattle price margin (difference in the total

price [\$ per head] of the calf going on to cornstalks and the total price [\$ per head] of the calf coming off cornstalks) was the greatest influencer of profit variation in the yearling winter phase relative to the other variables. The next most important determinant was WCGF price, followed by cornstalk rental rate, purchase price of the feeder steer, and interest rates (see

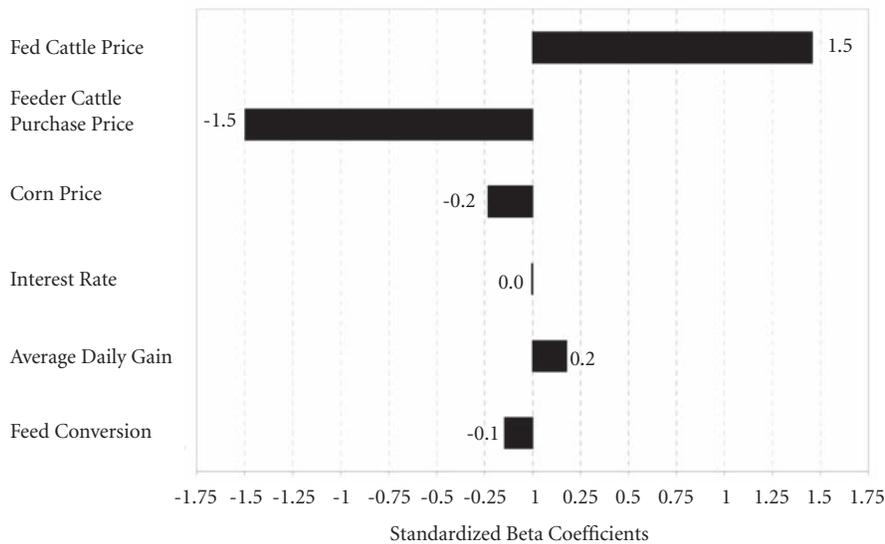


Figure 5. Yearlings (feedlot phase) profit variation caused by prices and performance, 1996-2007¹.

¹Solid bars represent statistically significant coefficients whereas striped bars are associated with coefficients that are not statistically different than zero.

Figure 3).

For the summer grazing profit variation analysis, all revenue-improving variables had positive signs and cost-related variables had negative signs. Similar to the yearling system's winter phase, the feeder cattle price margin had the greatest impact on

profit variation of all the variables (see Figure 4). The purchase price or value of the steer entering the summer pasture grazing phase had the second largest impact on profit variation. Pasture rental rates also had an impact on profit variation. Neither interest rates nor ADG were statistically significant

for summer phase profits.

In the yearling's feedlot phase model, purchase price of the feeder steer entering the feedlot was the most influential profit determinant (see Figure 5). Figure 5 also shows that fed cattle sales price was the next most important variable in influencing profit variation. Although they did not have as large an impact on profit variation, corn price, feedlot ADG, and F:G were important profit determinants as well.

All of the results showed that fed cattle sales price, feeder cattle price margins, feeder cattle purchase price, and corn price had the largest impact on profit variation for calf-feds and yearlings. In conclusion, to effectively manage profit risk associated with these two cattle production systems, it is important to manage cattle and corn price risk.

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Routine Hedging of Fed Cattle Sales Price for Calf-Fed and Yearling Production Systems

Rebecca M. Small
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Summary

Short futures hedges in the Chicago Mercantile Exchange live cattle futures contract were evaluated to determine if profit variability could be decreased for calf-fed and yearling production systems. Results indicated standard deviations of calf-fed profits could be reduced by \$35-\$47/head through routine hedging. Routine hedges of yearling cattle, however, resulted in profit declining nearly \$50/head, but profit variability also decreased.

Introduction

Research has shown that while several input prices and cattle performance variables impact profit risk, fed cattle sales prices are typically the largest determinant of cattle feeding profitability risk over time (Small et al., 2010 *Nebraska Beef Report*, pp. 46-49). Small et al. (2009 *Nebraska Beef Report*, pp. 40-42) illustrated the magnitude of profit variations from 1996-2007 for both calf-fed and yearling production systems. These studies concluded that hedging fed cattle sales prices would have the largest impact on reducing profit risks across years. Because the calf-fed and yearling production systems described by Griffin et al. (2007 *Nebraska Beef Report*, pp. 58-60) result in fed cattle being marketed at different times of the year, differences in seasonal price patterns and other factors may result in different degrees of success with hedging programs.

Generally, heavier calves are placed on feed in early November (following weaning) and finished in May (calf-fed system), while lighter weight calves weaned in early November are

backgrounded through the winter on crop residue, grown on grass pasture during the next summer, finished in the feedyard the following fall, and marketed in December (yearling system). The present study evaluated the use of a routine short futures hedge in the live cattle futures market, established at the time the feeder cattle are purchased. While some research has suggested that selective hedges produce higher average profits over time, strict routine hedges are used in this analysis in an effort to lower the riskiness of profits and because they are most easily initiated and maintained.

Procedure

Production systems data from Griffen et al. (2007) were used, along with CME Group live cattle futures prices. Fed cattle hedges associated with the calf-fed system were evaluated using two different live cattle contract months (April and June), although steers were generally expected to be finished in May. In all live cattle hedging scenarios for calf-feds, futures contracts were assumed to be sold when steers were placed on feed in November. Fed cattle hedges associated with the yearling system were evaluated assuming cattle were priced based on the deferred December live cattle contract month (the December approximately 13 months following weaning when the feeder cattle were placed into the yearling system). How-

ever, the yearling live cattle hedging scenarios were evaluated under the assumption that hedge initiation took place when either a) the steers were initially purchased and placed on winter cornstalks in early November, or b) the steers were placed in the feedlot in September after grazing summer pasture.

The live cattle hedging scenarios evaluated for calf-feds and yearlings are explained in Table 1.

In CL1 (calf-fed system, live cattle hedge in April futures), April CME live cattle futures contracts were sold when calf-feds entered the feedlot in November. These futures contracts were then offset (bought back to create an offsetting transaction) on the day cattle were marketed in April. For steers in the study that were marketed in May or June, the April CME live cattle futures contracts were offset on the day the April contract expired, at which point the fed cattle sales price was unhedged until the fed steers were sold in the cash market.

CL2 (calf-fed system, live cattle hedge in June futures) assumed cattle were hedged by selling the June CME live cattle futures contracts when cattle were placed on feed in November. Since all pens of calf-feds were marketed before the June CME live cattle futures contracts expired in every year of the study, all futures contracts were offset on the day cattle were marketed under CL2.

In YL1 (yearling system, live cattle

Table 1. Live cattle hedging scenarios evaluated for calf-feds and yearlings.

Label	Description
CL1	Sell April CME live cattle futures contracts at feedlot placement; lifted a) when fed cattle are sold in cash market in April, or b) at futures contract expiration.
CL2	Sell June CME live cattle futures contracts at feedlot placement; lifted when fed cattle are sold in cash market in April-June.
YL1	Sell December CME live cattle futures contracts at cornstalk placement; lifted a) when fed cattle are sold in cash market in December, or b) at futures contract expiration.
YL2	Sell December CME live cattle futures contracts at feedlot placement; lifted a) when fed cattle are sold in cash market in December, or b) at futures contract expiration.

Table 2. Live cattle hedging scenarios for calf-fed production systems, 1996-2007.

	Live Cattle Hedges		
	Calf-fed system		
	No hedge	CL1 (April)	CL2 (June)
Fed cattle price, (\$/cwt)	74.29	75.52	73.90
Avg profit, (\$/hd)	9.80	24.80	4.47
Max profit, (\$/hd)	149.66	111.89	52.13
Min profit, (\$/hd)	-107.79	-69.34	-87.11
Std dev profit, (\$/hd)	91.74	56.21	44.53
Profit difference, (\$/hd) ¹		+15.00	-5.33

¹Profit difference (\$/hd) is found by subtracting the average no hedge profit from the average hedged profit.

Table 3. Live cattle hedging scenarios for yearling production systems, 1996-2007.

	Live Cattle Hedges		
	Yearling system		
	No hedge	YL1	YL2
Fed cattle price, (\$/cwt)	76.19	71.90	73.72
Avg profit, (\$/hd)	7.76	-51.23	-25.76
Max profit, (\$/hd)	360.49	94.31	146.11
Min profit, (\$/hd)	-158.37	-231.68	-171.49
Std dev profit, (\$/hd)	161.01	96.82	113.98
Profit difference, (\$/hd) ¹		-58.99	-33.52

¹Profit difference (\$/hd) is found by subtracting the average no hedge profit from the average hedged profit.

hedge in December futures at weaning time), live cattle prices were hedged by selling December CME live cattle futures contracts when yearlings were initially purchased and placed on winter cornstalks in November. Therefore, entry into the live cattle futures market took place approximately 13 months before the futures contract was set to expire. These live cattle hedges were lifted on the day yearlings were marketed as fed cattle. However, yearlings that entered the feedlot in 1998, 1999, 2005, 2006, and 2007 were marketed in January of the following year. Thus, in those years the live cattle futures contracts were offset on the day the December contract expired, and fed cattle sales prices became unhedged for one to three weeks before fed steers were sold in the cash market.

The only difference between YL1 and YL2 (yearling system, live cattle hedge in December futures at feedlot placement time) is the day the December CME live cattle futures hedge was

initiated. In YL2, the futures contracts were sold on the day cattle were placed in the feedlot in September. The live cattle hedges were offset when cattle were sold or when the December live cattle futures contract expired, whichever occurred first.

All live cattle futures prices used in the analysis were daily futures closing prices from the Commodity Research Bureau for either the April, June, or December CME live cattle futures contracts. These futures prices were used to determine the net on futures, which is equal to the difference in the futures price from hedge initiation when the contract is sold until the hedge is offset. The cash price used was the Nebraska weekly weighted average live steer price reported for the week cattle were marketed. A commission cost of \$0.25/cwt also was applied to the actual sale price. Thus, the actual sale price was the sum of the cash market price plus the net on the futures trade, less the commission cost.

Results

Results of the hedges were compared to the fed cattle sales prices, average profits, and standard deviations of profit, assuming no hedging. In CL1, the live cattle hedge increased average profit by \$15.00/head, as compared to not hedging, and substantially decreased the standard deviation of profits from \$91.74 to \$56.21/head (see Table 2). While it was expected that standard deviation of profits would decrease as a result of hedging in the futures market, it was not expected that average hedged profit would increase relative to unhedged average profit. The calf-fed's hedged profits in 2003 (a year of unusually high profits) were high enough to offset losses incurred in other years, thus creating an overall average hedged profit for those cattle hedged using the April CME live cattle futures contract. Standard deviation of profits is still lower, however, because of reduced variability in all the other years.

CL2 involved initiation of a June live cattle hedge when calf-feds were placed on feed, and futures contracts were offset when fed steers were sold. Unlike CL1, all cattle would have been sold in the cash market before contract expiration. Although the average standard deviation of profits declined to \$44.53/head with the June live cattle hedges, the average hedged profit was \$4.47/head. This decrease in profit relative to cash market transactions occurred because the average hedged cattle sales price was \$0.39/cwt less than the average unhedged price of \$74.29/cwt (see Table 2). The results of this scenario indicate that unhedged cash market sales were more profitable than hedging fed cattle sales in the futures market during the 1996-2007 time period.

Using a June live cattle futures contract to hedge fed cattle provided price protection during the entire production period, and the profit standard deviation was reduced by an average 51.46% compared to the standard deviation of profits in the cash market. Note that only 36% of

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the pens of calf-feds would have been marketed before the April live cattle contract expired. Thus, this was not an ideal hedge in that the majority of calf-feds would be exposed to price risk during the end of the production period in May. However, the April live cattle hedging scenario was the more optimal of the hedges, in that it allowed for a greater average profit relative to selling in the cash market or using a June live cattle contract, and because it resulted in a nearly 40% decrease in standard deviation of profits (see Table 2). Much of the profit difference between CL1 and CL2 is due to the seasonality of fed cattle prices, which typically reach a seasonal high in April and decline substantially into the summer months when more fed cattle are marketed.

As shown in Table 3, the YL1 hedge decreased the average fed cattle sales price by \$4.29/cwt, which resulted in an average loss of \$51.23/head. This average loss yielded a difference of \$58.99/head between hedging and not hedging. Notice that standard deviation of profits was still reduced by \$64.19/head, so profit variation decreased as expected with hedging. The average hedged profit was -\$33.52/head less than the \$7.76/head profit available without hedging for YL2 (Table 3). The average hedged cattle sales price was \$2.47/cwt less than the average cash market price without hedging. Standard deviation

of profits was decreased to \$113.98/head.

The yearling production system loss generated by hedging live cattle futures contracts is due in part to the substantially greater fed cattle cash prices forgone in 2003, 2004, and 2007. In 2003 and 2004, fed cattle prices were unusually high due to increased domestic demand and overall lower supplies of beef due to a smaller cattle herd and ban on imports of cattle from Canada and other countries. The results also are confirmed by other research findings by Leuthold (1974), which indicated that dramatic changes in fed cattle prices cannot be very well estimated by the futures market and that hedges longer than four months may not help in stabilizing revenue. This may have been the cause of the large loss in YL1 when fed cattle sales prices were hedged approximately 13 months before cattle were marketed. Though both yearling live cattle hedging strategies were effective in decreasing standard deviation of profits, YL2 yielded a smaller average loss than did YL1.

So, depending upon an individual's risk preference, YL2 may be considered the optimal live cattle hedging strategy for the yearling system. Although YL1 was more effective in substantially decreasing standard deviation of profits, the larger average loss associated with this scenario makes it the least optimal strategy.

Note that if 2003, 2004, and 2007 were not included in the analysis (years with large unexpected rallies in fed cattle prices), YL1 would be more optimal relative to YL2. Excluding these three years, YL1 would have an average hedged profit of -\$32.01/head with a standard deviation of profits of \$85.18/head, and YL2 would have an average hedge profit of -\$50.51/head and a standard deviation of profits of \$115.57/head.

Hedging live cattle using scenarios YL1 and YL2 did cause reductions in standard deviation of profits. This reduction was the result of large decreases of positive profits. Note that when compared to the maximum profit available in the cash market, the hedged maximum profits in YL1 and YL2 were \$266.18/head and \$214.38/head lower, respectively (Table 3). Interestingly, the minimum profits in both scenarios actually decreased relative to the minimum profit offered by cash market sales. These lower minimum profits were partially due to high corn prices in certain years (e.g., 2007). However, the ratio between fed cattle sales prices and feeder cattle purchase prices played a larger role in the lower minimum profits.

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Routine Hedging of Corn Price for Calf-Fed and Yearling Production Systems

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Summary

Several corn hedging scenarios involving a combination of cash and futures market transactions were evaluated for calf-fed and yearling production systems. All yearling corn hedging scenarios assessed were effective in only slightly reducing profit risk, while the calf-fed corn hedging scenario actually increased profit risk. Calf-fed and yearling corn hedging scenarios generally generated positive average returns to hedging by lowering net corn prices. The yearling corn hedging scenarios initiated closer to feedlot placement were associated with greater average profits as compared to those hedges initiated when yearlings were initially purchased.

Introduction

Research has confirmed feedstuff prices are typically the second largest determinant of cattle profit risk, surpassed only by fed cattle and feeder cattle prices (Small et al., 2010 *Nebraska Beef Report*, pp. 46-49). Small et al. (2009 *Nebraska Beef Report*, pp. 40-42) demonstrated the magnitude of profit variations from 1996-2007 for calf-fed and yearling production systems, concluding that hedging corn or feedstuff prices would reduce year-to-year profit variability. Griffin et al. (2007 *Nebraska Beef Report*, pp. 58-60) described calf-fed and yearling production systems that involved finishing cattle for different lengths of time and at different times of the year, differences that may influence the success of corn hedging programs.

The calf-fed system involves placing heavier calves on feed in early November (following weaning) and finishing them in May. The yearling system places lighter weight calves on

winter crop residue in early November following weaning, followed by summer grass pasture, finishes them in the feedyard the following fall, and markets them in December. In many respects, cattle producers evaluating calf-fed versus yearling production systems have to weigh the risk of old crop corn price risk (for calf-fed finishing during the winter) with new crop corn price risk the following fall (for yearlings finished the next fall). The present study evaluates the use of a routine long futures hedge in the corn futures market established when the feeder cattle are purchased.

Procedure

Production systems data from Griffin et al. (2007) are used, along with CME Group corn futures prices, assuming that corn futures hedges would be lifted at different times throughout the feeding period corresponding to routine cash market corn purchases. The calf-fed system's feeding period

was divided into thirds, and the shorter yearling system's feeding period was divided into halves. The corn hedging scenarios associated with the yearling system were evaluated assuming futures entry occurred either a) when the cattle were purchased and placed on winter crop residue or b) a month before feedlot placement in the fall. Table 1 provides a list and brief explanation of the corn futures hedging scenarios evaluated.

On average, calf-feds entered the feedlot after weaning in November, following corn harvest when there are typically larger supplies of corn and lower prices. Therefore, because of these simultaneous actions in both the cattle sector and the crop sector, it follows that cash corn often can be purchased at a relatively cheap price when calf-feds are placed on feed. Thus, in CC1 (calf system, corn hedge, scenario one) it was assumed that a third of the corn needed to feed the steers for the entire ownership period

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Table 1. Corn hedging scenarios evaluated for calf-feds and yearlings.

Scenario	Label	Description
Calf-fed corn scenario one	CC1	Buy 1/3 of corn in cash market at feedlot placement. Buy March CME corn futures contracts at feedlot placement; lifted when 1/3 of corn is purchased in cash market in January. Buy May CME corn futures contracts at feedlot placement; lifted when 1/3 of corn is purchased in cash market in March.
Yearling corn scenario one	YC1	Buy December CME corn futures contracts at cornstalk placement; lifted when 1/2 of corn is purchased in cash market at feedlot placement in September. Buy December CME corn futures contracts at cornstalk placement; lifted when 1/2 of corn is purchased in cash market at feedlot midpoint in November.
Yearling corn scenario two	YC2	Buy December CME corn futures contracts at cornstalk placement; lifted when 1/2 of corn is purchased in cash market at feedlot placement in September. Buy 1/2 of corn in cash market at feedlot midpoint in November.
Yearling corn scenario three	YC3	Buy December CME corn futures contracts on first trading day of August (when steers are on pasture) and lifted when 1/2 of corn is purchased in cash market at feedlot placement in September. Buy December CME corn futures contracts on first trading day of August (when steers are on pasture); lifted when 1/2 of corn is purchased in cash market at feedlot midpoint in November.
Yearling corn scenario four	YC4	Buy December CME corn futures contracts on first trading day of August (when steers are on pasture); lifted when 1/2 of corn is purchased in cash market at feedlot placement in September. Buy 1/2 of corn in cash market at feedlot midpoint in November.

was purchased in the cash market on the day calves were placed on feed. It also was assumed that the second third of the corn needed for the feeding period was hedged by purchasing March corn futures contracts on the day calf-feds entered the feedlot. The final third of the corn required for the finishing ration also was hedged at feedlot entry by purchasing May corn futures contracts. The March corn futures contracts were offset in January when the second third of the corn was assumed to be purchased in the cash market. The final third of the corn was purchased in the cash market in March, at which point the May corn futures contracts were offset.

Because the yearlings' feeding period was divided into two parts, cash corn purchases were assumed to be made at two separate times. In YC1 (yearling system, corn hedge, scenario one), cash corn purchases were hedged by purchasing deferred December corn futures contracts when yearlings were placed on winter cornstalks in November. Note that these futures market transactions would have been occurring approximately 10 months before cattle were placed on feed. Half of the December corn futures contracts were offset on the day yearlings were placed on feed. Simultaneously, the amount of corn needed for the first half of the yearling feeding period was purchased in the cash market. The second half of the corn needed for the yearlings' feedlot ration was purchased in the cash market at the feeding period midpoint, which typically occurred in October or November. The remaining half of the December corn futures contracts were offset at this time.

YC2 (yearling system, corn hedge, scenario two) was similar to YC1 in that the first half of the corn needed for the feeding period was hedged by purchasing December corn futures contracts when yearlings were placed on winter cornstalks, and those corn futures contracts were offset about ten months later when yearlings entered the feedlot. However, the second half of the corn purchased at the feeding period midpoint was not hedged. Since the yearling feeding period

midpoint occurred at nearly the same time as harvest in Nebraska to take advantage of harvest price lows, the second half of the corn consumed by yearlings in YC2 was purchased strictly on a cash market basis.

The only difference between YC3 (yearling system, corn hedge, scenario three) and YC1 was the day the December CME corn futures contracts for the first and second half of the feeding period were initiated. In YC3, the corn futures contracts were purchased on the first trading day of August, while yearlings were on summer pasture, approximately one to two months before yearlings were placed in the feedlot. The December corn futures contracts were offset and cash market purchases in YC3 were analogous to the other two previously described yearling corn hedging scenarios (YC1 and YC2).

YC4 (yearling system, corn hedge, scenario four) was a combination of YC3 and YC2. As in YC3, it also was assumed in YC4 that the December corn futures contracts were purchased on the first trading day of August for the year that yearlings entered the feedlot. However, similar to YC2, the corn fed during the second half of the feeding period in YC4 was not hedged using futures contracts and assumed to be purchased in the cash market.

An actual purchase price was calculated for the corn hedging scenarios by subtracting the net gain on futures from the cash market purchase price paid for the corn and adding \$0.02/bushel for commission trading costs. The net on futures was the difference between the corn futures price at the conclusion of the hedge and the corn futures price when the hedge was initiated. To find the net on futures, daily futures closing prices for the March, May, and December corn futures contracts were used for those days when contracts were purchased and offset for 1996-2007, the years included in the study. Cash corn prices used for all cash market purchases, whether hedged or not, were weekly Omaha, Neb., cash corn prices corresponding to those weeks that cash market transactions occurred.

Results

The CC1 strategy decreased the average corn price by \$0.07/bushel, which was reflected in a \$3.14/head increase in average profits (holding everything else constant). Interestingly, as shown in Table 2, the standard deviation of hedged profits increased by \$0.39/head relative to the standard deviation of profits offered through cash market transactions.

This increase in standard deviation of profits in CC1 was opposite of expected. However, because one third of the corn was not hedged, it is understandable that standard deviations of profits would not be decreased substantially. In fact, cash corn price standard deviation, measured during those years included in the study, actually increased from a low in October until the beginning of February. In this scenario, the first third of the corn purchased in the cash market was purchased in November. Further, as Small et al. observed (*2010 Nebraska Beef Report*, pp. 46-49), cattle prices have a much larger impact on profit risk compared to corn prices. So, even though corn price risk was decreased using futures hedges, the relative impact of those corn futures hedges on overall profit risk was inconsequential in some cases.

YC1 evaluated the effect on profits from purchasing deferred December corn futures contracts in the previous November when cattle were placed on winter cornstalks. Cash corn purchases were made and futures contracts were offset at two times: when yearlings were placed on feed and at the midpoint of the yearling's feeding period. This scenario resulted in an increase in the average price paid for corn of \$0.07/bushel, causing average profits to decrease by \$1.58/head. Unlike CC1, standard deviation of profits declined by \$1.48/head (see Table 3).

In YC2, it was assumed that December corn contracts were purchased when yearlings were initially purchased and then offset when cattle entered the feedlot. The remainder of the corn consumed (which was assumed to equal half of the needed

Table 2. Corn hedging scenario for calf-fed production systems, 1996-2007.

	Corn Hedges	
	Calf-fed System	
	No hedge	CC1
Corn price, (\$/bu) ¹	2.43	2.36
Avg profit, (\$/hd)	9.80	12.94
Max profit, (\$/hd)	149.66	163.47
Min profit, (\$/hd)	-107.79	-113.73
Std dev profit, (\$/hd)	91.74	92.13
Profit difference, (\$/hd) ²		+3.14

¹Corn price (\$/bu) is on an as-is basis and does not include a dry rolled corn processing fee.

²Profit difference (\$/hd) is found by subtracting the average no hedge profit from the average hedged profit.

Table 3. Corn hedging scenarios for yearling production systems, 1996-2007.

	Corn Hedges				
	Yearling System				
	No hedge	YC1	YC2	YC3	YC4
Corn price, (\$/bu) ¹	2.37	2.44	2.38	2.32	2.31
Avg profit, (\$/hd)	7.76	6.18	7.81	9.77	9.61
Max profit, (\$/hd)	360.49	357.56	360.51	363.64	363.56
Min profit, (\$/hd)	-158.37	-177.03	-166.88	-157.48	-157.10
Std dev profit, (\$/hd)	161.01	159.53	160.24	157.41	159.29
Profit difference, (\$/hd) ²		-1.58	+0.05	+2.01	+1.85

¹Corn price (\$/bu) is on an as-is basis and does not include a dry rolled corn processing fee.

²Profit difference (\$/hd) is found by subtracting the average no hedge profit from the average hedged profit.

corn) was purchased (unhedged) in the cash market at the midpoint of the feeding period to take advantage of the expected lower corn prices at harvest time. Table 3 shows that this hedging strategy yielded a similar average corn price as compared to buying the corn in the cash market throughout the entire feeding period. However, average profits increased to \$7.81/head (due to rounding), and standard deviation of profits declined by \$0.77/head.

Lower minimum profits were realized in YC1 and YC2 compared to the minimum profit from not hedging (Table 3). In all three situations (No Hedging, YC1, and YC2), the minimum profit was incurred in 1998, a year in which fed cattle sales prices were relatively low. Also in 1998, corn prices went from an unhedged price of \$1.91/bushel to \$2.51/bushel in YC1 and to \$2.18/bushel in YC2. Therefore, the low fed cattle sales price coupled with higher corn prices created an overall lower minimum profit in YC1 and YC2.

YC3 was based on the assumption that December corn futures contracts

were initiated on the first trading day in August, before yearlings were placed on feed. Similar to YC1, half of the contracts were offset when yearlings were placed on feed, while the others were offset at the midpoint of the yearling's feeding period. By hedging corn under this method, the average price of corn used in the yearlings' feedlot rations was reduced from \$2.37/bushel to approximately \$2.32/bushel. This reduction in corn price was reflected in an increase in average profit from \$7.76/head to \$9.77/head. Moreover, standard deviation of profits was reduced by \$3.60/head (see Table 3).

YC4 considered the results of hedging half the corn by purchasing December corn contracts on the first trading day of August, when yearlings were still on pasture, and purchasing the second half of the corn in the cash market at the midpoint of the feeding period during corn harvest. Standard deviation of profits was lowered from \$161.01/head to \$159.29/head (see Table 3). The average profit in this scenario was \$9.61/head, which was \$1.85/head more profitable than not hedging and \$0.16/head less profitable

than YC3. The average price of corn consumed by yearlings in this scenario was about \$2.31/bushel.

Notice that the average corn prices are nearly the same in Table 3 for YC3 and YC4. The only difference between YC3 and YC4 is that in YC3, the second half of the corn was hedged using December corn futures contracts purchased at the beginning of August and offset at the yearlings' feeding period midpoint (November); in YC4, the second half of the corn was purchased in the cash market at the feeding period midpoint. The weekly December corn futures price hedged at the beginning of August remained relatively unchanged from the yearlings' feeding period midpoint (November) when contracts were offset. With little change in futures prices from hedge initiation until hedge conclusion, the average net on futures was close to zero.

It was assumed that a lower corn price would be realized if corn was purchased at the midpoint of the feeding period, which corresponds to corn harvest. Typically corn harvest is associated with the lowest corn prices of the year. However, in 2006 and 2007, corn prices made a dramatic counter-seasonal move; thus, corn prices in these years actually increased to their highest prices during harvest and throughout the end of the calendar year. Due to these counter-seasonal price moves in 2006 and 2007, purchasing cash corn during harvest may have actually lowered the average profit reported in YC4.

In comparing YC1-YC4, it can be concluded that YC3 was the optimal yearling corn hedging scenario. YC3 had the lowest standard deviation of profits, just over 2.23% lower than the standard deviation of the profits resulting from cash market transactions only. Additionally, it yielded the highest average profit relative to the other yearling corn hedging scenarios.

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Distillers Grains and Livestock are Important to Ethanol Energy and Greenhouse Gas Balance

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Summary

A life cycle assessment of the impact of distillers grains plus solubles (DGS) on mitigation of energy and greenhouse gas (GHG) emissions comparing corn ethanol to gasoline demonstrates the importance of feeding wet DGS (WDGS) to feedlot cattle to optimize the environmental benefit of ethanol production relative to gasoline. Ethanol produced in Nebraska has a superior environmental impact compared to ethanol produced in Iowa or Texas.

Introduction

An accurate understanding of the energy and greenhouse gas balance of ethanol production is needed to compare the environmental impact of ethanol vs. gasoline production. Utilization of distillers grains plus solubles (DGS) is an important part of this system. Biological studies have shown DGS to be an excellent livestock feed replacing corn, urea, and soybean meal in livestock diets. When DGS is fed, energy and GHG credit is given to ethanol production due to lesser need for corn, urea, and soybean meal in livestock feed.

Calculating the displacement credit requires identification of the energy efficiency of corn production for both ethanol production and cattle feeding, the amount of heat energy needed to process DGS at the ethanol plant, and the differences in livestock performance when cattle are fed DGS instead of corn. These variables indicate the related fossil fuel energy and GHG

emissions savings that result from not producing the displaced feeds.

Irrigation energy input and corn yield are main factors in calculating corn production efficiency. Higher yielding Iowa rain-fed corn is less energy intense than Nebraska-grown corn. In addition, Texas corn requires more irrigation and has lower yields than Nebraska corn. Therefore, the relative corn production efficiency is greatest for Iowa, intermediate for Nebraska, and least for Texas.

A major life-cycle efficiency determinant is ethanol plant co-product energy and GHG efficiency. All plants produce wet DGS; however, some plants must dry the DGS for livestock use if livestock are not in close proximity to the ethanol plant. Producing dry DGS (DDGS; 10% moisture) requires 170% the energy to produce wet DGS (WDGS; 68% moisture). Modified DGS (MDGS; 55% moisture) production requires an intermediate amount of energy input.

Depending on the livestock class, different traditional feeds are replaced when DGS is added to the diet. Corn and urea are replaced in feedlot diets. Corn and soybean meal are replaced in swine grow-finish diets and lactating dairy cow diets. Energy requirements for corn and soybean meal are based on corn and soybean production energy from cropping inputs; urea production energy is mainly from natural gas use.

Feedlot steers have improved performance when fed DGS relative to traditional corn diets (2008 Nebraska Beef Report, pp. 35-36). Therefore, one unit of DGS DM will replace more than one equal unit of diet components. Feedlot steers also are fed fewer days to reach the same end point as corn fed steers. Therefore, they emit methane fewer days. The type of DGS fed influences feedlot steer performance. Because steers fed WDGS perform better than steers fed DDGS or MDGS, a unit of WDGS DM will

replace more corn and urea than a similar DM unit of DDGS or MDGS. When finisher swine and dairy cattle are fed DGS, performance is similar to corn-based diets. In the swine and dairy diet, one unit of DGS replaces one equal unit of combined corn and soybean meal, but with no additional performance response like that exhibited by feedlot steers. The inability to handle wet feeds in commercial production barns prevents swine producers from utilizing WDGS.

The GHG emissions of corn produced in Nebraska and Texas are 111% and 172% of Iowa, respectively (Table 3), due to irrigation and yield differences. Iowa mainly produces DDGS, while Nebraska mainly produces wetter forms of DGS, and Texas produces only WDGS. As a result, Iowa has the highest energy input to process DDGS. The swine industry is the main DGS user in Iowa. The feedlot industry is the main user of DGS in Nebraska and Texas.

In the current study, the quantifiable differences described above were modeled as part of a corn-ethanol life cycle assessment model to evaluate the impact of feeding DGS on the energy balance and GHG emissions mitigation potential of corn ethanol compared to gasoline.

Procedure

A model was developed to evaluate the energy and GHG emissions from corn-ethanol production (www.bess.unl.edu). The Biofuel Energy Systems Simulator Model (BESS) integrated the energy and GHG emissions from corn production, ethanol plant operation, and credit due to feeding DGS to livestock. Incorporated into the BESS model were differences in energy efficiency and GHG balance of corn production for ethanol production and cattle feeding; the amount of heat energy needed to process DGS at the ethanol plant; and the differences in

Table 1. Energy and greenhouse gas (GHG) balance of Nebraska ethanol production when feeding DDGS, MDGS, or WDGS to feedlot steers¹.

	DDGS	MDGS	WDGS
Corn production state	NE	NE	NE
Livestock class	Beef	Beef	Beef
Biorefinery energy use, MJ/L EtOH	8.3	6.6	4.9
DGS energy savings, MJ/L EtOH ²	3.2	3.0	3.5
DGS GHG credit, gCO ₂ e/MJ EtOH ^{2,3}	17.7	15.7	20.9
GHG reduction, % less than gasoline ⁴	47.1	50.1	60.1

¹DDGS = dried distillers grains plus solubles; MDGS = modified distillers grains plus solubles; WDGS = wet distillers grains plus solubles; NE = Nebraska; DGS = distillers grains; EtOH = ethanol.

²Assumes 20% of diet DM is DGS. Improved cattle performance increases the credit.

³The calculation of gCO₂e is g CO₂ + (25 x g CH₄) + (298 x g N₂O).

⁴Incorporates the GHG balance of corn production, ethanol plant energy use, and DGS credit due to cattle feeding relative to gasoline GHG emissions.

Table 2. Energy and greenhouse gas (GHG) balance of Midwest ethanol production when feeding DDGS to beef, dairy, or swine¹.

	Beef	Dairy	Swine
Corn production	-----Midwest-----		
Co-product	-----DDGS-----		
DGS energy savings, MJ/L EtOH ²	2.7	1.5	1.5
DGS GHG credit, gCO ₂ e/MJ EtOH ^{2,3}	18	11.7	11.5
GHG reduction, % less than gasoline ⁴	47	41.2	40.9

¹DDGS = dried distillers grains plus solubles; DGS = distillers grains; EtOH = ethanol.

²Assumes 20%, 10%, and 9% of diet DM is DDGS for beef, dairy, and swine, respectively.

³The calculation of gCO₂e is g CO₂ + (25 x g CH₄) + (298 x g N₂O).

⁴Incorporates the GHG balance of corn production, ethanol plant energy use, and DGS credit due to livestock feeding relative to gasoline GHG emissions.

Table 3. Energy and greenhouse gas (GHG) balance of Iowa, Nebraska, and Texas ethanol production systems when feeding DGS to beef, dairy, and swine industries within the respective state¹.

	IA	NE	TX
Corn production, gCO ₂ e/kg corn ²	274	308	473
Biorefinery energy, MJ/L EtOH	7.6	5.7	4.9
Co-product type produced ³			
DDGS, % of co-product DM	72	14	0
MDGS, % of co-product DM	14	19	0
WDGS, % of co-product DM	14	67	100
Livestock classes fed ^{3,4}			
Beef, % of DGS production	18	74	97
Dairy, % of DGS production	10	2	3
Swine, % of DGS production	72	24	0
DGS Energy Savings, MJ/L EtOH	1.5	3.1	5.1
DGS GHG credit, gCO ₂ e/MJ EtOH ²	12	18.4	28.3
GHG reduction, % less than gasoline ⁵	47.2	55.3	48.8

¹DGS = distillers grains; EtOH = ethanol; DDGS = dried distillers grains plus solubles.

²The calculation of gCO₂e is g CO₂ + (25 x g CH₄) + (298 x g N₂O).

³Co-product production and livestock class profiles are based on survey data, National Agricultural Statistics Service data, and personal communication with knowledgeable sources.

⁴Assumes 20%, 10%, and 9% of diet DM is DDGS for beef, dairy, and swine, respectively.

⁵Incorporates the GHG balance of corn production, ethanol plant energy use, and DGS credit due to livestock feeding relative to gasoline GHG emissions.

performance of livestock fed DGS instead of traditional feeds.

Three scenarios were evaluated to determine the energy and GHG balance of ethanol relative to gasoline:

- 1) the effects of feeding Nebraska WDGS, MDGS, or DDGS to feedlot steers;
- 2) the effects of feeding Midwest DDGS to beef, dairy, or swine;
- 3) the effects of Iowa, Nebraska, and

Texas ethanol production systems.

Results

Table 1 summarizes the energy and GHG balance for feedlot steers. Feeding wetter forms of DGS improved the energy and GHG balance. An ethanol plant producing DDGS decreased energy use by 41% when switching to WDGS production. The benefits to the ethanol plant and the feedlot of feeding WDGS instead of DDGS represented a 28% improvement in the GHG reduction potential of ethanol relative to gasoline. The benefit of feeding MDGS was intermediate to the benefits of feeding WDGS and DDGS.

Feeding DDGS to feedlot steers instead of dairy cows or grow-finish pigs improved the energy and GHG credit associated with DGS (Table 2), which resulted in a 15% improvement in the GHG emissions reduction potential of ethanol production associated with feedlots vs. swine or dairy production operations.

The Texas, Iowa, and Nebraska production systems had differing DGS energy and GHG balances due to the different types of DGS produced and fed (Table 3). Texas had the greatest number of DGS credits because more energy-intense corn was replaced by DGS. The most important calculation was the overall GHG reduction potential of the whole corn, ethanol, and livestock system relative to gasoline. In Nebraska, GHG emissions relative to gasoline were improved by 17% and 13% relative to Iowa and Texas, respectively. The balance of moderate corn production energy requirement with WDGS feeding to feedlot steers offered the optimum energy and GHG balance of DGS fed to livestock.

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The Economic Impact of Feeding Wet Corn Co-Products in Nebraska

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Summary

Isoquants that illustrate combinations of various inputs to produce a given level of output were estimated for wet corn co-products using UNL cattle feeding trial data and applied to actual producer data. Producer economic benefits from feeding wet co-products compared to corn were calculated. Although the combined producer savings from all three wet co-products totaled nearly \$39 million, this value was not net of all cost differences between co-products and corn, including transportation, storage, and handling costs.

Introduction

The symbiotic relationship between Nebraska agricultural producers and ethanol plants is in part due to the ability of the state's growers to supply a large quantity of corn while at the same time utilizing the co-products of ethanol production as a feedstuff in cattle rations. The objective of this study was to estimate the aggregate economic benefit to Nebraska cattle producers from feeding wet co-products in feedlot rations versus corn-only (no co-product) rations in 2007. This analysis updates and expands a study by Perrin and Klopfenstein in 2001 (*2001 Nebraska Beef Report*, pp. 45-47) that analyzed the direct economic benefit of feeding wet co-products in Nebraska by measuring the difference between the feed value of the wet co-products and their alternative use as dried feeds.

Procedure

To determine the economic benefit to Nebraska cattle producers from feeding wet co-products in feedlot

rations versus rations containing no co-product, a unit isoquant was estimated for three distinct wet corn co-products: wet distillers grains plus solubles (WDGS), wet corn gluten feed (WCGF), and Sweet Bran[®]. An isoquant represents different combinations of two inputs (in this case co-product and corn) needed to produce a constant output (in this case one pound of beef gain). Separate isoquants were estimated for WDGS, WCGF, and Sweet Bran[®] using UNL cattle feeding trial and performance data. These isoquants were then used along with feeding practices reported by Nebraska producers in 2007 to calculate the economic benefit associated with feeding WDGS, WCGF, and Sweet Bran[®], respectively.

Experimental data from UNL cattle feeding trials included days on feed, feedstuff inclusion levels as a percentage of the total ration (DM basis), daily DM intake, and average daily gain. Pounds of feedstuff per pound of beef gain for each ration ingredient were calculated by multiplying daily DM intake by the feedstuff ration inclusion percentage (DM basis) for each respective feedstuff. This calculation yielded the pounds

(DM) of each feedstuff consumed daily, which was then divided by ADG to arrive at lbs of feedstuff (DM) per pound of gain (F_i:G) for each feedstuff included in the experimental data rations. The average F_i:G ratios for co-products were 1.54, 3.34, and 1.90 for WDGS (n = 31), WCGF (n = 17), and Sweet Bran[®] (n = 16) rations, respectively. The average F_i:G ratios for rolled corn and/or high moisture corn associated with the WDGS, WCGF, and Sweet Bran[®] rations were 3.86 (n = 40), 3.24 (n = 25), and 3.76 (n = 24), respectively.

Figure 1 graphically represents the statistically estimated isoquants for WDGS, WCGF, and Sweet Bran[®]. Not only do the isoquants portray various combinations of co-product and corn needed to produce one pound of gain, but the graphs also illustrate the relative feeding values associated with the three different co-products. Sweet Bran[®] has a higher feeding value (smaller quantities of both corn and co-product are required) than WCGF at all levels of co-product inclusion. WDGS has the highest feeding value of the three over a range of inclusion levels from approximately 13% to approximately 55%. The feeding

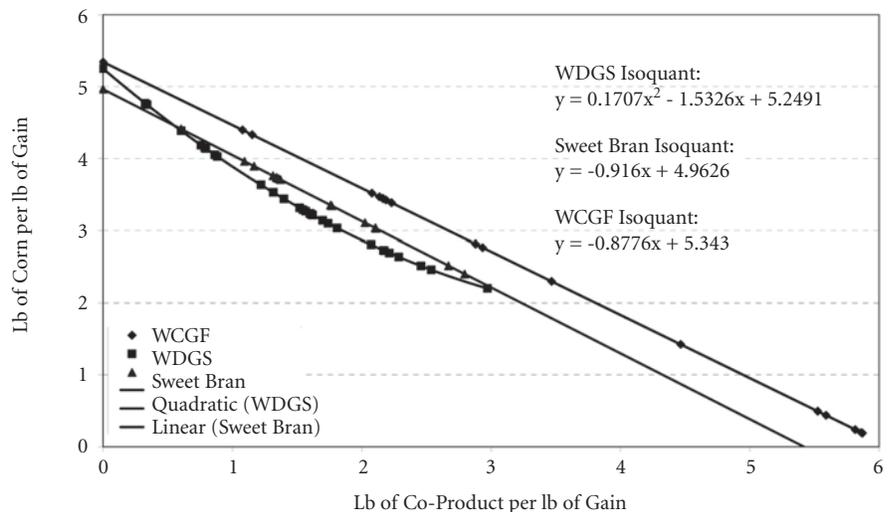


Figure 1. WDGS, WCGF, and Sweet Bran[®] experimental isoquants.

Table 1. Savings to producers from feeding wet corn co-products, 2007¹.

WDGS		
	\$/lb of gain	\$/ton co-product fed, DM
Method 1	0.0397	70.46
Method 2	0.0425	71.94
Method 3	0.0423	74.00
Method 4	0.0424	71.74
Average	0.0417	72.04
WCGF		
	\$/lb of gain	\$/ton co-product fed, DM
Method 1	0.0125	25.34
Method 2	0.0132	27.00
Method 3	0.0114	24.20
Method 4	0.0120	24.64
Average	0.0123	25.29
Sweet Bran®		
	\$/lb of gain	\$/ton co-product fed, DM
Method 1	0.0097	15.51
Method 2	0.0098	15.53
Method 3	0.0109	15.76
Method 4	0.0099	15.66
Average	0.0101	15.62

¹Savings estimated as the difference between costs per lb of gain in rations containing co-product and corn-only rations.

value associated with WDGS actually decreases relative to WCGF and Sweet Bran® as co-product inclusion levels decline below approximately 30%.

The primary objective of this study was to calculate the benefits actually realized by Nebraska producers in 2007. To do so, the estimated isoquants for WDGS, WCGF, and Sweet Bran® were applied to actual 2007 producer data from the Ethanol Co-Product User Survey discussed in Waterbury et al. (2009 *Nebraska Beef Report*, pp. 50-52). Although this survey did not provide complete ration information, it did elicit information about producer co-product inclusion levels, allowing prediction of producers' locations on the experimental isoquants in Figure 1.

Producer economic benefit from feeding wet co-products was estimated by comparing ration costs per pound of gain at the reported co-product inclusion level, with the ration cost for corn as the only grain, using prices reported by the respondents. Alternative methods of aggregating results across producers were used, as described below.

Respondents to the Ethanol Co-

Product User Survey were asked to provide information regarding the price paid and the ration inclusion level for each co-product purchased in 2007. Although most included both pieces of information, some included only price or only inclusion level information. Therefore, to account for some missing data, producer savings per pound of gain for each co-product were estimated using four different methods as outlined below. The basic framework of all four methods is identical, with variation occurring only in regard to the use of original producer data versus average producer inclusion data (1.22, 0.99, and 1.25 lbs of co-product [DM] per lb of gain for WDGS, WCGF, and Sweet Bran®, respectively) and average producer price data (\$118.48/ton, \$98.58/ton, and \$113.84/ton DM, FOB plant for WDGS, WCGF, and Sweet Bran®, respectively):

1. Individual producer pounds of co-product per pound of gain; average co-product price for all observations: 65, 20, and 29 for WDGS, WCGF, and Sweet Bran®, respectively.

2. Individual producer pounds of co-product per pound of gain; individual producer co-product price with average producer price replacing missing price data: 65, 20, and 29 for WDGS, WCGF, and Sweet Bran®, respectively.
3. Individual producer pounds of co-product per pound of gain with average producer pounds of co-product per pound of gain replacing missing inclusion data and individual producer co-product price: 52, 13, and 17 for WDGS, WCGF, and Sweet Bran®, respectively.
4. Individual producer pounds of co-product per pound of gain with average producer pounds of co-product per pound of gain replacing missing inclusion data; individual producer co-product price with average producer price replacing missing price data: 73, 21, and 29 for WDGS, WCGF, and Sweet Bran®, respectively.

For each of the four applicable methods, savings per pound of gain were calculated separately for each producer using each of the three distinct co-products included in this analysis. Savings per pound of gain values were then divided by each producer's associated pounds of co-product per pound of gain (either individual or average data) to arrive at savings per lb, or per ton, of co-product fed. The average savings value across all producers for each co-product was multiplied by the respective total tons of co-product (DM) produced by ethanol plants in Nebraska in 2007, to arrive at the aggregate producer benefits from feeding co-products rather than corn.

Results

Given the prices reported in the survey, the average cost savings to producers per pound of gain and per ton of co-product fed (DM) were greatest for WDGS, followed by

(Continued on next page)

WCGF and Sweet Bran® (Table 1). Based on the relative feeding values of the three co-products estimated by the experimental isoquants (Figure 1), WCGF would result in lower benefits than Sweet Bran® if co-product prices were equal. The savings to producers in Table 1 account for co-product cost in addition to cattle performance. The average WCGF price was \$98.58/ton DM, while the average Sweet Bran® price was \$113.84/ton DM, so the price differential was greater than the feeding value differential. Even more interesting is the fact that the average WDGS price reported by producers (\$118.48/ton DM) was actually greater than both WCGF and Sweet Bran® prices. Again, these results show that the feeding value associated with WDGS was great enough to offset the increased cost of the co-product, thereby allowing producer savings from WDGS to be the greatest among the three.

Producer savings also were expanded to the entire state of Nebraska by using the tons of each respective wet co-product produced by ethanol plants in 2007 (Table 2). WDGS again represented the largest portion of total producer economic benefit with \$33.88 million in savings. Although the savings per pound of gain and per ton of co-product fed (DM) were greater for WCGF than for Sweet Bran® (Table 1), the total state savings were actually greater for the latter at \$2.51 million. In 2007, ethanol plants produced nearly 69,000 more tons (DM) of Sweet Bran® than WCGF. The larger production of Sweet Bran® was more than enough to compensate for the lower producer savings per pound of gain and per

Table 2. Savings to Nebraska from feeding wet corn co-products, 2007¹.

	Method 1	Method 2	Method 3	Method 4	Average
WDGS (mil of \$)	33.14	33.84	34.81	33.75	33.88
WCGF (mil of \$)	2.34	2.49	2.23	2.27	2.33
Sweet Bran® (mil of \$)	2.49	2.50	2.53	2.52	2.51
Total (mil of \$)	37.97	38.83	39.57	38.54	38.72

¹Producer savings based on Nebraska production of each co-product.

ton of co-product fed (DM), thereby allowing Sweet Bran® to represent a greater proportion of the total producer economic benefit. All three wet co-products combined yielded \$38.72 million in total state savings, while the per ton (DM) savings from feeding wet co-products compared to corn for all three wet co-products were \$25.30/ton.

Purchase costs vary between corn and wet co-products as described above, but there also are other cost differentials. The savings to producers reported here are not net of expenses such as transportation, handling, and storage costs. In addition, all wet co-product produced in Nebraska in 2007 was assumed to be included as a ration ingredient for feedlot cattle. Finally, because no data exist regarding Nebraska imports and exports of wet co-product, these values were assumed to be equal, allowing them to be ignored for the purposes of this analysis.

When compared to the study done by Perrin and Klopfenstein (2001), the average WDGS savings to Nebraska in 2007 was \$25.71 million greater than the average state savings from 1994 to 1999 (\$8.17 million). This significant increase in total state savings seems reasonable as WDGS production in Nebraska from 1999 to 2007 increased

nearly 118,000 tons (DM). Although not related to the increased production of WDGS, the producer benefit per ton of WDGS fed (DM) in 2007 was \$72.04/ton as compared to \$32.95/ton (DM) as reported in the previous study. The large differential in savings per ton of WDGS fed between the previous and current study may be due to differences in corn and/or co-product prices, producer co-product inclusion levels, or a combination of both.

The state savings in 2007 for WCGF and Sweet Bran® equaled a combined total of \$4.84 million, approximately \$8.16 million less than the average state savings calculated by Perrin and Klopfenstein (2001) for 1992 to 1999. However, it is important to note that the current study estimated the average producer benefit for traditional WCGF and Sweet Bran® at \$25.29/ton and \$15.62/ton DM, respectively. The analysis done by Perrin and Klopfenstein (2001) estimated this value to be \$25.71/ton of WCGF fed (DM) (including Sweet Bran®). So, the savings in dollars per ton (DM) of WCGF and Sweet Bran® fed in 2007 are similar to the average from 1992 to 1999.

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Update: Meta-Analysis of UNL Feedlot Trials Replacing Corn with WDGS

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Summary

An updated meta-analysis of UNL feedlot trials replacing dry rolled (DRC) or high moisture (HMC) corn with wet distillers grains plus solubles (WDGS) indicated feeding performance similar to previous estimates. The feeding value of WDGS was similar for winter-fed calves, summer-fed yearlings, and fall-fed yearlings. The improvement in F:G from both WDGS and HMC was synergistic compared to DRC with or without WDGS. Feeding WDGS at increased levels in HMC-based diets provided performance superior to DRC with or without WDGS.

Introduction

A previous meta-analysis of UNL feedlot trials evaluated replacing corn with WDGS (2008 *Nebraska Beef Report*, pp. 35-36). Since publication of the original meta-analysis, additional trials have been completed that augment the original dataset.

Previous UNL research has shown high moisture corn (HMC) to have increased feeding value relative to dry rolled corn (DRC) in feedlot diets with no byproducts. However, the previous meta-analysis was not robust enough to accurately evaluate the impact of corn processing type on feeding value of WDGS.

The UNL feedlot research utilizes spring-born black crossbred steers weaned in the fall for most research trials. After an initial receiving period, the largest steers are fed as calf-feds in the winter, the medium steers are fed as short yearlings in the summer after wintering on cornstalks, and the small steers are win-

tered on cornstalks, grazed on grass through the summer, and finished in the fall to market by 24 months of age. Previous UNL research has shown the winter-fed calves to be more efficient than yearlings at converting feedlot diets to gain (2007 *Nebraska Beef Report*, pp. 58-60). We realize that season of feeding and calf age are confounded; however, the data set allows for the evaluation of WDGS feeding value with winter-fed calf-feds, summer-fed short yearlings, and fall-fed long yearlings.

The objectives of this meta-analysis were to update the existing meta-analysis and to more accurately evaluate the impact of corn type and season of feeding on the feeding value of WDGS.

Procedure

The criteria for trial inclusion in the dataset were the same as for the previous meta-analysis. Five additional UNL feedlot trials replacing corn with WDGS have been completed since the previous meta-analysis publication (2009 *Nebraska Beef Report*, pp. 59-61; 2009 *Nebraska Beef Report*, pp. 66-69; 2009 *Nebraska Beef Report*, pp. 76-78; 2009 *Nebraska Beef Report*, pp. 86-88; 2010 *Nebraska Beef Report*, pp. 43-45). Five winter, six summer, and three fall studies (n = 2,534 steers) were included in the dataset with 46 treatment means. Seven trials fed a blend (mainly 1:1) of HMC and DRC; seven trials fed DRC only; and one of the DRC trials also fed HMC diets without DRC. In all trials, WDGS replaced corn in the diets (0 to 50% of diet DM).

An iterative meta-analysis was used to integrate quantitative findings from multiple studies using the PROC MIXED procedure of SAS. Trials were weighted by number of WDGS levels to prevent artificial linear responses from trials with only 0 and one other

level of WDGS. The initial model (similar to the previous analysis) included the effects of trial and WDGS inclusion as percentage of diet DM (linear, quadratic, and cubic effects when significant). The advanced model for evaluating F:G for season of feeding and corn processing (DRC, HMC, and a 1:1 DRC:HMC blend) also included the effects of season (winter, summer, or fall), percentage of diet corn as HMC, and the linear interaction of percentage of diet corn as HMC with WDGS inclusion level.

Results

Replacement of corn up to 50% of diet DM as WDGS resulted in superior performance compared to cattle fed no WDGS (Table 1). These data agree with the previous meta-analysis. Dry matter intake, ADG, F:G, 12th rib fat, and marbling score improved quadratically as WDGS inclusion level increased. The feeding value of WDGS was consistently higher than that of corn when WDGS was included up to 50% of diet DM. The feeding value was greater at lower WDGS inclusion levels and decreased as inclusion level increased. The increased feeding value of WDGS was due to improvements in ADG when WDGS replaced corn.

According to the advanced model calculations, winter-fed calves have F:G superior to summer- and fall-fed yearlings (Table 2). The feeding value of WDGS was similar for calves fed in the winter, short yearlings fed in the summer, and long yearlings fed in the fall.

Feeding HMC instead of DRC in 0% WDGS diets improved F:G by 23% when adjusted for roughage and supplement inclusion in the diet (Table 3). This value may be inflated from actual biological value due to the synergistic effect of feeding a DRC and HMC blend with WDGS in the diet that is not accounted for by the model.

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Table 1. Finishing steer performance when fed different dietary inclusions of wet distillers grains plus solubles (WDGS).

WDGS Inclusion ¹	0WDGS	10WDGS	20WDGS	30WDGS	40WDGS	50WDGS	Lin ²	Quad ²	Cubic ²
DMI, lb/day	23.0	23.3	23.4	23.1	22.5	21.6	0.05	< 0.01	0.63
ADG, lb	3.52	3.73	3.85	3.88	3.82	3.68	< 0.01	< 0.01	0.33
F:G	6.55	6.27	6.07	5.94	5.88	5.90	< 0.01	0.03	0.46
12 th rib fat, in	0.49	0.52	0.54	0.55	0.54	0.51	0.05	0.03	0.09
Marbling score ³	521	528	530	527	520	507	0.85	0.03	0.70
Feeding value, % ⁴	100	148	142	136	129	123			

¹Dietary treatment levels (DM basis) of wet distillers grains plus solubles (WDGS): 0WDGS = 0% WDGS; 10WDGS = 10% WDGS; 20WDGS = 20% WDGS; 30WDGS = 30% WDGS; 40WDGS = 40% WDGS; 50WDGS = 50% WDGS.

²Estimation equation linear, quadratic, and cubic term t-statistic for variable of interest response to WDGS level.

³500 = Small⁰.

⁴Percentage of corn feeding value, calculated from predicted feed conversion relative to 0WDGS feed conversion, divided by WDGS inclusion.

The feeding value of WDGS in a diet containing HMC was in addition to the feeding performance benefit of HMC. The WDGS in the 40% WDGS diet with HMC was worth 135% the feeding value of HMC. The 42.5% HMC and 40% WDGS were both worth 139% the feeding value of DRC. This means the 42.5% HMC with WDGS had feeding value at least equal to that of the 40% WDGS. The feeding value of the HMC was improved when it was fed with WDGS.

An intermediate, synergistic improvement in F:G is seen when a blend of DRC and HMC is fed with 40% WDGS relative to DRC or HMC as the only corn source. The WDGS in this diet was worth 125% the feeding value of the DRC:HMC blend. The 21% HMC and 40% WDGS were both worth 131% the feeding value of DRC.

These data suggested feeding WDGS with HMC provides improved feedlot performance relative to DRC diets with or without WDGS. No significant difference in feeding value was observed when WDGS was fed to winter calves, summer yearlings, or fall yearlings.

Table 2. Finishing steer performance when fed different dietary inclusions of wet distillers grains plus solubles (WDGS) in winter, summer, or fall.

WDGS Inclusion ¹	0WDGS	10WDGS	20WDGS	30WDGS	40WDGS	50WDGS
Winter F:G ^a	5.97	5.70	5.50	5.40	5.45	5.68
Summer F:G ^a	6.75	6.40	6.15	6.03	6.09	6.38
Fall F:G ^a	6.19	5.91	5.69	5.59	5.63	5.88
Winter Feeding Value, % ²		147	142	134	124	110
Summer Feeding Value, % ²		153	148	139	127	111
Fall Feeding Value, % ²		148	144	136	124	110

¹Dietary treatment levels (DM basis) of wet distillers grains plus solubles (WDGS): 0WDGS = 0% WDGS; 10WDGS = 10% WDGS; 20WDGS = 20% WDGS; 30WDGS = 30% WDGS; 40WDGS = 40% WDGS; 50WDGS = 50% WDGS.

²Percentage of corn feeding value, calculated from predicted feed conversion relative to 0WDGS feed conversion, divided by WDGS inclusion.

^aSignificant season of feeding effect ($P < 0.01$) and no season by WDGS level interaction ($P = 0.93$).

Table 3. Finishing steer performance when fed different dietary inclusions of wet distillers grains plus solubles (WDGS) in diets containing dry rolled corn (DRC), high moisture corn (HMC), or a 1:1 blend of DRC:HMC.

WDGS Inclusion ¹	0WDGS	10WDGS	20WDGS	30WDGS	40WDGS	50WDGS
DRC F:G ^a	6.78	6.52	6.33	6.28	6.41	6.82
DRC:HMC F:G ^a	6.29	5.99	5.77	5.66	5.71	5.97
HMC F:G ^a	5.86	5.54	5.30	5.16	5.15	5.30
DRC feeding value, % ²		141	136	127	115	99
DRC:HMC feeding value, % ²		150	145	137	125	111
HMC feeding value, % ²		157	153	145	135	121

¹Dietary treatment levels (DM basis) of wet distillers grains plus solubles (WDGS): 0WDGS = 0% WDGS; 10WDGS = 10% WDGS; 20WDGS = 20% WDGS; 30WDGS = 30% WDGS; 40WDGS = 40% WDGS; 50WDGS = 50% WDGS.

²Percentage of corn feeding value, calculated from predicted feed conversion relative to 0WDGS feed conversion, divided by WDGS inclusion.

^aSignificant corn processing effect ($P < 0.01$) and significant corn processing by WDGS level interaction ($P < 0.01$).

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Evaluation of Feedlot and Carcass Performance of Steers Fed Different Levels of E-Corn, a Potential New Feed Product from Ethanol Plants

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Summary

A pre-process fractionation produces a feed product called E-corn, which is low in fat and contains heat-treated starch. E-corn replaced dry rolled corn at 0, 20, 40, or 60% (DM basis) in finishing diets containing either 30% wet distillers grains plus solubles (WDGS) or 30% wet corn gluten feed (WCGF). E-corn level x byproduct type interactions were not observed. Dry matter intake increased quadratically to E-corn inclusion level ($P = 0.04$), while F:G responded cubically with 20% and 60% E-corn inclusion having the lowest F:G ($P = 0.02$). However, when E-corn level increased from 0 to 60% of diet DM, linear decreases in marbling, fat depth, and calculated yield grade were observed ($P < 0.01$). Steers fed WDGS had lower DMI ($P < 0.01$) and F:G ($P = 0.02$) compared to steers fed WCGF. It appears that optimal inclusion of E-corn is 20% of diet DM.

Introduction

Improving the efficiency of ethanol production has included refined milling processes by ethanol companies. One such refinement has led to either partial or complete fractionation of the germ, endosperm, and bran. In addition to increasing ethanol production efficiency, opportunities may arise to develop “novel” byproducts intended for livestock feed use. Specifically, the product E-corn was created

as the remaining meal from the fractionation of corn into the endosperm used for ethanol, and the germ, from which corn oil is extracted and sold as food-grade corn oil. Previous research on the use of E-corn in swine diets has shown a feeding value equal to that of corn. Therefore, it is hypothesized the use of E-corn in beef cattle finishing diets will yield similar cattle performance and carcass characteristics compared to corn-based diets.

Procedure

A 153-day finishing trial was conducted utilizing 120 crossbred yearling steers (BW = 821 ± 14 lb) in a random-

ized complete block design. Steers were fed individually using Calan electronic gates. Five days prior to initiation of the trial, steers were limit fed to minimize variation in rumen fill (1:1 ratio of alfalfa hay and wet corn gluten feed at 2% BW). Steers were then weighed individually on days -1, 0, and 1 to determine initial BW. Animals were blocked by BW, stratified within block, and assigned randomly to one of eight treatments in one of four barns. Animal served as the experimental unit, and there were a total of 15 replications per treatment.

Dietary treatments were designed as a 2 x 4 factorial arrangement (Table 1), with the first factor being type of

(Continued on next page)

Table 1. Dietary treatments for individually fed finishing steers to evaluate E-corn in diets containing either WCGF or WDGS.

Ingredient	E-corn Level ¹			
	0	20	40	60
<i>WCGF diets</i>				
Dry rolled corn	60.0	40.0	20.0	0.0
WCGF	30.0	30.0	30.0	30.0
E-corn	0.0	20.0	40.0	60.0
Stalks	5.0	5.0	5.0	5.0
Supplement ²	5.0	5.0	5.0	5.0
<i>Nutrient composition³</i>				
Crude protein	14.5	14.6	14.8	15.0
Fat	3.7	3.1	2.6	2.1
Sulfur	0.26	0.26	0.26	0.27
NDF	25.6	25.8	26.0	26.1
<i>WDGS diets</i>				
Dry rolled corn	60.0	40.0	20.0	0.0
WDGS	30.0	30.0	30.0	30.0
E-corn	0.0	20.0	40.0	60.0
Stalks	5.0	5.0	5.0	5.0
Supplement ²	5.0	5.0	5.0	5.0
<i>Nutrient composition³</i>				
Crude protein	17.2	17.4	17.6	17.7
Fat	6.3	5.8	5.3	4.7
Sulfur	0.37	0.38	0.38	0.38
NDF	25.6	25.7	25.9	26.0

¹E-corn inclusion level represented as a percentage of diet DM.

²Formulated to contain 59.1% fine ground corn, 41.0% limestone, 6.0% salt, 1.0% beef trace mineral (10% Mg, 6% Zn, 4.5% Fe, 2% Mg, 0.5% Cu, 0.3% I, and 0.05% Co), 0.30% vitamin premix (1500 IU vitamin A, 3000 IU vitamin D, 3.7 IU vitamin E per g), 320 mg/hd/d monensin, 40g/lb thiamine, and 90 mg/hd/d tylosin.

corn byproduct utilized (WDGS or WCGF) and the second factor being level of E-corn inclusion (0, 20, 40 or 60% diet DM). E-corn replaced DRC in all diets (on equal DM basis), and all diets contained 5% cornstalks and 5% dry supplement. On day 28 of the experiment, calves were implanted with Revalor-S (Intervet, Millsboro, Del.). Throughout the course of the experiment, feed refusals were collected twice weekly, weighed and analyzed for DM content to determine accurate DMI. Feed ingredients were collected weekly, frozen, and stored until the conclusion of the trial and then composited by month and analyzed for DM, CP, fat, sulfur, and NDF content to determine nutrient composition of the diets. All steers were slaughtered on day 153 at Greater Omaha (Omaha, Neb.). On the day of slaughter, hot carcass weight (HCW) and liver abscess data were recorded. Following a 48-hour chill, USDA marbling score, 12th rib fat thickness, and LM area data were collected. Hot carcass weights were used to calculate adjusted final BW by dividing HCW by a common dressing percentage (63%). Average daily gain and F:G were calculated from adjusted final BW. Yield grade was calculated using the USDA yield grade equation, yield grade = 2.5 + 2.5(12th rib fat thickness, in) - 0.32(LM area, in²) + 0.2(KPH fat, %) + 0.0038 (HCW, lb).

Steer performance and carcass data were analyzed using the MIXED procedures of SAS (SAS Institute, Cary, N.C.). The model was designed to include corn byproduct type, E-corn inclusion level, and byproduct type x E-corn inclusion level interaction. Orthogonal contrasts were used to determine linear and quadratic effects of E-corn inclusion level. If a significant interaction existed, effects of E-corn were evaluated within byproduct type. When no interaction was observed, only the main effect of E-corn level was evaluated.

Table 2. Steer performance when individually fed varying levels of E-corn for 153 days.

Ingredient	E-corn Level ¹							
	0	20	40	60	Lin ²	Quad ³	Cub ⁴	Int ⁵
Live Performance								
Initial BW, lb	819	821	822	821	0.81	0.82	0.97	0.99
Final BW ⁶ , lb	1280	1305	1270	1272	0.46	0.51	0.23	0.41
DMI, lb/d	21.6	22.0	22.3	21.0	0.37	0.04	0.35	0.93
ADG, lb	3.01	3.16	2.93	2.94	0.36	0.53	0.21	0.36
G:F	0.139	0.144	0.131	0.140	0.59	0.53	0.02	0.30
F:G ⁷	7.19	6.94	7.63	7.14				
Carcass Performance								
HCW, lb	806	822	800	801	0.45	0.50	0.23	0.41
Marbling score ⁸	528	484	485	444	<0.01	0.94	0.25	0.92
12 th rib fat, in	0.46	0.45	0.40	0.37	<0.01	0.72	0.61	0.64
LM area, in ²	12.4	13.2	12.5	13.3	0.05	0.89	<0.01	0.07
Calculated YG ⁹	3.25	3.03	3.04	2.70	<0.01	0.49	0.11	0.43

^{abc}Within a row means without a common superscript letter differ ($P < 0.10$).

¹E-corn inclusion level represented on a % of diet DM basis.

²Contrast for the linear effect of E-corn level P -value.

³Contrast for the quadratic effect of E-corn level P -value.

⁴Contrast for the cubic effect of E-corn level P -value.

⁵Interaction between E-corn inclusion level and corn byproduct type P -value.

⁶Calculated from hot carcass weight, adjusted to a 63% yield.

⁷Calculated as 1/G:F.

⁸400 = Slight, 450 = Slight 50, 500 = Small 0, etc.

⁹Yield grade = 2.5 + 2.5(12th rib fat, in) - 0.32(LM area, in²) + 0.2(KPH fat, %) + 0.0038(HCW, lb).

Table 3. Steer performance when individually fed either 30% wet distiller grains plus solubles (WDGS) or wet corn gluten feed (WCGF) for 153 days.

Ingredient	TYPE			
	WCGF	WDGS	SEM	P -Value ¹
Initial BW, lb	823	818	20	.54
Final BW ² , lb	1284	1279	6	0.75
DMI, lb/d	22.4	21.0	0.1	<0.01
ADG, lb	3.02	3.01	0.03	0.95
G:F	0.134	0.143	0.001	0.02
F:G ³	7.46	6.99		
HCW, lb	809	806	4	0.76
Marbling score ⁴	488	483	12	0.76
12 th rib fat, in	0.41	0.43	0.38	0.37
LM area, in ²	13.0	12.7	1.0	0.29
Calculated YG ⁵	2.95	3.06	0.06	0.17

¹F-test statistic for the effect of byproduct type.

²Calculated from hot carcass weight, adjusted to a 63% yield.

³Calculated as 1/G:F.

⁴400 = Slight, 450 = Slight 50, 500 = Small 0, etc.

⁵Yield grade = 2.5 + 2.5(12th rib fat, in) - 0.32(LM area, in²) + 0.2(KPH fat, %) + 0.0038(HCW, lb).

Results

E-Corn Inclusion Level

Corn Byproduct Type X E-Corn Inclusion Level

No interaction between corn byproduct type and E-corn inclusion level was observed for steer performance ($P > 0.10$).

Live steer performance and carcass characteristics for the effect of E-corn inclusion level are presented in Table 2. Regardless of corn byproduct type, steers fed increasing levels of E-corn had similar final carcass adjusted body weights ($P = 0.49$). Intake responded quadratically to increasing

inclusion of E-corn ($P = 0.04$). Steers that consumed 0 to 40% diet DM of E-corn had similar DMI, while steers consuming 60% diet DM E-corn had lower DMI. Alternatively, as the level of E-corn increased from 0 to 60% of the diet DM, no differences in ADG were observed ($P > 0.10$).

Feed efficiency responded in a cubic manner as the level of E-corn inclusion increased from 0 to 60% of diet DM. Steers fed 20 or 60% E-corn had the numerically lowest F:G and were statistically similar ($P = 0.52$), while steers fed 0 or 40% E-corn had the poorest F:G. This would suggest that replacing DRC with E-corn at 60% of the diet DM in diets containing corn byproducts would result in comparable live steer performance while potentially decreasing average DMI.

Carcass weight was not affected by the increasing inclusion of E-corn ($P = 0.49$). However, as the level of E-corn increased, linear decreases in marbling score, fat depth, and calculated yield grade were observed ($P < 0.01$). When DRC was replaced by E-corn at 20% of the diet DM, decreases of 8.3, 2.2, and 6.8% in marbling score, fat depth, and calculated YG were observed when compared to the DRC-based control. Similarly, when E-corn replaced all of the DRC (60% diet DM E-corn inclusion), decreases of 15.9, 19.6 and 16.9% in

marbling score, fat depth, and calculated yield could be expected. Including 40% of the diet DM as E-corn would show intermediate decreases in carcass characteristics, compared to 20% or 60% E-corn inclusion.

Corn Byproduct Type

Live steer performance and carcass characteristics for the effect of corn byproduct type inclusion are presented in Table 3. Final carcass adjusted body weight was not different between steers consuming WDGS or WCGF ($P = 0.75$). Steers consuming WDGS had lower DMI than steers consuming WCGF ($P < 0.01$), while maintaining similar ADG ($P > 0.10$). As a result, steers consuming WDGS had a 6% improvement in feed efficiency versus steers consuming WCGF ($P = 0.02$). Carcass characteristics were unaffected by corn byproduct type ($P > 0.10$).

The feeding value of E-corn was maximized (118% the relative value of corn) at 20% diet DM; total replacement of DRC with E-corn at 60% diet DM showed only a minimal improvement in the feeding value of E-corn versus DRC (101% the relative value of corn). This could be due to the total replacement of corn, which contains more fat and thereby decreases the total energy value of the diet. Furthermore, decreasing the total energy content of the diet appears to have

had the greatest impact on carcass characteristics, and reducing the fat content of the diet compromised marbling score, fat depth, and calculated yield grade, indicating a lower degree of finish compared to including DRC only in the diet.

It could be hypothesized that while carcass adjusted final body weight was similar across E-corn inclusion levels, additional days on feed may be required to reach the same degree of finish. Additionally, it appears that inclusion of E-corn with WDGS would reduce DMI but maintain F:G, and optimum performance can be expected at 20% E-corn diet DM inclusion.

It is unclear why the inclusion of E-corn had such profound impacts on carcass finish while not negatively impacting DMI, ADG, or F:G. The fact that there was no difference in ADG and F:G between 0 and 60% E-corn inclusion suggests E-corn may replace corn in diets containing WDGS or WCGF; however, further research is necessary to explain decreases in marbling score, fat depth, and YG (with no effect on HCW).

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Effects of Using Wet Distillers Grains with Solubles to Adapt Cattle to Finishing Diets on Feed Intake, Ruminal pH, and Ruminal Hydrogen Sulfide Concentration

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Summary

An adaptation strategy with wet distillers grains with solubles (WDGS) fed at decreasing levels (87.5 to 35%) was compared to a traditional grain adaptation with decreasing forage (45 to 7.5%) when adapting steers to a common finishing diet. Traditionally adapted steers had higher intake in steps one through three compared to steers adapted with distillers grains. However, DMI was not different between the two adaptation systems in step four, or when steers were on the finishing diet. Ruminal pH was higher for traditionally adapted steers compared to steers adapted to distillers grains in adaptation diets two and three. Ruminal hydrogen sulfide concentration did not appear to be a problem.

Introduction

Huls et al. (2009 *Nebraska Beef Report*, pp 53-58) reported that decreasing wet corn gluten feed instead of forage is a viable method for adapting feedlot cattle to high-concentrate diets. Despite this, little research has been done to determine the effects of using wet distillers grains with solubles (WDGS) during grain adaptation, primarily because when WDGS is fed at high levels in finishing diets, dietary sulfur levels may exceed nutritional guidelines, and the risk of inducing polioencephalomalacia becomes a concern. Nonetheless, the objectives of this research were to 1) determine if decreasing the level of WDGS and increasing corn is a preferred method for grain adaptation when compared to a traditional

adaptation diet using forage, and 2) determine the effect of WDGS on ruminal hydrogen sulfide concentration (H₂S) during adaptation.

Procedure

Eight ruminally fistulated steers (766 ± 74 lb) were assigned randomly to one of two adaptation systems: 1) decreased alfalfa hay and increased dry rolled corn while supplement and WDGS were constant (CON); and 2) decreased WDGS and increased dry rolled corn while supplement and alfalfa were constant (TRT). Four 7-day adaptation diets (steps 1 to 4) were fed within each adaptation system followed by 7 days on a common finishing diet. Table 1 provides diet composition for both adaptation systems.

Steers were individually housed in free box stalls (8.5'x10'), and diets were fed in feed bunks suspended from load cells. Constant data acquisition of feed disappearance was obtained through use of computer software connected to feed bunks. Feed weight in each bunk was recorded once every minute and data were continuously stored for each steer throughout the day. Bunks were read once daily at 0700 hr and feed offerings were adjusted accordingly for

feeding at 0730 hr. All feed refusals were weighed to accurately measure DMI.

Wireless submersible pH probes were placed into the rumen of each steer for the duration of the trial. Each pH electrode was enclosed in a weighted, PVC material cover that maintained the electrode in the ventral sac of the rumen. Ruminal pH was recorded once every minute continuously for 7 days. On day 7 of each step, the probe was briefly removed from the rumen, pH data were downloaded, pH electrodes were recalibrated, and then the self-contained pH probe was reinserted into the rumen.

Ruminal hydrogen sulfide concentration was measured through gas collection devices inserted via the ruminal cannula prior to feeding on day 7. Gas samples were collected 8 hours post feeding on day 7 for each step. Four gas samples were taken from each steer at each time point.

Data were analyzed by adaptation system to show the effect of the two adaptation systems throughout the adaptation period using the MIXED procedure of SAS. Fixed model effects were adaptation diet, adaptation system, and adaptation diet x adaptation system interaction. Animal nested within adaptation system was

Table 1. Dietary treatments used to compare two grain adaptation systems (% DM basis).

Days fed	1-7	8-14	15-21	22-28	29-35
Adaptation	1	2	3	4	5
CON ¹					
DRC ²	15.0	25.0	35.0	45.0	52.5
WDGS ³	35.0	35.0	35.0	35.0	35.0
Alfalfa hay	45.0	35.0	25.0	15.0	7.5
Supplement ⁴	5.0	5.0	5.0	5.0	5.0
TRT ¹					
DRC ²	0	13.13	26.25	39.38	52.5
WDGS ³	87.5	74.38	61.25	48.13	35.0
Alfalfa hay	7.5	7.5	7.5	7.15	7.15
Supplement ⁴	5.0	5.0	5.0	5.0	5.0

¹Adaptation systems where CON = decreasing forage and increasing corn through adaptation periods; TRT = decreasing wet distillers grains with solubles and increasing corn through adaptation periods.

²DRC = dry rolled corn.

³WDGS = wet distillers grains with solubles.

⁴Dry supplement formulated to provide 90 mg/hd/day of tylosin and 300 mg/hd/day monensin; TRT adaptation system formulated to provide 150 mg/hd/day thiamine.

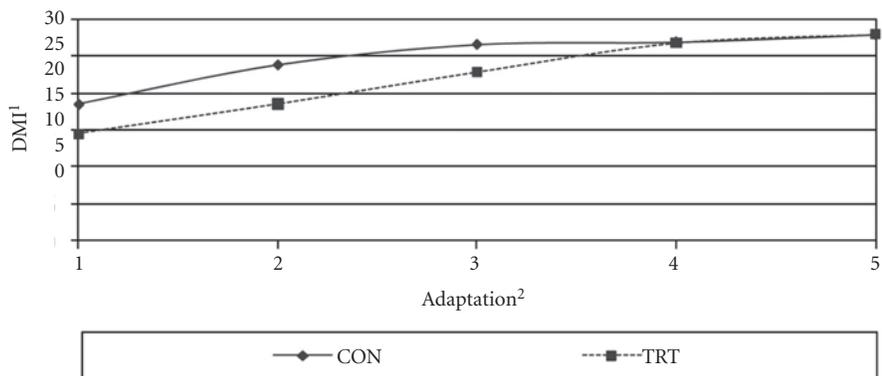


Figure 1. Effect of two grain adaptation systems on DMI.

¹DMI expressed in lb/d.

²Adaptation systems where CON = decreasing forage and increasing corn through adaptation periods; TRT = decreasing wet distillers grains with solubles and increasing corn through adaptation periods. Cattle were on a common finishing diet in adaptation five.

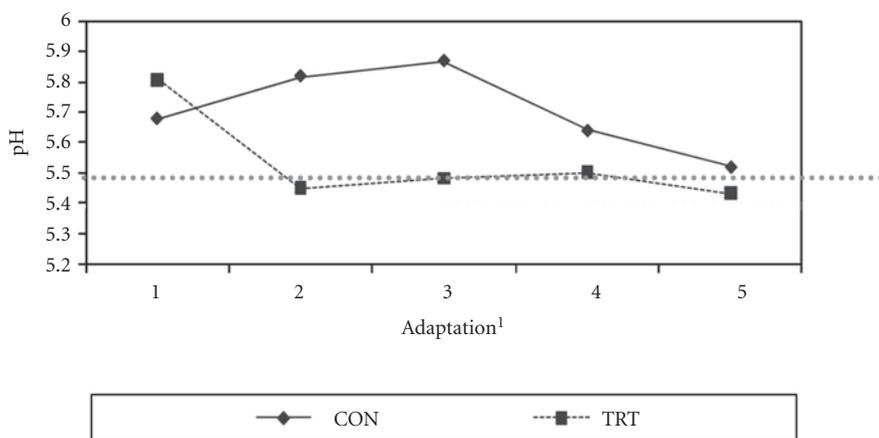


Figure 2. Effect of two grain adaptation systems on average ruminal pH.

¹Adaptation systems where CON = decreasing forage and increasing corn through adaptation periods; TRT = decreasing wet distillers grains with solubles and increasing corn through adaptation periods. Cattle were on a common finishing diet in adaptation five.

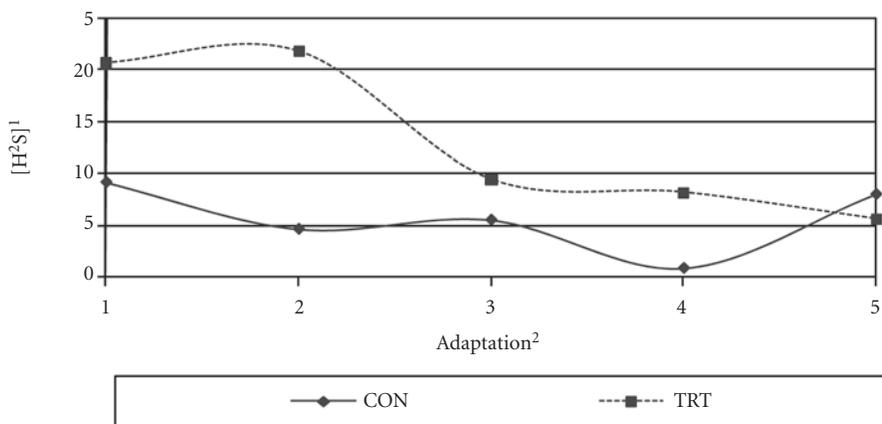


Figure 3. Effect of two grain adaptation systems on ruminal H₂S concentration.

¹[H₂S] = ruminal hydrogen sulfide concentration expressed in µmol H₂S gas /L rumen gas collected.

²Adaptation systems where CON = decreasing forage and increasing corn through adaptation periods; TRT = decreasing wet distillers grains with solubles and increasing corn through adaptation periods. Cattle were on a common finishing diet in adaptation five.

considered a random effect. A protected F-test was used during analyses where numbers represent *P*-values for variation due to adaptation diet or adaptation system.

Results

Figures 1, 2, and 3 show the effect of the WDGs adaptation system compared to the traditional adaptation for DMI, ruminal pH, and H₂S, respectively. During the first adaptation diet, no differences in ruminal pH were observed; however, TRT steers had lower DMI (*P* = 0.01) than CON steers. During adaptation diet two, steers on TRT had lower DMI (*P* = 0.01) and lower average pH (*P* = 0.01) when compared to CON steers. Likewise, during the third adaptation diet, TRT steers had lower DMI (*P* = 0.06) and average pH (*P* = 0.01) when compared to CON steers.

No differences in DMI, pH, or H₂S were observed between TRT and CON steers on the finishing diet (*P* > 0.36). No drastic decreases in DMI or ruminal pH (SD similar to CON) were observed in steers adapted with TRT, with lowest average pH (5.43) on the finishing diet. However, the average pH of both CON and TRT steers on the finishing diet (pH = 5.48; Figure 2 dotted line) supports the conclusion that the TRT adaptation system did not trigger acidosis (pH < 5.3).

Steers on TRT tended to have greater H₂S (*P* = 0.05) only during the second adaptation diet, with the greatest concentration being 21.8 µmol H₂S gas/L rumen gas collected. Despite this finding, previous research (2009 *Nebraska Beef Report*, pp 81-85) and visual appraisal indicate that dietary sulfur levels were not a problem.

Adapting cattle to finishing diets with WDGs may lower both DMI during the first phases of adaptation and pH, but appear to “adapt” cattle to corn, since no differences were observed on the finishing diet.

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Relating Hydrogen Sulfide Levels to Polioencephalomalacia

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Summary

Data from a finishing trial and a metabolism study were used to relate incidence of polioencephalomalacia (polio) with ruminal hydrogen sulfide gas concentration. The finishing trial included different inclusion levels of byproducts with differing alfalfa hay levels. Similar diets were used in the metabolism study. The feedlot trial had 12 cases of polio on a 75% byproduct diet with no alfalfa and no cases of polio when alfalfa was included at 7.5%. The metabolism study reported the highest concentration of H₂S with the high byproduct diet with no grass hay, and lower concentrations when grass hay was included. These data would indicate that forage inclusion can reduce the risk of polio and that polio is related to ruminal H₂S concentrations.

Introduction

Sulfur content in byproduct diets of feedlot cattle may increase risk of cattle developing polioencephalomalacia (polio). Our previous research (2009 *Nebraska Beef Report*, pp. 79-80) indicated that the risk of polio is low when the sulfur content of the diet is below 0.46% (four of 3,137 cattle, or 0.13%, developed polio). As the sulfur content increased up to 0.56%, the incidence of polio increased to 0.35%, or 3 in 857. Sulfur content above 0.56% dramatically increased the risk of cattle developing symptoms of polio, with 6.06% or 6 in 99 developing symptoms. One treatment with zero forage inclusion was not included in this summary because diets with no forage would not be fed in usual feedlot production. Therefore, the objective of this research was

to relate incidences of polio to ruminal hydrogen sulfide (H₂S) gas concentrations associated with byproduct inclusion levels.

Some of the sulfur in byproducts comes from the protein in the corn from which the byproduct is made. Additionally, some of the sulfur is in the form of sulfate. Therefore, byproducts are a combination of both organic and sulfate sulfur. Microbes in the rumen reduce sulfate compounds to H₂S. It is believed the H₂S directly or indirectly (thiaminase) causes polio. This concern has led to research measuring H₂S concentration either *in vitro* or in the rumen. Research has shown mixed results on the effect of monensin in the diet of feedlot cattle and the effect on ruminal H₂S. When sulfur levels were high (1.2%), a significant increase in the *in vitro* concentration of H₂S was observed when monensin was added to the substrate material (1998 *J. Dairy Sci.* 81:2251-2256). However, when sulfur levels ranged from 0.2% to 0.6%, there was no observed influence of monensin on the H₂S concentration *in vivo* (2009 *Midwestern Section ASAS Abstract # 272*).

Procedure

The metabolism study used a 2 × 3 factorial treatment arrangement with two byproduct types and three grass hay levels in a 6 × 6 latin square arrangement with 6 fistulated steers (2009 *Nebraska Beef Report*, pp. 81-83). The two byproducts that were tested were 50% wet distillers grains plus solubles (WDGS) and a 50:50 blend of WDGS and wet corn gluten feed (WCGF), each included in the diet at 37.5% DM basis. Grass hay was included in the diets at 0, 7.5 or 15% DM basis. Hydrogen sulfide gas was collected using tubing inserted through the cannula plug. The tube was connected to a foam block that floated on the mat layer in the rumen.

The end of the tube was covered with a filter to reduce the amount of material that entered the tube and allow gas to flow freely. Samples were taken from the tube using a syringe and mixed with water in a serum bottle to solubilize H₂S. The concentration of H₂S was analyzed using a spectrophotometric method developed by Kung et al. (1998 *J. Dairy Sci.* 81:2251-2256). The study was statistically analyzed as a 2 × 3 factorial using the MIXED procedure of SAS. There was a byproduct by grass hay level interaction ($P < 0.01$); therefore, simple means for each treatment are reported.

The feedlot study (2005 *Nebraska Beef Report*, pp. 45-46) tested levels (25, 50, or 75%) of a 50:50 blend of WDGS and WCGF. Level of roughage also was studied, resulting in a treatment with 37.5% WCGF, 37.5% WDGS, and no roughage, similar to the diet used in the metabolism study. The feedlot study involved 288 yearling steers in 35 pens (8 steers/pen) and 40 steers per treatment.

Results

In the metabolism trial, the concentration of ruminal H₂S decreased linearly ($P < 0.01$) with an increase in inclusion of grass hay in the diet (Table 1). Overall there were only small differences between byproducts for H₂S concentration in the rumen. However, for the 50% WDGS diet, H₂S concentrations decreased from 32.7 to 27.6 and 20.7 μmol sulfur per L of rumen gas as grass hay inclusion increased from 0 to 7.5 and 15%, respectively. The results of the combination byproduct diet were similar to the 50% WDGS diet; however, the combination diet with 0% grass hay had a greater concentration of H₂S than the WDGS diet. The concentrations of H₂S were 80.5, 27.7, and 12.4 μmol sulfur per L of ruminal gas as the grass hay level in the diet increased from 0 to 7.5 and 15%,

Table 1. Ruminal hydrogen sulfide concentrations in byproduct diets at 8 hours post feeding¹.

Byproduct	WDGS ²			WDGS/WCGF ³		
	0.0	7.5	15	0	7.5	15
Grass hay						
8 h H ₂ S μmol/L	32.7 ^b	27.6 ^b	20.7 ^b	80.5 ^c	27.7 ^b	12.4 ^b
Diet S, % ^a	0.43	0.42	0.41	0.47	0.46	0.45

¹2009 *Nebraska Beef Cattle Report*, pp. 81-83. Six steers per treatment mean.

²Wet distillers grains plus solubles, 50% of diet dry matter.

³Wet distillers grains and wet corn gluten feed, each at 37.5% of dry matter.

^aByproduct type × hay level, $P < 0.01$.

^{b,c}Means with unlike superscripts are different ($P < .05$).

respectively. At zero grass hay inclusion, steers fed the combination diet had a H₂S concentration of 80.5 μmol sulfur per L of collected rumen gas, while those fed the WDGS diet had a concentration of 32.7 μmol sulfur per L of rumen gas (Table 1).

The feedlot study reported in the 2005 *Nebraska Beef Report* (pp. 45-46) tested different levels of 50:50 WDGS/WCGF fed to feedlot cattle. When the byproduct combination was fed at 75% of the diet with 0% forage, 12 cases of polio were observed out of 40 steers on the treatment, while no cases of polio were observed in steers on the 75% combination diet with 7.5% alfalfa. Dietary S content observed in the study described in the 2005 *Nebraska Beef Report* was 0.45%. When the combination diet was fed in the metabolism study (2009 *Nebraska Beef Report*, pp. 81-83), the dietary S concentration was 0.47%. The feedlot and metabolism studies differed in grain and roughage sources. Diets from the metabolism study contained dry rolled corn (DRC) and grass hay while diets from the feedlot study contained a 50:50 blend of DRC and high moisture corn (HMC) and alfalfa hay. In the feedlot study, symptoms

of polio were diagnosed visually by the health crew at the research feedlot located near Mead, Neb. When cattle showed visual signs of polio, steers were treated with an IV injection of 2,000 mg of thiamin.

In a feedlot study testing different byproduct inclusion levels and combinations (2009 *Nebraska Beef Report*, pp. 76-78), five steers exhibited signs of polio. Four of the steers that exhibited signs of polio were on a high combination diet consisting of a 50:50 blend of WDGS and WCGF, included in the diet at 87.6%, and 7.5% alfalfa. The fifth steer was on a diet that contained a 50:50 blend of WDGS and WCGF, included at 65.6% of the diet, and 21.9% soy hulls. The dietary sulfur contents of these two diets were 0.587% and 0.476%, respectively. Another diet tested consisted of 65.6% WDGS, 7.5% alfalfa, and 21.9% grass hay (DM basis). This diet had a sulfur content of 0.549% and did not induce polio in any cattle. This is consistent with the results from the metabolism study reported in the 2009 *Nebraska Beef Report* (pp. 81-83) that concluded increased forage levels in the diet decrease the risk of developing polio.

A summary of sulfur level and in-

cidence of polio was reported in 2009 *Nebraska Beef Report*, pp. 79-80. Since that time four new cases of polio have been observed in the University of Nebraska research feedlot. One case of polio developed when a steer was fed a diet containing a 50:50 blend of DRC and HMC at 45% of the diet with 35% WCGF, 15% corn silage, and 5% supplement. The dietary sulfur content of this diet was 0.29% (Huls et al., 2009 *Nebraska Beef Report*, pp. 53-55). One steer developed symptoms of polio when consuming a diet consisting of 85% WDGS, 10% straw, and 5% supplement with a dietary sulfur content of 0.67% (Rich et al., unpublished). The last two steers that showed symptoms of polio were from the same trial; one steer died, and one was treated. These steers consumed a diet consisting of 50% HMC, 40% WCGF, 5% straw, and 5% supplement (Dib et al., unpublished). The dietary sulfur concentration of this diet was 0.26%.

In conclusion, most diets mentioned in this report had S contents higher than 0.30%. Therefore, diets above 0.30% S may be safely fed to feedlot cattle, at least when the source of sulfur is byproducts; however, it is important to maintain roughage levels in these diets. Furthermore, the relationship between dietary S and roughage levels to ruminal H₂S concentration has been demonstrated.

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Feeding Fiber from Wet Corn Gluten Feed and Corn Silage in Feedlot Diets Containing Wet Distillers Grains Plus Solubles

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Summary

A feedlot experiment evaluated the effect of increasing fiber in distillers grains diets on ADG, F:G, and nutrient mass balance. The treatments consisted of 1) 30% modified distillers grains plus solubles, no roughage (MDGS), and 2) 30% modified distillers grains plus solubles, 30% wet corn gluten feed, and 15% corn silage (MDGS+fiber). The remainder of each diet consisted of a 1:1 ratio of high moisture corn and dry rolled corn and 5% supplement. Feeding MDGS+fiber increased ($P \leq 80.02$) ADG, DMI, and HCW; however, it did not improve F:G compared to MDGS. By increasing the fiber content of the diet, more organic matter (OM) and N remained in the manure. Percentage N loss was not different between dietary treatments; however, amount of N lost increased with MDGS + fiber due to the greater N intake and excretion.

Introduction

Previous research focused on reducing N losses by increasing the C:N ratio of feedlot manure or the amount of organic matter on the pen surface by using either roughage or corn milling byproducts (1996 *Nebraska Beef Report*, pp. 74-77; 2003 *Nebraska Beef Report*, pp. 54-58; 2004 *Nebraska Beef Report*, pp. 69-71). Corn bran, a component of wet corn gluten feed, was effective in reducing N losses (2000 *Nebraska Beef Report*, pp. 54-57), and cattle performance was maintained if steep was added with corn bran (2004 *Nebraska Beef Report*, pp. 61-63; 2005 *Nebraska Beef*

Report, pp. 54-56). Distillers grains plus solubles (DGS) improved cattle performance and was a source of neutral detergent fiber (NDF). Feeding wet DGS increased amount of OM in the manure and increased manure N (2008 *Nebraska Beef Report*, pp. 53-56) but not to the same extent as corn bran. The objective of this study was to evaluate the effects of feeding distillers grains or distillers grains with added fiber from corn gluten feed and roughage on cattle performance and nutrient mass balance.

Procedure

Cattle Performance

The experiment utilized 96 calves weighing 675 ± 15 lb, which were fed for 178 days in 12 pens from November to May of 2007. The steers were blocked by BW, stratified within block, and assigned randomly to a pen (8 steers/pen). Dietary treatments consisted of 1) 30% modified DGS, 65% corn fed as a 1:1 ratio of high moisture corn (HMC) to dry rolled corn (DRC) on a DM basis, and 5% supplement (MDGS); and 2) 30% modified DGS, 30% wet corn gluten feed (WCGF), 15% corn silage, 20% corn fed as a 1:1 ratio of HMC:DRC (DM basis), and 5% supplement (MDGS+fiber). Initial diet for the MDGS treatment consisted of HMC and DRC fed at a 1:1 ratio, 37.5% alfalfa hay, 15% corn silage, 5% supplement, and 30% MDGS. Over the 21-day adaptation period, the corn silage and alfalfa hay were replaced with a 1:1 ratio of HMC:DRC. For the MDGS+fiber treatment, cattle were fed 42.5% WCGF and modified DGS (1:1 ratio, DM basis), 37.5% alfalfa hay, 15% corn silage, and 5% supplement. Alfalfa hay was replaced by an increasing ratio of WCGF and modified DGS as well as HMC:DRC over a 21-day period. Steers received Rumensin,

Tylan, and Thiamine at 320, 90, and 130 mg/steer daily, respectively, in both treatments.

Steers were implanted on day 1 with Synovex Choice (Fort Dodge Animal Health) followed by a re-implant on day 85 with Synovex Choice. Steers were slaughtered on day 178 at a commercial abattoir (Greater Omaha). Hot carcass weight (HCW) and liver scores were recorded on day of slaughter, fat thickness, LM area, and USDA called marbling score were collected after a 48-hour chill. Final BW, ADG, and G:F were calculated based on HCW adjusted to a common dressing percentage of 63%. Feed efficiency data were analyzed as G:F and reported as F:G.

Nutrient Balance

Nutrient mass balance was determined using 12 open feedlot pens with retention ponds to collect runoff. When rainfall occurred, runoff collected in the retention ponds was drained and quantified using an ISCO air-bubble flow meter (ISCO, Lincoln, Neb.). After cattle were removed from pens, scraped manure was piled on a cement apron and sampled ($n = 30$) for nutrient analysis while being loaded. Manure was weighed before it was hauled to the University of Nebraska compost yard. Manure samples were freeze dried for nutrient analysis and oven dried for DM calculation. Ingredients were sampled weekly, and feed refusals were analyzed to determine nutrient intake using a weighted composite on a pen basis. Individual steer N retention was calculated using the NRC net energy and protein equations (NRC, 1996). Nutrient excretion was determined by subtracting nutrient retention from intake. Total N lost (lb/steer) was calculated by subtracting manure N and runoff N from excreted N. Percentage of N loss

Table 1. Effect of dietary treatments on performance and carcass characteristics for finishing steers.

Dietary Treatment ¹	MDGS	MDGS+fiber	SEM	P-Value ²
Performance				
Initial BW, lb	679	681	5	0.54
Final BW, lb	1259	1316	21	0.02
DMI, lb/day	19.5	21.3	0.6	0.01
ADG, lb	3.20	3.51	0.09	0.01
F:G	6.09	6.08	—	0.63
Carcass characteristics				
Hot carcass weight, lb	792	829	14.0	0.02
Marbling score ³	500	526	18.45	0.19
LM area, in ²	13.0	13.2	0.3	0.50
12th rib fat, in	0.39	0.45	0.03	0.09
Yield grade	2.84	3.06	0.13	0.12

¹Dietary treatments: MDGS = modified distillers grains plus solubles; MDGS+fiber = modified distillers grains plus solubles, 30% wet corn gluten feed, 15% corn silage.

²F-test statistic for dietary treatments.

³400=Slight 0, 500=Small 0.

Table 2. Effect of dietary treatment on nitrogen mass balance¹.

Dietary Treatment ²	MDGS	MDGS+fiber	SEM	P-Value ³
N intake	90.7	118.3	1.7	<0.01
N retention ⁴	11.8	13.0	0.4	0.01
N excretion ⁵	78.9	105.4	1.5	<0.01
N manure	23.7	35.7	4.6	0.01
N run-off	1.1	1.1	0.2	0.98
N lost	54.1	68.6	4.7	0.01
N loss % ⁶	68.6	5.0	5.1	0.50
DM removed	2144	3455	547	0.04
OM removed	380	652	81	0.01

¹Values are expressed as lb/steer over entire feeding period unless noted.

²Dietary treatments: MDGS = modified distillers grains plus solubles; MDGS+fiber = modified distillers grains plus solubles, 30% wet corn gluten feed, 15% corn silage.

³F-test statistic for dietary treatment.

⁴Calculated using the NRC net protein and net energy equations.

⁵Calculated as N intake – N retention.

⁶Calculated as N lost divided by N excretion.

was calculated as N lost divided by N excreted.

Animal performance and nutrient balance data were analyzed as a complete randomized design with pen as the experimental unit using the MIXED procedure of SAS. The effects of treatment were included in the model as fixed effects.

Results

Cattle Performance

Dry matter intake ($P = 0.01$), ADG ($P = 0.01$), final BW ($P = 0.02$), and

HCW ($P = 0.02$) were greater for cattle consuming MDGS+fiber compared to cattle being fed MDGS (Table 1). However, F:G was not different between dietary treatments ($P = 0.63$). Steers fed MDGS+fiber tended to have greater fat depth ($P = 0.09$) and greater USDA yield grades and marbling scores.

Nutrient Balance

Nitrogen intake, retention, and excretion were greater for the cattle fed MDGS+fiber ($P < 0.01$) compared to those fed MDGS (Table 2).

Excretion was increased by 33.6% due to both greater DMI for cattle fed MDGS+fiber and greater % CP in MDGS+fiber diets compared to MDGS. Amount of OM and N removed in the manure was increased by 71.6% and 50.6%, respectively, for the MDGS+fiber treatment ($P = 0.01$) compared to MDGS. There was no difference ($P = 0.98$) between treatments observed in the small amount of N in the run off, with only 1.0 to 1.4% N in runoff as a percentage of N excretion. There was a difference ($P = 0.01$) in the amount of N lost, with a greater amount lost in the MDGS+fiber treatment compared to MDGS. Steers fed MDGS+fiber excreted 26.5 lb more N over the 178 days ($P < 0.01$). A portion of the extra excreted N was removed in manure (12.0 lb), and a greater amount was lost into the air (14.5 lb) for MDGS+fiber treatment compared to MDGS. There was not a difference ($P = 0.50$) between treatments in the percentage of N loss expressed as a percentage of N excreted, which was 68.6% for MDGS and 65.0% for MDGS+fiber treatments.

These data indicate increasing fiber from wet corn gluten feed and corn silage increased DMI and ADG without impacting F:G. However, dietary CP concentration was increased which increased N intake and excretion. A portion (54.7%) of the extra N excreted when fiber and protein were increased in the diet was lost into the air and a portion was removed as manure N (45.3%).

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Fiber Digestibility and Rumen pH for Diets Containing Wet Corn Gluten Feed or Wet Distillers Grains with Solubles

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Summary

Seven ruminally cannulated steers were used to evaluate fiber digestibility and rumen pH for diets containing 35 or 88% wet corn gluten feed (WCGF) or 35% wet distillers grains with solubles (WDGS). These diets were top-dressed with or without a direct-fed microbial (DFM). Interactions were observed for DM and NDF digestibility. Feeding 88% WCGF decreased DM digestibility, but NDF digestibility increased especially with the DFM. Rumen pH was greatest for steers fed 88% WCGF and lowest for steers fed 35% WCGF.

Introduction

Increased ADG and decreased F:G associated with feeding wet corn gluten feed (WCGF) and wet distillers grains plus solubles (WDGS) in finishing diets up to 50% of the diet (2008 Nebraska Beef Report, pp. 33-34; 2008 Nebraska Beef Report, pp. 35-36) may be due to improved rumen pH from WCGF, high fat from WDGS, or high fiber digestibility from both WCGF and WDGS. Feed digestibility has improved in some cases when DFM is fed (Weinberg et al., *Journal of Dairy Science* 90: 4754-4762). The objectives of the current study were to evaluate three diets of 35% WCGF, 35% WDGS, and 88% WCGF with or without a DFM to determine effects on nutrient digestibility and rumen pH.

Procedure

Seven ruminally cannulated steers (BW = 796 lb) were used in a 6 x 6 unbalanced Latin square to evaluate effects of feeding WCGF or WDGS

Table 1. Composition of dietary treatments (DM basis)¹.

Ingredient	35WDGS	35WCGF	88WCGF
WDGS ²	35	—	—
WCGF ²	—	35	88
DRC ²	53	53	—
Alfalfa hay	7	7	7
Dry supplement ³	5	5	5
Diet DM%	54.1	75.7	62.2
Diet NDF%	23.8	24.5	38.4

¹35WDGS = 35% WDGS; 35WCGF = 35% WCGF; 88WCGF = 88% WCGF.

²WDGS = wet distillers grains plus solubles; WCGF = wet corn gluten feed (Sweet Bran); DRC = dry rolled corn.

³All diets were formulated to contain a minimum of 0.65% Ca, 0.60% K, 320mg/steer daily Rumensin[®], 90mg/steer daily Tylan[®], and 140mg/steer daily thiamine.

in diets and top-dressing a DFM on nutrient digestion, intake, and rumen pH. Treatments were arranged in a 3 x 2 factorial design with diets containing 35% WCGF (35WCGF), 35% WDGS (35WDGS), or 88% WCGF (88WCGF; DM basis; Table 1). The three diets were top-dressed at feeding with or without the DFM consisting of 1×10^9 CFUs of *Lactobacillus buchneri* strain 40788 (Lallemand Animal Nutrition North American, Milwaukee, Wisc.). All diets contained 7% alfalfa hay and 5% dry supplement with dry rolled corn (DRC) as the remainder of the diets.

Periods were 21 days in length, including a 12-day adaptation period followed by a 9-day collection period. Steers were individually fed in pens once daily at 0800 hr. Daily feed refusals were collected. Wireless pH probes were submersed in the rumen from day 13 through day 21. Ruminant pH measurements included average, minimum, and maximum pH; magnitude of pH change; pH variance; time spent below pH 5.6; and area of pH below 5.6 (time below x magnitude below). Chromic oxide (7.5g/dose) was used as an indigestible marker for estimating fecal output and was dosed intraruminally at 0800 hr and 1800 hr daily from day 13 to day 20, with two doses given at 0800 hr on day 13. Fecal grab samples were collected three times daily at 0800 hr, 1300 hr, and 1800 hr on day 17 through day 21 and composited by

weight daily. Fecal samples, WDGS, and WCGF were freeze dried. Alfalfa, DRC, and feed refusals were oven dried at 60°C for 48 hours. A period composite was made from equal dried weights of daily fecal samples for nutrient digestibility calculations.

Intake and digestibility data were analyzed as a 3 x 2 factorial treatment arrangement and Latin square experimental design using the MIXED procedure of SAS. Interaction between diet type and DFM addition were tested. If no significant interaction was observed, then main effects of either diet type or DFM supplementation were presented. If a significant interaction was observed, then the simple effects of DFM supplementation within diet type were presented. Period was included in the model as a fixed effect and steer was a random effect. Ruminant pH data were analyzed as a repeated measure with a Cholesky covariance structure.

Results

No significant interactions between diet and DFM resulted for DM or NDF intake ($P \geq 0.97$, Table 2). Feeding 35WCGF resulted in the greatest ($P < 0.01$) DMI, which was 3.4 lb greater than feeding 35WDGS ($P < 0.01$). Because steers fed 88WCGF had the greatest diet concentration of NDF, intake of NDF was the greatest ($P < 0.01$) for this diet (8.0 lb). 35WCGF and 35WDGS had similar

Table 2. Effects of diet¹ and DFM on nutrient intake and digestibility.

Performance	No DFM			With DFM			Diet <i>P</i> -value	DFM <i>P</i> -value	Inter ²
	35WDGS	35WCGF	88WCGF	35WDGS	35WCGF	88WCGF			
DM									
Intake, lb/day	18.4	21.7	20.6	19.6	23.1	21.9	< 0.01	0.04	0.99
Digestibility, %	79.2 ^c	79.4 ^c	73.7 ^a	77.7 ^{bc}	79.0 ^c	76.2 ^b	< 0.01	0.82	0.08
NDF									
Intake, lb/day	4.40	5.39	7.79	4.63	5.67	8.11	< 0.01	0.10	0.97
Digestibility, %	68.2 ^{ab}	68.1 ^a	69.0 ^{ab}	64.8 ^a	65.8 ^a	72.3 ^b	0.05	0.61	0.15

¹35WDGS = 35% WDGS; 35WCGF = 35% WCGF; 88WCGF = 88% WCGF.²Interaction for diet and DFM.^{ab,c}Means within the same row without a common superscript differ ($P \leq 0.10$).**Table 3. Main effects of diet and DFM on ruminal pH.**

Item	Diet ¹				DFM ²			Inter ³
	35WDGS	35WCGF	88WCGF	<i>P</i> -value	Neg	Pos	<i>P</i> -value	
Average pH	5.38 ^b	5.13 ^a	6.07 ^c	< 0.01	5.57	5.47	0.14	1.00
Maximum pH	6.00 ^b	5.76 ^a	6.60 ^c	< 0.01	6.14	6.10	0.66	0.57
Minimum pH	5.01 ^b	4.82 ^a	5.52 ^c	< 0.01	5.16 ^b	5.08 ^a	0.08	0.60
pH change	0.99	0.94	1.06	0.18	0.97	1.03	0.20	0.81
pH variance	0.04	0.05	0.05	0.75	0.04	0.05	0.23	0.42
Time < 5.6, min/day	1160 ^b	1261 ^b	125 ^a	< 0.01	816	881	0.49	0.98
Area < 5.6, min/day ³	453 ^b	672 ^{0a}	< 0.01	370	370	1.00	0.91	

¹Main effects for diet; 35WDGS = 35% WDGS; 35WCGF = 35% WCGF; 88WCGF = 88% WCGF.²Main effects for DFM; Neg = no DFM; Pos = with DFM.³Interaction for diet and DFM.^{a,b,c}Means within the same main effect and the same row without a common superscript differ ($P \leq 0.01$).

diet NDF. Therefore, steers fed 35WCGF consumed more NDF (5.5 lb) due to greater DMI, compared to steers fed 35WDGS (4.5 lb). Top-dressing the diets with the DFM increased DMI ($P = 0.04$) and NDF intake ($P = 0.10$).

A significant interaction ($P = 0.08$) was observed between diet and DFM for DM digestibility. An interaction tendency ($P = 0.15$) resulted for NDF digestibility. Feeding 35WCGF or 35WDGS resulted in greater DM digestibility regardless of DFM, compared to feeding 88WCGF ($P \leq 0.10$). However, feeding steers the 88WCGF diet with the DFM resulted in increased DM digestibility, compared to not feeding the DFM ($P = 0.06$). The numerically greatest NDF digestibility resulted from providing the DFM with the 88WCGF diet. Steers fed this combination had statistically greater ($P \leq 0.10$) NDF digestibility compared to steers fed the 35WCGF diet with or without the DFM as well as steers fed the 35WDGS with the DFM, likely due to greater fiber intakes. Steers fed 88WCGF had the greatest NDF digestibility, possibly due to little starch interference with fiber digestion, a higher proportion of fiber from WCGF in relation to poorly digested

fiber from alfalfa hay, or higher rumen pH making for a more favorable environment for fiber digestion.

No significant interactions between diet and DFM resulted for any ruminal pH variables ($P \geq 0.42$), so only main effects of diet and DFM are reported (Table 3). Average, maximum, and minimum pH were significantly different ($P < 0.01$) for diets fed to steers. The greatest ruminal pH was observed in steers fed 88WCGF. Feeding 35WDGS resulted in intermediate values, and the lowest ruminal pH was recorded in steers fed 35WCGF. Minimum pH was statistically different ($P = 0.08$) for DFM, as a decrease was observed after providing the DFM to steers. No differences in pH change or pH variance resulted from diet treatment or DFM treatment. Time and area below pH 5.6 were statistically significant ($P < 0.01$) for dietary treatment. Steers fed 88WCGF had the lowest ($P < 0.01$) time (125 minutes/day) and area (0 minutes*pH units < 5.6/day) below pH 5.6. Additionally, steers fed 35WDGS had decreased area below pH 5.6 (453 minutes*pH units < 5.6/day) compared to steers fed 35WCGF (672 minutes/day³, $P < 0.01$). No effects of DFM on time

and area below pH 5.6 were observed. Therefore, feeding 88WCGF helped to alleviate any acidosis challenges, with increased average pH and very little time and area below pH 5.6.

In conclusion, steers had the greatest DMI when they were fed 35WCGF and the greatest NDF intake when fed 88WCGF. Digestibility of DM was the least for steers fed 88WCGF, suggesting corn in the diets improved DM digestibility for 35WCGF and 35WDGS. However, 88WCGF, which had no corn, resulted in the greatest NDF digestibility, especially when DFM was provided. Steers fed 88WCGF with no corn had the greatest pH values with the least amount of time spent experiencing subacute acidosis. Greater pH values were also observed for steers fed 35WDGS compared to 35WCGF, suggesting differences in how byproducts interact with the ruminal environment. Few ruminal pH effects resulted from feeding the DFM.

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Metabolism Characteristics of Feedlot Diets Containing Different Fat Sources

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Summary

A metabolism trial was conducted to evaluate the effects of dietary fat source on the metabolism characteristics of feedlot steers fed 8.5% fat (7% fatty acids) diets. Steers fed condensed corn distillers solubles (CCDS) had lower average pH and greater DM digestibility than those fed corn oil, tallow, or WDGS. Steers fed CCDS also had greater fat and fatty acid digestibility than corn and corn oil fed steers and greater NDF digestibility than corn oil or tallow fed steers. Although CCDS fat is similar to corn oil, the two feeds are digested differently. The omasal fatty acid profile of steers fed WDGS is less saturated than cattle fed corn diets with or without corn oil, CCDS, or beef tallow. In addition, the efficiency of fat and fatty acid absorption was not decreased with high fat feedlot diets.

Introduction

Previous research (2008 Nebraska Beef Report, pp. 35-36) indicates part of the increased feeding value of WDGS is due to fat content of the feed. The fatty acid composition of the WDGS fat may influence individual fatty acid digestibility in the small intestine, a potential mechanism of increased feeding value of WDGS (2007 Nebraska Beef Report, pp. 39-42).

Rumen microorganisms have the ability to biohydrogenate fatty acids prior to intestinal absorption. Research has shown that when added directly to the diet, WDGS fat is less susceptible to rumen biohydrogenation than fat in dry rolled corn or corn oil (2007 Nebraska Beef Report, pp. 39-42). UNL research also has

shown increases in the amount of polyunsaturated fatty acids in carcass fat in steers fed WDGS compared to steers fed a corn control diet (2009 Nebraska Beef Report, pp. 107-109). It is unknown if there are differences in rumen biohydrogenation protection, digestion, and absorption of the fat in distillers solubles compared to wet distillers grains that comprise WDGS when fed to finishing steers.

The current study was conducted to determine the effect of dietary fat source on metabolism characteristics of steers fed feedlot finishing diets.

Procedure

Five ruminally cannulated steers were used in a completely randomized, five-period Latin square designed study. Each steer was assigned randomly to one of five balanced treatment sequences. Treatments were five diets with different dietary fat sources (Table 1). The CORN diet contained no added fat. The OIL and TAL diets contained 4.8% of diet DM as corn oil or beef tallow, respectively. The CCDS diet contained added fat in the form of condensed corn distillers solubles (CCDS). The WDGS diet contained added fat from WDGS. The

four diets with added fat were formulated to be isofat with total diet fat at 8.5% of diet DM. Post-trial analysis indicated the four diets consisted of 8.2% to 8.6% dietary fat. All diets contained Rumensin, thiamine, and Tylan at the rates of 309, 112, and 77 mg per steer daily, respectively.

Steers were fed 6 times daily with Ankom automatic feeders at *ad libitum* intake and *ad libitum* access to fresh water. The CCDS and WDGS were from a single load of each commodity for the entire trial from the same ethanol plant (Abengoa Bio-energy, York, Neb.).

Period duration was 21 days, including a 12-day adaptation period. Corn bran *in situ* bags were ruminally incubated for 0, 12, 24, or 48 hours on days 13 to 15. Quadruplicate bags were incubated in each steer per time point. Bags were inserted at staggered times. All bags were removed the morning of day 15, rinsed, refluxed in NDF solution, and dried for corn bran NDF digestibility calculation. Chromic oxide (7.5 g/dose) was dosed intraruminally at 0800 hr and 1600 hr daily on days 13 to 20. Omasal and fecal samples were collected at 0800 hr and 1600 hr on days 16 to 20. Omasal samples were collected via

Table 1. Diets fed to steers in the digestibility experiment evaluating dietary fat sources (% of diet DM).

Diet ¹	CORN	OIL	TAL	CCDS	WDGS
Dry rolled corn	80.0	82.7	82.7	62.0	31.5
Grass hay	-----		7.5	-----	
Supplement	-----		5.0	-----	
Molasses	7.5	—	—	—	—
Corn oil	—	4.8	—	—	—
Tallow	—	—	4.8	—	—
CCDS	—	—	—	25.5	—
WDGS	—	—	—	—	56
Diet					
CP, %	11.9	11.4	11.4	12.7	22.4
Fat, %	3.6	8.5	8.5	8.2	8.6
Fatty acid, %	3.1	7.3	6.9	6.6	7.2
Sulfur, %	0.15	0.11	0.11	0.45	0.58
NDF, %	14.0	14.0	14.0	12.6	28.5

¹CORN = corn control diet; OIL = corn diet with added corn oil; TAL = corn diet with added beef tallow; CCDS = corn diet with added fat from condensed corn distillers soluble; WDGS = corn diet with added fat from corn wet distillers grains plus solubles.

Table 2. Effects of dietary fat source on nutrient intake and total tract DM, fat, fatty acids, and NDF digestibility.

Diet ¹	CORN	OIL	CCDS	TAL	WDGS	SE	P-value
DM							
Intake, lb/day	24.6	21.2	21.9	22.7	23.4	1.5	0.43
Total tract digestibility, %	81.3 ^{cd}	77.3 ^{ab}	83.8 ^d	80.3 ^{bc}	75.8 ^a	2.5	< 0.01
Total fat							
Intake, lb/day	0.9 ^a	1.8 ^b	1.8 ^b	1.9 ^b	2.0 ^b	0.1	< 0.01
Total tract digestibility, %	89.2 ^a	90.9 ^{ab}	94.2 ^c	92.9 ^{bc}	90.3 ^a	1.2	< 0.01
Fatty Acids							
Intake, lb/day	0.8 ^a	1.6 ^b	1.5 ^b	1.6 ^b	1.7 ^b	0.1	< 0.01
Omasal fatty acid profile, % of total omasal fatty acids							
Palmitic acid (C16:0)	12.5 ^a	12.4 ^a	14.3 ^b	19.8 ^c	14.2 ^b	0.6	< 0.01
Stearic acid (C18:0)	51.5 ^b	57.4 ^c	49.4 ^b	47.3 ^b	39.1 ^a	2.3	< 0.01
C18:1 (all isomers)	16.0 ^a	17.5 ^{ab}	19.8 ^b	17.9 ^{ab}	25.0 ^c	1.4	< 0.01
C18:2 (all isomers)	13.1 ^b	7.6 ^a	11.4 ^b	7.5 ^a	17.0 ^c	1.3	< 0.01
C18:3 (all isomers)	1.0 ^{bc}	0.9 ^{ab}	1.1 ^{bc}	0.8 ^a	1.1 ^c	0.06	0.02
Unsaturated							
FA:Saturated FA	0.49 ^a	0.39 ^a	0.52 ^a	0.40 ^a	0.83 ^b	0.06	< 0.01
Digestibility, % of fatty acid reaching omasum²							
Palmitic acid (C16:0)	93.7	95.0	97.2	96.6	96.0		
Stearic acid (C18:0)	95.6	94.9	97.4	95.5	94.9		
C18:1 (all isomers)	92.6	94.6	96.9	96.2	96.1		
C18:2 (all isomers)	88.8	84.2	92.6	91.0	92.9		
C18:3 (all isomers)	88.7	90.9	100.0	93.0	92.9		
Total	94.1 ^a	93.9 ^a	96.7 ^b	95.4 ^{ab}	95.2 ^{ab}	0.9	0.06
NDF							
Intake, lb/day	3.5 ^b	3.0 ^{ab}	2.7 ^a	3.2 ^b	6.7 ^c	0.3	< 0.01
Total tract digestibility, %	63.2 ^{bc}	49.1 ^a	68.8 ^c	60.2 ^b	65.0 ^{bc}	4.9	0.01

¹CORN = corn control diet; OIL = corn diet with added corn oil; CCDS = corn diet with added fat from condensed corn distillers solubles; TAL = corn diet with added beef tallow; WDGS = corn diet with added fat from corn wet distillers grains plus solubles.

²Calculated from the disappearance of omasal fatty acids (amount of fatty acid intake x individual fatty acid proportion of omasal profile with an assumed net zero addition of rumen biosynthesized fat) relative to actual quantity of individual fecal fatty acids.

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

Table 3. Effects of dietary fat source on *in situ* corn bran NDF digestibility.

Diet ¹	CORN	OIL	CCDS	TAL	WDGS
12h NDF digestibility, %	15.6 ^b	9.2 ^a	11.5 ^{ab}	13.5 ^{ab}	13.9 ^{ab}
24h NDF digestibility, %	22.6 ^b	17.1 ^a	21.4 ^{ab}	18.4 ^{ab}	19.1 ^{ab}
48h NDF digestibility, %	31.6 ^c	29.1 ^{bc}	22.1 ^a	26.2 ^{ab}	24.7 ^{ab}

¹CORN = corn control diet; OIL = corn diet with added corn oil; CCDS = corn diet with added fat from condensed corn distillers soluble; TAL = corn diet with added beef tallow; WDGS = corn diet with added fat from corn wet distillers grains plus solubles.

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

Table 4. Effects of dietary fat source on ruminal pH parameters.

Diet ¹	CORN	OIL	CCDS	TAL	WDGS	SE	P-value
Ruminal pH							
Average	5.41 ^{ab}	5.75 ^c	5.31 ^a	5.60 ^{bc}	5.56 ^{bc}	0.09	0.01
Variance	0.07 ^d	0.06 ^c	0.04 ^a	0.05 ^b	0.04 ^a	0.01	< 0.01
Time < 5.6, min/day	1091 ^{bc}	564 ^a	1289 ^c	618 ^a	843 ^{ab}	147	< 0.01

¹CORN = corn control diet; OIL = corn diet with added corn oil; CCDS = corn diet with added fat from condensed corn distillers soluble; TAL = corn diet with added beef tallow; WDGS = corn diet with added fat from corn wet distillers grains plus solubles.

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

Table 5. Effects of dietary fat source on rumen fluid volatile fatty acid parameters.

Diet	CORN	OIL	CCDS	TAL	WDGS	SE	P-value
Total, mM	140.3	125.5	131.7	142	129.2	8.4	0.54
Acetate, mol/100 mol	50.5 ^{bc}	50.9 ^c	45.3 ^a	46.4 ^{ab}	52.0 ^c	1.9	0.07
Propionate, mol/100 mol	34	32.4	40.6	38	32.8	2.6	0.15
Butyrate, mol/100 mol	11.8	11.1	9.8	9.4	9.7	1	0.21
Acetate:Propionate	1.55	1.63	1.16	1.26	1.62	1.2	0.25

¹CORN = corn control diet; OIL = corn diet with added corn oil; CCDS = corn diet with added fat from condensed corn distillers soluble; TAL = corn diet with added beef tallow; WDGS = corn diet with added fat from corn wet distillers grains plus solubles.

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

tube inserted in the omasal orifice from the rumen canula. Omasal and fecal samples were composited by day, freeze dried, ground, and composited by animal within period for chromic oxide, fat, and NDF analysis. Individual feed ingredients and omasal and fecal composites were analyzed via gas chromatography for fatty acid profile and quantification. Continuous pH data were collected with intraruminal pH probes on days 15 to 20. Rumen fluid samples were collected at 0800 hr and 1600 hr on days 19 and 20 for volatile fatty acid analysis.

Data were analyzed as a crossover design using the MIXED procedure of SAS (SAS Inst. Inc.) Period was included in the model as a fixed effect and the random effect was steer. A Cholesky covariance structure was utilized for pH repeated measures analysis. Treatment differences were evaluated when overall significance was less than $P = 0.10$.

Results

Dry matter intake was numerically least for OIL and numerically greatest for CORN fed steers (Table 2). Fat intake was similar for all fat-supplemented diets, but roughly 2 times greater for fat-supplemented diets than for CORN. Diet NDF intake was roughly 2 times greater for WDGS than for the other diets due to the increased NDF content of WDGS relative to the other feed ingredients.

Total tract DM digestibility was greatest for CCDS and lowest for WDGS. Total tract fat digestibility was greatest for CCDS and lowest for CORN and WDGS. All fat digestibilities were greater than 89%, indicating that fat absorption efficiency at the small intestine was not decreased with the high fat diets. Diet NDF digestibility was greatest with CCDS and least for OIL. This result is interesting considering the fatty acid profile and rumen biohydrogenation potential of corn oil and solubles are expected to be similar.

Rumen *in situ* corn bran NDF digestibility was generally poorer than

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expected for all treatments (Table 3). Total tract NDF digestibilities were roughly 2 to 3 times greater than *in situ* corn bran digestibilities, indicating that either the *in situ* values are artificially low or significant lower-gut NDF digestion occurred. The NDF digestibilities may be artificially low due to dietary fat clogging pores on the *in situ* Dacron bag and preventing microbial contact with corn bran samples. This argument is supported by the CORN diet (lowest fat diet) having the greatest NDF digestibility at all three time points. The bran incubated in steers fed CCDS had the greatest rate of fiber digestion between 12 and 24 hours of incubation. However, the CCDS treatment had the lowest extent of digestion at 48 hours and lowest rate of digestion from 24 to 48 hours. This may indicate a different rumen fermentation pattern of corn bran when steers are fed solubles relative to other fat sources.

Ruminal average pH was lowest for CCDS and highest for OIL (Table 4). Time of ruminal pH below 5.6 was greatest for CCDS and least for

OIL and TAL. These differences were interesting considering the DMI, fat profiles, and fat forms were similar for CCDS and OIL. In addition, CCDS contained less starch. Dry matter digestibility was similar between CCDS and OIL, while NDF digestibility was significantly lower for OIL. Anecdotal observations suggested rumens of steers fed CCDS were fuller, frothier, and more likely to spill rumen contents when the cannula plugs were removed than when the same steers were fed the remaining four diets.

The omasal fatty acid profile of WDGS was less saturated than other treatments due to proportionately greater C18:1 and C18:2 and less C18:0 synthesis. This is due to WDGS fatty acid protection from rumen biohydrogenation of fatty acids. The degree of fatty acid saturation at the omasum did not change the digestibility of the WDGS fatty acids relative to the more saturated omasal fatty acids of other treatments. Total fatty acid digestibility was 93.9% or greater for all treatments.

Rumen VFA proportion of acetate was greatest for OIL and WDGS and

least for CCDS (Table 5). Although not significantly different, the acetate to propionate ratio was lowest for CCDS.

These findings indicate an interesting difference in CCDS digestion relative to other fat sources. Although CCDS fat is similar to corn oil, the two feeds were digested differently. Steers fed CCDS had lower average pH and greater DM digestibility than steers fed corn oil, tallow, or WDGS. Steers fed CCDS also had greater fat and fatty acid digestibility than corn and corn oil fed steers, and greater NDF digestibility than corn oil or tallow fed steers. The omasal fatty acid profile of steers fed WDGS was less saturated than that of cattle fed corn diets with or without corn oil, CCDS, or beef tallow. In addition, the efficiency of fat absorption was not decreased with high fat feedlot diets.

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Lipid and NDF Analysis of Ethanol Byproduct Feedstuffs

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Summary

A newly developed biphasic feed lipid extraction procedure has increased accuracy relative to Goldfish ether extraction, especially for condensed corn distillers solubles samples. A pre-NDF fat extraction must be completed prior to analyzing high fat feeds for NDF. Corn should be ground through a 1-mm screen on a Tecator Cyclotec sample mill to accurately determine corn NDF content.

Introduction

The ether extract procedure, a standard of lipid extraction for many years, may have limitations in accuracy with samples containing condensed corn distillers solubles (CCDS). Furthermore, fat content may decrease the accuracy of feed sample NDF determination, because fat may not be completely dissolved with the Van Soest procedure. Therefore, three experiments were conducted to optimize the performance of a new lipid analysis procedure for feedstuffs. Also, two studies were conducted to improve accuracy of determining corn NDF with the Van Soest beaker procedure.

Procedure

Experiment 1

Exp. 1 evaluated proper incubation time of distillers grains plus solubles (DGS) samples with a new biphasic lipid extraction procedure to optimize quantity of lipid extract compared to Goldfish diethyl ether extraction.

Five corn DGS samples were analyzed in duplicate for all incubation times. The biphasic extraction utilized 0.38 g of DGS DM incubated with 4 mL of a 1:1 ratio of hexane to diethyl ether in 16 x 125 mm screw-top test tubes for 0.1, 2, 4, 6, 8, 10, or 12 hours at 50°C. Four mL of solvent were sufficient to extract at least 0.5 g of lipid from the samples. After incubation, 3 mL of dilute hydrochloric acid water (1 drop concentrated hydrochloric acid/40 mL distilled water) were added to the tube to elevate the solvent and lipid extract layer above the remaining feed. The tube was recapped and vigorously shaken for 2 seconds to facilitate solvent removal from feed particles. The tubes were then centrifuged at 900 x g for 6 minutes to improve solvent phase separation. The upper lipid phase was transferred with a glass pipette to a pre-weighed test tube. An additional 2 mL of the solvent were added to the original tube, shaken, and transferred to the same corresponding tube with the same glass pipette. Previous unpublished research has shown that 2 extracts are sufficient for complete removal of lipid from the samples. Solvent was evaporated at 50° C under nitrogen, and lipid residue was weighed.

The diethyl ether procedure for lipid extraction using the Goldfish fat extractor (Laboratory Construction Company, Kansas City, Mo.), utilized 1.2 g of DGS suspended in a thimble. Thirty five mL of diethyl ether were continuously refluxed through the sample for 4 hours. The solvent was then evaporated from the extract, and the lipid residue was weighed.

The PROC MIXED procedure of SAS with Tukey adjusted mean separation was utilized to analyze the effect of incubation time on biphasic lipid extract.

Experiment 2

Exp. 2 evaluated the effect of the hexane:diethyl ether ratio on ef-

iciency of lipid extraction from dry DGS, modified DGS, wet DGS, dry rolled corn, corn germ meal, and CCDS samples. Five hexane:diethyl ether ratios were evaluated (1:0, 1:3, 1:1, 3:1, and 0:1) with a 9-hour biphasic incubation procedure similar to that employed in Exp. 1. Lipid extracts were prepared as fatty acid methyl esters for GC analysis with a methanolic boron trifluoride procedure, using heptadecanoic fatty acid as internal standard for 12- to 20-carbon fatty acid quantification.

Experiment 3

Exp. 3 compared CCDS lipid extraction from the Goldfish diethyl ether procedure to the biphasic extraction with 1:1 ratio of hexane:diethyl ether or 100% diethyl ether. Three CCDS samples from previous UNL feedlot research trials were lyophilized and pulverized with a mortar and pestle. The three samples were analyzed in triplicate for each of four methods.

Method 1: The Goldfish apparatus was the same as in Exp. 1. The solvent was evaporated, and the lipid residue was weighed in pre-weighed beakers. Hexane was then added to the extract to separate the lipids from the hexane insoluble materials and transferred to a test tube; hexane was evaporated under nitrogen at 50° C, and lipid was methylated for fatty acid analysis by GC. The hexane insoluble material (a clear material with physical properties similar to glycerol) was solubilized in isopropanol. This material was plated on a thin layer chromatography plate and analyzed for phospholipids, glycerol, and starch.

Methods 2 & 3: Samples were extracted using a biphasic extraction procedure with a 10-hour incubation procedure similar to that employed in Exp. 1, with either a 1:1 ratio of hexane:diethyl ether (Method 2) or diethyl ether alone (Method 3). The

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lipid fractions were methylated for GC fatty acid analysis.

Method 4: Samples were refluxed with the Goldfisch diethyl ether procedure as in Method 1. However, instead of evaporating the diethyl ether upon completion of the reflux period, the diethyl ether extract mixture was transferred to a screw top test tube. Three mL of the dilute hydrochloric acid solution from Exp. 1 were added to the tubes. Tubes were shaken, and the diethyl ether fraction was quantitatively transferred to an additional tube. Two additional mL of diethyl ether were added to the original tubes, and a second quantitative transfer was performed. The diethyl ether and water were evaporated from the respective tubes, and each tube was weighed to calculate diethyl ether and water-soluble CCDS fractions. The diethyl ether fraction was methylated for fatty acid analysis by GC.

Experiment 4

In the Van Soest NDF procedure, 0.5 g of sample (ground through a 1 mm screen in a Wiley Mill) was weighed into a tall-form 600 mL beaker, adding 100 mL of neutral detergent solution, refluxing for 1 hour, filtering the residue, and drying the filters. Three methods were evaluated to improve filtering capability and decrease fat contamination of DGS when measuring NDF. These methods included 1) the Van Soest method with an acetone residue rinse at filtering; 2) method 1 with 2 times the amount of neutral detergent solution; and 3) a biphasic fat extraction on the samples (same as Method 2 of Exp. 3), then rinsing the non-lipid residue into a beaker with 100 mL of neutral detergent solution and an acetone residue rinse. Sodium sulfite and alpha-amylase (20,350 LU/ mL) were used in all of the methods to digest protein and starch at 0.5 g and 0.5 mL per beaker, respectively. The samples used included varying levels of CCDS added to the DGS. These are represented as 0, 33, 67, 100, and 110% of the normal incorporation of CCDS to grains.

Table 1. Average lipid content of five DGS samples incubated for different times utilizing a new biphasic lipid extraction procedure¹.

Incubation time, hours	0.1	2	4	6	8	10	12
DGS lipid, % of DM ²	11.1 ^a	11.9 ^b	12.0 ^b	12.0 ^b	12.1 ^{b,c}	12.2 ^{b,c}	12.3 ^c

¹DGS = lyophilized distillers grains plus solubles samples.

²Samples also were analyzed with the Goldfisch method and averaged 12.2% ether extract.

^{a,b,c}Means with unlike superscripts are different at $P < 0.05$.

Table 2. Average lipid content of six feedstuffs incubated with different ratios of hexane:diethyl ether with a new biphasic lipid extraction procedure¹.

Hexane:Diethyl Ether	1:0	3:1	1:1	1:3	0:1
Gravimetric lipid, % of DM	12.4 ^a	12.6 ^a	12.7 ^a	13.8 ^b	14.2 ^b
GC fatty acids, % of DM	11.0	11.3	11.4	11.2	11.3
GC:Gravimetric	0.90 ^a	0.90 ^a	0.90 ^a	0.81 ^b	0.79 ^b

¹GC = gas chromatography analysis of 12 to 20 carbon length fatty acids with heptadecanoic acid as internal standard.

^{a,b}Means within a row with unlike superscripts are different at $P < 0.05$.

Table 3. Average lipid content of three lyophilized condensed corn distillers solubles samples with four different laboratory procedures¹.

Method	1	2	3	4
Gravimetric lipid, % of DM	23.4	17.6	20.0	17.5
GC fatty acids, % of DM	14.9	15.5	16.8	15.2
GC:Gravimetric	0.64 ^a	0.88 ^b	0.84 ^b	0.87 ^b

¹Method 1 = Goldfisch extraction with diethyl ether; Method 2 = biphasic extraction with 1:1 hexane:diethyl ether; Method 3 = biphasic extraction with diethyl ether; Method 4 = Goldfisch extraction with subsequent biphasic extraction; GC = gas chromatography analysis of total fatty acids with heptadecanoic acid as internal standard.

^{a,b}Means within a row with unlike superscripts are different at $P < 0.05$.

Experiment 5

To obtain accurate corn NDF values, the same corn hybrid (1-mm Wiley Mill grind) was used to compare NDF for dry rolled and high moisture processing types in addition to a steam-flaked corn sample. Sodium sulfite (0.5 g) was added, and alpha-amylase (0.5 mL; 20,350 LU/ mL) was administered during the hour reflux once, twice, or four times to digest corn starch.

Experiment 6

The effect of milling equipment on corn NDF content was evaluated. Four dry rolled corn samples were ground through a 1-mm screen on either a Wiley Mill (Thomas Scientific, Swedesboro, N.J.) or a Tecator Cyclotec sample mill (American Instrument Exchange, Haverhill,

Mass.). Alpha-amylase was administered at the beginning of the reflux and 10 minutes prior to filtering (0.5 mL each). Sodium sulfite (0.5 g) was used in all corn NDF analyses.

Results

Experiment 1

Lipid extraction efficiency increased as incubation time increased from 0.1 to 12 hours in Exp. 1 (Table 1). The 0.1-hour extract was the least efficient of all levels evaluated ($P < 0.01$). Efficiency of the 12-hour incubation also was significantly greater than that observed at the intermediate incubation times ($P = 0.03$). However, efficiency at 12-hour incubation was not significantly different from that at 8- and 10-hour incubation. The extract at 10 hours yielded 12.2% lipid, which was

Table 4. Percentage NDF and fat for DGS samples with different condensed corn distillers solubles levels with three different methods for controlling fat.

Method ¹	CCDS% of DGS DM				
	0	33	67	100	110
1 ^a	43.4	38.1	33.6	31.3	31.8
2 ^b	41.6	37.9	34.8	30.7	30.7
3 ^c	41.0	36.8	32.8	30.1	28.8
Fat ²	7.1	9.2	10.8	12.8	13.9

¹Method 1 = 100mL neutral detergent solution with acetone rinse at filtering; Method 2 = 200mL neutral detergent solution with acetone rinse at filtering; Method 3 = use residue remaining after biphasic fat extraction with 100 mL neutral detergent solution and acetone rinse at filtering.

²Lipid extract from pre-NDF fat extract of Method 3.

^{a,b,c}Methods with unlike superscripts differ ($P < 0.01$).

Table 5. Dosage of alpha-amylase for determining NDF content for corn processing types.

Alpha-amylase doses ² / reflux	Sample ¹				Average
	DRC	HMC	SFC		
1	23.9	20.7	20.8		21.8 ^a
2	14.2	12.4	12.0		12.9 ^b
4	12.6	12.0	11.9		12.2 ^b

¹DRC = dry rolled corn for hybrid 1; HMC = high moisture corn for hybrid 1; SFC = steam flaked corn (not hybrid 1).

²Doses = number of doses with 0.5 mL alpha-amylase added (20,350 LU/ mL).

^{a,b}Number of alpha-amylase doses with unlike superscripts differ ($P < 0.01$).

Table 6. Effect of milling equipment with 1-mm screen on NDF content of dry rolled corn samples with 2 doses of alpha-amylase.

Milling equipment	Dry rolled corn sample				Average
	1	2	3	4	
Wiley, corn % NDF	13.9	16.7	17.7	14.9	15.8 ^b
Tecator Cyclotec, corn % NDF	10.6	10.4	9.7	9.5	10.1 ^a

^{a,b}Different grinds with unlike superscripts differ ($P < 0.01$).

similar to the amount yielded by the Goldfish ether extract.

Experiment 2

Gravimetric quantification of the lipid extraction increased as proportion of diethyl ether increased in the solvent mixture (Table 2). Solvents with a diethyl ether concentration equal to or greater than the hexane concentration had increased lipid extract ($P < 0.01$). However, when the extracts were methylated and analyzed by GC, there were no differences in percent total fatty acids ($P > 0.30$) across solvent compositions. The ratio of GC-analyzed extract:gravimetric extract decreased as solvent diethyl ether content increased above hexane content. The ratio of 0.90 for the

three highest proportions of hexane was greater than the ratio for the two lesser proportions of hexane (average ratio of 0.80; $P < 0.01$). The expected GC-analyzed:gravimetric ratio is approximately 0.90, because approximately 10% triglyceride glycerol content of the crude extract is not accounted for in the GC fatty acid analysis. Increased inclusions of diethyl ether extracted non-lipid material from the samples.

Experiment 3

Gravimetric CCDS lipid extraction was numerically greatest for the Goldfish extraction method in Exp. 3 (Table 3). Biphasic lipid extraction with 1:1 hexane:diethyl ether (Method 2) was numerically similar to lipid

extraction when water soluble impurities were removed with biphasic extraction from the Goldfish extract (Method 4). CCDS lipid content with Methods 2 and 4 was 17.6% and 17.5%, respectively. CCDS non-lipid extract from the Goldfish procedure ranged from 3 to 10% of sample and averaged 5.8% of CCDS DM. There were no significant differences in CCDS percent of GC-analyzed fatty acids. The ratio of GC: gravimetric extract was lowest for the Goldfish procedure ($P = 0.01$) and similar for the other three procedures, indicating that non-lipid material was being extracted with the Goldfish procedure. The percentage of CCDS DM in the water soluble fraction of Method 4 averaged 6.2%, which is similar to the difference in extraction between the Goldfish and the 1:1 biphasic methods.

The water soluble impurities did not move from the origin when spotted on thin layer chromatography plates, indeed indicating the material was devoid of neutral lipid. In addition, enzymatic laboratory assays indicated there was very little phospholipid, glycerol or starch content in the water soluble material. We currently hypothesize the material is a yeast extract from the ethanol fermentation process; however, this has not been verified in the laboratory.

These data collectively indicate that a 10-hour incubation of samples with a 1:1 hexane:diethyl ether solvent for biphasic extraction of feedstuff lipids, especially from CCDS, is superior to Goldfish ether extraction.

Experiment 4

As increased levels of solubles were added to the distillers grains, NDF content decreased (Table 4). This is to be expected as solubles contain very little NDF (2-8% of DM). Using 200 mL of neutral detergent solution did not aid in filtering (~15 minutes/beaker) or decrease the fat coating on the filters compared to using the Van Soest method, as shown by little change in percent NDF ($P = 0.72$).

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However, when using the pre-NDF fat extraction, filtering was more efficient (~5 minutes) with no film on the filters. This procedure also decreased the analyzed NDF content compared to the other two methods ($P < 0.01$). Therefore, combining the biphasic fat procedure with NDF analysis provides an effective way to analyze both nutrients for high fat byproduct feeds.

Experiment 5

The NDF content for high moisture corn was lower than for dry rolled corn with the same corn hybrid, suggesting more starch breakdown (Table 5). With addition of more alpha-amylase, NDF values decreased ($P < 0.01$) and filtering became easier with a decrease in filtering time from

30 to 60 minutes down to 15 minutes. However, the NDF values were greater than 12% regardless of processing type, with observable granular, non-fibrous particles remaining in the filter.

Experiment 6

The four dry rolled corn samples had decreased NDF values (average = 10.1%, $P < 0.01$) and increased ease of filtering (5 minutes) when ground through the Tecator Cyclotec mill compared to the Wiley Mill (Table 6). When corn was ground through a Tecator Cyclotec, the NDF content was in the expected range (NRC, 1996).

Having accurate corn NDF values is important when evaluating the

DGS produced from corn. The recommended NDF procedure is to grind the corn samples through a Tecator Cyclotec mill with a 1-mm screen and add 0.5 g sodium sulfite and 2 doses of 0.5 mL alpha-amylase during the reflux period, because this grinding method resulted in only observed fiber residue in the filter with no starch granules.

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Evaluation of a New Single Implant Strategy vs. Two Common Implant Strategies in Beef Finishing Steers

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Summary

A finishing trial was conducted to compare the response to three implant strategies on performance and carcass characteristics of feedlot steers: 1) Component TE-IS with Tylan followed with Component TE-S with Tylan (TE-IS/S); 2) Component TE-200 with Tylan (TE-200); or 3) Revalor XS (Rev-XS) single implant. Final BW, DMI and ADG were unaffected ($P > 0.05$) by implant strategy. Steers on the TE-IS/S treatment had a lower ($P < 0.01$) feed:gain ratio (F:G) compared to those on the Rev-XS and TE-200 treatments. F:G calculated on a live basis was improved ($P < 0.05$) for reimplanted cattle compared to those on the TE-200 treatment; F:G for the Rev-XS was intermediate. No differences ($P > 0.05$) were observed for HCW, 12th rib fat, percentage USDA Choice and calculated USDA yield grade among treatments. Cattle implanted with Rev-XS had greater ($P < 0.05$) marbling scores than those implanted with TE-IS/S. Carcasses from TE-IS/S implanted steers presented larger ($P = 0.03$) longissimus muscle areas than both the TE-200 and Rev-XS treatment groups. These results suggest that F:G was improved with reimplanting.

Introduction

Revalor XS (Rev-XS; Intervet/Shering-Plough, Millsboro, Del.) is a new 10-capsule implant containing 40 mg estradiol and 200 mg trenbolone acetate. The last 6 capsules are coated with a biodegradable polymer that provides extended release (200 days). This new implant was developed to eliminate the need to reimplant cattle. Component TE-IS with Tylan (TE-IS; VetLife, West Des Moines, Iowa) is a

growth promoting implant that contains 16 mg estradiol, 80 mg trenbolone acetate, and 29 mg tylosin. Component TE-S with Tylan (TE-S; VetLife) is an implant that contains a combination of 24 mg estradiol, 120 mg trenbolone acetate, and 29 mg tylosin. These compounds are typically used in programs in which TE-S is administered 80 days after the initial TE-IS implant. Component TE-200 with Tylan (TE-200; VetLife) is a single implant that contains 20 mg estradiol and 200 mg trenbolone acetate. This study evaluated both feedlot and carcass performance of cattle on a typical reimplant vs. the two single implant programs.

Procedure

A common reimplant program consisting of Component TE-IS/S was compared to single implant strategies using Component TE-200 and Revalor XS. A 167-day finishing trial utilized 360 yearling steers purchased from a commercial order buyer (British cross-breed; initial BW = 711 ± 48 lb) in a randomized complete block design experiment conducted at the Panhandle Research Feedlot (UNL Panhandle Research and Extension Center). Cattle were limit fed (2% of BW) a 50% forage diet for a total of 5 days before the initiation of the trial. Cattle were individually weighed 2 consecutive days (day 0 and day 1) after the limit feeding period to obtain an initial BW. Body weights measured on day 0 were used to block the animals into 3 weight blocks. Cattle were stratified by BW within respective weight block and assigned randomly to 24 pens. Pens were assigned randomly to 1 of the 3 treatments with 8 pens per treatment and 15 steers per pen.

A 21-day step-up period was used, in which incremental percentages of dry rolled corn replaced alfalfa hay to allow cattle to become acclimated to the final finishing diet. The final diet consisted of 55.6% dry rolled

corn, 30.0% wet distillers grains with solubles, 8.0% alfalfa hay, 6.0% liquid supplement, and 0.4% limestone (DM basis). The liquid supplement provided 339 mg/hd/day Rumensin (Elanco Animal Health; Greenfield, Ind.) and 85 mg/hd/d Tylan (Elanco Animal Health). On day 1, steers received a single implant of either TE-IS, TE-200, or Rev XS. Each implant was administered subcutaneously in the upper middle third of the ear. On day 85, IS-S cattle were reimplanted with TE-S and were injected (s.c.) with 2 ml of Bovi-Shield Gold (Pfizer Animal Health, New York, N.Y.) to vaccinate against IBR, BVD types I and II, PI3, and BRSV. Because vaccinating cattle during reimplant is part of the protocol at the Scottsbluff research facility, any differences in feedlot performance when comparing the reimplanted cattle to the two single implant treatments may be an effect of implant and revaccination. During time of reimplant, cattle in both the TE-200 and Rev-XS treatment groups were allowed to remain in their pens.

Feed bunks were visually evaluated each morning and were managed to allow for trace amounts of feed to remain in each bunk before feed delivery. Cattle were individually weighed at the end of the trial. This weight (shrunk by 4%) was used to calculate overall live performance and dressing percentage. Overall carcass adjusted performance was calculated using carcass weights adjusted to a common dressing percentage of 63%.

Cattle were slaughtered at the JBS Swift plant in Greeley, Colo. Carcass data were collected by Diamond T Livestock Services (Yuma, Colo.). Liver scores and HCW measurements were taken on the day of slaughter. Carcass 12th rib fat, preliminary yield grade, percentage of KPH, marbling score, LM area and USDA yield and quality grades were recorded following a 48-hour carcass chill. Animal performance and carcass data were

Table 1. Performance of steers implanted with either Component TE-200 with Tylan (TE-200) or Revalor XS (Rev-XS) on day 1 compared to steers implanted with Component TE-IS with Tylan on day 1 followed by Component TE-S with Tylan (TE-IS/S) on day 85.

	TE-200	Rev-XS	TE-IS/S	SEM	P-value
<i>Carcass adjusted performance^{ce}</i>					
Pens, n	8	8	8		
Steers, n	127	126	126		
DOF, days	167	167	167		
Initial BW, lb	711.5	711.7	711.3	0.70	0.89
Final BW, lb	1385	1388	1410	10.9	0.23
DMI, lb/d	24.7	24.3	24.1	0.17	0.09
ADG, lb/d	4.03	4.05	4.18	0.06	0.22
G:F	0.163 ^a	0.166 ^a	0.173 ^b	0.002	0.01
F:G	6.13 ^a	6.02 ^a	5.78 ^b		0.01 ^f
<i>Overall live performance^d</i>					
Final BW, lb	1400	1396	1409	9.40	0.63
ADG, lb/d	4.12	4.10	4.17	0.06	0.63
G:F	0.167 ^a	0.169 ^{ab}	0.173 ^b	0.002	0.04
F:G	5.99 ^a	5.92 ^{ab}	5.78 ^b		0.04 ^f

^{ab}Within a row means without a common superscript differ ($P < 0.05$).

^cAll BW are shrunk 4% except initial BW.

^dOverall live performance calculated from live BW on a pen basis collected prior to study initiation and on day of slaughter.

^eOverall carcass performance calculated using 63% dressing percentage for all three treatments.

^fP-value calculated from G:F.

Table 2. Carcass characteristics of steers implanted with either Component TE-200 with Tylan (TE-200) or Revalor XS (Rev-XS) on day 1 compared to steers implanted with Component TE-IS with Tylan on day 1 followed by Component TE-S with Tylan (TE-IS/S) on day 85.

	TE-200	Rev-XS	TE-IS/S	SEM	P-value
<i>Carcass characteristics</i>					
HCW, lb	873	874	888	6.85	0.23
Marbling ^c	575 ^{ab}	592 ^a	554 ^b	9.90	0.04
% Choice	79.8	87.3	77.0	3.99	0.19
Fat depth, in	0.64	0.62	0.62	0.02	0.69
LM area, in ²	12.8 ^b	12.7 ^b	13.3 ^a	0.15	0.03
Calc. YG ^d	3.71	3.72	3.57	0.08	0.39

^{ab}Within a row means without a common superscript differ ($P < 0.05$).

^c450 = Slight⁵⁰, 500 = Small⁰, 520 = Small²⁰, etc.

^dCalculated as $2.5 + (2.5 * \text{fat depth}) - (0.32 * \text{REA}) + (0.2 * 2.0 \text{ KPH}) + (0.0038 * \text{HCW})$.

analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, N.C.) as a randomized complete block design with pen as the experimental unit.

Results

During the course of this trial, ears were examined by a VetLife representative to check for abscesses or missing implants. At reimplant time, cattle that received the Component TE-IS with Tylan implant presented no defects. On the final day of the trial, 14.4% of the cattle that were implanted with Revalor-XS had ears that were either abscessed or missing an implant. In the TE-200 and TE-IS/S treatment groups, 1.68% and 2.51%, respectively, had abscessed ears or were missing an implant. This difference in defects between the Revalor-XS treatment group and the Component treatments

is attributed to the tylosin tartrate that is added to both of the Component implants used in this trial. The results indicate tylosin in the Component implants acts as a local antibacterial significantly reducing the occurrence of abscesses. The cattle in the Revalor-XS treatment group that tested positive for ear abscesses most likely did not receive the full payout of this implant due to abscesses. In this study, reimplanted cattle had lower F:G than Revalor-XS cattle. The decrease in F:G may have been in response to the Tylan added to each Component TE-IS and TE-S implant.

Implant strategy had no effect on feed intake ($P > 0.05$) (Table 1). A decrease in DMI was not observed for cattle subjected to stresses of reimplant. Based on carcass adjusted final BW, there were no differences in final BW or ADG. Feed efficiency (F:G) was

($P < 0.01$) impacted by implant strategy. Cattle reimplanted at day 85 had lower F:G than both Rev-XS and TE-200 treatments. Final BW (shrunk by 4%) and ADG were not different ($P = 0.07$). Cattle in the TE-IS/S treatment group were more efficient ($P = 0.04$) than cattle in the TE-200 group. Animals that received the Rev-XS treatment were intermediate in feed efficiency compared to the other two treatment groups.

Hot carcass weight, percentage of choice carcasses, 12th rib fat, and calculated yield grade were not different ($P > 0.05$) across treatments (Table 2). Carcasses from cattle that received a Component TE-IS implant on day 1 followed by a terminal implant on day 85 presented larger ($P < 0.05$) LM areas (13.3 in²) than both the Rev-XS (12.7 in²) and TE-200 (12.8 in²) treatment groups. The Rev-XS treatment group had a significantly greater ($P < 0.05$) marbling score (592) than the TE-IS/S treatment group (554). Marbling scores were not significantly different when comparing TE-200 (575) to either Rev-XS or TE-IS/S.

In this trial, feed efficiency was improved when cattle were reimplanted rather than implanted at the beginning of the feeding period. Hormone concentration supplied should have been equivalent between Rev-XS and TE-IS/S treatments. Feedlot performance was not negatively impacted for cattle that were reimplanted in this study. However, treating with Rev-XS significantly improved marbling, compared to a reimplant program of TE-IS followed by TE-S. Interestingly, marbling was intermediate for cattle given TE-200 and not different from the other two treatments. It is not clear why differences in feed efficiency or marbling were observed in this study.

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Comparison of Revalor-XS vs. Two Common Implant Strategies in Finishing Steers

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Summary

A commercial feedlot experiment was performed to compare the effects of a Component TE-IS/TE-S with Tylan (TE-IS/S) implant strategy to a Component TE-200 with Tylan (TE-200) or a Revalor XS (Rev-XS) single implant strategy on performance and carcass characteristics of feedlot steers. Cattle receiving the TE-IS/S implants and the Rev-XS implant had greater ($P < 0.05$) final BW and lower F:G ($P < 0.05$) than the cattle that received the TE-200 treatment. Daily gain was improved ($P = 0.04$) when comparing TE-IS/S to TE-200, but intermediate for steers that received the Rev-XS treatment. Quality grade categories were unaffected by implant strategy. Cattle given TE-IS/TE-S had a greater number ($P < 0.05$) of yield grade 1 and 2 carcasses than other implant treatments, while cattle receiving TE-200 had greater ($P < 0.01$) yield grade 3 and 5 carcasses.

Introduction

Revalor XS (Intervet/Shering-Plough, Millsboro, Del.) is a new delayed release implant that contains 40 mg estradiol and 200 mg trenbolone acetate. This implant consists of a total of 10 capsules, 6 of which are coated with a polymer that begins to break down at approximately 80 days post implant administration. The Revalor-XS implant was developed to eliminate the need to reimplant cattle. Component TE-200 with Tylan (VetLife,

Overland Park, Kan.; 20 mg estradiol and 200 mg trenbolone acetate) has a 130-day pay-out period and is given once to feedlot steers during the feeding period. A common reimplant program utilized by feedlots is Component TE-IS with Tylan (VetLife; 16 mg estradiol and 80 mg trenbolone acetate) given on day 1, with the terminal implant Component TE-S with Tylan (VetLife; 24 mg estradiol and 120 mg trenbolone acetate) administered 80 days after the initial implant. Therefore, the objective of this commercial study was to evaluate and compare both feedlot and carcass performance for steers on a common reimplant program vs. single dose implant strategies.

Procedure

In the current study, Revalor-XS and Component TE-200 with Tylan were compared against a common reimplant program. A commercial feedlot experiment was conducted at Ward Feedyard in Larned, Kan. Yearling steers ($n = 2,095$; initial BW = 760 ± 11 lb) from ranches and auction barns in Oklahoma, Missouri, Kansas, and South Dakota were utilized for this trial. Steers were allocated to pens by sorting every 3 steers into 1 of 3 pens prior to processing. Steers were weighed (pen basis) after sorting, but before processing for determination of initial BW. Pens were assigned randomly to 1 of 3 treatments (7 pens/treatment). The treatments for this trial involved a reimplant and 2 single implant strategies: Component TE-IS with Tylan given on day 1 followed by Component TE-S with Tylan on day 80 (placed in the opposite ear of the Component TE-IS implant; TE-IS/S); Component TE-200 with Tylan given on day 1 (TE-200); and Revalor XS also administered on day 1 (Rev-XS). Implants were injected in the upper middle third of the ear under the skin. During initial processing, along with an implant cattle were given 1 dose of

preresponse pasteurella, 1 dose Pyramid-5, 4cc Ivomec, and a visual identification tag. During reimplant time, cattle that received the terminal implant (Component TE-S with Tylan) were given a single dose of Titanium 3 which aids in the prevention of disease caused by bovine rhinotracheitis virus and bovine virus diarrhea virus, Type I and Type II. Revaccinating cattle at reimplant time is part of Ward's normal standard operating procedure.

A step-up period in which incremental percentages of steam-flaked corn replaced forage was used to acclimate cattle to the final finishing ration. The finishing ration consisted of 69% steam-flaked corn, 17% wet distillers grains with solubles, 5% liquid supplement, 3.5% mixed hay, 3.5% mixed silage, and 2% fat. The supplement was formulated to provide 320 mg/hd/day Rumensin (Elanco Animal Health; Greenfield, Ind.) and 90 mg/hd/day Tylan (Elanco Animal Health).

On day 1 after cattle were allocated to pens, individual lots were weighed on a pen scale, and individual weight was calculated by applying a 4% pencil shrink to the pen weight. Live performance was calculated from final BW shrunk 4% to account for gastrointestinal fill. Carcass performance was calculated using final BW based on HCW divided by a common dressing percentage of 63.5%. Cattle were slaughtered at a commercial abattoir (Tyson, Holcomb, Kan.) approximately 160 days after being placed on trial. On day 1 of slaughter, HCW measurements were recorded and used to calculate both carcass performance and dressing percentage. After allowing for a 48-hour carcass chill, both USDA quality and yield grades were recorded.

Seven animals from the Rev-XS, 6 animals from the TE-IS/S, and 13 animals from TE-200 treatment groups died from non-treatment related illnesses during the course of

Table 1. Performance of yearling steers implanted with either Component TE-200 with Tylan (TE-200) or Revalor XS (Rev-XS) on day 1 compared to steers implanted with Component TE-IS with Tylan on day 1 followed by Component TE-S with Tylan (TE-IS/S) on day 80.

	TE-200	TE-IS/S	Rev-XS	SEM	P-value
<i>Feedlot performance¹</i>					
<i>Carcass²</i>					
Pens	7	7	7		
Steers	684	693	692		
Initial BW, lb	760 ^{ab}	766 ^a	753 ^b	4.29	0.02
Final BW, lb	1390 ^a	1418 ^b	1413 ^b	7.13	0.01
DMI, lb/d	22.5	22.7	22.4	0.27	0.67
ADG, lb/d	3.94 ^a	4.11 ^b	4.08 ^b	0.06	0.01
G:F	0.175 ^a	0.182 ^b	0.182 ^b	0.002	0.01
F:G ³	5.71 ^a	5.50 ^b	5.50 ^b		0.01
<i>Live</i>					
Final BW, lb	1399 ^b	1419 ^a	1413 ^a	13.1	0.01
ADG, lb/d	3.98 ^b	4.10 ^a	4.06 ^{ab}	0.09	0.02
G:F	0.177	0.181	0.181	0.003	0.09
F:G ³	5.66	5.52	5.54		0.09

¹Due to differences in initial body weight ($P = 0.02$), data were analyzed with initial BW as a covariant.

²Overall carcass performance calculated using 63.5% dressing percentage for all three treatments.

³P-value calculated from G:F.

^{ab}Means with different superscript within column differ ($P < 0.05$).

Table 2. Carcass characteristics of yearling steers implanted with either Component TE-200 with Tylan (TE-200) or Revalor XS (Rev-XS) on day 1 compared to steers implanted with Component TE-IS with Tylan on day 1 followed by Component TE-S with Tylan (TE-IS/S) on day 80.

	TE-200	TE-IS/S	Rev-XS	SEM	P-value
<i>Carcass characteristics¹</i>					
HCW ²	883 ^a	902 ^b	896 ^b	3.83	0.01
% Yield	63.1 ^a	63.4 ^b	63.7 ^b	0.33	0.001
<i>USDA quality grade, as percentage of total³</i>					
Prime	0.15	0.29	0.87		0.10
Choice	62.1	57.9	59.5		0.27
Select	34.9	38.6	37.4		0.35
Standard	2.34	3.03	1.59		0.21
Dark	0.00	0.00	0.29		0.14
Blood	0.00	0.00	0.00		
Commercial	0.44	0.14	0.29		0.60
<i>USDA yield grade, as percentage of total³</i>					
YG 1	7.16	11.96	8.96		0.01
YG 2	26.8	33.3	31.2		0.03
YG 3	52.3	43.1	48.4		0.003
YG 4	10.4	11.0	9.68		0.74
YG 5	3.36	0.72	1.73		0.002

¹Data were analyzed using the MIXED procedure of SAS.

²Hot carcass weight, lb.

³Data were compared using the χ^2 option of the frequency procedure of SAS.

^{ab}Means with different superscripts within column differ ($P < 0.05$).

this study. Three carcasses from the TE-200 treatment group and one carcass from the Rev-XS treatment group were condemned and removed from the study for reasons that were not related to implant treatment.

Both feedlot and carcass data were analyzed using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, N.C.) with pen as the experimental unit. PROC FREQ of SAS was

used for the Chi Square distribution analysis for both quality and yield grade distributions.

Results

On the last day of the study, VetLife representatives examined ears that received implants for possible abscesses or missing implants that may have occurred during implant-

ing. 14.7% of the cattle that received a Revalor-XS implant presented an ear that was either abscessed or missing an implant. Ears of cattle that received a Component TE-200 with Tylan or Component TE-IS with Tylan followed by a terminal Component TE-S with Tylan implant had 5.6 and 1.4% abscesses or missing implants. The difference in abscesses and missing implants between the Revalor-XS treatment and the two Component implant treatments may be due to the fact that Tylan is added to the Component implants to minimize infection.

There were no differences in DMI when comparing the reimplant treatment to the 2 single-dose implant treatments ($P = 0.67$; Table 1). For feedlot performance calculated on a carcass basis, final BW ($P < 0.01$), and F:G ($P = 0.01$) were significantly different among the 3 treatments. The cattle that received either the single Rev-XS or the Component TE-IS followed by a TE-S implant had significantly larger final BW ($P < 0.01$) than the Component TE-200 cattle. In addition to final BW, cattle that were placed on the Rev-XS or the reimplant treatment expressed lower F:G than cattle that received TE-200 ($P = 0.01$). Cattle that were placed on the reimplant treatment or the Rev-XS treatment had significantly greater ($P < 0.05$) ADG than cattle that were on the Component TE-200 treatment. Feedlot data calculated on a live basis produced results similar to those data analyzed on a carcass basis. Final BW was significantly greater ($P < 0.01$) for both Rev-XS and TE-IS/S steers when compared to TE-200 treated cattle. Average daily gain was significantly ($P = 0.02$) improved for cattle that were placed on the reimplant treatment compared to TE-200 cattle; Rev-XS steers were intermediate.

Carcass data are presented in Table 2. Cattle that received the TE-200 implant had lighter ($P < 0.01$) HCW than both the Rev-XS and TE-IS/S treatments. Dressing percentage was significantly increased ($P < 0.01$) for both TE-IS/S and Rev-XS when compared to the TE-200

(Continued on next page)

treatment group. Cattle in the Rev-XS treatment tended to have a greater ($P = 0.10$) number of carcasses grade Prime than cattle assigned to TE-200 and TE-IS/S treatments. The other USDA quality grade categories taken at the plant were not significantly impacted by implant regimen. Cattle implanted with Component TE-IS on day 1 then reimplanted with TE-S 80 days later had a greater ($P < 0.05$) number of car-

casses that graded USDA yield grade 1 and 2 than the other 2 single implant treatments. The TE-200 treatment had a greater ($P < 0.01$) number of yield grade 3 and 5 carcasses than both the TE-IS/S and Rev-XS treatments.

Summary

In conclusion, data from this study suggest feedlot and carcass perfor-

mance was relatively similar for cattle administered either a single Revalor XS implant or a combination of 2 implants during the feeding period.

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Comparison of Revalor XS to a Revalor IS / Revalor S Implant Strategy in Finishing Steers

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Summary

A commercial feedlot study compared effects of Revalor IS/Revalor S (RevIS-S) implant strategy to a Revalor XS (RevX) single implant strategy on performance and carcass characteristics of feedlot cattle. There were no differences ($P > 0.90$) in DMI, final BW, ADG, or F:G. Hot carcass weight, marbling score, 12th rib fat, LM area and calculated yield grade also were unaffected ($P > 0.10$) by implant strategy. The RevX treatment resulted in a greater ($P < 0.01$) percentage of Choice carcasses than RevIS-S. Cattle receiving Revalor XS performed similar to cattle implanted with RevIS-S using a traditional reimplant program.

Introduction

Revalor XS is a new extended release implant that contains 40 mg estradiol and 200 mg trenbolone acetate. The last six capsules of this 10-capsule implant are coated with a polymer that allows for the delayed breakdown and release of hormone to mimic a reimplant program. This single implant strategy contains similar

quantities of hormone as a reimplant program consisting of Revalor IS-S. Revalor IS contains 16 mg estradiol and 80 mg trenbolone acetate, whereas Revalor S contains 24 mg estradiol and 120 mg trenbolone acetate. The following experiment compared feedlot and carcass performance for steers receiving either Revalor XS or Revalor IS implant followed by Revalor S in a commercial feedlot.

Procedure

Yearling steers ($n = 1,356$; initial BW = 689 ± 35 lb) from ranches and auction barns in Montana, Wyoming, Nebraska, Idaho, Missouri, and North Dakota were blocked by arrival date (5 blocks). This commercial trial was conducted at Hi Gain feedlots near Farnam, Neb. Steers were allocated to pens based on sorting every 2 steers into one of two pens prior to processing. Pens were assigned randomly to one of two treatments (eight pens/treatment). Treatments consisted of two implant strategies, either a single Revalor XS implant given on day 1 (RevX) or Revalor IS given on day 1 followed by Revalor S on day 80 (RevIS-S). All steers received Vista 3SQ, Safe Guard, and Ivomec on arrival. Mean days on feed across blocks was 157 days. A step-up period consisting of three adaptation diets was used to adapt cattle to the finishing ration. During the step-up period, incremental percentages of dry rolled corn replaced ground hay. The finishing diet consisted of 54.9% dry rolled corn, 35% WDGS, 5.5% mixed grass

hay, and 4.6% liquid supplement. The supplement contained Rumensin formulated to provide 330 mg/steer daily and Tylan formulated to provide 90 mg/steer daily. Pen weight and individual BW were collected on day 1; however, performance was calculated from pen BW, pencil shrunk 4% to adjust for fill. Carcass-adjusted performance was calculated using final BW, based on HCW divided by a common dressing percentage of 63%. Cattle were slaughtered at a commercial abattoir (Tyson, Lexington, Neb.) on three different dates according to the date they were placed on trial. On day 1 of slaughter, both liver score and HCW were recorded. After a 24-hour chill, KPH, 12th rib fat thickness, color score, LM area, USDA quality grade, and yield grade were recorded. Data were analyzed using the PROC MIXED procedure of SAS with pen as the experimental unit. PROC FREQ of SAS was used for the Chi Square distribution analysis for both quality and yield grade distributions.

Results

There were no differences in DMI between steers assigned to RevIS-S or RevX treatments (Table 1). Using carcass-adjusted performance, no differences in final BW or ADG were observed. Therefore, F:G also was unaffected by implant strategy. Similar results were observed when evaluating performance using final live BW.

There were no differences in HCW, USDA marbling score, fat depth, LM area or calculated USDA yield

Table 1. Performance of steers implanted with either Revalor-IS on day 1 followed by Revalor-S on day 80 (RevIS-S) compared to steers implanted with Revalor-XS on day 1 (RevX).

	RevIS-S	RevX	SEM	P-value
Pens	8	8		
Steers	671	671		
<i>Carcass-adjusted performance^{ab}</i>				
Initial BW, lb	700	701	18.0	0.89
Final BW, lb	1345	1347	14.2	0.90
DMI, lb/d	24.0	24.0	0.39	0.96
ADG, lb/d	4.14	4.15	0.05	0.94
F:G	5.79	5.79		0.96 ^d
<i>Live performance^c</i>				
Final BW, lb	1320	1327	15.3	0.67
ADG, lb/d	3.98	4.01	0.06	0.67
F:G	6.03	5.98		0.55 ^d

^aAll BW are shrunk 4%.

^bOverall carcass performance calculated using 63% dressing percentage for both treatments.

^cOverall live performance calculated from live BW on a pen basis collected prior to study initiation and on day of slaughter.

^dP-value calculated from G:F.

Table 2. Carcass characteristics of steers implanted with either Revalor IS on day 1 followed by Revalor-S (RevIS-S) on day 80 compared to steers implanted on day 1 with Revalor-XS (RevX).

	RevIS-S	RevX	SEM	P-value
<i>Carcass characteristics</i>				
Hot carcass weight, lb	850	854	9.90	0.69
Marbling ^a	534	532	8.32	0.86
Fat depth, in	0.63	0.62	0.04	0.95
LM Area in ²	14.1	14.1	0.43	0.78
Calc. YG ^b	3.40	3.40	0.20	0.97
<i>USDA quality grade, % of total</i>				
Prime	1.50	0.75		0.20
Upper Choice	4.80	3.47		0.22
Mid Choice	13.04	12.97		0.97
Low Choice	50.22	58.37		< 0.01
Select	29.99	23.68		< 0.01
Standard	0.45	0.75		0.47
Choice or >	69.57	75.57		0.01
Select or <	30.43	24.43		0.01
<i>USDA yield grade, % of total</i>				
YG 1	1.20	1.66		0.48
YG 2	11.84	10.29		0.37
YG 3	38.98	40.54		0.56
YG 4	40.48	37.52		0.27
YG 5	7.50	9.98		0.11

^a450 = Slight⁵⁰, 500 = Small⁰, 540 = Small⁴⁰, etc.

^bCalculated as $2.5 + (2.5 \times \text{fat depth}) - (0.32 \times \text{REA}) + (0.2 \times \text{KPH}) + (0.0038 \times \text{HCW})$.

grade when comparing the two treatments (Table 2). Implanting steers with Revalor XS increased ($P < 0.01$) the number of carcasses that graded low Choice, and decreased ($P < 0.01$) the number of carcasses that graded Select. Overall, when comparing the two implant strategies, the RevX treatment group had a higher number ($P = 0.01$) of carcasses that graded Choice or better and therefore had a lower number ($P = 0.01$) of carcasses that graded Select or worse. There was a tendency ($P = 0.11$) for the RevX treatment to have more USDA yield grade 5 carcasses than the RevIS-S group.

In conclusion, this study indicates cattle implanted once up front with Revalor XS will perform similar to cattle that are implanted initially with Revalor IS and then reimplanted with Revalor S.

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Vaccination to Reduce the Prevalence of *Escherichia Coli* O157:H7 in Feedlot Cattle Fed Wet Distillers Grains Plus Solubles

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Summary

A clinical trial in summer of 2008 evaluated effects of feeding 0 (CONTROL) or 40% wet distillers grains plus solubles (WDGS) with and without vaccination against E. coli O157:H7 on the probability of shedding E. coli O157:H7 in the feces. No interaction (P = 0.97) was observed between vaccination and diet for E. coli O157:H7 shedding. Steers fed WDGS were 2.1 times more likely (P < 0.01) to shed E. coli O157:H7 than cattle fed CONTROL. Vaccination resulted in cattle that were 43% less likely (P < 0.01) to test positive for E. coli O157:H7 than the unvaccinated cattle.

Introduction

Results of vaccinating feedlot cattle against type III secreted proteins of *Escherichia coli* O157:H7 as have been reported in several beef reports (2008 *Nebraska Beef Report*, pp. 92-94; 2006 *Nebraska Beef Report*, pp. 68-69; 2006 *Nebraska Beef Report*, pp. 70-71; 2005 *Nebraska Beef Report*, pp. 61-63). Peterson et al. (2007, *Journal of Food Protection* 70:287-291) tested the effects of vaccinating cattle against *E. coli* O157:H7 in feces and colonization at the terminal rectum in cattle on diets including 0, 10, 20, 30, 40, and 50% inclusion of distillers grains. Cattle fed 0% distillers had numerically greater colonization than steers fed 10, 20, or 30% distillers, but the difference was not statistically significant. Like-

wise, numerically fewer steers fed 0% distillers were colonized with *E. coli* O157:H7 compared to steers fed 40% or 50% distillers, but again, the difference was not statistically significant. In that study, the significant diet effect was for steers fed 40 or 50% distillers compared to steers fed 10, 20, or 30% distillers. Our objective was to test the effect of feeding 0 and 40% distillers grains, with or without vaccinating against type III secreted proteins of *E. coli* O157:H7, on shedding of *E. coli* O157:H7 in feces of feedlot cattle.

Procedure

The clinical trial was conducted from May to October of 2008 at the beef research feedlot at the University of Nebraska Agricultural Research and Development Center using 480 steers in 60 pens. Pens were assigned randomly to one of four treatments (15 pens per treatment) in a 2x2 factorial treatment design. The two factors were diet and vaccination treatment. The dietary treatments were either 0% distillers finishing diets (CONTROL) or diets containing 40% wet distillers grains plus solubles (WDGS). The vaccination treatment was a 3-dose vaccination regimen or no vaccination. The treatments were assigned to pens of cattle within two sampling blocks and assigned randomly to either the north or south feeding facilities. The vaccine, marketed in Canada as Econiche by Bioniche Life Sciences, was administered as a 2-ml subcutaneous injection. In the present study, a 3-dose vaccine regimen was given on feeding days 1, 25, and 53 to the cattle receiving that treatment. Steers that were not vaccinated were handled similar to the vaccinated steers, but received no vaccine injection. Five days prior to the initiation of the trial, steers were limit fed at 2% of BW to minimize variation

in rumen fill. Steers were fed a 1:1 ratio (DM basis) of alfalfa hay and wet corn gluten feed during limit feeding. Steers were weighed individually on days 0 and 1 to determine initial BW. Steers (783 +/- 40 lb) were stratified by BW and assigned randomly to pens (8 steers/pen) based on day 0 BW.

All diets contained 15% corn silage, 5% supplement, and corn fed as high moisture corn (HMC) and dry rolled corn at a 3:2 ratio (DM basis). The WDGS treatment contained wet distillers grains with solubles at 40% inclusion, which replaced the corn mixture. Steers were adapted to finishing diets in 21 days by replacing alfalfa hay with the 3:2 mixture of HMC and DRC. On day 25 of the experiment, calves were implanted with Revalor-S. Steers were slaughtered on day 159.

Fecal samples were obtained from the rectum on days 75, 96, 117, and 138. The samples were labeled with a bar code, which blinded the laboratory personnel to animal identification and treatment, and sent within a few hours of collection to Food Safety Net Services in San Antonio, Tex., for culture. Standard broth enrichment and plate culture methods (2008 *Nebraska Beef Report*, pp. 92-94) with modifications were used to yield a positive or negative result for the presence of *E. coli* O157:H7 in the feces. Identity of each isolate was confirmed by standard methods, including PCR.

The effect of vaccine treatment on the probability of detecting *E. coli* O157:H7 from feces was modeled using multi-level logistic regression (GENMOD, SAS Institute, Cary, N.C.). Factors included in the model were the main effects of dietary treatment and vaccination, the interaction between diet and vaccination, sampling block, location within the feedlot, and test period (date of sampling). Least squared means of the

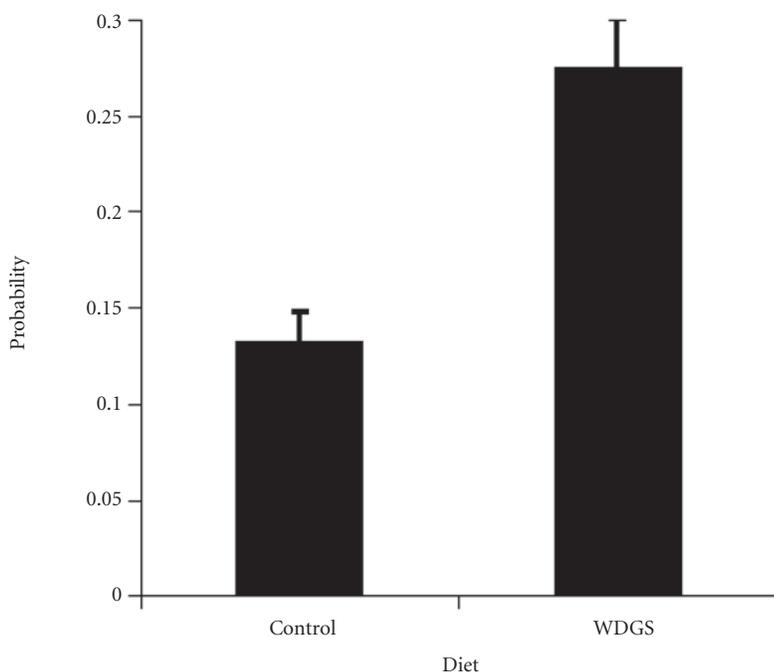


Figure 1. Probability of steers shedding *E. coli* O157:H7 in the feces as influenced by feeding 40% wet distillers grains (WDGS) or none (CONTROL) to finishing cattle.

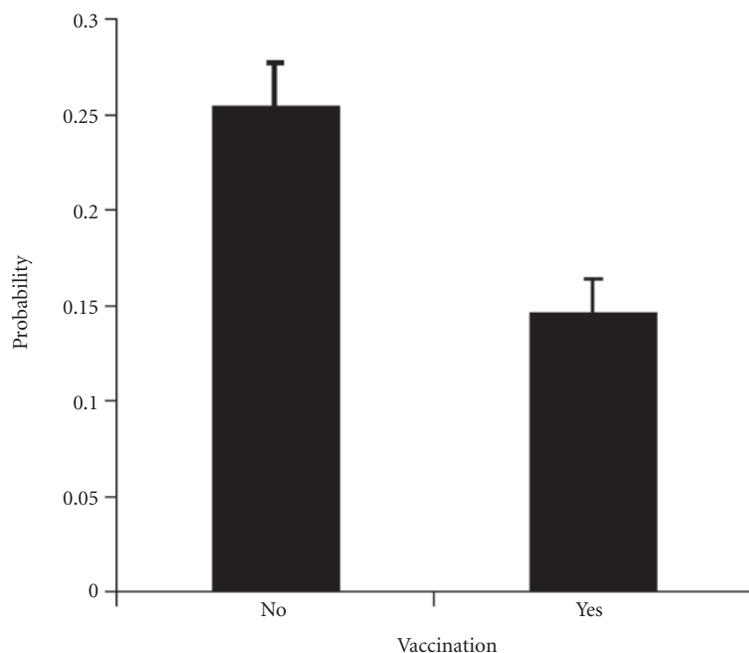


Figure 2. Probability of steers shedding *E. coli* O157:H7 in feces as influenced by vaccination treatment.

parameter estimates from the multi-variable analysis were used to calculate adjusted probabilities for fecal shedding by treatment level. Relative risk (RR) values for each vaccine treatment were calculated from the adjusted probabilities.

Results

There was no interaction ($P = 0.97$) between diet and vaccination; therefore, the main effects of diet and vaccination are presented. Likewise, no test period by treatment interaction

was observed ($P > 0.40$) or effect of test period ($P = 0.17$). Sampling block and location within the feedlot were variables impacting *E. coli* O157:H7 shedding ($P < 0.01$) and were accounted for in the model. *E. coli* O157:H7 was detected in 369 of the 1899 fecal samples or 19%. For steers fed WDGS and vaccinated, *E. coli* O157:H7 was detected in 94 of 477 samples, or 19.7%, and 43 of 478 samples for vaccinated steers fed CONTROL, or 9.0%. Among unvaccinated steers, *E. coli* O157:H7 was detected in 154 of 470 samples (32.8%) for steers fed WDGS, versus 78 of 474 samples (16.5%) for CONTROL steers.

Feeding WDGS increased ($P > 0.01$) the probability for shedding *E. coli* O157:H7 by 2.1 times in this study when distillers was fed at 40% of diet DM (Figure 1). Vaccinating steers was effective ($P < 0.01$) at reducing *E. coli* O157:H7 shedding by 43%, a slightly lower effect than seen in previous vaccine trials (Figure 2). Previous data collected by Peterson et al. (2007) suggested that feeding higher levels (40 and 50% DM) of wet distillers grains increases the prevalence of *E. coli* O157:H7; however, the lower levels that are more commonly fed resulted in significantly lower colonization than high levels. Peterson et al. (2007) also reported that there was not a significant difference between any level of WDGS inclusion and their control or 0% distillers grains. Results from the current study suggest that feeding 40% WDGS increases the shedding of *E. coli* O157:H7, similar to the numerical differences in colonization observed by Peterson et al. (2007). The impact of feeding distillers grains on shedding of *E. coli* O157:H7 is likely dependent on dietary inclusion; however, vaccination mitigates the risk.

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Evaluation of ProTernative Stress Formula and ProTernative Continuous Fed Formula in a High Energy Feedlot Diet

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Summary

Cross-bred yearling steers were used in a feeding trial to compare the use of two different direct fed microbials (DFM), ProTernative CF (DFM-CF) and ProTernative SF (DFM-SF). The treatment design was a 2x2 factorial with a control (no DFM), DFM-CF, DFM-SF, and both (CF+SF). Diets consisted of 40% WCGF with high moisture corn with no feed additives other than the DFM treatments. No differences were observed in feedlot performance or carcass characteristics.

Introduction

The two direct fed microbials (DFM) under investigation from Ivyp Natural Solutions were ProTernative Continuous Formula (*Saccharomyces cerevisiae*, strain I-1077) and ProTernative Stress Formula (*Saccharomyces cerevisiae* boulardii, strain I-1079). These DFMs have been evaluated for their respective performance and health effects but not in direct comparison to one another in typical high grain finishing diets with corn by-products. The objective of the present trial was to evaluate live performance and carcass characteristics for steers receiving a feedlot finishing diet with corn milling byproducts with or without each DFM.

Procedure

Three hundred and twenty cross-bred yearling steers (712 ± 16 lb) were used in a feeding trial at the University of Nebraska–Lincoln Research

feedlot located at Mead, Neb. Steers were limit fed for 5 days at 2% BW. Individual BWs were collected for two consecutive days (day 0 and day 1) with steers blocked by 3 weight groups (heavy, medium, and light). Treatments were randomly assigned to pens. Treatment replications were: one in the heavy block, three in the medium weight block, and four in the light block, for a total of 8 replications per treatment. Steers were housed in outdoor pens with ten steers per pen. On day 1, steers were implanted with Component TE-C (Vet Life). Steers were re-implanted on day 72 with TE-S (Vet Life).

All steers were fed a common diet with the only difference between treatments being the DFM delivered. Treatments for this experiment were arranged as a 2x2 factorial design, with a control diet containing no DFM (CON). The other three treatments were ProTernative Continuous Formula containing *Saccharomyces cerevisiae*, strain I-1077 (DFM-CF); ProTernative Stress Formula containing *Saccharomyces cerevisiae* boulardii, strain I-1079 (DFM-SF); and a combination of both (CF+SF). Steers were adapted to the finishing diet with decreasing levels of alfalfa and increasing levels of HMC. Four adaptation diets were delivered for 3, 4, 7, and 7 days, respectively. The finishing diet for the steers consisted of 50% HMC, 40% WCGF (Sweet Bran, Cargill Inc., Blair, Neb.), 5% corn stalks, and 5% supplement. No Rumensin or Tylan was fed in any of the diets (Table 1). DFM treatments were added directly to the truck prior to feed delivery. Five pounds of DFM were mixed in the feed truck to deliver 2 oz of DFM to each steer daily, to ensure 0, 400, 500, or 900 mg of active ingredients were delivered for the CON, DFM-CF, DFM-SF, and CF+SF treatments, respectively.

Steers were fed for 162 days, then

slaughtered at a commercial abattoir (Greater Omaha Packing, Omaha, Neb.). At time of slaughter, hot carcass weights (HCW) and liver scores were collected. Livers were scored using 0 (no abscesses), A-, A, and A+ (severely abscessed). Carcasses were then chilled for 48 hours, after which back fat thickness, LM area, and marbling scores were collected. Yield grade was calculated based on LM area, back fat thickness, marbling score, HCW, and 2.5% kidney, pelvic, and heart fat (KPH).

Data for this experiment were analyzed using the PROC MIXED procedure (SAS Inc.). Treatment and block were included as fixed effects. Treatments were analyzed as a factorial. If the interaction between DFM-CF and DFM-SF was significant, the simple effects were analyzed. If no interaction was observed, only the main effects of either DFM-CF or DFM-SF are presented. Means were separated using least square means separation procedures of SAS. Chi-square analysis was performed on the individual liver scores to determine treatment effects.

Results

No interactions were observed ($P > 0.27$) between the DFMs in this study for feedlot performance (Table 2). Final BW and ADG were not impacted by treatment ($P > 0.58$). Dry matter intake was not influenced by DFM-CF ($P = 0.95$); however, steers fed DFM-SF tended ($P = 0.09$) to have greater DMI than CON or DFM-CF steers. However, no differences in G:F were observed due to treatment ($P > 0.63$).

No interaction was observed between DFMs for carcass characteristics ($P > 0.27$). Hot carcass weight was not impacted by treatment ($P > 0.59$), with an overall average of 856 lb. Fat thickness averaged 0.53 in

Table 1. Adaptation and finishing diet composition.

Days Diet	1-3 1	4-7 2	8-14 3	15-21 4	22-162 Finisher
WCGF	40.0	40.0	40.0	40.0	40.0
HMC	16.0	26.0	36.0	43.5	51.0
Corn stalks	5.0	5.0	5.0	5.0	5.0
Alfalfa hay	35.0	25.0	15.0	7.5	0.0
Supplement	4.0	4.0	4.0	4.0	4.0
CP, %	17.2	16.6	16.0	15.6	15.2

WCGF = wet corn gluten feed (Sweet Bran® supplied by Cargill, Blair, NE); HMC = high moisture corn; CP = crude protein. Supplement contained no Rumensin® or Tylan®.

Table 2. Feedlot and performance data of steers receiving different direct-fed microbial treatments.

	CON	DFM-CF	DFM-SF	CF+SF	SE	Int.	CF	SF
Initial BW, lb	735	734	735	735	1	0.71	0.33	0.71
Final BW, lb	1395	1379	1388	1398	12	0.27	0.80	0.58
DMI, lb/d	26.3	26.0	26.4	26.7	0.2	0.29	0.95	0.09
ADG, lb	4.02	3.93	3.98	4.04	0.07	0.31	0.87	0.63
G:F	0.155	0.153	0.153	0.153	0.003	0.59	0.78	0.63
HCW, lb	879	869	875	881	7	0.27	0.80	0.58
Marbling ²	506	512	520	539	11	0.54	0.28	0.07
LM area	13.3	13.2	13.2	13.2	0.2	0.85	0.78	0.82
Fat depth	0.55	0.57	0.54	0.54	0.02	0.75	0.48	0.34
YG calc. ³	3.0	3.0	2.9	3.0	0.1	0.69	0.65	0.69

¹None = 0 DFM; CF = ProTernative DFM CF; SF = ProTernative DFM SF; CF+SF = ProTernative DFM CF and SF.

²Marbling score: 400 = Slight⁰, 500 = Small⁰, etc.

³Yield grade (YG) calculated using the equation $(2.5 + (2.5 \times \text{fat thickness}) + (0.2 \times 2.5\% \text{ KPH}) + (0.0038 \times \text{HCW lbs}) - (0.32 \times \text{LM area in}^2))$.

and was not impacted by treatment ($P > 0.40$). No differences in LM area were observed ($P > 0.79$) with the overall average of 13.1 in² ($P > 0.79$). There was a tendency for marbling score to be greater for steers receiving the DFM-SF ($P = 0.07$) treatment compared to DFM-CF. Liver scores were categorized and no differences for A+/adhered abscesses ($P > 0.46$), A abscesses ($P > 0.28$), or no abscesses ($P > 0.11$) were observed. There was, however, a tendency for CON steers to have more A- liver abscesses than steers in all other treatments ($P = 0.06$); 11 steers had A- liver scores compared with 7, 2, and 5, respectively, for DFM-CF, DFM-SF, and CF+SF treatments. For finishing diets containing 40% WCGF, and low-stress steers, no positive impacts were observed for using either DFM in this study.

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Tympanic Temperature of Steers Fed Different Levels of Metabolic Energy Intake During Summer and Winter

Rodrigo A. Arias
Terry L. Mader¹

Summary

Tympanic temperatures (TT) of steers were recorded during July (8 days) and January (6 days). In each experiment, steers were fed 11, 18, or 25 Mcal/day ME in a roughage-based diet, or 18, 25, or 32 Mcal/day ME in a concentrate-based diet. Tympanic temperatures were greater during summer than during winter. Also, steers fed a concentrate diet had greater TT than those fed a roughage diet. Linear equations were obtained to estimate TT of cattle for summer and winter seasons. During the winter, TT response to MEI was dependent on the type of diet. Results demonstrate that increases in the energy level of the diet result in increases in TT. However, the response appears to be dependent on season of year.

Introduction

Altering metabolizable energy intake (MEI) by diluting high concentrate diets with fiber is a diet change that aids in keeping cattle on feed in the winter, but could also lower total heat production in the summer. However, it is uncertain whether the greater heat increment per unit of digestible energy, often associated with fiber, may offset any advantages from dilution. A better understanding of the interactions among diet type, MEI, and environment is needed. The objectives of this study were to assess the effects of MEI and diet composition on body temperature changes during winter and summer seasons.

Procedure

The dataset used for this analysis was derived from two experiments conducted at the University of

Nebraska–Lincoln Haskell Agricultural Laboratory at Concord, Neb. Experiment 1 was conducted during the summer, in which 96 steers with an average beginning weight of 950 lbs were randomly assigned to 12 pens of 8 steers per pen. Pens were subsequently randomly selected to receive one of six diets. Three diets were energy-based and three were roughage-based. The three diets in each category consisted of differing levels of metabolizable energy (ME) to be controlled by the amount of feed offered. The daily MEI levels for the roughage diet were 11, 18, or 25 Mcal, whereas daily MEI levels of the concentrate diets were 18, 25, or 32 Mcal. Diet composition was the same in both experiments (Table 1), and MEI levels were obtained by adjusting DMI. Experiment 2 was conducted during the winter utilizing cattle type, number, and weights comparable to those utilized in Exp. 1; the number of pens and pens/treatment were also the same.

In Exp. 1, 30 predominantly Angus and Angus crossbred steers (5 steers/diet treatment; 2 or 3 steers/pen) were fitted with a Stowaway XTI[®] data logger to record hourly tympanic temperature (TT). Data loggers were attached to a thermistor placed near the tympanic membrane and remained in the steers for 8 days during July 2006. In Exp. 2, 24 predominantly Angus and Angus crossbred steers (4 steers/diet treatment) were fitted with the same type of data loggers, which were placed in the ear utilizing the same procedure described in Exp. 1. The devices remained in the steers for a 6-day period in January 2007.

Cattle were fed the respective diet and level for a minimum of 14 days prior to obtaining TT. Environmental variables (Table 2) were collected hourly from a weather station located in the feedlot and included air temperature (AT), wind speed (WS),

relative humidity (RH), and solar radiation (SR).

Data were analyzed using incomplete factorial structure in a complete randomized design. Descriptive statistics analyses were obtained using JMP (SAS Inc., Cary, N.C.). PROC MIXED of SAS was utilized for the repeated measurement analysis and for the incomplete factorial analysis. This last analysis was performed within season, with MEI as the quantitative variable and three MEI levels and type of diet as the qualitative variables to obtain equations to predict TT by season.

Results

During summer, cattle received a mean net solar radiation of 326.2 Langleys/day more than during winter (Table 2). Wind speed was greater during winter (11.4 vs. 4.8 mph), while there was a trend for greater relative humidity during winter. The effect of type of diet and MEI levels on TT are presented in Table 3. Tympanic temperatures were greater during summer and dependent upon the level and type of diet fed to cattle ($P < 0.05$). During the summer, the greatest ($P < 0.05$) TTs were obtained in cattle consuming 25 Mcal ME of the roughage diet and in cattle consuming 25 and 32 Mcal ME of the concentrate diet. During the winter, for cattle consuming the roughage diet, the lowest ($P < 0.05$) TTs were reached in cattle consuming 11 Mcal ME, with the greatest ($P < 0.05$) TTs obtained in cattle receiving 25 Mcal of the concentrate diet. Mean TT was 0.5°F greater in summer than in winter (102.0 vs. 101.5°F, respectively, $P < 0.01$). Tympanic temperatures were consistently greater during the entire day in the summer ($P < 0.01$), regardless of diet type.

Cattle fed diets based on concentrates showed greater TT between 1000 hr and 1500 hr, as well as at 0700 hr, than those cattle fed diets based on

Table 1. Composition of rations fed to steers during experimental period.

Ingredient	Diet type (DM basis)	
	Roughage, %	Concentrate, %
Alfalfa	27.00	9.00
Corn silage	47.75	9.00
Rolled corn	22.00	77.25
Soybean meal	0.00	1.50
Liquid supplement	3.25	3.25
Energy content		
Mcal ME/lb	1.19	1.38
Mcal NEg/lb	0.49	0.63

Table 2. Environmental variables and indexes collected during experimental periods.

Experimental Period	AT	RH	THI	WS	SR	WCI
Summer						
Mean	76.7	75.7	73.3	4.8	537.2	—
SD	1.7	3.5	1.2	0.8	49.3	—
Range	12.7	25.3	9.6	5.7	396.9	—
Winter						
Mean	19.7	84.8	—	11.4	211.0	8.7
SD	4.8	4.0	—	2.4	15.5	6.4
Range	26.1	24.8	—	13.3	105.4	30.5

AT = Ambient air temperature (°F); RH = Relative humidity (%); THI = Temperature-humidity index; WS = Wind speed (mph); SR = Solar radiation (Langleys); and WCI = Wind-chill index (°F).

Table 3. Mean tympanic temperature (°F) by diet treatment and season.

	Diet type, ME (Mcal) intake/day						SE
	Roughage			Concentrate			
	11	18	25	18	25	32	
Summer	101.8 ^a	101.9 ^{ab}	102.1 ^c	102.0 ^{bc}	102.2 ^d	102.3 ^d	.033
Winter	101.1 ^a	101.5 ^d	101.6 ^d	101.3 ^b	101.9 ^e	101.4 ^c	.031
Both seasons	101.5 ^a	101.7 ^b	101.9 ^d	101.8 ^c	102.1 ^e	101.9 ^d	.025

abcde Means in a row with different superscripts differ ($P < 0.05$).

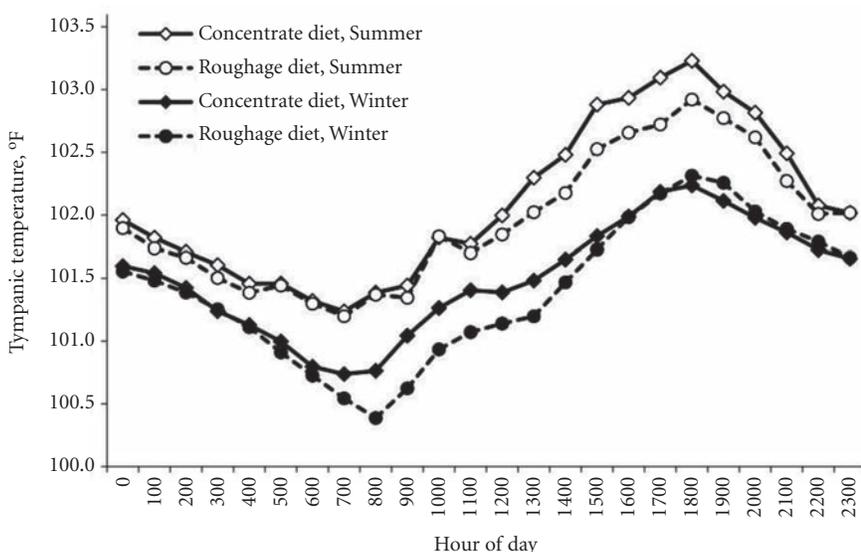


Figure 1. Average hourly tympanic temperature, by season, for steers fed concentrate vs. roughage diets.

roughages (Figure 1). Roughage diets allowed TT to reach the lowest levels in the winter, while concentrate diets allow TT to reach the highest levels in the summer. In contrast, TT of steers provided concentrate vs. those on roughage diets were similar during the coolest (0700 hr) part of the day during the summer and were also similar when TT peaked (1800 hr) in the winter.

There were no diet-by-ME intake level interactions during the summer season, with only main effects being significant ($P < 0.01$ for diet and MEI). Therefore, a common regression equation (similar slopes) for both types of diet was fit (Figure 2) with different intercepts for each diet. Thus, for both diets, cattle increased their TT 0.023°F per each Mcal increase in daily MEI. During the winter, MEI had a quadratic effect ($P < 0.01$) on TT. In addition, there was an interaction for type of diet by MEI ($P < 0.01$). Thus, TT response to MEI is dependent on the type of diet fed to cattle (Figure 3). The predicted values of TT were: a) concentrate diet, $\text{TT} = 95.08 + (0.535 * \text{MEI}) - (0.0106 * \text{MEI}^2)$; and b) roughage diet, $\text{TT} = 99.87 + (0.145 * \text{MEI}) - (0.0030 * \text{MEI}^2)$.

For the most part, differences in TT among MEI levels would be expected due to differences in metabolic heat load, although the rate of change in TT per unit change in MEI was relatively small during the summer. However, these cattle were not experiencing significant heat stress during this time; thus, the cattle were able to efficiently dissipate metabolic heat. Under more adverse conditions, differences in TT among MEI levels increase with the build-up of metabolic heat, as reported in previous studies (2001 Nebraska Beef Report, pp. 69-77), in which managed or restricted feeding programs reduced TT up to 1.5°F with limited effects on performance. The quadratic response of TT in the winter would possibly be due to altered or enhanced passage rate resulting from cold stress. Ingested feed residence time and

(Continued on next page)

overall digestibility are reduced under cold stress. Higher energy diets, which generally are composed of smaller particles, have the potential to exit the rumen and digestive tract much more quickly than higher fiber diets, although among diet types the higher concentrate diet generally produced greater overall metabolic heat. However, within the concentrate diet type, the MEI level for optimum metabolic heat production appears to be less than the highest MEI achievable.

In summary, results presented herein demonstrate an increase in energy level of the diet has a positive relationship with TT. However, the response depends upon season of year. Data suggest a linear response in TT for the summer and a quadratic response during the winter. In the summer, TT increases as MEI increases, while in the winter, peak TT would occur in steers consuming approximately 24 Mcal ME per day of a roughage diet and 25 Mcal ME per day of a concentrate diet.

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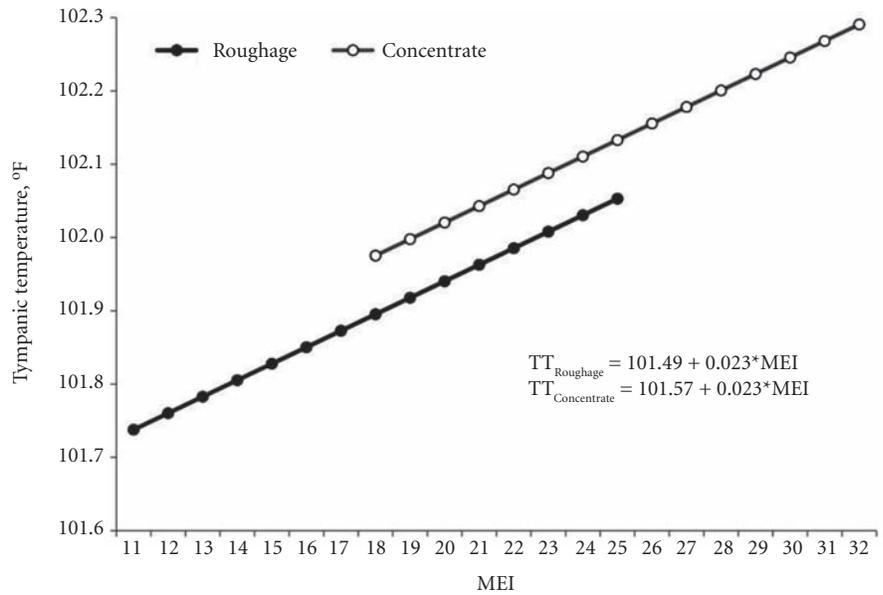


Figure 2. Predicted average daily tympanic temperature (TT) of steers during the summer.

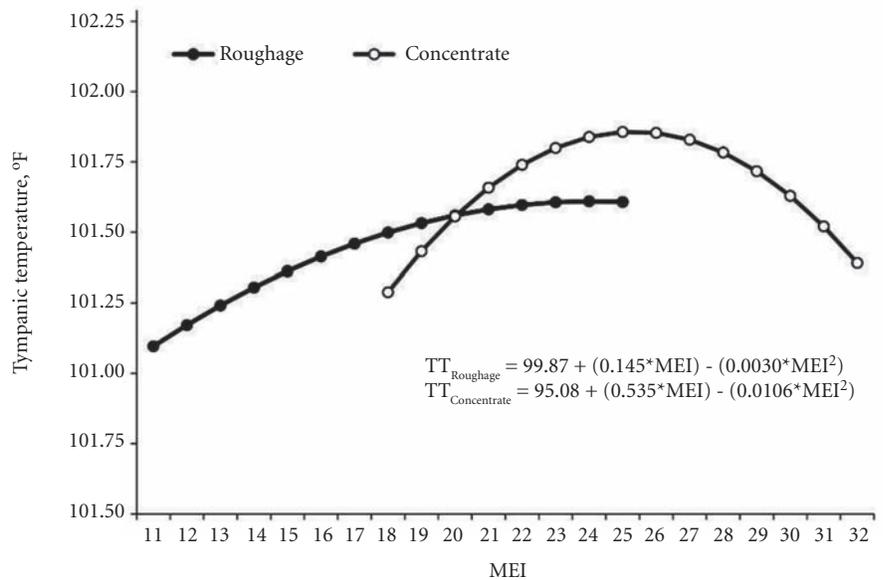


Figure 3. Predicted average daily tympanic temperature (TT) of steers during the winter.

Tympanic Temperature Profiles of Confined Beef Cattle

Terry L. Mader
Leslie J. Johnson¹

Summary

Angus crossbred yearling steers were used to evaluate tympanic temperature (TT) profile of cattle displaying high, moderate, or low levels of heat stress. Data indicate cattle that do not adequately cool down at night are prone to greater body temperatures during a subsequent hot day. Cattle that are prone to displaying moderate levels of heat stress but can cool at night will maintain average tympanic temperatures at or near those of cattle that tend to consistently maintain lower peak tympanic temperatures. In addition, during cooler and moderately hot periods, cattle change TT in a stair-step or incremental pattern, while under hot conditions, average TT of group-fed cattle moves in conjunction with ambient conditions, indicating that thermoregulatory mechanisms are at or near maximum physiological capacity.

Introduction

Previous studies (2006 *Nebraska Beef Report*, pp. 79-82) suggest that the range of daily TT may vary with the extent cattle are challenged by the heat event and that cattle may compensate (cool more at night if opportunities exist) by lowering TT to below normal TT levels after an excessive heat load event. The objectives of this study were to compare tympanic temperature profiles of feedlot steers that differ in heat stress susceptibility under varying summer environmental conditions.

Procedures

Tympanic temperature (TT) profiles from previously published research (2007 *Nebraska Beef Report*, pp. 77-79) were compared based on the magnitude of the TT displayed. Profiles were compared among animals that displayed high (> 107°F), moderate (106 to

107°F), and low (106 <°F) peak TT during the hottest day of the study, based on the temperature humidity index [THI; THI = ambient temperature - (0.55 - (0.55 * (relative humidity/100))) * (ambient temperature - 58)].

Details of the cattle utilized, management protocol, and study procedures are outlined in the 2007 *Nebraska Beef Report* (pp. 77-79). An equal number of animals were utilized in the high, moderate, and low profile groups (8 head/group). Tympanic temperatures (TT) were recorded using Stowaway XTI® data loggers and thermistors (Onset Corporation, Pocasset, Mass.). Dataloggers recorded temperatures at 1-hour intervals in 24

animals from 8 pens (3 animals/pen) during a six-day period in which a severe heat event occurred. The event included a cool day (day 41), moderately hot (MHOT B-days 42 to 43) days, and hot (HOT B-days 44 to 46) days. The hot period was defined as successive days with maximum temperatures above a threshold of 90°F.

Performance data were analyzed using the MIXED procedure of SAS (Statistical Analysis Service, Cary, N.C.). Tympanic temperatures among groups of animals displaying low, moderate, and high TT were analyzed using a repeated measures model that included TT group, day, time of day,

(Continued on next page)

Table 1. Daily tympanic temperature (TT) of cattle exhibiting high, moderate, and low TT during day 41 through day 46 of study.

	Cattle, TT, °C ¹				
	High	Moderate	Low	SE	P-value
Cool Day					
Minimum	—	—	—	—	—
Noon	102.3 ^a	101.6 ^b	101.8 ^b	0.2	0.04
Maximum (1700)	103.2 ^a	102.2 ^b	102.6 ^b	0.2	0.01
Midnight	102.6	102.2	102.1	0.2	0.25
Day -2					
Minimum (0800)	101.1	100.9	100.9	0.1	0.67
Noon	102.5 ^a	101.9 ^b	102.1 ^{ab}	0.1	0.04
Maximum (1800)	104.5 ^c	103.9 ^d	103.9 ^d	0.2	0.06
Midnight	102.4	102.0	102.2	0.1	0.15
Day -1					
Minimum (0800)	101.0	100.6	100.8	0.1	0.16
Noon	102.7 ^a	101.8 ^b	102.2 ^{ab}	0.2	0.02
Maximum (1700)	104.5 ^a	103.7 ^b	103.6 ^b	0.2	0.03
Midnight	102.3	101.9	102.2	1.7	0.21
Day 0 (start of hottest day)					
Minimum (0700)	101.6 ^a	100.9 ^b	101.2 ^b	0.1	0.02
Noon	103.8 ^a	102.7 ^b	102.9 ^b	0.1	0.01
Maximum (1800)	107.6 ^a	106.7 ^b	105.7 ^c	0.2	0.01
Midnight	103.4	102.9	103.3	0.3	0.32
Day 1					
Minimum (0700)	101.1 ^a	100.5 ^b	101.3 ^a	0.2	0.01
Noon	104.5 ^a	103.6 ^b	103.8 ^b	0.3	0.06
Maximum (1700)	106.4 ^c	105.6 ^d	105.4 ^d	0.2	0.02
Midnight	103.0 ^a	102.2 ^b	102.3 ^b	0.2	0.02
Day 2					
Minimum (0700)	101.7 ^a	100.7 ^b	101.3 ^a	0.2	0.01
Noon	105.2 ^a	103.8 ^b	104.2 ^b	0.3	0.01
Maximum (1500)	106.7 ^a	105.4 ^b	105.6 ^b	0.3	0.01
Midnight	103.0 ^a	102.2 ^b	102.8 ^{ab}	0.2	0.01

¹Classification based on peak TT observed on day 0 (7/22/2005).

^{a,b,c}Means within a day and time with unlike superscripts differ ($P < 0.05$).

^{d,e}Means within a day and time with unlike superscripts differ ($P < 0.10$).

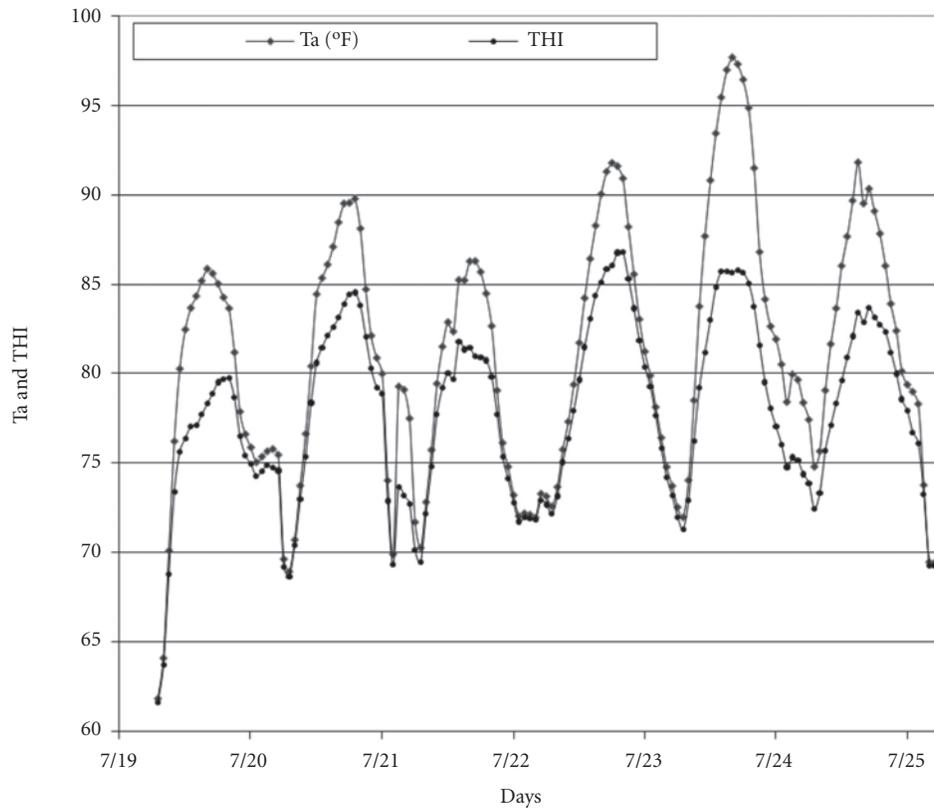


Figure 1. Ambient temperature (Ta) and temperature-humidity index (THI) for days 41 to 46 of study.

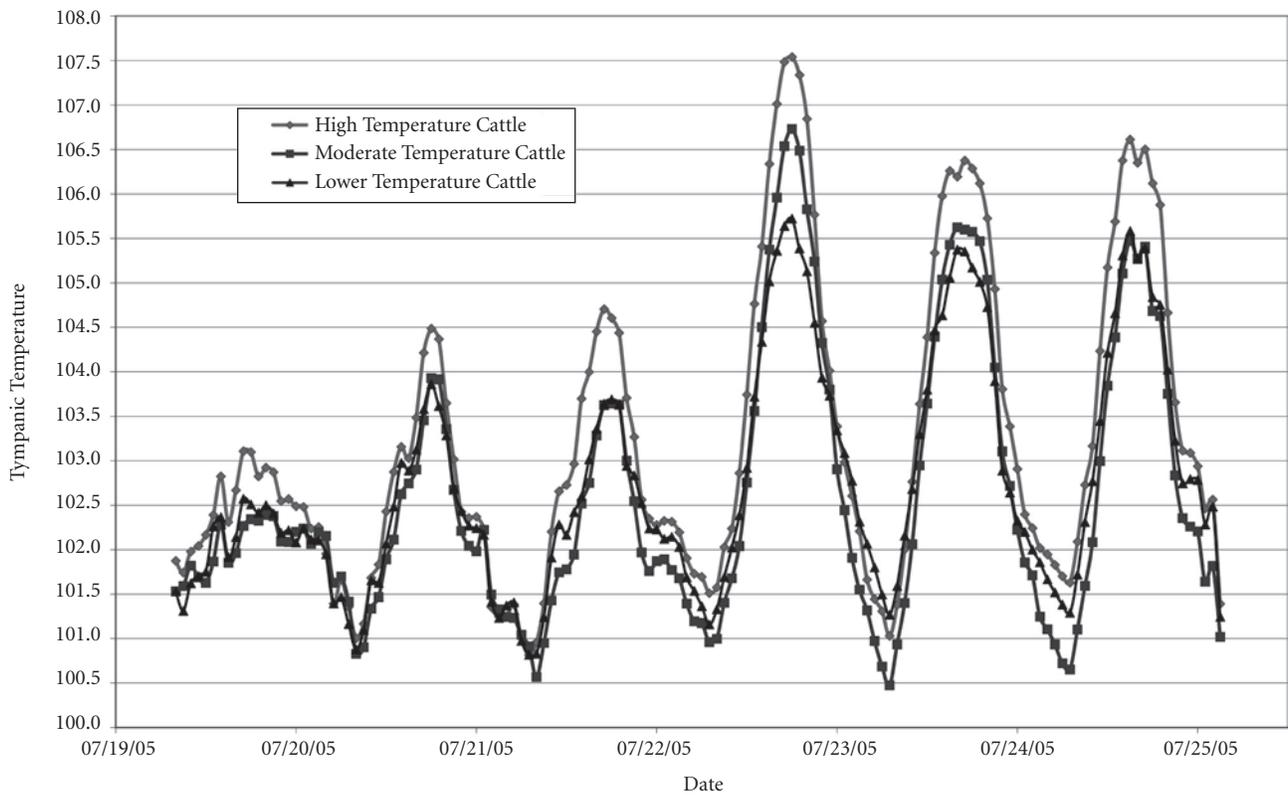


Figure 2. Diurnal tympanic temperature (TT) pattern for cattle exhibiting high (peak TT > 107°F), moderate (107°F > peak TT > 106°F), or low (peak TT < 106°F) heat stress levels on 7/22/2005.

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and all possible interactions. The specified term for the repeated statement was animal within day.

Results

A heat wave occurred during this study (Figure 1) in which the THI averaged or exceeded 84 for 3 days in a row (days 44 to 46). A THI of 84 or greater is considered to be in an emergency category, in which cattle are experiencing extreme heat stress. Cattle deaths in surrounding feedlots were documented during this period, although no cattle in this study died.

TT profiles of cattle exhibiting high, moderate, or low levels of heat stress are shown in Table 1 and Figure 2. From these data, it is evident that cattle with high TT had elevated TT even during the first day (cool day) at 1200 hr and 1700 hr. However, cattle with a moderate TT appeared to have the most elasticity in TT than either the high or low group, reaching moderately high TT during the hot days, but able to reach a lower ($P < 0.05$) TT by morning than either the high (days 0, 1, and 2) or the low (days 1 and 2) group. This could be related to feed intake and possibly performance; however, over the entire study, the ADGs of the low, moderate, and high TT groups were 3.40, 3.31, and 3.57 lb/day, respectively.

Based on TT profiles, these data suggest cattle that fail to cool down at night are prone to achieving greater body temperatures during hot days. Cattle that are prone to get hot but can cool at night can keep peak body temperatures at or near those of cattle that tend to consistently maintain lower body temperatures. Thus, cattle that have the ability and /or opportunity to dissipate body heat at night tend to have lower peak TT during the day. In the current study, TT profile of the moderate group displayed some TT compensation with lower morning TT during the three hot days than the high and low profile groups. However, the average magnitude of difference (day 0 high minus day 1 low) was similar for the high ($107.55 - 101.05 = 6.50^{\circ}\text{F}$) and moderate ($106.74 - 100.47 = 6.27^{\circ}\text{F}$) profile groups vs. the low ($105.73 - 101.26 = 4.47^{\circ}\text{F}$) TT profile group. The magnitude of TT change, as calculated from day 1 maximum minus day 2 minimum values, were 4.71, 4.95, and 4.07, respectively for the high, moderate, and low groups. In addition, during cooler and moderately hot periods, TT of cattle changes in a cyclical or stair-step (up and down) pattern. However, under hot conditions, TT moves in conjunction with ambient conditions, indicating that thermoregulatory mechanisms are

near maximum physiological capacity for preventing TT from rising. It should be noted that these data are based on the average of a group of animals, which tends to smooth the body temperature curve. Individual animals may display a more erratic TT profile pattern.

Conclusion

There may be considerable variation in heat stress tolerance among cattle. Some cattle are more susceptible to heat stress than others, but this tolerance is not necessarily performance related. Nevertheless, cattle are remarkable in their ability to mobilize coping mechanisms when challenged by environmental stressors. Under three-day heat events, such as the one found in this study, thermoregulatory processes are unable to maintain a constant TT, and TT therefore tends to mirror changes in environmental conditions as defined by ambient temperature and THI.

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Relationship of Metabolizable Protein Balance, Purine Derivative Excretion, and 3-Methyl Histidine Excretion to Feed Efficiency in Individually Fed Finishing Heifers

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Summary

Individually fed heifers were used to determine the relationship of 3-methyl histidine, purine derivatives, and metabolizable protein balance to feed efficiency. Heifers were fed finishing diets that were either deficient or sufficient in metabolizable protein. Urine samples were collected and analyzed for early, late, and entire feeding period concentrations of 3-methyl histidine, purine derivatives, and creatinine. Results from this study indicated a negative relationship between feed efficiency and metabolizable protein balance, and no relationship between 3-methyl histidine excretion and feed efficiency, suggesting that protein turnover and microbial protein synthesis are not related to feed efficiency

Introduction

In cattle production we are always looking for ways to explain differences among cattle in feed efficiency (G:F) and methods to improve G:F. Protein supply can have an impact on BW gain and feed efficiency. Metabolites excreted in urine can be used to measure protein turnover (3-methyl histidine; 3MH) and microbial protein production (purine derivatives; PD). As is the case with energy, protein use efficiency may be different among animals, especially when fed different finishing diets. This suggests that cattle may differ in protein turnover rates leading to differences in measured feed efficiency. Greater protein

turnover increases 3MH excretion in the urine or a greater 3MH-to-creatinine (Cr) ratio. Urinary Cr can be used as a marker of urine output. Therefore, by measuring urinary PD, 3MH, and Cr in spot samples of urine, microbial CP production and protein turnover can be estimated. Using spot samples of urine allows for use of a greater number of animals than metabolism studies and allows for experiments in typical production settings. In addition, the metabolizable protein balances (MPB) may help explain differences observed in G:F. Therefore, the objective of this study was to evaluate the relationship of PD, 3MH, and MPB to G:F.

Procedure

Data from an experiment (2007 *Nebraska Beef Report*, pp. 103-105) utilizing 78 individually fed heifers (912 ± 72 lb) were used to determine relationships of G:F to MPB, excretion of PD:Cr, and 3-MH:Cr excretion. Heifers were fed steam-flaked corn-based diets containing either 0 (NEG) or 1.5% (POS) urea for 95 days, resulting in CP levels of 9.6% and 13.7% for NEG and POS, respectively. Animal BW and spot urine samples were collected at 3 different times (28, 56, and 84 days) and urine was analyzed for PD, Cr, and 3MH using HPLC. Data from this experiment were analyzed by period because predicted metabolizable protein and energy requirements changed for the heifers as BW increased. Data were analyzed from 3 periods: early (day 1 to 55; urine 28 day), late (day 56 to 95; urine 84 day), and overall (day 1 to 95; urine days 28, 56, and 84).

Daily gain, DMI, and final BW adjusted to equal (28%) empty body fat were used as inputs for the 1996 NRC model to determine MPB. Data were analyzed using the PROC CORR

procedure of SAS to determine the correlations (r) of PD:Cr to G:F; MPB to G:F; 3MH to G:F; DMI to PD:Cr; DMI to MPB; and DMI:3MH. Because heifers were individually fed, animal was the experimental unit. Results are presented by treatment and significance was determined when $P < 0.05$.

Results

Animal performance for this experiment is presented in the 2007 *Nebraska Beef Report*, pp. 103-105 (Table 1). In the early period, a positive relationship was observed between PD:Cr and G:F in both the POS ($P = 0.02$) and NEG ($P < 0.01$) diets. In addition, a negative relationship between MPB and G:F was observed in both diets during the early period ($P < 0.01$). For the overall feeding period, heifers fed NEG exhibited a negative relationship between MPB and G:F ($P < 0.01$) and a positive relationship between DMI and MPB ($P < 0.01$). When heifers were fed POS, a negative relationship between MPB and G:F ($P < 0.01$) and a positive relationship between MPB and DMI ($P < 0.01$) were observed. In addition both the NEG and POS treatments exhibited positive relationships for DMI and PD:Cr. Relationships between 3MH and other measured variables were not significant for either the POS or NEG treatments.

The negative relationship between MPB and G:F is counterintuitive. This seems to indicate that the more efficient animals were more efficient in either production or utilization of metabolizable protein. Three-methyl histidine is a measure of muscle protein turnover. A lower level of 3MH (lower 3MH:Cr ratio) would indicate lower protein turnover and therefore lower metabolizable protein requirements. We found no relationship between 3MH and G:F,

suggesting muscle turnover is not the explanation for the MPB to G:F relationship.

Another possible explanation for the G:F-to-MPB relationship is protein supply. If heifers eat more, more microbial protein is expected. That was demonstrated with the relationship between DMI and PD:Cr ratio. For the overall feeding period, there was not a relationship between PD:Cr and G:F, suggesting microbial protein synthesis was not the explanation for the MPB to G:F relationship. However, because the protein requirement prediction was higher for heifers during the first part of the feeding period, we determined the relationship of PD:Cr to G:F for the early period. The relationship was positive and significant ($P = 0.02$) for both POS and NEG treatments. This is an indication that microbial protein synthesis differences among the heifers may partially explain the MPB to G:F relationship.

Results from this study indicate no relationship between 3MH excretion and G:F, suggesting that protein turnover did not explain differences in feed efficiency. In addition it was a consistent response in both diets that MPB and G:F were negatively related. The lack of response between 3MH excretion and G:F and the positive response of PD to G:F in the first period lead us to conclude differences in feed efficiency are perhaps more closely related to microbial protein and efficiency of microbial crude protein production than to protein turnover within the animal.

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Table 1. Main effects of dietary treatment on live performance and carcass characteristics¹.

Item	Treatment ²		
	SFC	UREA	P-value
DMI, lb/day	17.4	19.5	< 0.01
ADG, lb	2.44	3.52	< 0.01
F:G	7.13	5.54	< 0.01
Carcass weight, lb	720	772	< 0.01
Dressing %	62.4	63.1	0.15
Marbling ³	501	512	0.03
Longissimus area, in ²	14.0	14.0	0.54
12th rib fat depth, in	0.38	0.45	< 0.01

¹Data presented are from 2007 Nebraska Beef Report, pp. 103-105.

²SFC = 85% SFC, 9.6% CP; UREA = 85% SFC + 1.5% urea, 13.7% CP.

³Marbling score called by USDA grader where 500 = small⁰⁰ and 550 = small⁵⁰.

Table 2. Relationship of excreted metabolites and feeding performance measures¹.

Item	POS ²	NEG ³	P-value ⁴	
			POS	NEG
Early Period ⁵				
PD:Cr and G:F	0.38	0.54	0.02	< 0.01
MPB and G:F	- 0.77	- 0.81	< 0.01	< 0.01
3MH and G:F	- 0.27	- 0.16	0.10	0.32
DMI and PD:Cr	0.27	0.35	0.10	0.03
DMI and MPB	0.47	0.08	< 0.01	0.61
DMI and 3MH	0.10	0.01	0.53	0.94
Overall ⁶				
PD:Cr and G:F	- 0.05	- 0.11	0.78	0.54
MPB and G:F	- 0.79	- 0.65	< 0.01	< 0.01
3MH and G:F	- 0.08	0.14	0.63	0.37
DMI and PD:Cr	0.31	0.32	0.05	0.06
DMI and MPB	0.51	0.56	< 0.01	< 0.01
DMI and 3MH	0.00	0.05	1.00	0.77

¹PD = purine derivative; Cr = creatinine; MPB = metabolizable protein balance; 3MH = 3-methyl histidine; RFI = residual feed intake.

²POS = 85% SFC + 1.5% urea, 13.7% CP.

³NEG = 85% SFC, 9.6% CP.

⁴P-value is represented for each variable within treatment.

⁵Early period = days 1 through 55 on feed.

⁶Overall period = days 1 through 95 on feed.

Fatty Acid Profile of Beef from Steers Fed Wet Distillers Grains Plus Solubles (WDGS) and Vitamin E

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Summary

The aim of this work was to investigate the fatty acid profile of *m. teres major* (TER) and *m. infraspinatus* (INF) from steers fed 0 or 40% WDGS (DM basis) with or without 500 I.U. of vitamin E/steer daily for 100 days. Thirty-two steers were allocated to 4 treatments: Corn; Corn + vit. E; 40% WDGS; or 40% WDGS + vit. E. After 7 days of aging, 2 TER and 2 INF muscles were excised from the shoulder clods of each animal. Fatty acids were analyzed from raw TER and INF, pan fried TER and INF, and grilled INF. For all muscles, higher levels of polyunsaturated and 18:1 trans fatty acids and lower values of 18:1(n-7) were observed in beef from animals fed WDGS ($P < 0.05$). Vitamin E supplementation did not affect the fatty acid profile of either muscle. Feeding WDGS increased polyunsaturated fatty acids and decreased 18:1 (n-7), which may lead to oxidation and off flavors, respectively.

Introduction

Feeding wet distillers grains plus solubles (WDGS) is often practiced during beef cattle finishing in a period that may vary from 100 to 160 days. Although research demonstrated a linear increase in average daily gain, feed conversion, hot carcass weight, and marbling score when steers were fed up to 40% WDGS (2008 Nebraska Beef Report, pp. 107-109), feeding 30% WDGS increased polyunsaturated fatty acids (PUFA) in the ribeye (*m. longissimus thoracis*) (2009 Nebraska Beef Report, pp. 107-109). Higher levels of PUFA contribute to higher oxida-

tion, lower shelf life, and off flavor development. Our research was conducted to verify the effects of feeding WDGS and vitamin E supplementation on fatty acid profile of *m. teres major* (TER) and *m. infraspinatus* (INF).

Procedure

Yearling steers (n = 32) were allocated to four dietary treatments (Corn, Corn + vit. E, 40% WDGS, or 40% WDGS + vit. E) and fed for 100 days. Vitamin E dose was 500 I.U./steer daily. After 7 days of aging, TER and INF muscles were excised from shoulder clods, trimmed of subcutaneous fat and epimysial connective tissue, and frozen until cooking and fatty acid analysis could be made. Muscles were pan fried (TER and INF) and grilled (INF) until internal temperature reached 160°F. For fatty acid analysis, raw and cooked samples were submerged in liquid N, pulverized and stored at -112°F. Compounds were analyzed by gas chromatography and separated using a capillary column. Oven temperature was programmed from 284 to 428°F at 35.5°F/min and held at 428°F for 20 min. Injector and detector temperatures were

maintained at 518 and 572°F, respectively. The carrier gas was Helium at a flow rate of 30 mL/min. Fatty acids were identified by comparison of retention times with known standards.

Fatty acid profile was arranged on a 4x3 factorial design for INF (4 dietary treatments and 3 cooking procedures: raw, pan fried, and grilled) and on a 4x2 factorial for TER (2 cooking procedures: raw and pan fried). Data were analyzed using the GLIMMIX procedure of SAS (Version 9.1, Cary, N.C., 2002). When significance ($P \leq 0.05$) was indicated by ANOVA, means separations were performed using the LSMEANS and DIFF functions of SAS.

Results

No interactions of treatment and cooking method and main effect of vitamin E supplementation were observed either for TER or INF ($P > 0.05$). Therefore, muscles were analyzed for treatment differences between raw and within each cooking procedure.

For raw TER samples, feeding WDGS increased levels of 18:0, 18:1 trans, 18:1Δ13, 18:1Δ14, 18:2(n-6), 18:3(n-3), PUFA, ω 6, and ω 3 fatty acids (Table 1), whereas no differences were observed in values of 18:1 trans,

Table 1. Weight percentage of fatty acids¹ of raw *m. teres major* from steers fed WDGS and Vitamin E.

Fatty acid	Treatments				P-value	Contrast
	Corn	Corn + vit E	40% WDGS	40% WDGS + vit E		Corn vs WDGS
17:1(n-7)	1.34 ^a	1.36 ^a	0.87 ^b	1.00 ^b	0.0005	< 0.0001
18:0	12.39 ^b	12.91 ^b	14.65 ^a	13.71 ^{ab}	0.01	0.004
18:1 trans	2.35 ^b	2.18 ^b	3.95 ^a	3.79 ^a	< 0.0001	< 0.0001
18:1(n-9)	39.87 ^a	40.00 ^a	36.83 ^b	36.40 ^b	0.0005	< 0.0001
18:1 (n-7)	0.70 ^{ab}	0.81 ^a	0.50 ^c	0.59 ^{bc}	0.01	0.002
18:1Δ13	0.06 ^b	0.12 ^b	0.23 ^a	0.14 ^b	0.004	0.005
18:1Δ14	0.08 ^c	0.12 ^{bc}	0.19 ^a	0.17 ^{ab}	0.002	0.0006
19:0	0.02	0.00	0.05	0.00	0.09	0.27
18:2(n-6)	3.85 ^b	3.48 ^b	5.88 ^a	5.62 ^a	< 0.0001	< 0.0001
18:3(n-3)	0.16 ^a	0.12 ^b	0.19 ^a	0.19 ^a	0.004	0.0009
PUFA	5.97 ^b	5.49 ^b	7.87 ^a	7.72 ^a	0.0008	< 0.0001
ω 6	5.80 ^b	5.37 ^b	7.68 ^a	7.53 ^a	0.0009	< 0.0001
ω 3	0.16 ^a	0.12 ^b	0.19 ^a	0.19 ^a	0.004	0.0009
ω 6 / ω 3	36.00	37.00	40.38	40.39	0.32	0.09

¹Weight percentage values are relative proportions of all peaks observed by gas chromatography. ^{a,b,c}Means in the same row having different superscripts are significant at $P \leq 0.05$ level.

18:2(n-6), 18:3(n-3), PUFA, ω 6, and ω 3 for INF (Table 2). For both muscles, lower levels of 17:1(n-7) and 18:1(n-7) were observed when steers were fed WDGS.

The PUFA are more easily oxidized by factors such as reactive oxygen species and other free radicals. High levels of PUFA in beef are associated with higher values of oxidation and compromised beef color. In addition, oxidation of lipids produces ketones and aldehydes which may affect beef flavor. Higher levels of 18:1 trans fatty acids and 18:0 in raw lean samples may be a response of WDGS composition, which has higher lipid content and greater fat digestibility when compared with corn (2006 Nebraska Beef Report, pp. 51-53). Conversely, feeding WDGS decreased 17:1(n-7) in both raw muscles and 18:1(n-7) in raw TER. A numeric decrease of 18:1(n-7) in INF was observed and values approached significance ($P = 0.06$).

When cooked (TER pan fried and INF pan fried and grilled), samples from animals fed WDGS showed higher 18:1 trans values and increased PUFA compared to samples from steers fed corn (Table 3). In contrast, values of 18:1(n-7) did not differ between cooked muscles from steers fed WDGS and corn.

Higher levels of PUFA in cooked beef may also develop a rancid/oxidized flavor, commonly called warmed-over flavor, when meat is re-heated. Additionally, research showed a negative correlation of off flavor intensity and 18:1(n-7) (2007, *Journal of Animal Science*, 85:3072-3078). Therefore, lower values of this fatty acid in raw muscle from animals fed WDGS may represent a risk to off flavor development.

Grilled INF had higher values of 20:3(n-6), 20:4(n-6), 22:4(n-6), and 22:5(n-3) when compared with raw

Table 2. Weight percentage of fatty acids¹ of raw *m. infraspinatus* from steers fed WDGS and Vitamin E.

Fatty acid	Treatments (% WDGS (DM basis), Vitamin E)				P - value	Contrast
	Corn	Corn + vit E	40% WDGS	40% WDGS + vit E		Corn vs WDGS
17:1(n-7)	1.38 ^a	1.39 ^a	1.00 ^b	0.96 ^b	0.0004	< 0.0001
18:0	13.60	13.44	14.75	14.10	0.31	0.10
18:1 trans	2.27 ^b	2.19 ^b	3.41 ^{ab}	3.68 ^a	0.05	0.01
18:1(n-9)	40.07	41.30	38.83	38.50	0.13	0.03
18:1 (n-7)	0.86 ^{ab}	0.94 ^a	0.66 ^c	0.73 ^{bc}	0.03	0.06
18:1 Δ 13	0.19	0.21	0.23	0.21	0.64	0.30
18:1 Δ 14	0.17	0.18	0.22	0.20	0.15	0.06
19:0	0.07	0.11	0.14	0.14	0.06	0.02
18:2(n-6)	2.68 ^b	2.41 ^b	4.56 ^a	4.77 ^a	< 0.0001	< 0.0001
18:3(n-3)	0.15 ^b	0.14 ^b	0.19 ^a	0.21 ^a	< 0.0001	< 0.0001
PUFA	3.83 ^b	3.55 ^b	5.82 ^a	6.24 ^a	< 0.0001	< 0.0001
ω 6	3.41 ^b	3.68 ^b	5.63 ^a	6.03 ^a	< 0.0001	< 0.0001
ω 3	0.15 ^b	0.14 ^b	0.19 ^a	0.21 ^a	< 0.0001	< 0.0001
ω 6 / ω 3	24.86	24.78	30.11	29.64	0.17	0.03

¹Weight percentage values are relative proportions of all peaks observed by gas chromatography.

^{a,b,c}Means in the same row having different superscripts are significant at $P \leq 0.05$ level

Table 3. Weight percentage of fatty acids¹ of cooked *m. teres major* (TER) and *m. infraspinatus* (INF) from steers fed wet distillers grains plus solubles WDGS and Vitamin E.

Muscle	Treatments				P - value	Contrast
	Corn	Corn + vit E	40% WDGS	40% WDGS + vit E		Corn vs WDGS
Pan fried TER						
18:1 trans	2.06 ^b	2.30 ^b	4.17 ^a	4.23 ^a	< 0.0001	< 0.0001
18:1(n-7)	0.73	0.85	0.59	0.57	0.06	0.01
PUFA	7.06 ^b	6.27 ^b	8.57 ^a	8.84 ^a	0.002	0.0004
Pan fried INF						
18:1 trans	2.16 ^b	1.95 ^b	3.84 ^a	3.91 ^a	< 0.0001	< 0.0001
18:1(n-7)	0.78	0.96	0.71	0.61	0.07	0.03
PUFA	4.56 ^b	4.05 ^b	6.09 ^a	6.19 ^a	0.0004	< 0.0001
Grilled INF						
18:1 trans	2.16 ^b	1.98 ^b	3.72 ^a	3.27 ^a	0.01	0.001
18:1(n-7)	0.86	0.97	0.81	0.74	0.37	0.14
PUFA	4.73 ^b	4.77 ^b	6.58 ^a	6.78 ^a	0.002	0.0002

¹Weight percentage values are relative proportions of all peaks observed by gas chromatography.

^{a,b}Means in the same row having different superscripts are significant at $P \leq 0.05$ level.

samples. Similar results were observed in pan fried TER, except for 20:3(n-6). However, no major effects of cooking were observed in other fatty acids.

Feeding WDGS modifies the fatty acid profile of *m. teres major* and *m. infraspinatus*, and vitamin E supplementation does not mitigate these changes.

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Effects of Feeding Wet Distillers Grains Plus Solubles and Vitamin E on Beef Tenderness and Color Under Different Packaging Systems

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Summary

The effects of feeding wet distillers grains plus solubles (WDGS), vitamin E supplementation (E), and modified atmosphere packaging (MAP) on Warner Bratzler shear force (WBSF) and sensorial tenderness were investigated in *m. longissimus lumborum* aged 7 or 21 days. Steers (n = 90) were allocated to dietary treatments consisting of corn or 35% WDGS with 0, 100, 300, 500, and 1000 I.U. of E per head daily. After aging, muscles were displayed for 5 days under O₂ permeable film, high O₂ and low O₂ atmospheres. Feeding 1000E extended color stability of permeable film-packaged steaks during retail display. Feeding WDGS led to higher discoloration in steaks packaged under high O₂ when compared to other treatments. High O₂ packaging led to lower tenderness when compared to other packaging methods (P < 0.05), and vitamin E supplementation provided color stability to steaks from animals fed WDGS.

Introduction

Previous research showed feeding wet distillers grains plus solubles (WDGS) led to higher lipid oxidation and decreased color stability in beef due to an increase in polyunsaturated fatty acids (PUFA) (2009 Nebraska Beef Report, pp. 107-109). These fatty acids are more easily oxidized compared to mono and saturated lipids. When vitamin E is supplemented in diets, it is deposited at the cellular membrane and offers protection to PUFA against pro-oxidant factors.

Therefore, detrimental oxidation caused by feeding WDGS may be mitigated by adding 500 I.U. of vitamin E daily during the same feeding period (2009 Nebraska Beef Report, pp. 113-115; 2009 Nebraska Beef Report, pp. 115-117). However, we hypothesize that the same pro-oxidant factors might also affect proteins, which could lower tenderness due to oxidation of calpain and protein crosslinking.

Procedure

Yearling steers (n = 90) were randomized to six dietary treatments (Corn, WDGS, WDGS +100E, WDGS+300E, WDGS+500E, WDGS+1000E) where level of WDGS was 35% (DM basis) and vitamin E was 100, 300, 500, or 1000 I.U. per head daily beyond the basal diet. The basal diet for corn contained 189.8 I.U. of vitamin E per head daily, whereas the basal diet for WDGS contained 211.4 I.U. Dietary treatments lasted 128 days. *M. longissimus lumborum* (LD) were excised from both short loins of each carcass and aged for 7 or 21 days. After aging, four 1-inch thick steaks were cut from each strip loin. Steaks were vacuum packaged and frozen following 5 days of retail display in O₂-permeable film, low O₂ or High O₂ modified atmosphere packages (MAP). Four display cases were set at 32 - 36°F, and light

intensity varied from 60 to 200 Lux. For WBSF and sensorial tenderness analysis, steaks were grilled to 95°F, then flipped and grilled until they reached 158°F at the geometric center. A nine-member panel was screened, selected, and trained to evaluate tenderness on an eight-point hedonic scale (from 1 = extremely tough to 8 = extremely tender). For WBSF, after cooking, steaks were cooled for 1 hour at 39°F and cores were removed with a drill press parallel to muscle fiber orientation. From each steak, 6 cores (0.5 inch in diameter) were sheared on an Instron Universal Testing Machine with a Warner-Bratzler blade. The crosshead speed was 250 mm/min with a 500 kg load cell. The tenderness differential (Δ) between 0 and 5 days of retail display was calculated by subtracting day 5 values (WBSF and sensorial tenderness) from day 0 values. Thus, a negative value indicates a loss of tenderness during retail display. Discoloration was assessed by a four-member panel that scored visual discoloration from 0% red (not discolored) to 100% brown (completely discolored) every day during four days of display. Data were analyzed as a split-split plot design where the whole plot was diet, the split plot was aging, and the split-split plot was MAP. Animal (both muscles) within diet was considered the whole plot error term, aging by diet the split plot error term, and MAP by aging by diet the split-

Table 1. Tenderness of steaks displayed under different packaging systems.

Trait ¹	Packaging System			Standard Error
	High O ₂ MAP	Low O ₂ MAP	O ₂ -Permeable	
WBSF, kg	3.63 ^b	3.39 ^a	3.37 ^a	0.03
Δ WBSF, kg	-0.19 ^b	0.04 ^a	0.05 ^a	0.05
Tenderness rating	5.87 ^b	6.16 ^a	6.16 ^a	0.04
Δ tenderness rating	-0.13 ^b	0.17 ^a	0.08 ^a	0.04

¹WBSF = Warner-Bratzler shear force; tenderness rated on an 8-point hedonic scale where 1 = extremely tough and 8 = extremely tender.

^{a,b}Means in the same row with different superscripts are significantly different (P < 0.05).

Table 2. Dietary effects on tenderness characteristics of beef strip steaks.

Trait ¹	Treatment means							P-value for Contrasts				
	Corn	WDGS					Standard Error	Linear	Quadratic	Corn vs WDGS (no E)	Corn vs WDGS (with E)	WDGS (no E) vs WDGS (with E)
		0 E	100 E	300 E	500 E	1000 E						
WBSF, kg	3.59	3.51	3.28	3.60	3.46	3.33	0.08	0.24	0.04	0.54	0.02	0.19
Δ WBSF, kg 7 days aged	0.18	-0.13	0.37	0.07	-0.03	0.29	0.11	0.29	0.30	0.06	0.99	0.02
Δ WBSF, kg 21 days aged	-0.29	-0.15	-0.24	-0.11	-0.22	-0.18	0.11	0.29	0.93	0.33	0.30	0.80
Tenderness rating	5.93	5.95	6.17	6.23	5.98	6.00	0.04	0.03	0.02	0.83	0.01	0.04

¹WBSF = Warner-Bratzler shear force; Delta = shear force differential during retail display (d 5-d 0); tenderness rated on 8-point hedonic scale where 1 = extremely tender and 8 = extremely tough.

split plot error term. Data were analyzed using the GLIMMIX procedure of SAS (Version 9.1, Cary, N.C., 2002). When significance ($P \leq 0.05$) was indicated by ANOVA, means separations were performed using the LSMEANS and DIFF functions of SAS.

Results

Results of WBSF and taste panel (TP) tenderness are shown in Tables 1 and 2. High O₂ MAP resulted in greater shear force values and lower TP tenderness ratings compared to the other two packaging systems, likely due to protein oxidation. In addition, display under high O₂ MAP conditions caused a significant decrease in tenderness, measured by shear force or taste panel tenderness ratings, during the display period. This implies that the decrease in tenderness occurred as a result of oxidation of myofibrillar or cytoskeletal proteins rather than through oxidation of the calpains, as the tenderness decrease was observed even after 21 days post mortem, when most of the proteolytic activity from calpains would have been complete.

Vitamin E provided a small, but significant protective effect against oxidation-induced toughening in beef from cattle fed WDGS and E, which had lower shear force values and higher sensorial tenderness ratings compared to corn-fed beef with no supplemental E.

The beneficial effects of E were evident when comparing beef from cattle fed WDGS without supplemental E to cattle fed WDGS with E – those without the supplemental E became tougher during retail display after 7

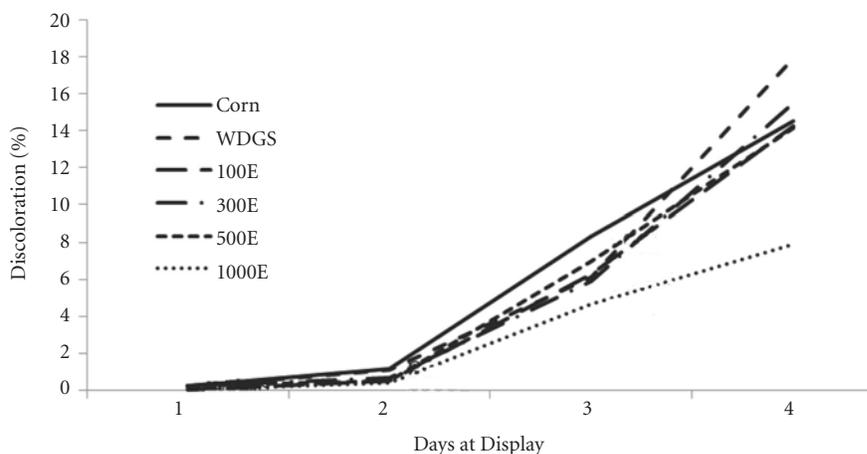


Figure 1. Discoloration of steaks aged 21 days and packaged with O₂-permeable film.

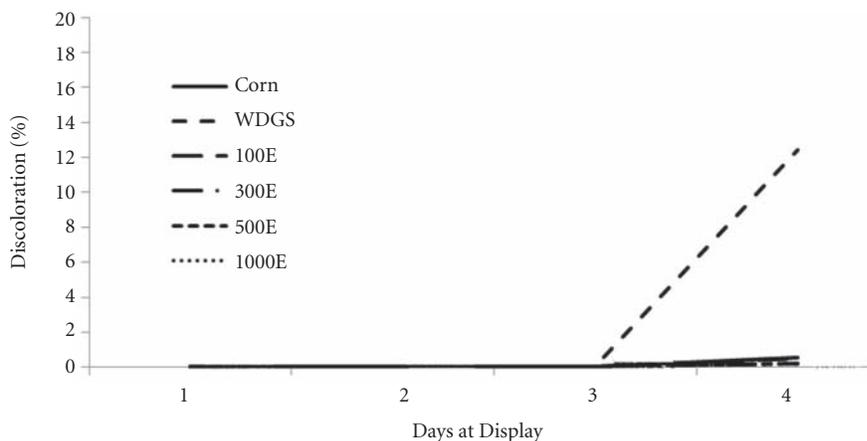


Figure 2. Discoloration of steaks aged 21 days and packaged under high O₂ atmosphere.

days of aging. After 21 days of aging, however, there were no differences among treatments, suggesting that aging reduced the capacity of the meat to resist oxidation, regardless of the amount of supplemental dietary E. The tenderness response to supplemental dietary vitamin E was quadratic in nature, with the lowest shear force values and among the highest

sensorial tenderness ratings for cattle fed WDGS + 100 E. The curvilinear nature of these relationships is difficult to explain.

Regarding color, significant effects were observed when the strips were aged for 21 days (Figures 1 and 2). Long aging periods occur when beef is exported to other countries, and these

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periods usually take more than 21 days, when reduction in color stability may cause lower shelf-life. Low O₂ atmosphere led to 100% discoloration in the first day of display. In O₂-permeable film at the end of the display period, 1000 I.U. of vitamin E resulted in improved color stability when compared to other treatments. When High O₂ was used for packaging, steaks from animals fed WDGS had higher discoloration compared to those fed only corn at the conclusion of retail display period. However, any level of vitamin E supplementation mitigated detrimental effects on color when steaks were packaged with high O₂.

Red color of beef is due to the presence of oxymyoglobin; this pigment is formed by O₂ and myoglobin. In MAP with high levels of O₂, oxymyoglobin is more stable due to the high partial pressure of this gas inside the pack. This can explain less discoloration in steaks packaged under high O₂, where oxymyoglobin cannot be reduced

to metmyoglobin. Metmyoglobin is responsible for brown color and discoloration. In this experiment, we observed that high O₂ packaged steaks had overall less discoloration and less tenderness compared to steaks packaged with low O₂ and O₂-permeable film. However, despite improved color stability due to oxymyoglobin stability, high O₂ atmosphere led to lower tenderness. This statement agrees with the findings of Lund et al. (2007 *Meat Science* 77:295-303) who showed that high O₂ atmosphere tended to increase toughness in meat due to protein oxidation. When vitamin E is supplemented, it is deposited in the cell membrane, protecting lipids from oxidation. In this experiment, up to 1000 I.U. of E per head daily was needed to provide better color stability to steaks packaged with permeable film.

Conclusion

We conclude that storing beef in high O₂ MAP caused a reduction in

tenderness. Feeding supplemental dietary vitamin E provided a small, but significant protective effect against this oxidation-induced toughening, even in meat from animals fed WDGS. However, extended aging minimized the beneficial effects of E. The reduction in tenderness caused by protein oxidation appeared to be independent of calpain oxidation. This work demonstrated that the combination of high O₂ MAP and vitamin E supplementation improves the case life of beef from animals fed WDGS but decreases tenderness.

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²This project was funded in part by the Beef Checkoff.

Wet Distillers Grains Diets Supplemented with Vitamin E Affect Sensory Attributes of Beef *m. longissimus lumborum*

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Summary

The effects of feeding 0% or 40% wet distillers grains plus distillers solubles (WDGS) with or without vitamin E (E) supplementation on sensory attributes (tenderness, juiciness, connective tissue content, and off-flavor intensity) of 7-day and 28-day aged beef strip steaks during retail display were investigated by a trained panel. Feeding WDGS or E did not influence tenderness, juiciness, or connective tissue ratings. However, feeding WDGS significantly increased the off-flavor intensity of 7-day aged beef following retail display. Feeding WDGS increased the incidence of livery off-flavor. The protective ability of vitamin E supplementation against livery flavor production was significant in beef aged 28 days. Therefore, feeding WDGS increased livery and off-flavor intensities and vitamin E supplementation helped to reduce livery flavor when steaks were aged for 28 days.

Introduction

Feeding wet distillers grain plus solubles (WDGS) increases levels of polyunsaturated fatty acids (PUFA) in beef (de Mello et al., 2008 *Nebraska Beef Report*, pp. 108-109; Senaratne et al., 2009 *Nebraska Beef Report*, pp. 110-112). Increased PUFA in beef can have detrimental effects on sensory attributes of beef, such as discoloration and off-flavor production during retail display. Bright redness of beef is the indicator of freshness to consumers. Also, due to elevated levels of PUFA in beef, lipid and myoglobin are rapidly oxidized and subsequently deteriorate beef color and flavor profile.

Dietary vitamin E supplementation to cattle prior to slaughter is an

effective strategy to control color and lipid oxidation of beef during retail display. Parallel studies with this meat also proved that dietary vitamin E supplementation mitigates increased lipid oxidation and color deterioration during retail display of aged beef due to WDG and distillers soluble feeding (Senaratne et al., 2009 *Nebraska Beef Report*, pp. 113-115 and 116-117). The purpose of this study was to evaluate effects of vitamin E supplementation on sensory attributes of short- and long-term aged beef during retail display from cattle fed WDGS diets.

Procedure

Thirty-six strip loins (*m. longissimus lumborum*; IMPS # 1180A; NAMP, 2007) used for this study were from a subset of strip loins (both USDA Choice and Select grades) from the study described by Senaratne et al. (2009 *Nebraska Beef Report*, pp. 110-112). Strip loins from animals fed 0 and 40% WDGS with or without vitamin E diets were selected. Two 1-inch thick steaks were removed from each strip loin after 7 and 28 days of aging at 32 to 36°F. The first steak was immediately vacuum-packaged and stored at -4°F to use as the 0 day retail displayed sample. The second steak was overwrapped with an oxygen permeable polyvinyl chloride film and placed on a table in a cooler at 0 to 36°F under continuous 1000 to 1800 lux warm white fluorescent lighting to provide simulated retail display conditions. After 7 days of retail display, steaks were removed from simulated retail display conditions, vacuum-packaged, and stored at -4°F until they were used as the 7 day retail displayed samples for the taste evaluation.

Steaks from 0- and 7-day retail display were thawed for 24 hours at 39°F. Thawed steaks were grilled on a Hamilton Beach indoor-outdoor grill, turning over once at 95°F, until

they reached an internal temperature of 160°F. Internal temperature was monitored using an OMEGA thermometer with a type T thermocouple. Cooked steaks were kept warm in a countertop warmer prior to cubing not more than 15 minutes before serving. Steaks were cubed into 0.5 × 0.5 × 1 in pieces using a plexiglass sample sizer. During taste panel sessions, panelists were allocated to individual ventilated booths lighted with red fluorescent lights to remove visual differences among steak pieces. At each taste panel session, panelists evaluated 8 samples (2 from each dietary treatment) served in random order. Each sample was evaluated based on 8-point hedonic scales for tenderness; juiciness (8 = extremely desirable; 7 = very desirable; 6 = moderately desirable; 5 = slightly desirable; 4 = slightly undesirable; 3 = moderately undesirable; 2 = very undesirable; 1 = extremely undesirable); connective tissue (8 = none; 7 = trace amount; 6 = slight amount; 5 = small amount; 4 = modest amount; 3 = moderate amount; 2 = slightly abundant; 1 = abundant amount); and off-flavor intensity (8 = extremely intense; 7 = very intense; 6 = moderately intense; 5 = slightly intense; 4 = slightly mild; 3 = moderately mild; 2 = very mild; 1 = extremely mild). Panelists evaluated the presence or absence of off-flavors (metallic, sour, oxidized, livery, bitter, and charred) in each sample.

Taste panel data were analyzed using analysis of variance (ANOVA) in the GLIMMIX procedure of SAS as a 2 × 2 factorial design (2 levels of vitamin E: with and without and 2 levels of WDGS: 0% and 40%) for 2 aging periods and retail display days separately. Least square means were calculated using LSMEANS of SAS and mean separation was conducted using DIFF and LINES of SAS at the

(Continued on next page)

Table 1. Least square means of taste panel rating of 7- and 28-day aged strip loin (*m. longissimus lumborum*) from cattle fed different dietary regimes after 0 and 7 days of retail display.

	Retail display (d)	Supplemented with E		Non-supplemented with E		SEM	P-values		
		0 WDGS	40 WDGS	0 WDGS	40 WDGS		E	WDGS	E × WDGS
7-day aged									
Tenderness	0	5.90	5.59	5.66	5.68	0.15	0.59	0.31	0.27
	7	5.87	6.04	6.31	5.97	0.14	0.21	0.52	0.10
Connective tissue	0	5.32	5.16	5.14	5.23	0.15	0.72	0.79	0.40
	7	5.46	5.62	5.68	5.48	0.15	0.76	0.85	0.23
Juiciness	0	5.19	5.10	5.09	4.88	0.12	0.17	0.20	0.58
	7	4.98	5.14	5.32	5.15	0.12	0.16	0.96	0.18
Off-flavors	0	2.17	2.41	2.33	2.35	0.07	0.48	0.05	0.16
	7	2.37	2.36	2.36	2.55	0.08	0.26	0.26	0.22
28-day aged									
Tenderness	0	6.37	6.23	6.42	6.47	0.12	0.22	0.68	0.40
	7	6.56	6.22	6.20	6.36	0.12	0.35	0.45	0.06
Connective tissue	0	5.86	5.83	5.99	5.72	0.13	0.90	0.27	0.37
	7	6.09	5.69	5.85	5.84	0.12	0.69	0.12	0.12
Juiciness	0	5.18	5.21	5.53	5.25	0.11	0.11	0.28	0.22
	7	5.27	5.16	5.21	5.18	0.11	0.86	0.56	0.67
Off-flavors	0	2.66	2.61	2.55	2.51	0.10	0.32	0.66	0.99
	7	2.73	2.98	2.98	3.10	0.12	0.12	0.14	0.55

WDGS = wet distillers grains plus distillers soluble; 0 and 40% on DM basis.
E = vitamin E.

significance levels of $P \leq 0.05$.

Results

Neither vitamin E supplementation, WDGS nor their combination significantly affected tenderness, connective tissue content, and juiciness ratings of 7- and 28- day aged steaks after 0 and 7 days of retail display (Table 1). There were no significant differences in off-flavor ratings, except for samples from cattle fed 40% WDGS without vitamin E following 7 days of retail display. These trends, though significant ($P = 0.12$ to 0.26), followed the results for frequency of livery flavor, in which samples from cattle fed WDGS had the highest numerical frequency of livery off-flavor scores following retail display, which was significant after 7 days of aging (Figure 1a; $P < 0.05$), and fol-

lowed the same trend after 28 days of aging (Figure 1b; $P = 0.03$). A parallel study with this meat documented that WDG feeding increases level of polyunsaturated fatty acids (PUFA) (2009 *Nebraska Beef Report*, pp. 110-112). Furthermore, mineral analysis of this meat described by Senaratne et al. (2010 *Nebraska Beef Report*, pp. 104-106) showed that inclusion of distillers solubles in the diet increased the level of Fe, which can act as a transitional metal ion in inducing lipid oxidation. Therefore, increased levels of PUFA and Fe may cause production of off-flavor compounds in beef from animals fed WDGS diets, compared to corn diets. In addition, Senaratne et al. (2009 *Nebraska Beef Report*, pp. 113-115 and 116-117) showed that vitamin E supplementation to cattle significantly reduced lipid oxidation and discoloration of beef. There were

no significant effects of vitamin E supplementation, WDGS, or their interaction on frequency scores of metallic, sour, oxidized, bitter, and charred off-flavors in strip steaks of both aging and retail display groups by the panelists (data not shown).

These data suggest that feeding WDGS may compromise the flavor stability of beef, especially following a period of retail display, and that feeding vitamin E provides some protective effect against these changes. The beneficial effect of E appears strongest when beef is aged 28 days.

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²This project was funded in part by the Beef Checkoff and the Nebraska Beef Council.

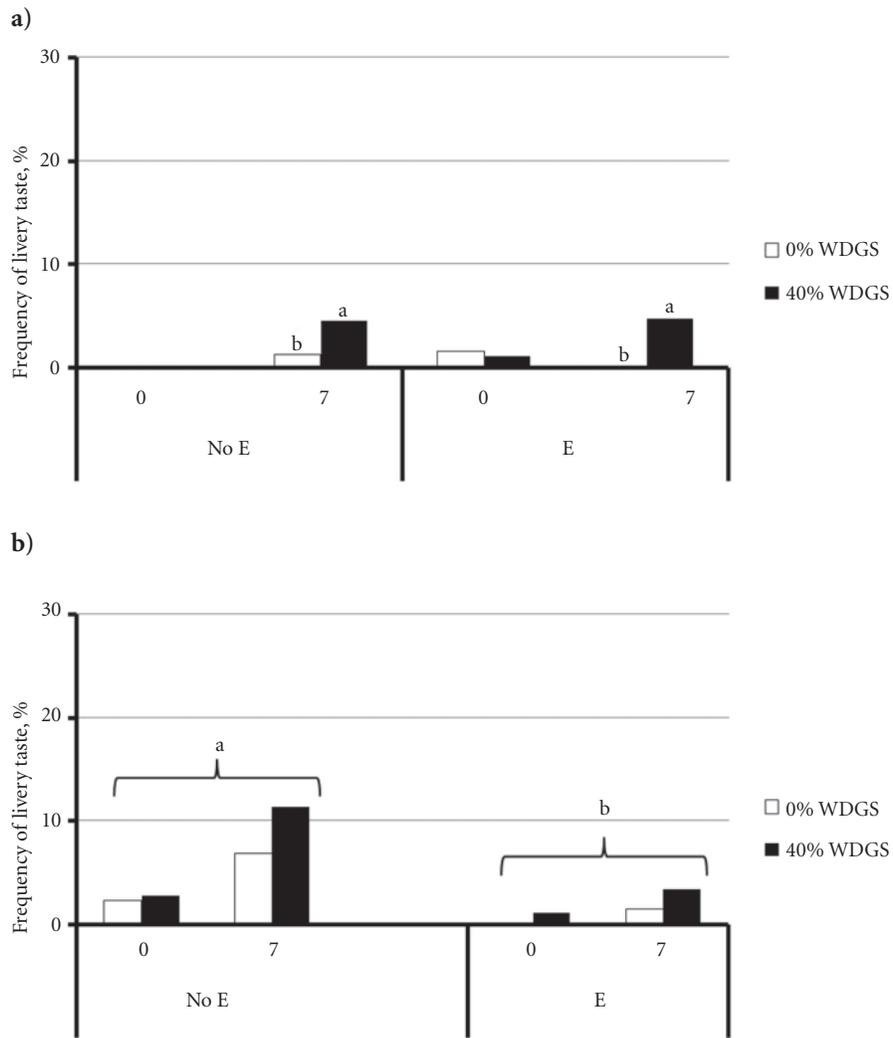


Figure 1. Frequency of livery flavor identified by panelists of a) 7-day aged and b) 28-day aged strip loin (*m. longissimus lumborum*) steaks from animals fed diets containing 0%, 40% WDGS with or without E supplementation during simulated retail display conditions.
^{a,b}Means in the same graph with different superscripts significantly differ ($P \leq 0.05$).

Wet Distillers Grains Diets Supplemented with Vitamin E Alter the Mineral Composition of Beef *m. longissimus lumborum* and *m. psoas major*

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Summary

Crossbred yearlings ($n = 90$) were allotted to one of 10 diets containing 0, 20 or 40% wet distillers grains (WDG) with or without vitamin E supplementation and distillers solubles (DS). Strip loin and tenderloin steaks were obtained and tested for their mineral (Ca, P, K, Mg, Zn, Fe, Mn, Cu, S, and Na) compositions using atomic absorption spectroscopy. Cattle fed DS diets had higher ($P \leq 0.05$) levels of Ca, Fe, P, Mn, and S in strip loins than cattle fed non-DS diets. Feeding DS significantly reduced Mg and Na in tenderloins. Neither WDG nor vitamin E diets significantly affected the mineral composition of strip loins and tenderloins. In conclusion, feeding DS altered the mineral composition of strip loins. Changes in the mineral composition of beef are a consequence of dietary inclusion of DS, not WDG or vitamin E.

Introduction

Calkins and Hodgen (2007 *Meat Science*, 77:63-80) mentioned that changes in mineral composition of beef due to different diets may cause off flavors in beef. Yancey et al. (2006 *Meat Science*, 73: 680-686) also reported that Fe played a key role in liver-like off-flavors in beef. Moreover, Lawrie (*Meat Science* 6th edition, Woodhead Publishing Ltd, Cambridge, England) mentioned that sulfur-containing compounds were also responsible for off flavors in meat. Jenschke et al. (2007 *Journal of Muscle Foods*, 18:341-348) showed that high levels of Na also caused off

flavors in cooked beef. Therefore, it is important to consider how the mineral profile of beef changes with cattle diets.

Dry-milling ethanol production utilizes only the starch portion of the corn distillers grains. All the other nutrients (protein, fat, fiber, minerals, and vitamins) are concentrated about three-fold. The mineral portion of the grain is concentrated in the distillers byproducts in the ethanol production process. Previous studies have shown that feeding wet distillers grains plus distillers solubles (WDG plus DS) increases the level of polyunsaturated fatty acids (PUFA) in the beef and subsequently reduces beef lipid and color stability during retail display (2009 *Nebraska Beef Report*, pp. 110-112; 2008 *Nebraska Beef Report*, pp. 108-109). Senaratne et al. (2009 *Nebraska Beef Report*, pp. 113-115 and 116-117) showed that vitamin E (E; α -tocopherol) supplementation suppressed the elevated lipid and pigment oxidation of beef due to WDG \pm DS feeding.

However, it is unknown how feeding WDG, DS, and vitamin E affect the mineral composition of beef. Therefore, the aim of the current study was to determine the effect of feeding vitamin E with different levels of WDG, with or without DS, on mineral composition of beef strip loin (*m. longissimus lumborum*) and tenderloin (*m. psoas major*).

Procedure

Ninety crossbred steers (out of 336 total) were randomly selected for one of six diets containing 0, 20, or 40% WDG (DM basis) with or without E supplementation (500 I.U. of α -tocopherol acetate/steer daily) beyond the basal diet. Vitamin E was fed for the last 100 days. Distillers

solubles also were added to 20 and 40% WDG diets with or without E at a ratio of WDG to DS of 100:0 and 70:30 to create four additional diets. Diets containing DS were named as high soluble [H] diets whereas diets containing no DS were named as low soluble [L] diets. Composition of these diets was presented by Godsey et al. (2009 *Nebraska Beef Report*, pp. 59-61.) Steers were fed for a total of 140 days and slaughtered at Greater Omaha Packing Co. (Omaha, Neb.). After grading, short loins from 90 carcasses (10 from each treatment – 5 USDA Choice and 5 USDA Select) were vacuum-packed, transported under refrigeration to Loeffel Meat Laboratory at the University of Nebraska–Lincoln and aged for 7 days at 32 to 36°F. After fabrication, strip loins (*m. longissimus lumborum*) and tenderloins (*m. psoas major*) were sliced into 1-inch thick steaks. Steaks of each sample were immediately vacuum-packaged and stored at -4°F. Each steak was diced, pulverized after dipping in liquid nitrogen, stored at -112°F and tested for mineral (Ca, P, K, Mg, Zn, Fe, Mn, Cu, S, and Na) composition using atomic adsorption spectroscopy at a commercial laboratory (Ward Laboratories, Inc., Kearney, Neb.). The Ca, P, K, Mg, S, and Na were expressed as percentages, and Zn, Fe, Mn, and Cu were expressed as ppm on a dry matter basis.

An analysis of variance (ANOVA) using the GLIMMIX procedure of SAS (version 9.1, Cary, N.C., 2002) was used to analyze the data as two factorial designs. Analysis I dealt with data from all low DS diets containing 0, 20, or 40% WDG with or without E supplementation and analyzed them as a 2 \times 3 factorial design (three levels of WDG – 0, 20, and 40%, and two levels of E supplementation – with or without). Analysis I was performed

Table 1a. Least square means of mineral composition of strip loins (*m. longissimus lumborum*) from cattle fed different dietary regimes.

	Supplemented with E					Non-supplemented with E					SEM
	0	20 L	20 H	40 L	40 H	0	20 L	20 H	40 L	40 H	
Ca ¹	0.011	0.016	0.019	0.015	0.018	0.019	0.011	0.020	0.015	0.020	0.001
P ¹	0.195	0.192	0.203	0.199	0.206	0.204	0.198	0.205	0.195	0.208	0.003
K ¹	0.338	0.332	0.333	0.348	0.340	0.324	0.348	0.329	0.338	0.349	0.007
Mg ¹	0.023	0.021	0.021	0.023	0.021	0.022	0.024	0.021	0.024	0.025	0.001
Zn ²	34.70	36.32	35.53	35.14	36.41	35.29	34.24	34.60	33.44	35.43	1.25
Fe ²	14.13	14.33	18.00	15.00	18.60	17.50	16.10	17.13	16.40	17.75	0.85
Mn ²	1.625	2.111	2.000	1.250	2.900	2.700	1.000	2.875	1.200	2.625	0.60
Cu ²	0.738	0.811	1.374	0.738	0.620	0.830	0.840	1.288	0.640	0.600	0.25
S ¹	0.168	0.200	0.204	0.185	0.191	0.186	0.158	0.205	0.171	0.211	0.01
Na ¹	0.049	0.050	0.051	0.051	0.051	0.051	0.051	0.050	0.051	0.051	0.001

¹% on dry matter basis.

²ppm on dry matter basis.

WDG = wet distillers grains 0, 20, and 40% on DM basis.

Distillers soluble (DS) levels: L = 100:0 of WDG:DG, H = 70:30 of WDG:DS on DM basis.

E = vitamin E.

Table 1b. P-values of mineral levels of strip loins (*m. longissimus lumborum*) from analysis I and II.

	Analysis I ¹			Analysis II ²						
	E	WDG	E × WDG	E	WDG	DS	E × WDG	E × DS	DS × WDG	E × DS × WDG
Ca	0.37	0.36	0.0004	0.70	0.50	<.0001	0.15	0.05	0.25	0.33
P	0.19	0.43	0.16	0.59	0.37	0.0002	0.32	0.91	0.87	0.34
K	0.69	0.26	0.11	0.58	0.10	0.43	0.53	0.91	0.26	0.05
Mg	0.30	0.80	0.54	0.04	0.22	0.43	0.55	0.95	0.58	0.20
Zn	0.29	0.70	0.49	0.10	0.93	0.42	0.92	0.59	0.29	0.90
Fe	0.0019	0.75	0.45	0.53	0.34	<.0001	0.88	0.04	0.91	0.87
Mn	0.94	0.16	0.09	0.74	0.99	0.01	0.96	0.30	0.44	0.19
Cu	0.95	0.69	0.84	0.86	0.04	0.31	0.91	0.99	0.16	0.84
S	0.26	0.99	0.09	0.33	0.80	0.01	0.19	0.04	0.89	0.82
Na	0.31	0.59	0.59	0.97	0.46	0.97	0.97	0.62	0.97	0.42

¹Analysis of treatments containing low levels of DS with 0, 20, or 40% WDG with or without E.

²Analysis of treatments containing low and high levels of DS with 20 or 40% WDG with or without E.

in order to find the effect of feeding WDG, vitamin E supplementation or their combinations on each parameter in the absence of DS in the diet. In analysis II, diets containing 20 or 40% WDG with low or high levels of DS and with or without E were analyzed as a 2 × 2 × 2 factorial design (2 levels of WGD, 20 and 40%; two levels of E, with or without; and two levels of DS, low or high). Analysis II was carried out to find the effects of feeding WDG, DS, E or their combinations on each parameter. Least square means were calculated using LSMEANS of SAS. The P-values of E, WDG, DS, and their interactions were separately tabulated to determine their effect on each parameter analyzed. Significant effects were tested at P < 0.05. Mean separation was performed using DIFF and LINES options of SAS at P < 0.05.

Results

Mineral composition (Ca, P, K, Mg, Zn, Fe, Mn, Cu, S, and Na) of strip loins obtained from animals fed different dietary treatments are shown in Table 1a. There were no significant effects of feeding WDG or E on mineral levels of strip loins, except that vitamin E-supplemented diets in analysis I resulted in less Fe in strips than non-E supplemented diets among diets without DS (Table 1b). In analysis II, Ca, P, Fe, Mn, and S levels significantly increased in strip loins from animals fed DS compared to cattle fed no DS diets. Although there was a significant interaction effect of E and DS on Fe and S levels in strip loins, diets containing DS always showed higher levels of Fe and S than diets without DS (Table 1a). Feeding DS increased

Fe levels in strip loin steaks by 3-4 ppm when E was added to the diet; without supplemented E, the increase was about 1 ppm. Results of this study also showed that feeding DS increased S and Fe levels in strip loins; therefore, DS may cause off-flavor production in beef (Senaratne et al., 2010 *Nebraska Beef Report*, pp. 101-103).

Mineral levels and P-values of tenderloins are shown in Tables 2a and 2b, respectively. Similar effect of E, WDG, and DS as shown in strip loins were not observed in tenderloins. Tenderloins from cattle fed diets without DS supplemented with E contained lower levels of P and Mg than tenderloins from cattle fed non-E supplemented diets (P < 0.05). Neither WDG nor E significantly affected Ca, K, Zn, Fe, Mn, Cu, S, and Na levels

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Table 2a. Least square means of mineral composition of tenderloins (*m. psoas major*) from cattle fed different dietary regimes.

	Supplemented with E					Non-supplemented with E					SEM
	0	20 L	20 H	40 L	40 H	0	20 L	20 H	40 L	40 H	
Ca ¹	0.020	0.020	0.019	0.019	0.017	0.016	0.017	0.018	0.019	0.014	0.002
P ¹	0.205	0.203	0.201	0.210	0.206	0.198	0.204	0.200	0.199	0.199	0.003
K ¹	0.339	0.333	0.326	0.343	0.338	0.329	0.338	0.329	0.331	0.334	0.004
Mg ¹	0.030	0.029	0.025	0.030	0.024	0.026	0.029	0.024	0.028	0.026	0.001
Zn ²	32.29	34.09	35.66	34.29	35.46	35.56	34.41	34.91	33.26	34.30	1.08
Fe ²	20.88	20.56	21.13	21.63	20.50	21.10	19.90	21.13	21.00	21.75	0.66
Mn ²	1.625	0.667	1.500	1.125	1.900	1.700	1.800	0.500	0.700	0.625	0.47
Cu ²	3.163	1.656	1.225	1.488	1.180	1.510	2.020	1.225	1.770	1.550	0.54
S ¹	0.208	0.234	0.229	0.224	0.240	0.222	0.223	0.215	0.219	0.223	0.01
Na ¹	0.050	0.050	0.048	0.050	0.047	0.047	0.050	0.049	0.050	0.048	0.001

¹% on dry matter basis.

²ppm on dry matter basis.

WDG = wet distillers grains 0, 20, and 40% on DM basis.

Distillers soluble (DS) levels: L = 100:0 of WDG:DG, H = 70:30 of WDG:DS on DM basis.

E = vitamin E.

Table 2b. P-values of mineral levels of tenderloins (*m. psoas major*) from analysis I and II.

	Analysis I ¹			Analysis II ²						E × DS ×WDG
	E	WDG	E × WDG	E	WDG	DS	E × WDG	E × DS	DS × WDG	
Ca	0.10	0.87	0.42	0.09	0.26	0.07	0.77	0.68	0.14	0.22
P	0.04	0.65	0.21	0.02	0.50	0.18	0.02	0.81	0.81	0.46
K	0.13	0.81	0.14	0.46	0.11	0.13	0.05	0.66	0.22	0.42
Mg	0.04	0.62	0.20	0.83	0.69	0.0001	0.74	0.48	0.74	0.17
Zn	0.30	0.89	0.10	0.44	0.60	0.20	0.60	0.72	0.97	0.78
Fe	0.51	0.23	0.75	0.99	0.24	0.44	0.48	0.17	0.24	0.51
Mn	0.46	0.23	0.19	0.22	0.93	0.85	0.15	0.02	0.36	0.31
Cu	0.49	0.48	0.17	0.42	0.91	0.17	0.82	0.83	0.58	0.72
S	0.95	0.41	0.44	0.18	0.91	0.86	0.93	0.67	0.34	0.77
Na	0.21	0.21	0.21	0.61	0.61	0.01	0.83	0.61	0.61	0.83

¹Analysis of treatments containing low levels of DS with 0, 20, or 40% WDG with or without E.

²Analysis of treatments containing low and high levels of DS with 20 or 40% WDG with or without E.

in tenderloins from animals fed non-DS diets. Feeding DS significantly reduced the concentration of Mg and Na in tenderloins compared to feeding non-DS diets, regardless of feeding WDG or E together. Feeding DS diets had less dramatic effect on mineral contents of tenderloins than on mineral contents of strip loins.

Intuitively, differences among muscles could be expected for mineral

contents as influenced by diet, likely caused by vascularity, muscle function, and fiber type composition. However, the biological reason is unclear for differences in mineral content observed here.

As a whole, the presence or absence of vitamin E or WDG had few effects on mineral composition of both strip loins and tenderloins. Feeding DS significantly increased the Ca, Fe, P,

Mn, and S contents of strip loins over non-DS diets.

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Sensory Attributes of Beef from Steers Fed Field Peas

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Summary

Field peas were fed at inclusion rates of 0, 10, 20 and 30% (DM basis) to 139 yearling steers (initial BW = 900 ± 68 lb). Choice grade strip loins and carcass data were collected from the Tyson Fresh Meats Plant in Lexington, Neb. Consumer sensory ratings and Warner-Bratzler shear force data were collected. Feeding field peas caused a cubic response in overall like ($P = 0.009$), tenderness ($P = 0.006$), and flavor desirability ratings ($P = 0.06$), with the highest (most desirable) ratings occurring with 30% field peas. Shear force decreased linearly ($P = 0.02$) as field peas increased in the diet. These data indicate field peas increased tenderness and sensory attributes. Peas also improved the flavor of the beef. Field peas could be fed to cattle and give positive attributes to the quality of the meat up to 30% inclusion in the diet.

Introduction

Field pea (*Pisum sativum*) production is increasing rapidly in the Northern High Plains, increasing interest for use in feeder cattle diets. Limited data are available on the effects on meat quality of finishing cattle with field peas. Data from North Dakota State University suggest that increasing levels of field peas in finishing diets may decrease Warner-Bratzler shear force and increase tenderness and juiciness of beef. The objective of this study was to evaluate the effects of the inclusion of different levels of field peas in feedlot finishing diets on performance, carcass characteristic, tenderness, and taste panel ratings.

Table 1. Composition of finishing diets containing different levels of field peas.

	Treatment ¹			
	0	10	20	30
<i>Ingredients</i>				
Corn silage, %	10.00	10.00	10.00	10.00
Dry rolled corn, %	83.82	73.82	63.82	53.82
Field peas, %	0.00	10.00	20.00	30.00
Supplement, %	6.18	6.18	6.18	6.18
<i>Formulated composition</i>				
Dry matter, %	69.00	71.00	73.00	71.00
CP, %	12.20	13.84	15.48	17.12
Ca, %	0.66	0.68	0.69	0.70
P, %	0.30	0.31	0.32	0.34

¹Treatments 0, 10, 20, and 30 = 0, 10, 20, and 30% field peas in the finishing diets (DM basis).

Procedure

Field peas were fed to 139 yearling steers (British cross; initial BW = 900 ± 68 lb) with inclusion rates of 0, 10, 20 and 30% (DM basis) at the University of Nebraska Panhandle Research and Extension Center. Cattle were stratified by BW and assigned to one of sixteen pens (8 to 9 steers per pen). Dietary treatments are presented in Table 1. On day 1, which occurred after a 21-day adaptation period, steers received a single implant of TE-S with Tylan (VetLife, West Des Moines, Iowa). Cattle were fed for 119 days.

Cattle were slaughtered at the Tyson Fresh Meats plant in Lexington, Neb. The carcass data from this trial were collected by Cattlemen's Carcass Data Service (West Texas A&M University, Canyon, Tex.). Hot carcass weight measurements were taken on the day of slaughter. Carcass 12th rib back fat thickness, percentage of kidney, heart, and pelvic fat (KPH), marbling score, LM area, and USDA yield grade were recorded following a 48-hour carcass chill. Animal performance and carcass data were analyzed using the MIXED procedures of SAS (SAS Inst. Inc., Cary, N.C.) as a randomized complete block design with pen as the experimental unit. Orthogonal contrasts included the evaluation of linear, quadratic, and cubic effects of increasing levels of field peas.

Ninety-eight Choice grade short loins were collected. The short loins were cut into 1-inch steaks after 17 days of aging and then packaged and frozen. Steaks were shipped to the University of Florida for consumer sensory evaluation of flavor, juiciness and tenderness. Steaks were cooked on a Hamilton-Beach table top grill to 160°F and served to 32 panelists per session. The remaining steaks were cooked and sheared at University of Nebraska-Lincoln. Steaks were thoroughly thawed for 24 hours prior to being cooked to an internal temperature of 160°F on a Hamilton Beach indoor-outdoor grill, turning over once at 95°F, until they reached an internal temperature of 160°F. Internal temperature was monitored using an OMEGA thermometer (Model 450A, OMEGA Engineering Inc., Stamford, Conn.) with a type T thermocouple and chilled overnight in the cooler. The steaks were allowed to cool overnight prior to coring and shearing. Shearing was performed on an Instron universal testing machine using a Warner-Bratzler shear force attachment. Shear force data were analyzed as a completely randomized design, with animal as the experimental unit. ANOVA and means separation were performed by PROC GLIMMIX, LSMEANS and DIFF functions of SAS.

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Results and Discussion

Performance data are presented in Table 2. No differences ($P > 0.10$) were observed for final BW, ADG, and DMI of steers. Carcass data are presented in Table 3. No differences ($P > 0.10$) were observed for carcass characteristics, except for a cubic ($P = 0.05$) effect on calculated yield grade. No differences were observed on the distribution of percentage of cattle grading USDA Choice ($P > 0.10$; Table 4).

Shear force decreased linearly ($P = 0.02$) as field peas increased in the diet (Table 5), with the lowest shear force value occurring at the highest level of peas. Similarly, feeding field peas caused a cubic response in consumer panelists ratings for overall like ($P = 0.009$), tenderness ($P = 0.006$), and flavor desirability ($P = 0.06$); in all cases the highest (most desirable) ratings were observed with field peas at the 30% inclusion level. These data indicate field peas increased tenderness and sensory attributes. Field peas could be fed to cattle and give positive attributes to the quality of the meat up to 30% inclusion in the diet.

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Table 2. Effects of different levels of field pea grains on performance of beef steers.

Item	Treatment ¹				SE ³	P - value ²		
	0	10	20	30		L	Q	C
Initial BW, lb	905	894	896	906	32	0.07	0.46	0.87
Final BW, lb	1445	1467	1447	1457	34	0.67	0.45	0.32
ADG, lb	4.53	4.81	4.63	4.64	0.13	0.37	0.54	0.29
DMI, lb/d	27.11	27.53	26.89	26.49	0.71	0.17	0.84	0.98
F:G	6.00	5.73	5.81	5.73	0.19	0.99	0.66	0.28

¹Treatments 0, 10, 20, and 30 = 0, 10, 20, and 30% field peas in the finishing diets (DM basis).

²Observed significance levels for orthogonal contrasts: L= linear effects of increasing levels of field peas; Q = quadratic effects of increasing levels of field peas; and C = cubic effects of increasing levels of field peas.

³Standard error of treatment means, n = 4 pens/ treatment.

Table 3. Effects of different levels of field pea grains on carcass characteristics of beef steers.

Item	Treatment ¹				SE ³	Contrast P - value ²		
	0	10	20	30		L	Q	C
HCW, lb	882	904	888	912	23.9	0.68	0.27	0.13
Marbling ⁴	487.2	467.2	464.2	479.3	13	0.46	0.52	0.82
Fat thickness, in	0.52	0.59	0.60	0.62	0.039	0.69	0.86	0.25
LM area, sq. in.	12.98	12.62	12.90	12.98	0.33	0.23	0.69	0.50
Yield grade	3.41	3.86	3.67	3.84	0.14	0.92	0.31	0.05

¹Treatments 0, 10, 20, and 30 = 0, 10, 20, and 30% field peas in the finishing diets (DM basis).

²Observed significance levels for orthogonal contrasts: L= linear effects of increasing levels of field peas; Q = quadratic effects of increasing levels of field peas; and C = cubic effects of increasing levels of field peas.

³Standard error of treatment means, n = 4 pens/ treatment.

⁴Marbling score: 300 = Slight0; 400 = Small0; 500 = Modest0.

Table 4. Effects of different levels of field pea grains on distribution of percentage of cattle grading USDA Choice.

Item	Treatment ¹				SE ³	P - value ²		
	0	10	20	30		L	Q	C
Pr. ³ USDA choice	33.33	27.75	14.23	32.63	0.68	0.12	0.36	0.36
USDA choice	47.23	58.35	74.68	58.70	0.97	0.17	0.76	0.76
USDA select	19.43	13.88	11.10	8.68	0.52	0.92	0.50	0.50

¹Treatments 0, 10, 20, and 30 = 0, 10, 20, and 30% field peas in the finishing diets (DM basis).

²Observed significance levels for orthogonal contrasts: L= linear effects of increasing levels of field peas; Q = quadratic effects of increasing levels of field peas; and C = cubic effects of increasing levels of field peas.

³Pr. = Premium; upper 2/3 choice grade

Table 5. Sensorial attributes and WBSF of muscle *Longissimus dorsi* from steers fed peas¹.

Item	Treatments ²				SE ⁴	P-Value	P - value ³		
	0	10	20	30			L	Q	C
Overall like	6.32	6.47	6.34	6.66	0.10	0.04	0.02	0.01	0.009
Tenderness	5.99	6.26	6.09	6.45	0.14	0.07	0.002	0.06	0.006
WB shear force, kg	3.95	3.87	3.65	3.61	0.12	0.14	0.02	0.86	0.58
Juiciness	5.73	5.78	5.72	6.02	0.14	0.30	0.67	0.64	0.50
Flavor	6.39	6.45	6.36	6.63	0.09	0.04	0.23	0.12	0.06

¹Overall like (1 - dislike extremely, 9 - like extremely), Tenderness (1 - extremely tough, 9 - extremely tender), Juiciness (1 - extremely dry, 9 - extremely juicy), and Flavor (1 - dislike extremely, 9 - like extremely).

²Treatments 0, 10, 20, and 30 = 0, 10, 20, and 30% field peas in the finishing diets (DM basis).

³Observed significance levels for orthogonal contrasts: L= linear effects of increasing levels of field peas; Q = quadratic effects of increasing levels of field peas; and C = cubic effects of increasing levels of field peas.

⁴Standard error of the treatment means.

Intramuscular Tenderness Mapping and Muscle Fiber Directions of Small Muscles in the Beef Round

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Summary

The intramuscular tenderness variation of *m. pectineus* (PT), *m. sartorius* (SR), *m. gracilis* (GL), *m. vastus intermedius* (VI), and *m. vastus medialis* (VM) was investigated. The PT, SR, VI, and VM muscles ($n=10$ each) were grilled as whole muscles, whereas the GL was grilled after cutting into anterior and posterior regions. Grilled muscles were cut into equal size sections perpendicular to the long axis from proximal to distal. Cores were prepared from each section and Warner-Bratzler shear force (WBSF) was measured. The overall mean WBSF values for PT, SR, VI, GL, and VM were 8.29, 9.79, 10.54, 10.47, and 9.35 lb, respectively. The muscle fiber orientations of PT and VI were bipennate, GL and VM were unipennate, and SR was fusiform. Based on the WBSF ratings and muscle fiber orientation, all of these small muscles are relatively tender (especially the PT), and they could be merchandized as single-muscle steaks or medallions.

Introduction

About one-fifth (about 22%) of the weight of a beef carcass is represented by the round. Most large muscles of a beef carcass are located in the round, and they are known to be the least tender muscles of the carcass. However, in the last few decades, the wholesale price of beef round has been significantly increasing. Characterization of muscles in the beef round is necessary to evaluate value-added strategies. While tenderness differences among major muscles of the beef round and chuck and their intramuscular tenderness variations have

been well documented, there is little, if any, information on tenderness variation of small muscles in the beef round. In addition, the knowledge of muscle fiber orientation is important during meat fabrication so that muscles can be cut into steaks or pieces across the grain to improve tenderness. Therefore, this research was conducted to investigate the intramuscular tenderness variation and muscle fiber orientation of small muscles in the beef round, including *m. pectineus* (PT), *m. sartorius* (SR), *m. gracilis* (GL), *m. vastus intermedius* (VI), and *m. vastus medialis* (VM).

Procedure

Ten each of the PT, ST, GL, VI, and VM were purchased as USDA Choice boxed beef subprimals, aged for about 14 days from boxed date, and frozen after being vacuum-packaged. The PT, ST, and GL were fabricated from beef inside round cap (IMPS #168; NAMP, 2007) and VI and VM were obtained from beef round, knuckle peeled (IMPS #167A; NAMP, 2007). During fabrication, the anterior and distal domains of each muscle were appropriately tracked.

Whole muscles were thawed at 39°F for 24 hours. Anterior or distal domains of each muscle were tracked. The PT, SR, VI, and VM were grilled on a Hamilton Beach indoor-outdoor grill (Model 31605A, Proctor-Silex Inc., Washington, N.C.), turning over once at 95°F, until they reached an internal temperature of 160°F. Prior to grilling, the GL was cut into anterior and posterior sides to have portions of equal thickness. Internal temperature was monitored using a type T thermocouple inserted into the geometric center of each muscle. Grilled muscles were cooled at 39°F for 24 hours, then allowed to reach room temperature. The PT, SR, and VM were cut into proximal and distal zones and each distal and proximal end was cut into

inch-thick portions perpendicular to the long axis of the muscle. Each anterior and posterior side of the GL was divided into proximal and distal zones. Medial and lateral sides of VI were divided into sections from proximal to distal. From each section of PT, SR, VM, GL, and VI muscles, cores with 0.5 in diameter were removed parallel to the muscle fiber arrangement using a drill press. Cores were sheared on an Instron universal testing machine (Model 55R1123, Canton, Mass.) with a Warner-Bratzler shear attachment. An average of the peak Warner-Bratzler shear force (WBSF) for each muscle piece was calculated. Before making cores from each piece of muscle, the visible muscle fiber angle at the cutting surface was measured using a protractor from the proximal to the distal end of each muscle in order to illustrate the muscle fiber orientation.

Warner-Bratzler shear force values were analyzed by using the GLIMMIX procedure of SAS (version 9.1) with a model including zone (proximal to distal) of PT, ST, and VT muscles. The zonal difference (proximal vs. distal) of each muscle was analyzed using CONTRAST statements. For GL and VI muscles, zone (distal to proximal), side (anterior and posterior), and their interactions were included in the model. The zonal difference (proximal vs. distal) and side difference (anterior vs. posterior or medial vs. lateral) of GL and VI muscles were analyzed using CONTRAST statements of SAS. Least square means were calculated for each section using the LSMEANS of SAS. Mean separation was performed by the DIFF and LINES options of SAS at $P < 0.05$.

Results

The mean WBSF values of PT, SR, GL, VI, and VM were 8.29, 9.79, 10.54, 10.47, and 9.35 lb, respectively. The

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WBSF values for tenderness levels were investigated and reported as follows: “tender” = < 8.49 lb, “intermediate” = 8.49 to 10.78 lb, and “tough” = > 10.78 lb (Von Seggern et al., 2005 *Meat Science*, 71: 39-51). According to this classification, PT was “tender,” and SR, GL, VI and VM were “intermediate.”

There were no significant tenderness variations among sections of the PT (Figure 1a). However, the distal end of the PT muscle was significantly tougher ($P = 0.05$) than the proximal end (Table 1). The distal end of the PT is narrow and attaches to the femur. Lawrie (*Meat Science 6th edition*, Woodhead Publishing Ltd, Cambridge, England) mentioned that muscle fibers taper at the end and continue with non-contractile connective tissues in order to attach to the bones; therefore, muscles are tough at the distal end. The muscle fibers were attached to the connective tissue located at middle of the proximal end of the muscle producing a bipennate muscle fiber orientation. The muscle fiber angle changed at 110° to 50° from proximal to the distal end (Figure 1b). Based on its tenderness and muscle fiber orientation, PT should be grilled as a whole muscle and cut into medallions along the muscle or cut into medallions prior to grilling.

The tenderness of the SR significantly ($P = 0.01$) varied along the muscle (Figure 2a). As shown in Table 1, the proximal end was tougher than the distal end of ST muscle ($P = 0.04$). This is more likely due to tapering of the muscle at the proximal end. The muscle fibers of SR run parallel to the long axis of the muscle producing a fusiform muscle fiber orientation (Figure 2b). The SR could be grilled as a whole muscle and cut into medallions or cut into medallions prior to grilling.

As shown in Table 1, the tenderness of the proximal and distal ends of the VM were similar ($P = 0.12$). However, the most distal region of the

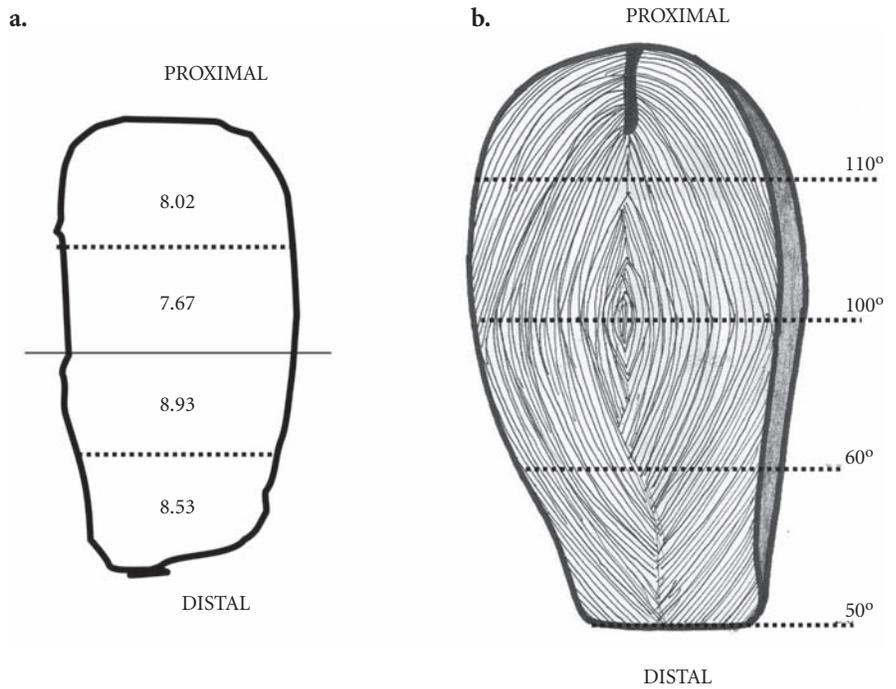


Figure 1. a. Least square mean Warner-Bratzler shear force values (lb) of each domain of *m. pectineus* ($P = 0.13$). b. Muscle fiber orientation of *m. pectineus* on the longitudinal cross section of the muscle. ^{a,b}Means in the same figure with different superscripts significantly differ ($P < 0.05$).

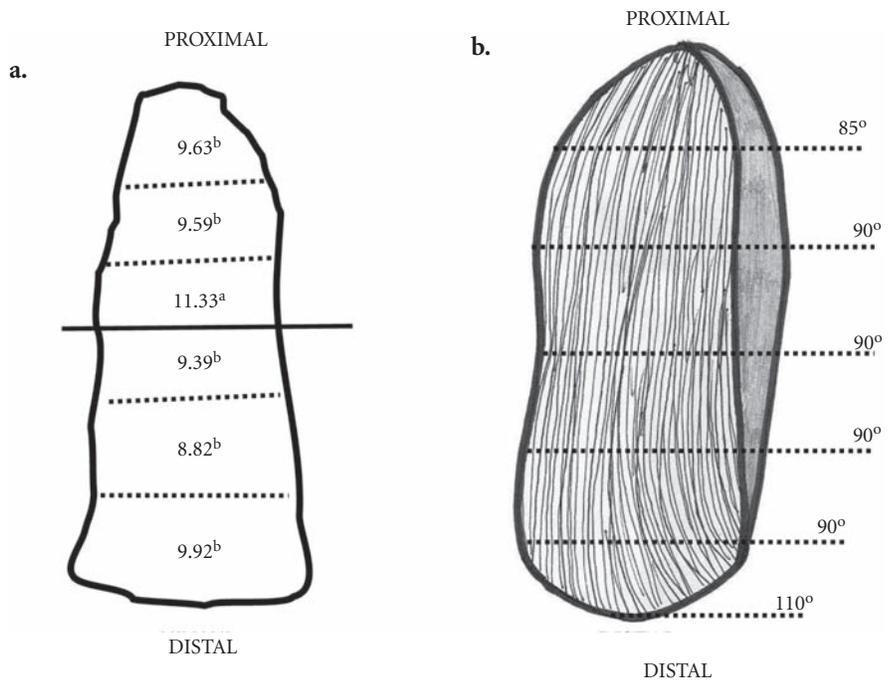


Figure 2. a. Least square mean Warner-Bratzler shear force values (lb) of each domain of *m. sartorius* ($P = 0.01$). b. Muscle fiber orientation of *m. sartorius* on the longitudinal cross section of the muscle. ^{a,b}Means in the same figure with different superscripts significantly differ ($P < 0.05$).

Table 1. Least square mean Warner-Bratzler shear force values (lb) of zones, sides, and regions of small muscles in beef round.

Muscle	Zone			Side			Region		
	Proximal	Distal	P-value	Medial	Lateral	P-value	Anterior	Posterior	P-value
<i>m. pectineus</i>	7.85 ^b	8.73 ^a	0.03	NA	NA	NA	NA	NA	NA
<i>m. sartorius</i>	10.19 ^a	9.37 ^b	0.04	NA	NA	NA	NA	NA	NA
<i>m. v. medialis</i>	8.99	9.68	0.12	NA	NA	NA	NA	NA	NA
<i>m. v. intermedius</i>	9.47 ^b	11.6 ^a	< .0001	8.93 ^b	12.15 ^a	< .0001	NA	NA	NA
<i>m. gracilis</i>	10.27	10.67	0.08	NA	NA	NA	10.25	10.69	0.07

NA – not applicable

^{a,b}Means in the same row under each domain with different superscripts significantly differ ($P < 0.05$).

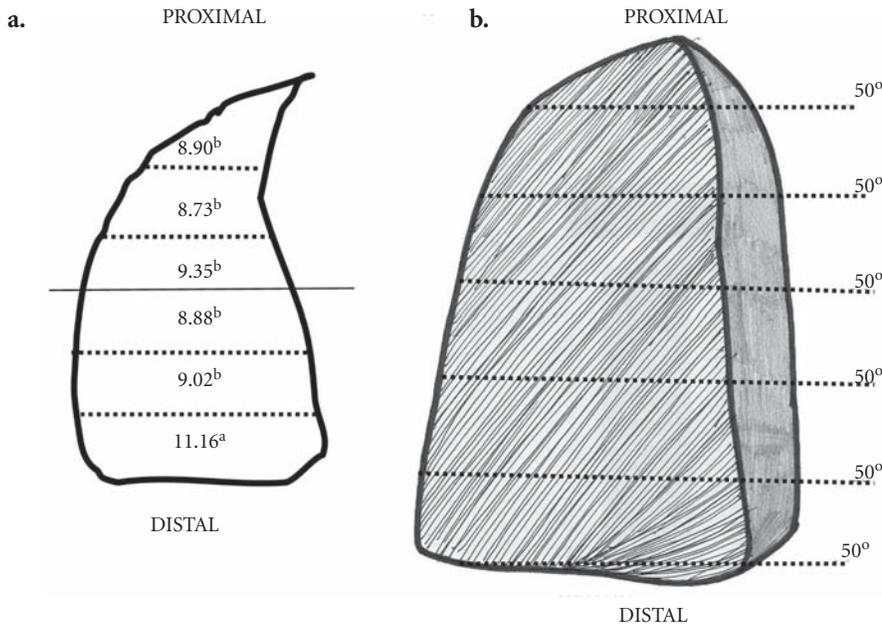


Figure 3. a. Least square mean Warner-Bratzler shear force values (lb) of each domain of *m. vastus medialis* ($P = 0.02$). b. Muscle fiber orientation of *m. vastus medialis* on the longitudinal cross section of the muscle.

^{a,b}Means in the same figure with different superscripts significantly differ ($P < 0.05$).

muscle was significantly tougher than the rest of the muscle (Figure 3a). The fiber orientation of VM was unipennate with an angle of 50° from the proximal to the distal end (Figure 3b). Therefore, the VM could be cut into medallions angular to the long axis of the muscle.

The tenderness of the VI muscle differed along the muscle (Figure 4a). The most lateral and distal region of the muscle was significantly tougher than the rest. The most tender region of the VI muscle was the most proximal and medial region (Figure 4a). The distal region of the muscle was significantly tougher ($P < 0.0001$) than the proximal region (Table 1). In addition, the medial side of the VI was significantly more tender ($P < 0.0001$) than the lateral side (Table 1). The VI had the bipennate muscle fiber orientation (Figure 4b). Muscle fibers extended medially and laterally from both sides of the tendon, which runs along the muscle between the medial and lateral portions of the muscle. In the medial side, the muscle fibers made a 125° angle with the tendon, whereas muscle fibers in the lateral side made a 50° angle with the tendon. The lateral and the medial portions of the muscle should be separated before making medallions. Medallion steaks could be made angular to the long axis of the lateral and medial sides in order to increase the size of the medallions.

There were no tenderness variations in the distal and proximal or anterior or posterior sections of the GL (Table 1). However, the most proximal section of the muscle was more tender than the rest (Figure 5a; $P = 0.002$). The muscle fiber orienta-

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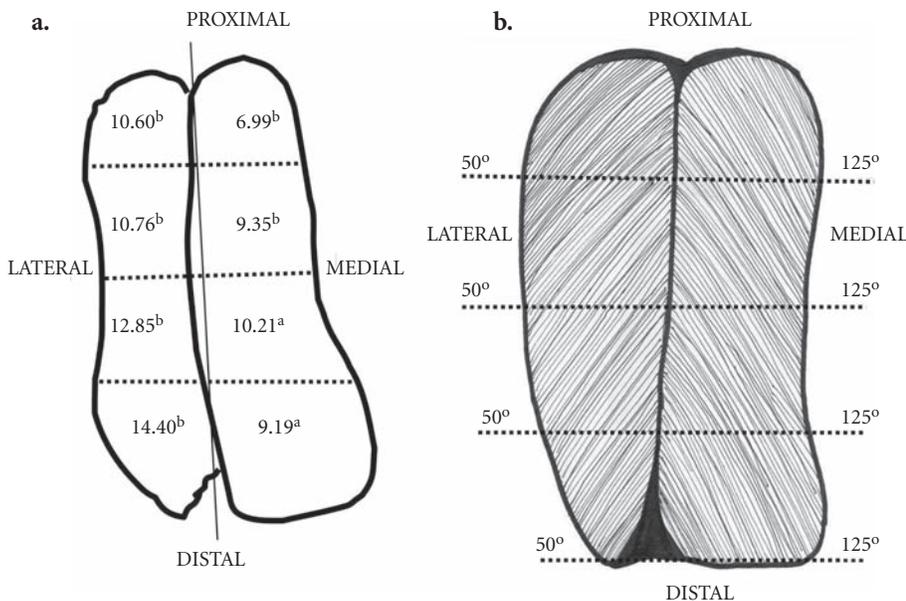


Figure 4. a. Least square mean Warner-Bratzler shear force values (lb) of each domain of *m. vastus intermedius* ($P = 0.04$). b. Muscle fiber orientation of *m. vastus intermedius* on the longitudinal cross section of the muscle.

^{a,b}Means in the same figure with different superscripts significantly differ ($P < 0.05$).

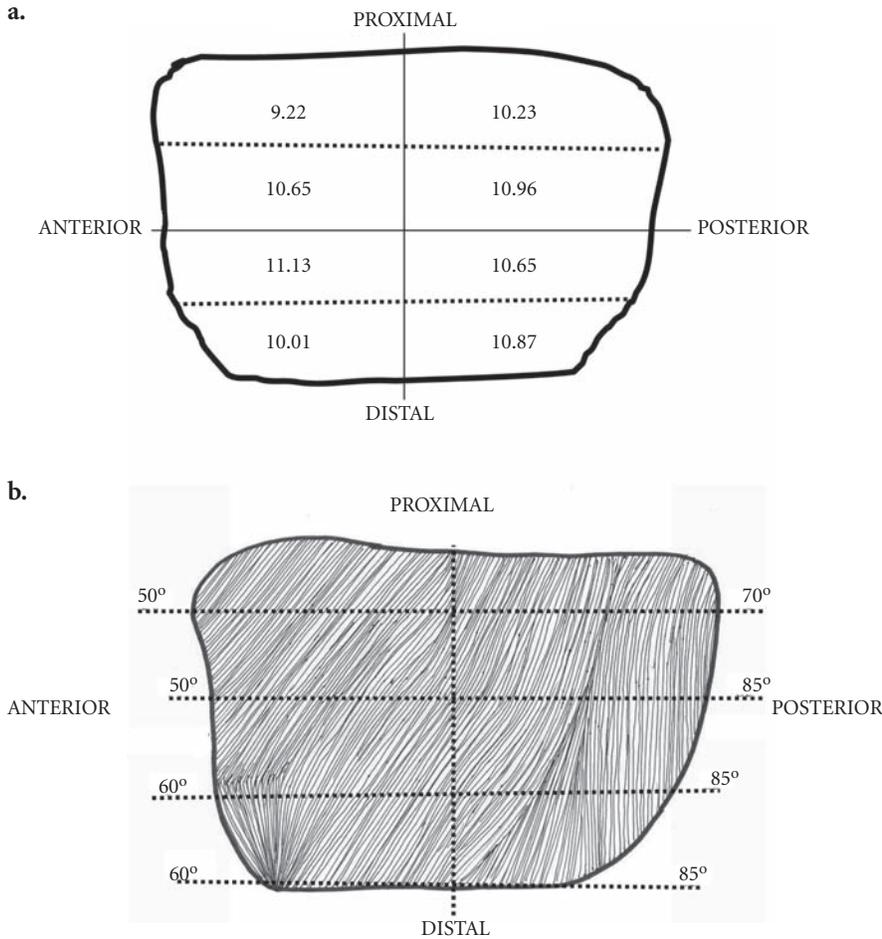


Figure 5. a. Least square mean Warner-Bratzler shear force values (lb) of each domain of *m. gracilis* ($P = 0.08$). **b.** Muscle fiber orientation of *m. gracilis* on the longitudinal cross section of the muscle.

tion of the GL was unipennate. In the posterior side of the muscle, muscle fibers were running angularly making 70° to 85° angles, whereas muscle fiber angles were changing from 50° to 60° in the anterior side toward the distal end of the muscle (Figure 5b). Prior to grilling, GL should be separated into the anterior and posterior regions. After grilling, steaks should be made perpendicular to the long axis of both portions of the muscle.

Despite tenderness differences along the muscles, the average Warner-Bratzler shear force testing showed that *m. pectineus* was tender and *m. sartorius*, *m. vastus medialis*, *m. gracilis* and *m. vastus intermedius* were intermediate tender muscles. Therefore, *m. pectineus*, *m. sartorius*, *m. vastus medialis*, *m. gracilis* and *m. vastus intermedius* can be marketed as single-muscle steaks or medallions.

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²This project was funded in part by the Beef Checkoff and the Nebraska Beef Council.

Alternative Muscles for Traditional Japanese and Korean Beef Recipes

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Summary

This research was conducted to identify alternative cuts that would be acceptable in popular dishes in Japan and Korea in order to encourage usage of a broader portion of beef carcasses that qualify for export. Typical dishes were tested twice (6 panels per country) using traditional and three alternative beef muscles. Dishes were compared regarding appearance, aroma, juiciness, tenderness, flavor, and overall acceptability by natives of each country who served as panelists. Japanese dishes were sukiyaki (sauté), shabu-shabu (hot pot), and yakiniku (grill); Korean dishes were jang jo rim (boiled), miyeok-guk (soup), and kalbi (grill). Alternative muscles were selected because of their cost, sensory characteristics, lack of popularity for export, and the opportunity to increase exports. There were relatively few differences among muscles in each of the dishes. Results indicate that other muscles may be used to replace traditional beef cuts in Japanese and Korean dishes, suggesting nontraditional U.S. beef cuts for the Asian market.

Introduction

Currently, only beef from animals less than 21 months of age is allowed to be exported from the U.S. into Japan. A relatively small percentage of U.S. cattle meet this requirement and are verifiable. As a result, carcasses that qualify are valuable, and the most return could be obtained by exporting as much of the beef from those carcasses as possible. Unfortunately, Asian countries typically limit their orders to a few cuts from the chuck and, to a lesser

degree, some steak cuts. Accordingly, this research was conducted to identify alternative muscles for export into Japan and Korea, our largest Asian markets.

Procedure

Popular meat dishes from Japan and Korea that commonly contain U.S. beef were selected. Each dish was prepared using four different muscles: the muscle traditionally used and three alternative muscles. The four versions of each dish were served to citizens of those countries in each of two different taste panel sessions. Three different dishes were evaluated, making a total of 6 panel sessions per country. The objective was to determine if citizens of Japan and Korea could tell a difference between the various muscles and if they had a preference for one muscle over another.

A citizen cook was identified from each country. These were people who had moved to the U.S. within the previous 2 years (approximately) and were familiar with the dishes, cooking styles and methods of their country. They were not trained chefs.

For Japan, the three dishes were sukiyaki (sauté), shabu-shabu (hot pot), and yakiniku (grill); Korean dishes were jang jo rim (boiled), miyeok-guk (soup), and kalbi (grill). These dishes were selected, in part, because they presented a variety of cooking methods.

Native Japanese (n = 30 per session) and Korean (n = 20 per session) consumers served as panelists. The cooking occurred in a university residence hall kitchen and panels were conducted in the dining area. Panelists were volunteers and their participation entered them into a prize drawing.

Beef came from upper 2/3 Choice carcasses. It was aged at least 2 weeks and was thinly sliced per instructions from the citizen cook.

Results

Table 1 lists the traditional muscle used for each dish, alternative muscles, their anatomical location, and the general cooking style/method. It is evident that alternative muscles came from parts of the carcass that are not traditionally exported into these countries. The alternative muscles were selected because of their cost, sensory characteristics, lack of popularity for export, and the opportunity to increase exports.

All of the muscles performed equally for the Japanese dish called sukiyaki (Table 2). There were no differences in sensory characteristics among the four versions of sukiyaki. This means any of the muscles could be used in this popular dish with equal consumer satisfaction. Of the four muscles used for shabu-shabu, only 1 was rated lower than the others in appearance, juiciness, tenderness and overall acceptability, and that was the *Semimembranosus* (top round). The m. *triceps brachii* (shoulder clod) was judged by panelists to be more tender than the traditional muscle (m. *rectus femoris* from the round knuckle). For yakiniku, the Japanese panelists easily picked out the traditional muscle (m. *serratus ventralis* or short rib) as being more desirable for juiciness, tenderness, flavor, and overall acceptability when compared to the m. *tensor fascia latae* (tri-tip). There were no differences among the other two alternative muscles studied and the traditional muscle used for yakiniku.

Collectively, there appears to be considerable opportunity to substitute alternative muscles in popular Japanese dishes. This represents economic opportunity for purveyors in Japan and for exporters here in the U.S.

For Korean consumers there were few differences among the muscle studies for jang jo rim (Table 3). The

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bottom round (*m. biceps femoris*) was judged to be significantly more tender than the traditional *m. semitendinosus* (eye of round). Otherwise there were no differences among muscles and traits for this popular dish. Similarly, no differences were found for kalbi. This is very encouraging because the traditional muscle (*m. serratus ventralis* – short rib) is highly prized and relatively expensive compared to the alternatives. The demand for *m. serratus ventralis*, in fact, is estimated by the U.S. Meat Export Federation to exceed supply in the next few years. The opportunity to offer alternative muscles will be attractive to consumers, processors, and exporters.

For miyeok-guk (often called wedding soup in Korea because of the occasion when it is often served), panelists were least satisfied with the *m. semimembranosus* (top round) as an alternative muscle. All other muscles were judged to be equal in individual sensory traits and in overall acceptability. Once again the advantages of marketing an alternative to the *m. serratus ventralis* should be of value.

Conclusion

Citizens from Japan and Korea demonstrated that there are a number of muscles from the round and sirloin region that are acceptable in popular recipes from these countries. The opportunity exists to significantly increase the value of selected muscles by selling them as alternatives to common cuts in these Asian markets.

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²This project was funded in part by the Beef Checkoff.

Table 1. Traditional and alternative muscles used in Japanese and Korean recipes.

Country	Dish	Muscle Category	Muscle Name	Carcass Location	Cooking Method
Japan	Sukiyaki	Traditional	<i>Longissimus dorsi</i>	Loin	Sauté
		Alternative	<i>Biceps femoris</i>	Bottom round	
		Alternative	<i>Rectus femoris</i>	Round knuckle	
		Alternative	<i>Semimembranosus</i>	Top round	
	Shabu Shabu	Traditional	<i>Rectus femoris</i>	Round knuckle	Hot pot
		Alternative	<i>Tensor fascia latae</i>	Tri-tip	
		Alternative	<i>Triceps brachii</i>	Shoulder clod	
		Alternative	<i>Semimembranosus</i>	Top round	
	Yakiniku	Traditional	<i>Serratus ventralis</i>	Short rib	Grill
Alternative		<i>Biceps femoris</i> (proximal end)	Top sirloin cap		
Alternative		<i>Infraspinatus</i>	Flat iron		
Alternative		<i>Tensor fascia latae</i>	Tri-tip		
Korea	Jang Jo Rim	Traditional	<i>Semitendinosus</i>	Eye of round	Boil
		Alternative	<i>Biceps femoris</i>	Bottom round	
		Alternative	<i>Trapezius</i>	Chuck lifter meat	
		Alternative	<i>Pectoralis major</i>	Brisket	
	Kalbi	Traditional	<i>Serratus ventralis</i>	Short rib	Grill
		Alternative	<i>Tensor fascia latae</i>	Tri-tip	
		Alternative	<i>Biceps femoris</i> (proximal end)	Top sirloin cap	
		Alternative	<i>Infraspinatus</i>	Flat iron	
	Miyeok-guk	Traditional	<i>Serratus ventralis</i>	Short rib	Soup
		Alternative	<i>Semimembranosus</i>	Top round	
		Alternative	<i>Digital extensor</i>	Heel	
		Alternative	<i>Tensor fascia latae</i>	Tri-tip	

Table 2. Sensorial attributes of the Japanese taste panel.

Dish	Attributes	Muscles				P-value
		<i>Biceps femoris</i>	<i>Longissimus dorsi</i> *	<i>Rectus femoris</i>	<i>Semimembranosus</i>	
Sukiaki						
	Appearance	8.40	8.20	8.23	8.01	0.28
	Aroma	7.97	8.17	7.76	7.14	0.10
	Juiciness	7.17	6.67	6.28	6.33	0.25
	Tenderness	7.00	7.49	7.11	6.87	0.68
	Flavor	8.35	8.57	7.75	7.46	0.10
	Overall	8.34	8.18	7.90	7.38	0.15
Shabu Shabu						
		<i>Tensor fascia latae</i>	<i>Rectus femoris</i> *	<i>Triceps brachii</i>	<i>Semimembranosus</i>	
	Appearance	8.69 ^a	7.65 ^{ab}	7.64 ^{ab}	6.67 ^b	0.0072
	Aroma	7.15	7.04	7.43	6.65	0.54
	Juiciness	7.60 ^a	7.22 ^{ab}	8.33 ^a	6.33 ^b	0.01
	Tenderness	7.98 ^{ab}	7.75 ^b	9.00 ^a	6.81 ^b	0.0057
	Flavor	8.18	7.53	8.49	7.19	0.17
	Overall	8.21 ^a	8.04 ^{ab}	8.88 ^a	7.04 ^b	0.02
Yakiniku						
		<i>Biceps femoris</i> (proximal end)	<i>Infraspinatus</i>	<i>Serratus ventralis</i> *	<i>Tensor fascia latae</i>	
	Appearance	9.45	8.97	9.28	9.05	0.85
	Aroma	9.20	8.59	9.13	8.51	0.49
	Juiciness	8.11 ^b	8.22 ^b	9.92 ^a	7.15 ^b	< 0.0001
	Tenderness	9.27 ^a	9.15 ^a	10.08 ^a	7.56 ^b	0.0003
	Flavor	9.86 ^a	8.72 ^{ab}	10.18 ^a	8.46 ^b	0.01
	Overall	9.61 ^a	8.95 ^{ab}	10.16 ^a	8.22 ^b	0.0018

*Traditional muscle cut used for each recipe.

Rating Scale - Unstructured line scale (15 cm long; 0 cm = undesirable and 15 cm = desirable).

^{a,b}Means in the same row having different superscripts are significant at $P \leq 0.05$.

Table 3. Sensorial attributes of the Korean taste panel.

Dish	Attributes	Muscles				P-value
		<i>Biceps femoris</i>	<i>Semitendinosus*</i>	<i>Trapezius</i>	<i>Pectoralis</i>	
Jang Jo Rim						
	Appearance	10.25	11.24	10.90	9.90	0.07
	Aroma	10.26	10.40	10.47	10.17	0.94
	Juiciness	9.84	8.84	8.90	9.28	0.36
	Tenderness	10.39 ^a	8.02 ^b	9.00 ^b	9.27 ^{ab}	0.01
	Flavor	9.85	8.38	9.47	9.52	0.11
	Overall	10.07	8.75	9.48	9.67	0.18
Kalbi						
		<i>Tensor fasciae latae</i>	<i>Serratus ventralis*</i>	<i>Biceps femoris</i> (proximal end)	<i>Infraspinatus</i>	
	Appearance	11.11	10.59	10.44	10.05	0.14
	Aroma	10.48	10.48	10.54	9.97	0.63
	Juiciness	10.45	10.26	10.17	9.45	0.26
	Tenderness	10.00	10.15	10.30	9.14	0.18
	Flavor	10.56	10.73	10.88	9.58	0.07
	Overall	10.64	10.59	10.77	9.71	0.13
Miyeok-guk						
		<i>Semi-membranosus</i>	<i>Digital extensor</i>	<i>Serratus ventralis*</i>	<i>Tensor fasciae latae</i>	
	Appearance	9.05	10.07	10.67	10.26	0.08
	Aroma	8.06 ^b	10.08 ^a	10.25 ^a	9.12 ^{ab}	0.02
	Juiciness	7.08 ^b	9.17 ^a	10.30 ^a	9.09 ^a	< 0.0001
	Tenderness	6.32 ^b	8.87 ^a	10.21 ^a	9.90 ^a	< 0.0001
	Flavor	7.35 ^b	10.00 ^a	10.37 ^a	9.39 ^a	0.0003
	Overall	7.40 ^b	9.79 ^a	9.83 ^a	9.56 ^a	0.0037

*Traditional muscle cut used for each recipe.

Rating Scale - Unstructured line scale (15 cm long; 0 cm = undesirable and 15 cm = desirable).

^{a,b}Means in the same row having different superscripts are significant at $P \leq 0.05$.

Steak-Quality Meat from the Beef Heel

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Lasika S. Senaratne
Jeremey B. Hinkle^{1,2}

Summary

This study was conducted to measure the shear force of beef heel (*m. gastrocnemius*) and to characterize the uncooked *m. gastrocnemius* for pH, water holding capacity, composition, and color. Ten heels were cut into steaks (for grilling) from the proximal to the distal end. Twenty additional heels were separated into lateral and medial portions; half were oven roasted and half were grilled as roasts. The proximal end steak was always less tender than the distal end steak. There were no differences in shear force between lateral and medial sides for any cooking treatment. The lateral side of heel has many connective tissue seams which were carefully avoided during shear force measurement. Heel roasts contained approximately 6% fat, had a pH of 5.59 and a mean shear force around 8.14 lb. Given the connective tissue distribution and tenderness properties, the medial side of the *m. gastrocnemius* appears to be of steak quality.

Introduction

Beef heel muscle is associated with the extension and relaxation of the hock and stifle joint. The resulting connective tissue content of the *m. gastrocnemius* generally leads people to conclude the muscle is only suitable for grinding. This may be true for the lateral side of the muscle, but the medial side appears to be lean and relatively free of connective tissue seams. In addition, the muscle has not been well characterized chemically. Accordingly, this study was conducted to measure the shear force of beef heel (*m. gastrocnemius*) and to characterize the uncooked *m. gastrocnemius* for pH, water holding capacity, composition, and color.

Procedure

Thirty beef heel muscles were obtained from a commercial packing plant. The *m. digital flexor*, a long, thin, high connective tissue muscle located on the internal side of the *m. gastrocnemius* next to the bone, was removed. Ten heels were cut into steaks (for grilling) from the proximal to the distal end. The center steak was used for chemical characterization and the others were frozen, thawed for 24 hours in a 39°F cooler, and cooked on a Hamilton Beach indoor-outdoor grill, turning over once at 95°F, until they reached an internal temperature of 160°F. Internal temperature was monitored using an OMEGA thermometer with a type T thermocouple. Twenty additional heels were separated into lateral and medial portions; after freezing and thawing, half were oven roasted in a 350°F oven and half were grilled as roasts. Roasts were removed from the oven when the internal temperature reached 158°F, thereby reaching 170°F with the post-cooking rise in temperature. Grilled heel roasts were removed from the grill when the internal temperature reached 158°F, but there was no meaningful post-cooking rise in temperature. After cooking, roasts were allowed to cool at room temperature so dimension and weight could be recorded. They were then chilled in a cooler overnight and sectioned into 1-inch slices. Cores (1/2-inch in diameter) were removed parallel to the fiber axis and sheared on an Instron universal testing machine using a Warner-Bratzler shear attachment. Before coring each steak, pictures were taken to map the fiber direction of the lateral and medial portions of heel muscle. Angles were measured by using a protractor on each steak.

A sample of raw *m. gastrocnemius* was used to test water holding capacity, and a centrifuge method was used at 32,500 × G for 15 min at 4°C to determine the expressible moisture. Color also was measured

Table 1. Warner-Bratzler shear force (lb) of the lateral and medial areas of the heel muscle¹.

	Area		P-value
	Lateral	Medial	
Oven roasted heel	9.46	9.08	0.34
Grilled steaks	9.04	8.58	0.41
Grilled heel roast	8.95	8.98	0.98

¹Areas were similar at the given P-values.

using a Hunter Lab Miniscan[®] XE Plus Model 45/0-L colorimeter with a 1-inch sample port, illuminant A, and the 10-degree standard observer settings. The remaining muscle was frozen, powdered in liquid nitrogen, and used for measurement of pH and composition (fat, moisture, and ash). The pH was determined by suspending 3-5 g of powdered meat in 50 mL of double distilled water using a Polytron blender for 30 seconds. Moisture and ash were determined using a LECO Thermogravimetric analyzer. Fat was measured using ether extraction.

Results

When shear force was measured, care was taken to avoid the connective tissue seams, which are quite tough and can elevate the shear force readings. For all three cooking methods, there were no differences between the lateral and medial lean tenderness as measured by Warner-Bratzler shear force (Table 1). We hypothesized that the perceived tenderness of the lateral portion would be lower because of the connective tissue that cannot be avoided during consumption.

For two of the three cooking methods, there was a significant tenderness gradient from the proximal to distal end of the muscle (Table 2). For oven-roasted heels and grilled heel steaks, the proximal end of the muscle was less tender than the distal end. It should be noted that the mean shear force value of *m. gastrocnemius* steaks is about 8.14 lb. It has been reported

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Table 2. Warner-Bratzler shear force (lb) of steaks from proximal to the distal end.

	Steaks (from the proximal to the distal)				P-value
	1	2	3	4	
Oven roasted heels	10.23 ^a	9.22 ^{ab}	9.02 ^b	8.65 ^b	0.04
Grilled steaks	10.74 ^a	8.21 ^b	8.18 ^b	8.14 ^b	0.006
Grilled heel roasts ¹	9.28 ^a	9.13 ^a	9.04 ^a	—	0.73

^{a,b}Means in the same row having different superscripts are significant at their P-values.

¹Only 3 steaks were obtained from grilled heel roast.

Table 3. Chemical composition (percentage) of beef heel (m. gastrocnemius).

	Area		P-value
	Lateral	Medial	
WHC ¹	37.52	37.13	0.83
pH	5.56	5.61	0.22
Fat	6.33	5.92	0.46
Ash	2.42	2.51	0.57
Moisture	73.41	73.29	0.76

¹WHC = water holding capacity.

Table 4. Objective color of lateral and medial areas of uncooked heels (m. gastrocnemius).

	Area		P-value
	Lateral	Medial	
L* (lightness)	35.70	33.93	0.06
a* (redness)	23.96 ^b	25.36 ^a	0.03
b* (yellowness)	18.49	19.42	0.17

^{a,b}Means having different superscripts within are different.

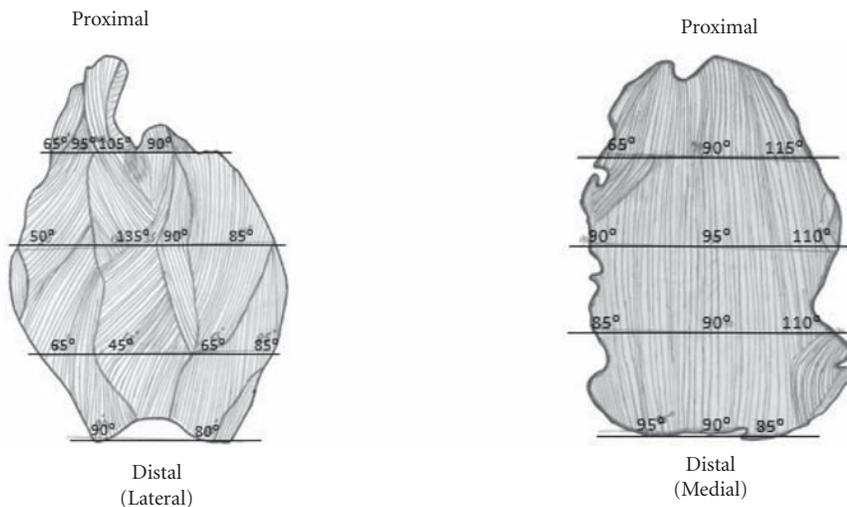


Figure 1. Fiber direction of lateral and medial areas of heels (m. gastrocnemius).

that the WBSF values for tenderness levels are described as “tender” for <8.47 lb, “intermediate” ranges from 8.47 to 10.75 lb, and “tough” for >10.75 lb (Von Seggern et al., 2005, *Meat Science*, 71: 39-51). Thus, the m. *gastrocnemius* appears to be acceptably tender for steak. This represents a significant value-added option for the beef heel.

Generally the m. *gastrocnemius* is about 6% fat and has a pH value of 5.6 (Table 3). Both of these values are in the normal range for beef cuts. Similarly, the water holding capacity of the heel seems to fall within the normal range. These data suggest the m. *gastrocnemius* could be used for a lean steak item that would have properties comparable to traditional steak meats.

Fiber angles from the medial portion of heels were somewhat consistent among steaks, but those measured from the lateral portions of heels were quite variable. The muscle fibers appear to be originating from each connective tissue lining in the lateral portion, so there is no regular fibrous structure (Figure 1).

The lateral portion of the raw heel is less red in color than the medial portion (Table 4). It may be that the connective tissue seams located in this region of the muscle contribute to the less intense red color.

Conclusion

Taken collectively, the results of this study indicate the medial side of the m. *gastrocnemius* found within the beef heel is of steak quality in tenderness, which represents a significant value-added opportunity for the heel.

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²This project was funded in part by the Beef Checkoff.

Acid Marination for Tenderness Enhancement of the Beef Bottom Round

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Summary

Two experiments were conducted to evaluate acid marination to enhance tenderness of the beef bottom round (*m. biceps femoris*). Both experiments consisted of 3 acid types (acetic, lactic, and citric) and two concentrations (0.1 and 0.5 M in Exp. 1; 0.75 and 1.5 M in Exp. 2). There were no effects of acid marination on beef tenderness in Exp. 1, although lightness (L^*) increased and redness decreased from 0 to 8 hours post-marination. Acetic and lactic acid (0.75 or 1.5 M) improved shear force values above those achieved by citric acid. Both lightness and redness permanently decreased in Exp. 2. Beef can be tenderized using lactic or acetic acid, but discoloration as a consequence of acid treatment may compromise acceptability.

Introduction

Most meat scientists attribute a substantial portion of the tenderness improvement from acid marination to solubilization of collagen – a pH effect. If that were all, tenderness improvement during acid marination would occur immediately, and there would be no benefit or detriment to changing the length of marination. That is, it would be possible to treat a muscle with the appropriate acid marinade and the product could then make its way through the distribution system without concern for over-tenderization.

Acids have been shown to enhance tenderness, but little work has been conducted on the interaction of acid strength and the length of time the

muscle would stay acceptable to consumers. The objective of the present research was to document the tenderness and color effects of marinating *m. biceps femoris* with various concentrations of lactic, acetic, and sodium citrate dihydrate (food grade citric acid).

Procedure

Seventy-two bottom round (*m. biceps femoris*) muscles were purchased and injected by hand with a multineedle injector with acetic, lactic, or sodium citrate dihydrate (food grade citric acid). In Exp. 1, acid concentrations were 0.1 and 0.5 M pumped to 107% of muscle weight. In Exp. 2, acid concentrations were 0.75 and 1.5 M pumped to 110% of muscle weight. Excess subcutaneous fat and the ischiatic head of the *m. biceps femoris* were removed before injection, leaving one continuous muscle from which to fabricate uniform, 1-inch thick steaks at the appropriate time. Muscles were placed in sealed plastic bags and tumbled for 30 minutes after injection to help distribute the acid marinade. Steaks were removed and frozen at 0 (untreated control), 1, and 8 hours and at 1, 3, 7, 14, 21, and 28 days (except the last 2 sampling days were omitted from Exp. 2). Location of the various steaks was randomized for each bottom round to avoid positional effects on tenderness. The control steaks were removed from random locations immediately prior to injection of the marinade.

Ten muscles were injected for each of the 6 treatments in Exp. 1; in Exp. 2, 3 muscles were injected for each 0.75 M acid marinade, and 4 muscles were injected for each 1.5 M acid marinade. Remaining steak samples were all cut and vacuum-packaged at the 8-hour post-marination sampling time and subsequently frozen on the appropriate day. Color measurements

of lightness (L^*), redness (a^*), and yellowness (b^*) were obtained using a Hunter colorimeter with a 1-inch sample port, illuminant A, and a 10-degree standard observer. Color was measured on steaks removed at 0, 1, and 8 hours after a 1-hour bloom time.

After thawing for 23 hours in a 34-36°F cooler, thawed steaks were grilled on a Hamilton Beach indoor-outdoor grill, turning over once at 95°F, until they reached an internal temperature of 160°F, monitored using an OMEGA thermometer with a type T thermocouple. Steaks were chilled overnight in the cooler. Then ½-inch-diameter cores were removed parallel to the fiber direction for determination of Warner-Bratzler shear force on an Instron universal testing machine with a Warner-Bratzler shear attachment.

Results

Experiment 1

No significant differences were observed among the acid treatments (Figure 1). Apparently, the low concentrations of acids used were not sufficient to degrade the connective tissue and improve tenderness. Almost all treatments increased significantly in lightness and decreased in redness from 0 to 8 hours post-marination (Tables 1 and 2). There were few differences among treatments, except meat treated with acetic acid tended to be darker and less red than citric-acid treated muscles. Meat treated with acetic or lactic acid had discoloration at the injection sites (observed subjectively), likely a pH effect. All discoloration was permanent. The acetic and citric acid treatments generally had greatest decreases in overall redness over time compared to the lactic acid treatment (Table 5).

(Continued on next page)

Table 1. Exp. 1. Lightness values (L*) of flat round steaks (m. Biceps femoris) acid-marinated with high and low concentrations of acetic, citric, or lactic acids [Significant effect = trt*time (P = 0.04)].

Time	Treatments ¹						Contrasts ²					
	AH	AL	CH	CL	LH	LL	AH vs AL	CH vs CL	LH vs LL	A vs C	A vs L	C vs L
0 ³	40.20	38.17 ^b	40.57 ^a	36.54 ^b	38.52	38.37 ^b	0.30	0.04	0.94	0.64	0.59	0.94
1	41.33	38.99 ^b	35.79 ^b	37.53 ^b	39.66	42.13 ^a	0.23	0.37	0.21	0.02	0.59	0.005
8	40.41	42.20 ^a	40.28 ^a	42.18 ^a	41.51	42.44 ^a	0.18	0.16	0.49	0.94	0.47	0.43

^{abc} Means in the same column having different superscripts are significant.

¹ AH = acetic acid high; AL = acetic acid low; CH = citric acid high; CL = citric acid low; LH = lactic acid high; LL = lactic acid low.

² A = acetic acid; C = citric acid; L = lactic acid.

³ 0hr = control, no treatments applied to sample.

Table 2. Exp. 1. Redness values (a*) of flat round steaks (m. Biceps femoris) acid-marinated with high and low concentrations of acetic, citric, or lactic acids [Significant effects = trt (P = 0.0002) and time (P < 0.0001)].

Time	Treatments ¹						Contrasts ²						
	AH	AL	CH	CL	LH	LL	Means	AH vs AL	CH vs CL	LH vs LL	A vs C	A vs L	C vs L
0 ³	24.47	24.03	24.13	25.09	25.30	26.47	24.92 ^d	0.72	0.43	0.34	0.67	0.06	0.14
1	23.31	23.01	23.97	25.56	23.98	26.21	24.34 ^d	0.83	0.28	0.13	0.13	0.07	0.75
8	16.36	19.68	19.76	20.35	17.20	22.08	19.24 ^e	0.02	0.66	0.0012	0.04	0.1	0.66
Means	21.38 ^c	22.24 ^{bc}	22.62 ^{bc}	23.67 ^{ba}	22.16 ^{bc}	24.92 ^a							

^{a,b,c} Means in the same row having different superscripts are significant.

^{d,e} Means in the same column having different superscripts are significant.

¹ AH = acetic acid high; AL = acetic acid low; CH = citric acid high; CL = citric acid low; LH = lactic acid high; LL = lactic acid low.

² A = acetic acid, C = citric acid, L = lactic acid.

³ 0hr = control, no treatments applied to sample.

Table 3. Exp. 2. Lightness values (L*) of flat round steaks (m. Biceps femoris) acid-marinated with high and low concentrations of acetic, citric, or lactic acids [No significant trt *time effect (P = 0.62)].

Time	Treatments ¹						Contrasts ²						
	AH	AL	CH	CL	LH	LL	Means	AH vs AL	CH vs CL	LH vs LL	A vs C	A vs L	C vs L
0 ³	43.88	43.21	45.46	41.11	42.53	40.39	36.65 ^d	0.76	0.06	0.34	0.87	0.19	0.25
1	39.20	40.78	40.39	37.95	38.99	39.80	4.02 ^e	0.47	0.17	0.71	0.72	0.70	0.98
8	35.11	39.62	39.86	38.58	36.20	38.33	33.67 ^e	0.05	0.57	0.34	0.24	0.95	0.22
Means	39.40 ^b	41.20 ^{ab}	42.09 ^a	39.22 ^b	39.24 ^b	39.51 ^b							

^{a,b,c} Means in the same row having different superscripts are significant.

^{d,e} Means in the same column having different superscripts are significant.

¹ AH = acetic acid high; AL = acetic acid low; CH = citric acid high; CL = citric acid low; LH = lactic acid high; and LL = lactic acid low.

² A = acetic acid, C = citric acid, L = lactic acid.

³ 0hr = control, no treatments applied to sample.

Table 4. Exp. 2. Redness values (a*) of flat round steaks (m. Biceps femoris) acid-marinated with high and low concentrations of acetic, citric, or lactic acids [Significant trt *time interaction (P < 0.0001)].

Time	Treatments ¹						Contrasts ²					
	AH	AL	CH	CL	LH	LL	AH vs AL	CH vs CL	LH vs LL	A vs C	A vs L	C vs L
0 ³	31.84 ^a	32.48 ^a	33.12	34.02	32.48 ^a	32.59 ^a	.51	.35	.98	.04	.52	.16
1	25.17 ^b	27.87 ^b	32.23	33.86	20.27 ^b	25.58 ^b	.20	.44	.01	< 0.0001	.02	< 0.0001
8	17.12 ^c	21.32 ^c	31.64	32.32	20.03 ^b	23.38 ^b	.10	.79	.19	< 0.0001	.17	< 0.0001

^{a,b,c} Means in the same column having different superscripts are significant.

¹ AH = acetic acid high; AL = acetic acid low; CH = citric acid high; CL = citric acid low; LH = lactic acid high; and LL = lactic acid low.

² A = acetic acid, C = citric acid, L = lactic acid.

³ 0hr = control, no treatments applied to sample.

Table 5. Exp. 1. Treatment and time effects on cooking loss percentage of flat round steaks (m. Biceps femoris) acid-marinated with high and low concentrations of acetic, citric, or lactic acids. (P values = trt < 0.0001, time = 0.0073, trt*time = 0.17).

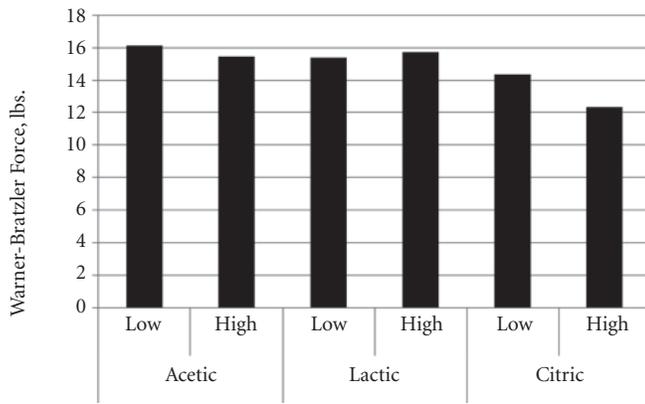
Treatment ¹	Time								
	0 hr ²	1 hr	8 hr	1 day	3 days	7 days	14 days	21 days	28 days
LL	20.23 ^f	26.32 ^f	24.43 ^f	25.85 ^{ef}	21.73 ^f	19.76 ^f	24.63 ^{fg}	21.37 ^{fg}	24.42 ^f
LH	23.2 ^{ef}	24.88 ^f	21.75 ^f	21.11 ^f	23.59 ^f	19.73 ^f	19.12 ^g	18.3 ^g	17.31 ^g
AL	24.58 ^{ef}	35.49 ^e	29.08 ^{ef}	31.34 ^e	35.27 ^e	29.82 ^e	25.61 ^{fg}	26.25 ^{ef}	32.22 ^e
AH	26.19 ^{be}	34.47 ^{ae}	33.46 ^{ae}	32.49 ^{ae}	34.98 ^{ae}	31.91 ^{af}	33.77 ^{ae}	29.89 ^{abe}	30.21 ^{abef}
CL	24.92 ^{be}	29.82 ^{abef}	33.20 ^{ae}	30.70 ^{abe}	27.29 ^{bef}	30.64 ^{abe}	28.05 ^{abef}	27.67 ^{abef}	27.75 ^{abef}
CH	26.3 ^{abcde}	26.95 ^{abcf}	23.82 ^{bcd}	21.07 ^{df}	23.10 ^{bcdef}	21.19 ^{cdf}	26.11 ^{abcdefg}	27.52 ^{abef}	32.04 ^{ae}

^{a,b,c} Means in the same row having different superscripts are significant.

^{d,e,f,g} Means in the same column having different superscripts are significant.

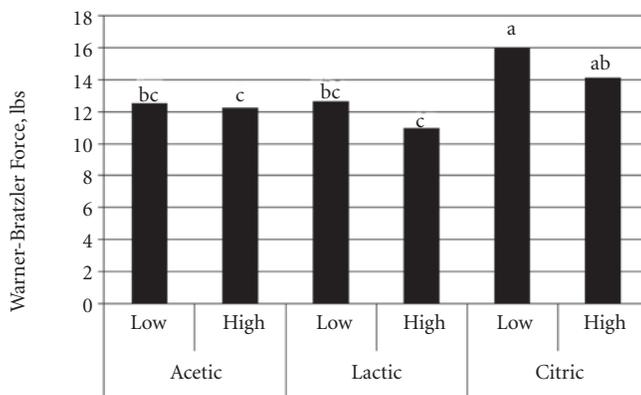
¹ AH = acetic acid high; AL = acetic acid low; CH = citric acid high; CL = citric acid low; LH = lactic acid high; and LL = lactic acid low.

² 0hr = control, no treatments applied to sample.



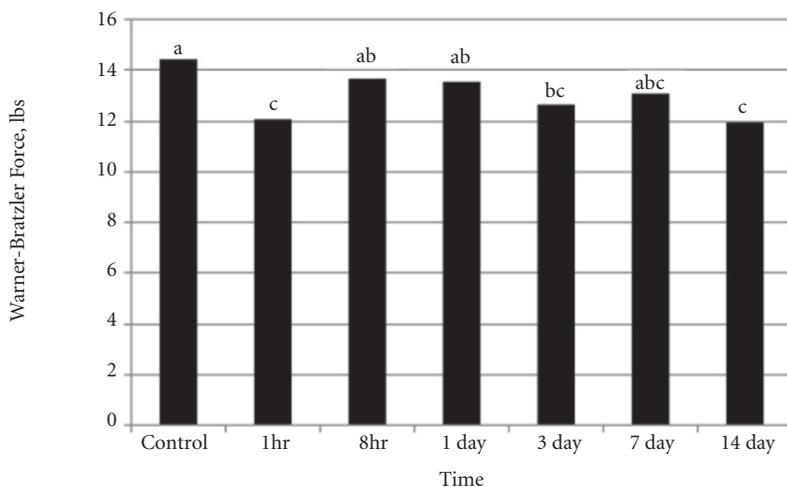
^{a,b,c}Means in the columns having different superscripts are significantly different at $P < 0.05$.

Figure 1. Exp. 1. Treatment effects on Warner-Bratzler shear force measurements of flat round steaks (*m. Biceps femoris*) acid-marinated with high and low concentrations of acetic, citric, or lactic acids.



^{a,b,c}Means in the columns having different superscripts are significantly different at $P < 0.05$.

Figure 2. Exp. 2. Treatment effects on Warner-Bratzler shear force measurements of flat round steaks (*m. Biceps femoris*) acid-marinated with high and low concentrations of acetic, citric, or lactic acids.



^{a,b,c} Means in the columns having different superscripts are significantly different at $P < 0.05$.

Figure 3. Exp. 2. Time effects on Warner-Bratzler shear force measurements of flat round steaks (*m. Biceps femoris*) for all acid treatments.

Experiment 2

The higher concentrations of lactic and acetic acid marinades significantly increased tenderness (decreased shear force) as compared to either concentration of sodium citrate dihydrate (Figure 2). For all treatments, tenderness immediately improved from 0 to 1 hours and returned to baseline after 8 hours. Significant improvements in tenderness were evident 3 days post-marination (Figure 3). Sodium citrate dihydrate had little to no effect on tenderness (data not shown). This is likely due to the fact that sodium citrate dihydrate is a buffered, food grade citrate with a relatively neutral pH at 8.1. In contrast, the pH readings of the acetic and lactic acid marinades were quite acidic, ranging from 1.65 to 2.2.

Over time, acid marination caused the steaks to become permanently darker (Table 3) and, for acetic and lactic acid, significantly less red (Table 4). The extent and severity of this discoloration was greatest at the injection sites and would create color issues.

Conclusions

Acid marination could be used to increase meat tenderness during distribution. Lactic and acetic acid, at 0.75 or 1.5 M concentration, did not appear to over-tenderize the product during a 2-week period. However, acid marination does pose color acceptability issues that remain unaltered over time.

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Multiple Antimicrobial Interventions for the Control of *Escherichia coli* O157:H7 in Very Small Beef Processing Facilities

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Summary

One-hundred and fifty beef carcasses from 3 very small beef processing plants were sponge sampled for aerobic plate count, generic *E. coli*, coliforms, Enterobacteriaceae, and *E. coli* O157:H7 before and after carcass intervention strategies. The control (C) treatment consisted of one 3% lactic acid (LA) wash applied at the end of slaughter, just prior to chilling. The multiple (M) intervention treatment received a 3% LA wash prior to evisceration, a hot water wash after carcass splitting and trimming, and a final LA wash just prior to chilling. The M treatment showed greater log reductions throughout the slaughter process prior to chilling for indicator bacteria. M and C treatments were similar for all bacteria after chilling. Both treatments were effective at reducing the occurrence of *E. coli* O157:H7.

Introduction

Beef processing plants of all sizes have implemented intervention technologies throughout the slaughter process to reduce or eliminate microorganisms. Published research has shown several different antimicrobial agents used as a carcass spray intervention to be effective at reducing a variety of bacteria and pathogens. Many antimicrobial agents involve the use of organic acids and/or heat as interventions, with lactic acid, acetic acid, and hot water being the most common antimicrobial interventions. Antimicrobial interventions can

be used alone or in conjunction with additional interventions throughout the slaughter process and are commonly referred to as multiple intervention systems. The use of multiple interventions has been effective at reducing bacterial contamination in a laboratory and large commercial beef processing facilities. However, little research is available on the effectiveness of multiple interventions in small or very small beef processing facilities, which comprise about 83% of the federally inspected processing plants in Nebraska. Therefore, the purpose of this study was to compare the effectiveness of multiple versus single antimicrobial interventions for the reduction of *E. coli* O157:H7 and other indicator bacteria during the slaughter process in small and very small meat processing facilities.

Procedure

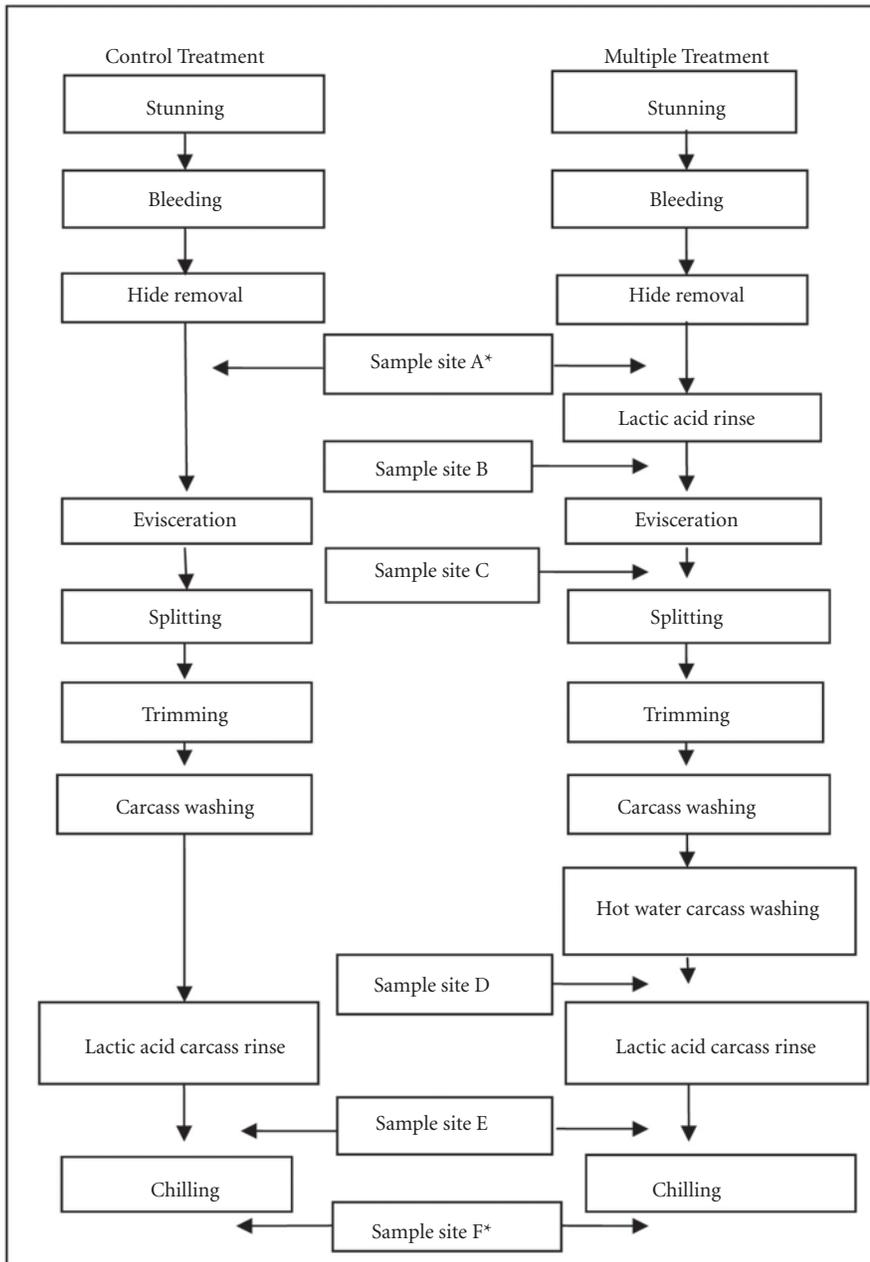
Experimental Design

A very small processing plant is defined under the final rule as having fewer than 10 employees or less than \$2.5 million in annual sales. One-hundred and fifty beef carcasses were sampled across three very small processing plants for aerobic plate count (APC), coliforms (CL), generic *E. coli* (EC), Enterobacteriaceae (EB), and *E. coli* O157:H7. The control (C) treatment (75 carcasses) consisted of a single antimicrobial intervention whereby a 3.0% (vol/vol) lactic acid (LA) spray ($\geq 132^{\circ}\text{F}$) was applied to the carcass at the end of the slaughter process prior to carcass chilling. The multiple (M) intervention treatment (75 carcasses) consisted of three antimicrobial interventions during the slaughter process: 1) 3.0% (vol/vol) LA spray ($\geq 132^{\circ}\text{F}$) was applied to the carcass immediately after hide removal

and prior to evisceration; 2) hot water intervention ($\geq 165^{\circ}\text{F}$) was applied after the final carcass wash at the end of the slaughter process; and 3) an additional 3.0% (vol/vol) LA spray ($\geq 132^{\circ}\text{F}$) was applied to the carcass at the end of the slaughter process just prior to carcass chilling. Chilling rates were recorded on randomly selected carcasses during the 24-hour post-slaughter chilling process.

Hot Water Application

The M intervention carcasses received a 2-minute hot water wash per side. A tankless portable water heater (Rinnai; Nagoya, Japan) with a side mount temperature gauge was utilized to heat water to $\geq 165^{\circ}\text{F}$ at carcass surface contact. An in-line water pressure gauge (Span Pressure Gauges; Waukesha, Wisc.) was inserted to measure water pressure at 45-75 psi. An in-line temperature gauge (Trend, Division of WIKA, Lawrenceville, Ga.) also was inserted where the hose and spray gun connect to measure water temperature at the end of the hose. The tip of the spray nozzle (McMaster-Carr, Chicago, Ill.; 50° angle, brass, flat fan spray) was ≤ 12 in from the carcass during hot water application to minimize heat loss. A thermocouple temperature gauge was used to measure water temperature flowing out of the spray nozzle. The temperature gauge was held 12 in from the spray nozzle and temperatures were recorded prior to carcass application. Temperatures were recorded at this distance from the spray nozzle to simulate the water temperature at carcass contact. The tankless water heater was programmed at 185°F to ensure final water temperature $\geq 165^{\circ}\text{F}$ for carcass application.



**E. coli* O157:H7 sampling locations

Sample site A: after hide removal prior to LA spray and evisceration; B) post LA spray prior to evisceration; C) post evisceration before hot water intervention; D) post hot water intervention; E) post final LA spray, and F) after chilling overnight

Figure 1. Location of antimicrobial interventions and indicator organism sampling sites in the beef slaughter process.

Lactic Acid Application

All carcasses received at least one LA spray for 1 minute per side per application. A 3% (vol/vol) concentration of LA (Birko, Denver, Colo.; Purac America, Lincolnshire, Ill.; 88%

food grade LA) was sprayed on the hot carcasses for both treatments. A stainless steel garden pump sprayer was modified with an air compressor adaptor (NIBCO®, Elkhart, Ind.) to achieve spraying pressure between 20-35 psi. A 1 gallon air compressor

(Campbell Hausfeld®; Harrison, Ohio) was used to pressurize the LA spray system. A pressure gauge was mounted in the tank line to record and monitor pressure. The LA solution had a target temperature above 131°F with an acceptable range between 130-140°F. Temperature was measured by a thermocouple temperature gauge prior to carcass application.

Carcass Sampling

Sampling locations were determined on the basis of where the hide was removed from the carcass and probable contamination sites. APC, CL, EC, and EB sponge samples were taken along the navel/plate/midline, brisket, and a portion of the outside round, totaling 100 cm² at each location and 300 cm² per swab. *E. coli* O157:H7 sampling locations were the foreshank, inside round, and the inside portion of the hindshank, as suggested by previous research. The location of antimicrobial interventions and microbiological sampling sites in the beef slaughter process for both treatments are shown in Figure 1. The C treatment was sampled on both sides of the carcass prior to evisceration, post LA spray prior to chilling, and after overnight chilling for indicator organisms.

Sample collection for the M intervention treatment was performed: A) after hide removal prior to LA spray and evisceration; B) post LA spray prior to evisceration; C) post evisceration before hot water intervention; D) post hot water intervention; E) post final LA spray; and F) after chilling overnight. Because of space restrictions on the carcass, the first three sampling sites (A, B, C) were sampled on one side of the carcass, and the last three sampling sites (D, E, F) were sampled on the corresponding side of the same carcass later in the slaughter process to eliminate the possibility of sampling the same area on the carcass. This sampling scheme rotated from side to side on every carcass in the M intervention treatment.

(Continued on next page)

Table 1. LS means for Aerobic Plate Count, *Enterobacteriaceae*, coliforms, and *E. coli* populations (log CFU/cm²) at each sampling site and treatment across all plants.

Sampling site ¹	Aerobic Plate Count			<i>Enterobacteriaceae</i>			Coliforms			<i>E. coli</i>		
	Control	Multiple	SEM	Control	Multiple	SEM	Control	Multiple	SEM	Control	Multiple	SEM
A	3.17 ^w	2.97 ^w	0.139	1.11 ^w	1.07 ^w	0.134	0.79 ^w	0.83 ^w	0.144	-0.70 ^w	-0.54 ^w	0.101
B	—	2.19 ^{xy}	—	—	0.43 ^x	—	—	-0.03 ^x	—	—	-1.11 ^{xy}	—
C	—	2.45 ^x	—	—	0.61 ^x	—	—	0.16 ^x	—	—	-1.00 ^{xy}	—
D	—	2.45 ^x	—	—	0.61 ^x	—	—	0.07 ^x	—	—	-0.95 ^x	—
E	2.26 ^{ax}	1.54 ^{bz}	0.169	0.51 ^{ax}	-0.01 ^{by}	0.134	0.00 ^{ax}	-0.39 ^{by}	0.142	-1.03 ^{ax}	-1.19 ^{by}	0.067
F	2.05 ^x	1.92 ^{yz}	0.179	0.31 ^x	0.42 ^x	0.149	-0.04 ^x	0.02 ^x	0.151	-1.18 ^y	-1.07 ^{xy}	0.065

¹A: log counts post hide removal, pre-evisceration, pre-lactic acid (LA).

B: log counts pre-evisceration, post LA.

C: log counts post evisceration, pre-hot water (HW).

D: log counts post evisceration, post HW, pre LA.

E: log counts post evisceration, post HW, post LA, pre-chill.

F: log counts post evisceration, post HW, post LA, post-chill.

^{ab}means within row of common bacteria with differing superscripts differ $P \leq 0.05$.

^{wxyz}means within column with differing superscripts differ $P \leq 0.05$.

SEM: standard error of the mean.

Analyses

Samples were shipped in coolers with ice packs to the food microbiology laboratory at the University of Nebraska for microbial analysis. Microbial data for APC, EC, CL, and EB were determined by plating 1 ml of diluted sample homogenate onto 1 of 3 types of Petrifilm™ (3M, St. Paul, Minn.): APC, *E. coli*, coliforms, and ENT (*Enterobacteriaceae*). Petrifilms™ were allowed to dry and then incubated for 48 hours at 95°F before counting. Colonies were reported as colony forming units per square centimeter (CFU/cm²). For the *E. coli*/Coliforms Petrifilm™, blue/purplish colonies with gas production were classified as *E. coli* and all remaining colonies as coliforms. Samples being analyzed for *E. coli* O157:H7 were tested by the

Table 2. LS means for Aerobic Plate Count populations (log CFU/cm²) for combined treatment by plant and sampling sites.

Sampling site ¹	Plant 1	Plant 2	Plant 3	Pr > F
A	2.96 ^a	3.13 ^a	3.11 ^a	0.63
E	1.74 ^a	1.28 ^a	2.68 ^b	< 0.01
F	1.61 ^a	1.51 ^a	2.85 ^b	< 0.01

^{ab}differing superscripts between plants at same sampling site differ $P \leq 0.05$.

¹A: log counts post hide removal, pre-evisceration, pre-lactic acid (LA).

E: log counts post evisceration, post hot water, post LA, and pre-chill.

F: log counts post evisceration, post hot water, post LA, and post chill.

USDA-accepted BAX® system PCR assay. An analysis of variance (ANOVA) using the MIXED procedure of SAS was performed for data analyses.

Results

Across all plants, LS means expressed as log counts (CFU/cm²) for APC, EC, CL, and EB were similar ($P \geq 0.15$) for C and M intervention

carcasses before interventions were applied (Table 1). The APC, EC, CL, and EB populations for the M intervention carcasses were less ($P \leq 0.03$) than C carcasses after evisceration, hot water, and LA and just prior to carcass chilling. However, treatments were similar ($P > 0.16$) for APC, EC, CL, and EB after chilling (Table 1). Table 2 shows the effect of plant on APC log counts (CFU/cm²) sampled

Table 3. LS means for Aerobic Plate Count, *Enterobacteriaceae*, coliforms, and *E. coli* reductions (log CFU/cm²) at each sampling site and treatment across all plants.

Sampling site ¹	Aerobic Plate Count			<i>Enterobacteriaceae</i>			Coliforms			<i>E. coli</i>		
	Control	Multiple	SEM	Control	Multiple	SEM	Control	Multiple	SEM	Control	Multiple	SEM
A – B	—	0.77	—	—	0.64	—	—	0.87	—	—	0.57	—
A – C	—	0.51	—	—	0.46	—	—	0.67	—	—	0.46	—
A – D	—	0.52	—	—	0.46	—	—	0.76	—	—	0.41	—
A – E	0.91 ^a	1.42 ^b	0.280	0.59 ^a	1.08 ^b	0.173	0.79 ^a	1.23 ^b	0.184	0.32 ^a	0.65 ^b	0.104
A – F	1.11	1.04	0.218	0.80	0.64	0.189	0.83	0.81	0.210	0.47	0.53	0.102

¹A – B: log reduction from (post hide removal, pre-evisceration, pre-lactic acid (LA)) to (pre-evisceration, post LA).

A – C: log reduction from (pre-evisceration, pre-LA) to (post evisceration, pre-hot water (HW)).

A – D: log reduction from (pre-evisceration, pre-LA) to (post evisceration, post HW).

A – E: log reduction from (pre-evisceration, pre-LA) to (post evisceration, post HW, post LA, pre-chill).

A – F: log reduction from (pre-evisceration, pre-LA) to (post evisceration, post HW, post LA, post chill).

^{ab}means with differing superscripts within similar bacteria log reduction columns differ $P \leq 0.05$.

SEM: standard error of the mean.

Table 4. LS means for reductions (log CFU/cm²) of Aerobic Plate Count by plant and sampling site.

Sampling site ²	Plant 1		Plant 2		Plant 3		Pr > F ¹
	Control	Multiple	Control	Multiple	Control	Multiple	
A - E	0.68 ^a	1.75 ^b	1.42 ^a	2.26 ^b	0.62 ^a	0.25 ^a	0.02

^{a,b}means within plant with differing superscripts differ $P < 0.05$.

¹F-test statistic for the difference of log reduction across plants and treatments.

²A - E: log reduction from sampling sites: (post hide removal, pre-evisceration, pre-lactic acid) - (post lactic acid, pre-chill).

Table 5. Number and percentage of *E. coli* O157:H7 positive samples by treatment across all plants.

	Control	Multiple
Sample site A¹		
Total positives	13 ^a	14 ^a
Total head sampled	75	75
Total percentage	17.33%	18.66%
Sample site F²		
Total positives	2 ^b	1 ^b
Total head sampled	75	75
Total percentage	2.67%	1.33%

^{a,b}differing superscripts within row and column differ $P \leq 0.05$.

¹Sample site A= after hide removal, before evisceration and interventions.

²Sample site F= after all interventions and after 24 hours of carcass chilling.

throughout the slaughter process (sample sites A, E, and F). Plant 3 showed greater ($P < 0.01$) APC populations at sampling sites E and F compared to plants 1 and 2. These data, along with our observation of slaughter operations, suggest plant 3 could standardize sanitary carcass dressing procedures and improve sanitation of skinning knives during slaughter. Similar intervention strategies have been used to reduce log (CFU/cm²) mean values for APC, CL, and EC, including a hot carcass wash (160-170°F) and organic acid sprays (1.6-2.6%; 109-140°F lactic or acetic acid), but in a large commercial setting.

The M intervention carcasses had a greater log reduction ($P = 0.02$) than the C carcasses (1.42 and 0.91 log CFU/cm², respectively) for APC throughout the harvesting process from pre-evisceration until just prior to carcass chilling across all plants (Table 3). EC, CL, and EB also showed greater log reductions ($P = 0.03$) in

the M intervention treatment prior to chilling. Similar log reductions ($P = 0.48$) for EC, CL, and EB on carcasses were observed after chilling; however, both treatments achieved greater than one log reduction (CFU/cm²) for APC post chill (Table 3). Table 4 shows reductions (log CFU/cm²) in APC on a plant by treatment basis, where an interaction is noticed. Plants 1 and 2 achieved greater reductions (log CFU/cm²) for the M treatment versus the C treatment throughout the slaughter process and prior to carcass chilling (sampling site A-E). However, plant 3 carcass samples did not show a difference in APC reductions (log CFU/cm²) between the two treatments.

Across all plants (Table 1), the M intervention carcasses, when compared to the C carcasses, experienced a numerical log (CFU/cm²) increase for APC from just prior to chilling (site E) to 24 hr post chill (site F). The reason for this is uncertain; however, it is possible the M intervention car-

cases may have experienced more drip loss from the additional four minute hot water wash, and in turn, diluted the concentration of the subsequent LA spray. The hot water wash may have allowed the M intervention carcasses to enter the cooler at warmer temperatures and taken longer to chill; however, temperatures between the treatments were the same. A numerical increase in log counts (CFU/cm²) for APC, EB, and CL was seen after the evisceration step (Sampling site C). Previous research has reported similar findings by using a LA rinse before evisceration and recording a slight increase overall for APC and EB after evisceration, prior to additional interventions and chilling.

Of the 27 positive *E. coli* O157:H7 samples found prior to interventions, 13 (17.3%) and 14 (18.6%) of the positive samples received the C and M intervention treatments, respectively, which were similar ($P = 1.00$) (Table 5). Two carcass samples (2.67%) receiving the C treatment tested positive for *E. coli* O157:H7 after chilling, and one sample (1.33%) in the M intervention treatment tested positive for *E. coli* O157:H7 after chilling. All three post-chill *E. coli* O157:H7 positive samples occurred on the same day at plant 3. Carcasses testing positive for *E. coli* O157:H7 after chilling were treated with a 5% LA solution and re-tested. All re-tested carcasses were negative for *E. coli* O157:H7. Treatments were similar ($P=0.69$) after the chilling process for positive *E. coli* O157:H7 samples. Both treatments were effective at reducing the occurrence of *E. coli* O157:H7 after interventions were applied.

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Statistics Used in the Nebraska Beef Report and Their Purpose

The purpose of beef cattle and beef product research at UNL is to provide reference information that represents the various populations (cows, calves, heifers, feeders, carcasses, retail products, etc.) of beef production. Obviously, researchers cannot apply treatments to every member of a population; therefore, they must sample the population. The use of statistics allows researchers and readers of the *Nebraska Beef Report* the opportunity to evaluate separation of random (chance) occurrences and real biological effects of a treatment. Following is a brief description of the major statistics used in the beef report. For a more detailed description of the expectations of authors and parameters used in animal science, see *Journal of Animal Science Style and Form* (beginning pp. 339) at <http://jas.fass.org/misc/ifora.shtml>.

- **Mean** — Data for individual experimental units (cows, steers, steaks) exposed to the same treatment are generally averaged and reported in the text, tables and figures. The statistical term representing the average of a group of data points is *mean*.
- **Variability** — The inconsistency among the individual experimental units used to calculate a mean for the item measured is the variance. For example, if the ADG for *all* the steers used to calculate the mean for a treatment is 3.5 lb, then the variance is zero. But, this situation never happens! However, if ADG for individual steers used to calculate the mean for a treatment ranges from 1.0 lb to 5.0 lb, then the variance is large. The variance may be reported as standard deviation (square root of the variance) or as standard error of the mean. The standard error is the standard deviation of the mean as if we had done repeated samplings of data to calculate multiple means for a given treatment. In most cases treatment means and their measure of variability will be expressed as follows: 3.5 ± 0.15 . This would be a mean of 3.5 followed by the standard error of the mean of 0.15. A helpful step combining both the mean and the variability from an experiment to conclude whether the treatment results in a real biological effect is to calculate a 95% confidence interval. This interval would be twice the standard error added to and subtracted from the mean. In the example above, this interval is 3.2-3.8 lb. If in an experiment, these intervals calculated for treatments of interest overlap, the experiment does not provide satisfactory evidence to conclude that treatment effects are different.
- **P Value** — Probability (*P Value*) refers to the likelihood the observed differences among treatment means are due to chance. For example, if the author reports $P \leq 0.05$ as the significance level for a test of the differences between treatments as they affect ADG, the reader may conclude there is less than a 5% chance the differences observed between the means are a random occurrence and the treatments do not affect ADG. Hence we conclude that, because this probability of chance occurrence is small, there must be difference between the treatments in their effect on ADG. It is generally accepted among researchers when *P* values are less than or equal to 0.05, observed differences are deemed due to important treatment effects. Authors occasionally conclude that an effect is significant, hence real, if *P* values are between 0.05 and 0.10. Further, some authors may include a statement indicating there was a “tendency” or “trend” in the data. Authors often use these statements when *P* values are between 0.10 and 0.15, because they are not confident the differences among treatment means are real treatment effects. With *P* values of 0.10 and 0.15, the chance random sampling caused the observed differences is 1 in 10 and 1 in 6.7, respectively.

- **Linear and Quadratic Contrasts** — Some articles refer to linear (L) and quadratic (Q) responses to treatments. These parameters are used when the research involves increasing amounts of a factor as treatments. Examples are increasing amounts of a ration ingredient (corn, byproduct, or feed additive) or increasing amounts of a nutrient (protein, calcium, or vitamin E). The L and Q contrasts provide information regarding the shape of the response. Linear indicates a straight line response and quadratic indicates a curved response. *P*-values for these contrasts have the same interpretation as described above.
- **Correlation (*r*)** — Correlation indicates amount of linear relationship of two measurements. The correlation coefficient can range from -1 to 1 . Values near zero indicate a weak relationship, values near 1 indicate a strong positive relationship, and a value of -1 indicates a strong negative relationship.

Animal Science

<http://animalscience.unl.edu>

Curriculum – The curriculum of the Animal Science Department at the University of Nebraska–Lincoln is designed so that each student can select from a variety of options oriented to specific career goals in professions ranging from animal production to veterinary medicine. Animal Science majors can also easily double major in Grazing Livestock Systems (<http://gls.unl.edu>) or complete the Feedlot Management Internship Program (<http://feedlot.unl.edu/intern>).

Careers:

Animal Health

Banking and Finance

Animal Management

Consultant

Education

Marketing

Technical Service

Meat Processing

Meat Safety

Quality Assurance

Research and Development

Veterinary Medicine

Scholarships – Thanks to the generous contributions of our supporters listed below, each year the Animal Science Department offers 44 scholarships to Animal Science students.

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