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2002 Cattlemen's Day

Kansas State University
Cattlemen's Day
2002

Report of Progress 890

Kansas State University
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EVALUATION OF PERFORMANCE IN RECEIVING HEIFERS FED DIFFERENT SOURCES OF DIETARY LIPID[1]

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H. J. LaBrune, S. P. Montgomery, J. J. Sindt,
C. M. Coetzer, R. D. Hunter, and J. J. Higgins[2]

Summary

Two 35-day receiving experiments were conducted using 668 highly stressed crossbred beef heifers to evaluate differences in growth performance, morbidity, and mortality when fed diets containing differing sources of dietary lipid. Heifers received diets containing beef tallow, tallow enriched with a micro-algae product containing a high proportion of docosahexaenoic acid (an omega-3 fatty acid), full-fat soybeans, or ground flaxseed. All diets contained approximately 60% concentrate and 40% roughage (alfalfa hay). Feed intake, daily gain, and feed efficiency were poorer ($P<0.05$) for cattle fed full-fat soybeans than for those fed the other treatments. Feed intake tended to be reduced when micro-algae was top-dressed to the diet, but gain was not negatively impacted. In Trial 2, feed efficiency was improved by the micro-algae. No notable differences among treatments were evident in the percentage of cattle treated for bovine respiratory disease, but cattle fed flaxseed tended to respond better to therapeutic treatments, requiring fewer retreatments.

(Key Words: Lipids, Receiving Cattle.)

Introduction

The health of weaned calves is often challenged by dramatic stresses such as pathogen exposure, dehydration, food deprivation, commingling, transportation, and climatic changes. These factors can result in multi-faceted diseases such as Bovine Respiratory Disease (BRD). BRD causes enormous economic losses for the U.S. beef industry. Lung damage from the disease can have lasting detrimental effects on animal performance and carcass value or even result in death of the animal. Gram-negative bacteria are the most common and damaging pathogens involved in BRD. Gram-negative bacterial infections are characterized by the animals' reaction to components of the bacterial cell wall, frequently resulting in elevated body temperature and production of a variety of compounds that cause exaggerated inflammatory responses. These inflammatory substances can cause irreversible damage to lung tissues, thereby compromising disease resistance and future productivity of the animal. Nutrition of the animal plays an important role in reducing susceptibility to disease. Some fatty acids (omega-3) have potent anti-inflammatory and immunomodulatory effects, which may prove beneficial when fed to highly stressed feeder calves. Consequently, we designed these studies to compare performance of stressed feeders fed receiving diets containing varying sources of dietary lipid. Treatments consisted of diets containing lipid from rolled full-fat soybeans (SOY), ground flaxseed (FLAX), tallow (TALLOW), and algae (ALGAE).

[1]This research was supported by a grant from the North Dakota Oilseed Council.
[2]Department of Statistics

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Experimental Procedures

Crossbred heifer calves (n = 688) were used in two receiving experiments to evaluate growth performance, morbidity, and mortality when fed diets containing different lipid sources. Dietary treatments (Table 1) were composed of a corn/alfalfa hay-based diet with added tallow (TALLOW), ground flaxseed (FLAX), rolled full-fat soybeans (SOY), or micro-algae top-dressed (ALGAE) on the TALLOW diet. The micro-algae contained a high proportion of docosahexaenoic acid. In Trial 1, algae was top-dressed to provide docosahexaenoic acid at 9.4 g/day for the first 10 days, 6.2 g/day for the second 10 days, and 3.2 g/day for the remaining 15 days. The amount of ALGAE top-dressed onto the ration was modified in Trial 2 to avoid what appeared to be an adverse effect on feed consumption within the first few days after arrival in the feedyard. In Trial 2, ALGAE was top-dressed to provide docosahexaenoic acid at 5.2 g/day for the first 10 days, 8.6 g/day for the second 10 days, and 5.0 g/day for the remaining 15 days.

Calves were purchased from sale barns in Kentucky and Tennessee and transported to the KSU Beef Cattle Research Center in Manhattan. Upon arrival at the feedlot, calves were allowed free choice access to long-stem prairie hay and water and were processed within 24 hours. Body weight and rectal temperature were recorded and heifers were administered Bovishield®-IV, Fortress®-7, Cydectin®, and a Ralgro® implant. Additionally, heifers were given a metaphylactic dose of Micotil® at 1.5 ml per 100 lb BW. A second dose of Bovishield-IV was administered 7 days after initial processing, and at this time rectal temperature and body weight were recorded. Calves were allotted randomly to treatments in each study and placed into pens containing 6 to 7 heifers each. Each experiment contained 13 pens per treatment. Heifers were fed their respective diets (Table 1) once daily throughout the 35-day experiments.

Animals that exhibited clinical signs of undifferentiated bovine respiratory disease (BRD) were identified each morning as candidates for therapeutic treatment. They were treated for BRD if clinical signs were accompanied by a rectal temperature of ≥103.5ºF or if they exhibited clinical signs of BRD for two consecutive days. The initial therapeutic treatment consisted of a subcutaneous injection of Micotil at 1.5 ml/100 lb BW. Heifers were returned to their home pen following treatment. In Trial 1, calves were retreated after 48 hours when clinical signs of BRD were accompanied by a rectal temperature of ≥103.5ºF. In Trial 2 calves were retreated after 48 hours, regardless of rectal temperature. Third-time treatment for both trials was a combination of 6 ml/100 lb BW LA-200® subcutaneously, and 5 ml/100 lb BW Tylan® intramuscularly.

Calves were weighed at the end of the 35-day receiving trials. Average daily gains and efficiencies were computed using the initial weight at processing, the 7-day weight at re-vaccination, and the final weight, all of which were measured approximately 24 hours after feeding.

Results and Discussion

Performance during the two 35-day receiving experiments is summarized in Table 2. In Trial 1, gain during the first 7 days was lowest for SOY and ALGAE. Feed efficiency and average daily gain for the entire receiving period were poorer ($P<0.05$) for SOY when compared to TALLOW, FLAX, and ALGAE. Feed intake for SOY was numerically the lowest, but not significantly different from ALGAE.

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In Trial 2, gain during the first 7 days was lowest for SOY, but not different than ALGAE (P=0.26). Average daily gain over the entire receiving period was lowest (P<0.002) for SOY when compared to FLAX, TALLOW, and ALGAE. Feed efficiency was poorest (P<0.004) for SOY and best for ALGAE, however ALGAE was not different than FLAX (P=0.45). Feed intake was highest for FLAX, though it was not significantly different from TALLOW.

The percentage of animals that received therapeutic treatment for undifferentiated bovine respiratory disease did not vary greatly among experimental diets. Moreover, we conclude that feeding full-fat soybeans to receiving cattle can decrease growth performance during the first 35-days after arrival. These studies indicate that the source of dietary lipid may impact growth performance, feed intake, and efficiency in different ways. However, the incidence of BRD was not greatly affected by dietary treatment.

Table 1. Composition of Receiving Diets in Trials 1 and 2 (100% Dry Basis)

Ingredient, %	TALLOW	FLAX	SOY	ALGAE
Steam-flaked corn	32.9	29.4	32.7	32.9
Alfalfa hay	39.4	39.4	39.5	39.4
Dehulled soybean meal	15.9	10.5	-	15.9
Flaxseed, ground	-	12.9	-	-
Full-fat soybeans, rolled	-	-	20.0	-
Micro-algae[a,b]	-	-	-	daily top-dress
Molasses, cane	4.8	4.8	4.8	4.8
Tallow	4.0	-	-	4.0
Ground corn	2.67	2.67	2.67	2.67
Salt	0.27	0.27	0.27	0.27
Vitamin/mineral premix[c]	0.06	0.06	0.06	0.06
Estimated nutrients[d]				
Trial 1				
Crude protein	18.4	18.6	18.5	18.4
Caclium	0.80	0.80	0.81	0.80
Phosphorus	0.40	0.42	0.37	0.40
Trial 2				
Crude protein	19.2	19.3	19.0	19.2
Calcium	0.66	0.68	0.67	0.66
Phosphorus	0.33	0.36	0.32	0.33

[a]Top-dressed to provide docosahexaenoic acid at 9.4 g/day for the first 10 days, 6.2 g/day for the next 10 days, and 3.2 g/day for the last 15 days per heifer in Trial 1.
[b]Top-dressed to provide docosahexaenoic acid at 5.2 g/day for the first 10 days, 8.6 g/day for the next 10 days, and 5.0 g/day for the last 15 days per heifer in Trial 2.
[c]Provided 1000 IU/lb vitamin A, 0.1 ppm Co, 10 ppm Cu, 0.60 ppm I, 60 ppm Mn, 0.1 ppm Se, 60 ppm Zn, and 25grams/ton Rumensin on a dry basis.
[d]Estimated from analysis of individual feed ingredients.

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Table 2. Performance of Feeder Heifers Fed Receiving Diets Containing Different Sources of Dietary Lipid

	Dietary Treatment				
Item	TALLOW	FLAX	SOY	ALGAE	SEM
Trial 1					
No. pens (heifers)	13 (83)	13 (83)	13 (83)	13 (83)	
Dry matter intake, lb/day	10.45[a]	10.40[a]	9.03[b]	9.93[ab]	0.45
Gain, days 1 to 7, lb/day	1.70[a]	1.80[a]	0.60[b]	0.50[b]	0.38
Gain, days 1 to 35, lb/day	2.74[a]	2.81[a]	2.02[b]	2.60[a]	0.17
Feed:Gain, days 1 to 35	3.81[a]	3.76[a]	4.50[b]	3.84[a]	
Therapeutic treatments, %	50.0	51.1	53.5	50.7	6.2
Retreatments, %	29.1	18.7	27.3	22.7	5.2
Trial 2					
No. pens (heifers)	13 (84)	13 (84)	13 (84)	13 (84)	
Dry matter intake, lb/day	10.35[ab]	10.60[a]	9.55[c]	9.83[bc]	0.26
Gain, days 1 to 7, lb/day	0.85[a]	1.33[a]	-0.12[b]	0.48[ab]	0.38
Gain, days 1 to 35, lb/day	2.65[a]	2.87[a]	2.09[b]	2.75[a]	0.12
Feed:Gain, days 1 to 35	3.90[ad]	3.71[a]	4.61[b]	3.58[ae]	
Therapeutic treatments, %	70.9	72.9	68.9	67.2	4.3
Retreatments, %	37.7	40.8	38.5	41.9	6.3

[a,b,c]Means in a row not bearing a common superscript are different ($P<0.05$).
[d,e]Means in a row not bearing a common superscript tend to be different ($P<0.1$).

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IMMUNE RESPONSE IN FEEDER CATTLE FED DIFFERENT SOURCES OF DIETARY LIPID[1]

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Summary

Two studies were conducted utilizing crossbred beef steers to evaluate immune response following endotoxin challenge. In Trial 1 steers (n = 20; 688 lb BW) were fed diets containing rolled full-fat soybeans (SOY) or tallow (TALLOW). In Trial 2, steers (n=18; 780 lb BW) were fed diets containing TALLOW, flaxseed (FLAX), or a micro-algae (ALGAE) top-dressed to the TALLOW diet. Both FLAX and ALGAE were sources of omega-3 polyunsaturated fatty acids. In both trials, diets were fed for a 14-day acclimation period prior to intravenous injection of a bacterial lipopolysaccharide(LPS) endotoxin. Injection of LPS in Trial 1 resulted in higher rectal temperatures for animals fed TALLOW compared to those fed SOY. In contrast, plasma concentrations of tumor necrosis factor-α (TNF) were higher for animals fed SOY. Haptoglobin and fibrinogen increased and total white blood cell count decreased in response to LPS, but these measures were not different ($P>0.1$) between SOY and TALLOW. In Trial 2, rectal temperature was higher for TALLOW ($P<0.05$) than for FLAX at 3, 4, 5, and 6 hours after the initial injection of LPS. In addition, rectal temperature for TALLOW was higher ($P=0.05$) at hour 4 when compared to ALGAE and tended ($P=0.1$) to be higher at hour 5. Serum haptoglobin concentration at 24 hours was higher ($P<0.05$) for animals fed ALGAE than those fed FLAX or TALLOW. Haptoglobin and fibrinogen concentrations increased at 24 hours after injection with LPS, but were not different at other times among treatments in either trial. Results show that source and type of dietary fatty acid may impact immune response in cattle.

(Key Words: Endotoxin Challenge, Immune Modulation, Lipids.)

Introduction

Undifferentiated Bovine Respiratory Disease (BRD) is common among post-weaning cattle. Losses attributable to this disease complex exceed $800 million annually. Gram-negative bacteria *Pasturella multocida* and *Pasturella haemolytica* are the most problematic pathogens involved in BRD. The animal's reaction to parts of the bacterial cell wall can lead to irreversible lung damage, resulting in reduced future productivity and disease resistance, expensive treatment costs, and even death. A disproportional, exaggerated inflammatory and immune response is the major cause of lung damage. Consequently, moderating the inflammatory response is of much interest. Studies with omega-3 polyunsaturated fatty acids have suggested that they have anti-inflammatory immunomodulatory effects in several species. Our objective was to evaluate responses to an endotoxin challenge in cattle fed diets with

[1]This research was supported by a grant from the North Dakota Oilseed Council.
[2]Food Animal Health and Management Center
[3]Department of Statistics

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and without supplemental sources of omega-3 polyunsaturated fatty acids.

Experimental Procedures

Trial 1. Twenty crossbred beef steers (688 lb BW) were stratified by weight and randomly assigned, within strata, to one of two treatments. Dietary treatments (Table 1) were TALLOW, a standard corn and soybean meal based diet with tallow as the added lipid source, and SOY, where soybean meal and tallow were replaced with rolled full-fat soybeans. Diets were fed once daily. Steers were fed and housed in individual pens with drinking water available at all times. They received equal levels of protein, vitamins, and minerals, and were fed their respective treatments for a 14-day acclimation period. On day 14, steers (n = 16) were fitted with jugular catheters and injected intravenously with bacterial endotoxin (0.09 µg/lb BW *E. coli* 055:B55 lipopolysaccharide; Sigma-Chemical Company, St. Louis, MO). Two steers from each diet were injected with saline to establish baseline blood parameters and temperature readings. Blood samples and rectal temperatures were obtained immediately before (at 0 hours), and at 2, 3, 4, 5, and 24 hours after LPS challenge. All blood samples were analyzed for concentrations of tumor necrosis factor alpha (TNF), fibrinogen, haptoglobin, and total white blood cell count.

Trial 2. Eighteen crossbred beef steers (780 lb BW) were stratified by weight and randomly assigned, within strata, to one of three treatments. Dietary treatments (Table 2) were: TALLOW, FLAX, where a portion of the soybean meal and corn were replaced with ground flaxseed, and ALGAE, in which the TALLOW diet was top-dressed daily with an algae fermentation product containing a high proportion of docosahexanoic acid. The ALGAE was top-dressed to provide docosahexaenoic acid at 10 g/animal daily. Both FLAX and ALGAE are sources of omega-3 fatty acids. Steers were housed under the same conditions as in Trial 1 and were fed their respective dietary treatments once daily for a 14-day acclimation period. On day 14, steers were fitted with jugular catheters and injected intravenously with bacterial endotoxin (0.09 µg/lb BW *E. coli* 055:B55 lipopolysaccharide). Blood samples and rectal temperatures were obtained immediately before (0 hour), and at 1, 2, 3, 4, 6, and 24 hours following LPS challenge. Blood samples were analyzed as in Trial 1.

Results and Discussion

Trial 1. Injection of the bacterial lipopolysaccharide (LPS) resulted in dramatic increases in rectal temperature, TNF, haptoglobin, and reductions in white blood cell count (Tables 3 and 4). Rapid changes in rectal temperatures, as well as changes in white blood cell count, TNF, and haptoglobin, relative to saline-injected animals, indicate that the model was effective in emulating a disease challenge.

After injection of LPS, rectal temperatures at hour 3 were greater ($P<0.03$) for TALLOW animals than for SOY and tended ($P=0.08$) to be higher at hour 4.

After injection of LPS, TNF was greater ($P<0.01$) for SOY than TALLOW at hour 2, but had returned to baseline by hour 5. White blood cell numbers were significantly reduced by 1 hour after injection of LPS, and by hour 24 the reduction was stabilized and white blood cell numbers returned to baseline. However, no differences between dietary treatments were observed. Changes in acute phase proteins (fibrinogen and haptoglobin) were not apparent other than in the sample obtained 24 hours after injection of LPS. That indicated a delayed response to the endotoxin challenge by these acute phase proteins. Fibrinogen and haptoglobin increased in response to LPS, but were not different for

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SOY and TALLOW (P>0.1). This study indicates that manipulating dietary lipid source may alter immune and inflammatory responses in challenged cattle.

Trial 2. As in Trial 1, injection of cattle with LPS resulted in elevated rectal temperature, TNF, acute phase proteins, and reduced white blood cell count (Tables 3 and 5).

Changes in rectal temperature following LPS administration were highest for TALLOW, intermediate for ALGAE, and lowest for FLAX. Rectal temperatures for animals fed TALLOW were higher (P<0.05) at hours 3, 4, 5, and 6, compared to those fed FLAX. Furthermore, rectal temperature for TALLOW was higher (P=0.05) at hour 4 and tended to be higher (P=0.10) at hour 5 that for animals fed ALGAE. ALGAE led to higher rectal temperatures than FLAX at hours 3 and 6 (P<0.09).

Rapid increases in TNF production were evident immediately after LPS injection, but returned to baseline by hour 4. Peripheral blood white blood cell count fell immediately after LPS injection on both days 14 and 17, and returned to pre-LPS injection levels by hour 24. This observation is in agreement with Trial 1. However, dietary treatments did not cause differences in white blood cell numbers after LPS injection.

Changes in acute phase proteins, fibrinogen and haptoglobin, were not evident other than in the sample taken 24 hours after LPS injection, indicating a delayed response to endotoxin challenge. Serum haptoglobin concentration for ALGAE was higher (P<0.05) at hour 24 when compared to TALLOW and FLAX.

These studies indicated that the source of dietary lipids may have a significant impact on immune response in cattle.

Table 1. Composition of Experimental Diets in Trial 1 (100% Dry Basis)

Ingredient, %	TALLOW	SOY
Full-fat soybeans	-	20.0
Tallow	3.8	-
Dry-rolled corn	22.3	22.0
Soybean meal	15.9	-
Alfalfa hay	25.0	25.0
Prairie hay	25.0	25.0
Cane molasses	5.0	5.0
Vitamin-mineral premix[a]	3.0	3.0

[a]Provided 1000 IU/lb vitamin A, 0.1 ppm Co, 10 ppm Cu, 0.60 ppm I, 60 ppm Mn, 0.1 ppm Se, 60 ppm Zn, and 25 grams/ton Rumensin on a dry matter basis.

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Table 2. Composition of Experimental Diets in Trial 2 (100% Dry Basis)

Ingredient, %	TALLOW	FLAX	ALGAE
Tallow	4.0	-	4.0
Microalgae[a]	-	-	daily top-dress
Ground flaxseed	-	12.9	-
Flaked corn	32.9	29.4	32.9
Alfalfa hay	39.4	39.4	39.4
Soybean meal	15.9	10.5	15.9
Vitamin mineral premix[b]	3.0	3.0	3.0
Cane molasses	4.8	4.8	4.8

[a]Top-dressed to provide docosahexaenoic acid at 10 g/animal daily.
[b]Provided 1000 IU/lb vitamin A, 0.1 ppm Co, 10 ppm Cu, 0.60 ppm I, 60 ppm Mn, 0.1 ppm Se, 60 ppm Zn, and 25 grams/ton Rumensin on a dry matter basis.

Table 3. Rectal Temperature Profiles, °F

	Hour after LPS injection							
Item	0	1	2	3	4	5	6	SEM
Trial 1[1]								
TALLOW-LPS	102.2	103.6	104.2	104.9[a]	104.7[c]	-	103.2	.35
SOY-LPS	102.1	103.3	103.5	103.8[b]	103.8[d]	-	103.1	.35
TALLOW-no LPS	102.6	101.7	101.9	101.9	101.6	-	101.9	.69
SOY-no LPS	102.1	102.2	102.1	102.3	101.7	-	101.6	.69
Trial 2								
TALLOW	102.4	103.7	104.0	104.9[a]	104.8[a]	103.9[a,c]	103.1[a]	.29
FLAX	102.2	103.6	103.7	103.6[b,c]	103.4[b]	102.8[b]	102.1[b]	.29
ALGAE	102.6	103.6	103.8	104.3[d]	104.0[b]	103.2[d]	102.9[a]	.29

[1]Contrast LPS vs. NO-LPS (P<0.05).
[a,b]TALLOW different from SOY at hour 3 (P<0.03).
[c,d]TALLOW tended to be different from SOY at hour 4 (P=0.08).
[a,b]Means within a column with different superscripts are different (P<0.05).
[c,d]Means within a column with different superscripts tended to be different (P<0.1).

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Table 4. Blood Constituents From Trial 1

	Hour After LPS Injection						
Item	0	2	3	4	5	24	SEM
TNF α, ng/ml[1]							
TALLOW-LPS	0.17	1.36[a]	0.48	0.26	0.18	-	0.15
SOY-LPS	0.17	2.04[b]	0.60	0.26	0.20	-	0.15
TALLOW-no LPS	0.15	0.16	0.16	0.11	0.12	-	0.31
SOY-no LPS	0.17	0.16	0.20	0.21	0.18	-	0.31
Fibrinogen, mg/dl							
TALLOW-LPS	438	463	438	450	338	538	53
SOY-LPS	350	300	325	288	263	425	53
TALLOW-no LPS	400	400	400	350	300	350	107
SOY-no LPS	350	400	400	300	200	300	107
Total white blood cell count, $\times 10^3$/ml							
TALLOW-LPS	9.9	2.5	1.7	2.4	3.2	10.6	0.44
SOY-LPS	10.5	2.4	1.5	1.7	2.4	10.5	0.44
TALLOW-no LPS	9.1	8.7	8.6	8.4	9.0	9.0	0.88
SOY-no LPS	9.6	9.2	8.9	9.2	8.9	8.8	0.88
Haptoglobins, mg %[1]							
TALLOW-LPS	7.9	9.6	12.4	13.3	8.9	27.9	0.98
SOY-LPS	7.5	9.0	12.8	12.8	9.6	29.1	0.92
TALLOW-no LPS	7.5	8.5	12.0	13.0	9.0	10.0	1.84
SOY-no LPS	10.5	9.0	13.0	13.0	9.5	10.5	1.84

[a,b]Means within columns with different superscripts are different ($P<0.01$).
[1]Contrast LPS vs. no-LPS ($P<0.05$).

Table 5. Blood Constituents From Trial 2

	Hour after LPS Injection							
Item	0	1	2	3	4	6	24	SEM
TNF-α, ng/ml								
TALLOW	0.17	0.88	0.51	0.24	0.20			0.13
FLAX	0.19	0.79	0.64	0.34	0.19			0.15
ALGAE	0.20	1.00	0.70	0.40	0.20			0.13
Fibrinogen, mg/dl								
TALLOW	350	350	317	300	267	317	400	48
FLAX	350	350	317	250	300	333	400	48
ALGAE	283	250	300	250	300	283	367	48
Total white blood cell count, $\times 10^3$/ml								
TALLOW	9.7	2.8	3.1	2.7	3.3	5.0	9.7	0.88
FLAX	10.5	3.1	3.7	3.6	3.8	6.3	10.3	0.88
ALGAE	11.5	3.3	3.2	3.0	3.2	5.3	10.3	0.88
Haptoglobin, mg/dl								
TALLOW	5.2	5.7	5.8	5.3	5.5	8.0	10.8[a]	0.86
FLAX	5.3	5.5	5.5	6.3	6.5	6.8	9.0[a]	1.05
ALGAE	6.5	5.7	5.7	5.8	7.0	6.5	15.0[b]	0.86

[a,b]Means within a column with different superscripts are different ($P<0.05$).

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EFFECTS OF GRAIN PROCESSING AND LIPID ADDITION TO FINISHING DIETS ON CATTLE PERFORMANCE AND BLOOD CONSTITUENTS[1]

H. J. LaBrune, J. S. Drouillard, A. M. Trater, J. N. Pike, S. M. Montgomery, T. B. Farran, and J. J. Sindt

Summary

Experiments were conducted to evaluate effects of grain processing and lipid source on finishing cattle performance, carcass characteristics, and plasma concentrations of glucose, urea, and α-amino nitrogen (amino acids). Eighty yearling Hereford x Angus steers (847 lb) were fed diets containing either steam-flaked corn or dry-rolled corn, both fed with and without 4% added tallow. In a fifth diet, ground flaxseed (equivalent to 4% lipids) replaced a portion of steam-flaked corn. Diets were fed once daily for 85 days. As expected, cattle fed steam-flaked corn were more efficient than steers fed dry-rolled corn. Adding tallow had little effect on performance. Including flaxseed resulted in performance similar to that with tallow addition. Plasma glucose concentrations measured 2 hours after feeding were higher for steers fed steam-flaked corn than for steers fed dry-rolled corn, and were higher for cattle fed tallow than for those fed no supplemental fat. Steers fed the flax/steam-flaked corn combination had lower plasma glucose concentrations 2 hours after feeding than those fed steam flaked corn with added tallow ($P<0.05$). Steam flaking corn increased performance and elevated glucose concentrations compared to dry rolling, suggesting that increasing the ruminal degradable starch allowed for a greater supply of substrates for gluconeogenesis. Adding flaxseed resulted in lower levels of plasma glucose after feeding, compared to tallow.

(Key Words: Steam-Flaked Corn, Dry-Rolled Corn, Flax, Tallow.)

Introduction

Compared with dry rolling, steam flaking of corn in cattle finishing rations increases ruminal digestibility of starch. In monogastric animals such as pigs, the degree of starch gelatinization can result in changes in circulating glucose concentrations after ingestion of a meal. Furthermore, these levels can be altered by both dietary fat concentration and fat type. Tallow is frequently an economical source of energy for cattle rations and is high in saturated fatty acids. Alternatively, flaxseed contains approximately 40% lipid, which is highly unsaturated, containing approximately 60% alpha linolenic acid. Our objectives were to evaluate effects of grain processing and dietary fat sources on animal performance, carcass attributes, and circulating glucose concentrations in finishing cattle.

Experimental Procedures

Eighty Hereford × Angus steers (847 lb BW) were adapted to a common dry-rolled corn diet for 7 days prior to initiating the experiment to minimize differences in gastrointestinal fill. Animals were stratified by initial weight and allotted, within strata, to five experimental treatments with 16 steers per treatment. The experiment was a randomized complete-block design with individual animal as the experimental unit.

[1]This research was supported by a grant from the North Dakota Oilseed Council.

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Dietary treatments (Table 1) were: steam-flaked corn, steam-flaked corn plus 4% tallow, dry-rolled corn, dry-rolled corn plus 4% tallow, or steam-flaked corn plus 10% ground flaxseed. Steers were placed into individual pens and fed their respective diets once daily for 85 days. Cattle were implanted with Component-TES. Cattle were weighed and blood was collected via jugular vein puncture approximately 15 hours after feeding on days 0, 43, 71, and at 2 hours after feeding on day 78.

On day 85, steers were individually weighed and shipped to a commercial slaughter facility where carcass data were collected. Hot carcass weights and liver abscess scores were obtained at slaughter. Percentage of kidney, pelvic, and heart fat; 12th-rib fat thickness; marbling score; longissimus muscle area; USDA yield grade; and USDA quality grade were obtained after a 24-chill. Dressing percentages were calculated on an individual basis as hot carcass weight divided by final live weight. Data were analyzed by analysis of variance as a $2 \times 2 + 1$ randomized complete block design using the MIXED procedure of SAS with individual animal as the experimental unit.

Results and Discussion

Diets are shown in Table 1. The crude protein concentration of the diet containing flaxseed was greater than that of other treatments. Long chain fatty acid concentrations of dietary lipid sources are presented in Table 2. As expected, Flaxseed contained much higher levels of polyunsaturated fatty acids than tallow. Tallow, on the other hand, contained greater amounts of saturated and monounsaturated fatty acids.

Steers fed diets containing steam-flaked corn had higher gains (Table 3), resulting in heavier carcasses compared to steers fed dry-rolled corn ($P<0.10$). Different dietary lipid sources (flax vs. tallow) resulted in similar ($P=0.60$) gains and feed efficiencies. Feed efficiency was better for steers fed diets containing steam-flaked corn than for those fed dry-rolled corn ($P<0.10$). Adding tallow to diets of finishing steers resulted in less subcutaneous fat deposition over the 12th rib when compared to diets with no added tallow ($P<0.10$; Table 3). There were no significant differences among diets in the percentages of carcasses grading USDA Choice, or in kidney, pelvic, and heart fat ($P>0.5$). Yield grade was lower ($P<0.10$) for steers fed dry-rolled corn than for those fed steam-flaked corn. Liver abscesses were significantly higher for steers fed flaked corn and steam-flaked corn with tallow compared to dry-rolled corn and dry-rolled corn with tallow ($P<0.10$).

Concentrations of plasma glucose, plasma urea nitrogen, and total α-amino nitrogen are presented in Table 4. Steers fed dry-rolled corn diets had lower glucose concentrations on days 43 and 78 than steers fed steam-flaked corn or steam-flaked corn with added tallow. On day 78, feeding flaxseed lowered post-feeding plasma glucose compared to adding tallow. Hydrothermal processes such as steam-flaking can drastically alter the protein characteristics.

Measurements of plasma urea nitrogen taken on days 43, 71 and 78 were lower for diets containing steam-flaked corn or steam-flaked corn with tallow compared to dry-rolled corn or dryrolled corn with tallow ($P<0.10$). This suggests greater absorption of ammonia from the rumen with dry-rolled corn. Tallow supplementation decreased plasma urea nitrogen concentrations on day 43 ($P<0.10$), but no effect was observed on days 71 or 78.

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Steam flaking corn created elevated concentrations of plasma glucose two hours after feeding compared to dry-rolled corn, suggesting a greater availability of glucogenic precursors. Steam flaking corn also allowed some protein to bypass ruminal degradation resulting in lower plasma urea nitrogen and higher plasma α-amino nitrogen compared to dry-rolled corn. Flax addition to steam-flaked corn diets resulted in lower plasma glucose concentrations compared to steers fed flaked corn diets containing tallow, which may reduce the incidence of certain metabolic disorders.

Table 1. Composition of Experimental Diets (100% Dry Basis)

	Diet				
Item	SFC[a]	SFC/ Tallow	DRC[b]	DRC/ Tallow	SFC/ Flax
Steam-flaked corn	79.6	75.6	-	-	69.6
Dry-rolled corn	-	-	79.6	75.6	-
Ground flaxseed	-	-	-	-	10.0
Alfalfa hay	8.0	8.0	8.0	8.0	8.0
Soybean meal	3.06	3.06	3.06	3.06	3.06
Urea	1.19	1.19	1.19	1.19	1.19
Molasses	4.0	4.0	4.0	4.0	4.0
Tallow	-	4.0	-	4.0	-
Salt	0.30	0.30	0.30	0.30	0.30
Limestone	1.15	1.15	1.15	1.15	1.15
Monocalcium phosphate	0.12	0.12	0.12	0.12	0.12
Vitamin/mineral mix[c]	0.29	0.29	0.29	0.29	0.29
Monensin/tylosin premix[d]	2.23	2.23	2.23	2.23	2.23
Crude protein[e], %	14.2	13.9	14.2	13.9	15.8

[a]Steam-flaked corn. [b]Dry-rolled corn. [c]Provided 8 ppm Cu, 0.1 ppm Co, 50 ppm Mn, 0.25 ppm Se, 50 ppm Zn, 1200 IU/lb vitamin A, and 9 IU/lb vitamin E. [d]Provided 33 ppm Rumensin and 11 ppm Tylan (100% dry basis) in a ground corn carrier. [e]Calculated value.

Table 2. Long Chain Fatty Acid Concentrations in Dietary Fat Sources

Fatty acid	Tallow	Flaxseed
	% of total fatty acids	
C14:0	3.2	-
C16:0	24.9	6.4
C16:1	3.2	-
C18:0	22.5	3.1
C18:1	43.6	20.3
C18:2	2.3	15.9
C18:3	0.3	54.2
C20:5	-	-

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Table 3. Performance and Carcass Traits of Finishing Steers

	Diets					
Item	SFC[a]	SFC/ Tallow	DRC[b]	DRC/ Tallow	SFC/ Flax	SEM
No. of steers	16	16	16	16	16	-
Initial weight, lb	886	895	902	888	888	37
Final weight, lb[c]	1228	1224	1193	1184	1224	53
Dry matter intake, lb/day	21.4	20.3	21.2	20.9	20.2	1.2
Gain, lb/day[c]	4.03	3.86	3.44	3.48	3.97	0.33
Feed:gain, lb/lb [c]	5.56	5.26	6.25	5.88	5.00	0.16
Carcass adj. gain, lb/day[g]	4.07	4.01	3.28	3.46	3.92	0.31
Hot carcass weight, lb[c]	761	761	728	728	754	33
USDA Yield grade[c]	2.69	2.81	2.56	2.25	2.63	0.14
USDA Choice, %	50	50	75	56	69	15.8
Marbling score[ef]	Sl^{85}	Sm^{21}	Sl^{94}	Sl^{86}	Sm^{04}	18.9
Fat over 12th rib, in[cd]	0.43	0.40	0.38	0.34	0.42	0.01
Ribeye area, sq in [d]	12.7	13.0	12.4	13.0	12.7	0.03
Kidney, pelvic, & heart fat, %	2.1	2.2	2.1	2.1	2.2	0.10
Liver abscesses, % [d]	25	0	13	0	0	7.9

[a]Steam-flaked corn. [b]Dry-rolled corn. [c]DRC and DRC/Tallow different from SFC and qSFC/Tallow (P<0.10). [d]DRC and SFC different from DRC/Tallow and SFC/Tallow (P<0.10). [e]SFC/Tallow different from Flax (P<0.10). [f]Sl=Slight, Sm=Small. [g](Hot carcass weight/0.6164) – initial weight/85.

Table 4. Plasma Concentrations for Glucose, Urea N, and Total α-Amino N

	Diets					
Item	SFC[a]	SFC/ Tallow	DRC[b]	DRC/ Tallow	SFC/ Flax	SEM
Glucose, mM						
Day 43[c]	4.63	4.84	4.48	4.32	4.78	0.23
Day 71	4.94	4.94	4.69	4.58	4.95	0.39
Day 78, (2 hours after feeding)[cd]	4.76	5.22	4.66	4.68	4.59	0.26
Urea N, mM						
Day 43[cde]	10.6	8.6	11.6	11.2	11.7	0.55
Day 71[ce]	9.7	10.0	12.9	12.0	11.8	0.58
Day 78, (2 hours after feeding)[ce]	14.3	12.8	15.6	15.0	16.2	0.89
Total α-amino nitrogen, mM						
Day 43[c]	2.77	2.70	2.47	2.41	2.86	0.11
Day 71[c]	2.63	2.77	2.54	2.37	2.84	0.12
Day 78, (2 hours after feeding)[c]	2.90	2.96	2.67	2.76	3.15	0.12

[a]Steam-flaked corn. [b]Dry-rolled corn. [c]DRC and DRC/Tallow different from SFC and SFC/Tallow (P<0.10). [d]DRC and SFC different from DRC/Tallow and SFC/Tallow (P<0.10). [e]SFC/Tallow different from Flax (P<0.05).

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EFFECTS OF MELENGESTROL ACETATE (MGA) ON PERFORMANCE AND CARCASS QUALITY OF FEEDLOT HEIFERS

J. T. Fox, J. S. Drouillard, M. F. Spire[1], T. J. Kessen, and M. J. Sulpizio

Summary

Sixty yearling heifers (827 lb initial body weight) were fed finishing diets an average of 95 days. To eliminate social interaction and riding, they were fed in individual pens. Diets were formulated using steam-flaked corn and alfalfa hay. Thirty of the heifers were given 0.5 mg/head daily of MGA. Feed intakes, daily gains, and feed efficiencies were not significantly affected by MGA. However, heifers fed MGA had a greater percentage of carcasses grading USDA Prime and Choice. There also was greater incidence of USDA yield grade 3 and 4 carcasses with MGA supplementation. MGA generally increased fat deposition, but had no significant effect on feedlot performance of individually fed heifers.

(Key Words: Finishing Heifers, Melengestrol Acetate (MGA), Performance, Carcass Quality.)

Introduction

As part of a larger study, we are looking at how MGA affected several blood constituents. This report focuses on how MGA affected the heifer's performance and carcass quality. Previous research indicates that MGA improves feed efficiency and rate of gain when fed to heifers in feedlot pens. For this trial, heifers were fed in individual pens to eliminate social interaction and riding behavior.

Our objective was to observe differences, when fed individually, in performance and carcass quality of heifers supplemented with 0.5 mg MGA per head daily versus heifers not supplemented.

Experimental Procedures

Sixty yearling heifers were placed into individual feeding pens and fed for an average of 95 days. The diets (Table 1) were formulated using alfalfa hay and steam-flaked corn. Upon arrival, heifers were weighed, dewormed with Cydectin®, implanted with Revalor-H®, and measured for subcutaneous fat thickness by ultrasound and metabolic profile via infrared imaging. Heifers were stratified by initial weight, initial ultrasound fat thickness, and initial thermal profile. Cattle were then randomly allotted, within strata, to dietary treatments (Table 1) that provided 0 or 0.5 mg/head daily of MGA. Cattle were placed into 5 ft × 22 ft, concrete-surfaced, partially covered individual feeding pens, each equipped with its own feed bunk. A water fountain was shared between two pens. The heifers were fed at approximately 8:00 a.m. each morning. Feed remaining in the bunk the following morning was collected and weighed to determine dry matter intake. Heifers were shipped to a commercial abattoir in Emporia, Kansas when they achieved an estimated 12th rib fat thickness of 0.5 inches. They were fed an average of 95 days.

[1]Food Animal Health and Management Center

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Results and Discussion

Performance of heifers and carcass data are shown in Tables 2 and 3, respectively. MGA had no significant effect on feedlot gains or efficiencies of individually fed heifers. By feeding animals individually, we may have reduced the potential benefits of MGA supplementation by eliminating the opportunity for bulling activity. Deposition of intramuscular fat was significantly greater for heifers fed MGA than for controls, thereby increasing the proportion of heifers that graded average Choice, high Choice, or Prime. Supplementation with MGA also resulted in greater deposition of kidney, pelvic and heart fat, and increased USDA yield grades. MGA appears to have effects on tissue accretion that are independent of cycling behavior, feed intake, and growth rate.

Table 1. Experimental Diets (% of Dry Matter)

	MGA	No MGA
Flaked corn	52.5	52.5
Corn distiller's dried grains	25.0	25.0
Corn steep liquor	8.0	8.0
Alfalfa hay	8.0	8.0
Ground corn	1.9	1.9
Limestone	1.19	1.19
Potassium chloride	0.43	0.43
Salt	0.30	0.30
Vitamin/trace mineral premix[a]	0.08	0.08
Rumensin, Tylan, MGA premix[b]	2.6	
Rumensin, Tylan premix[b]		2.6

[a]Vitamin/trace mineral premix provide (total diet dry matter) 20 ppm Cu, 0.1 ppm Co, 0.5 ppm Mn, 53 ppm Se, 50 ppm Zn, and 1200 IU vitamin A per lb of diet.

[b]Feed additives were included in a ground corn carrier and provided, where applicable, 300 mg Rumensin, 90 mg Tylan, and 0.5 mg melengestrol acetate per head daily.

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Table 2. Performance and Carcass Data

Item	MGA	No MGA	SEM	P-value
Number of heifers	30	30		
Initial weight, lb	827	827	11.9	0.96
Final weight, lb	1123	1122	14.0	0.94
Dry matter intake, lb/day	19.0	18.4	0.34	0.28
Average daily gain, lb/day	3.14	3.11	0.083	0.82
Feed:gain	6.05	5.94	0.120	0.52
Dress yield, %	61.66	61.64	0.258	0.95
Hot carcass weight, lb	693	692	9.9	0.91
12th rib fat thickness, in	0.50	0.48	0.031	0.73
Kidney, pelvic, & heart fat, %	2.13	1.86	0.07	<0.01
Ribeye area, in^2	12.2	12.7	1.9	0.25
USDA Prime, %	7.2	0	3.2	0.15
USDA Average Choice or better, %	25.6	9.0	5.7	0.04
USDA Choice, %	49.5	39.5	8.4	0.40
USDA Select, %	32.0	42.0	8.9	0.43
Yield grade 1, %	0	12.6	4.4	0.04
Yield grade 2, %	33.6	43.7	8.2	0.39
Yield grade 3, %	59.8	39.8	8.1	0.09
Yield grade 4, %	7.4	4.1	4.0	0.55

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EFFECT OF METHIONINE SUPPLEMENTATION ON METHIONINE METABOLISM IN GROWING CATTLE

B. D. Lambert, E. C. Titgemeyer and C. A. Löest

Summary

Methionine is often the first limiting amino acid for growing cattle. This study was conducted to determine how methionine metabolism is regulated in the liver of growing steers. Six ruminally cannulated steers were used in a replicated 3 × 3 Latin square experiment. Either 0, 5, or 10 g/day L-methionine was infused into the abomasum. These treatments were designed to be deficient, adequate, and in excess of the steers' requirements for methionine. Methionine supplementation linearly increased protein deposition and decreased the activity of methionine synthase (a methionine conserving enzyme). However, it had little effect on activity of cystathionine synthase (an enzyme that produces cysteine from methionine). Our results suggest that methionine metabolism and regulation in cattle may vary from that in monogastrics.

(Key Words: Methionine, Amino Acids, Growth.)

Introduction

Methionine is often the first limiting amino acid for growing cattle. We have previously evaluated methionine requirements in growing cattle and assessed some factors that impact how efficiently it is utilized. In species such as pigs and chickens, cysteine can reduce the requirement for methionine by about one-half under the appropriate conditions. However, we have been unable to observe this sparing effect in growing cattle. This study was conducted to determine how methionine metabolism is regulated in the liver of growing steers, with the ultimate goal of determining why cysteine has not been shown to spare methionine in cattle.

Experimental Procedures

Six ruminally cannulated steers (452 lb initial body weight) were used in a replicated 3 × 3 Latin square experiment. Steers were maintained in individual metabolism crates to allow for full collection of feces and urine. Nitrogen retention was used as an indicator of lean protein deposition, and liver biopsies were obtained to measure liver enzyme activities at different methionine intakes. Methionine was infused into the abomasum at either 0, 5, or 10 g/day L-methionine; levels designed to be deficient, adequate, and in excess of the steers' requirements for methionine, respectively. However, the nitrogen retention data suggested that the highest level did not greatly exceed the animals' needs.

Steers were fed 5.7 lb/day (dry matter basis) of a soybean hull-based diet (83% soyhulls, 8% wheat straw) twice daily. Steers received ruminal infusions of volatile fatty acids (180 g/day acetate, 180 g/day propionate, and 45 g/day butyrate) and abomasal infusions of 300 g/day dextrose to provide supplemental energy. In order to insure that methionine was the first limiting amino acid for lean tissue deposition, a supplemental mixture containing 300 g/day of essential and nonessential

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amino acids was infused into the abomasum.

Results and Discussion

Nitrogen balance data are presented in Figure 1. Nitrogen retention increased linearly ($P<0.01$) with methionine supplementation, which indicated that the steers were deficient in methionine when either 0 or 5 g/day was supplemented. Based on previous trials, we expected the steers' requirement to be near 5 g/day.

Methionine supplementation decreased the activity of liver methionine synthase (a methionine-conserving enzyme) (Figure 2). At low methionine levels, this enzyme prevents the conversion of methionine to cysteine. However, either 5 or 10 g/day of supplemental methionine reduced the activity of the enzyme, which would allow for conversion of methionine to cysteine.

Activity of cystathionine synthase (an enzyme that produces cysteine from methionine) in the liver of steers is shown in Figure 3. Based on other species, we expected that cystathionine synthase activity would increase as methionine supply increased, facilitating both the production of cysteine and the removal of excess methionine. Because we may not have supplied a true excess in methionine, it is not surprising that the activity of this enzyme was not altered.

The activities of these enzymes in our steers appear to be different than those measured in monogastric animals. Methionine synthase activity was higher than in rats, whereas cystathionine synthase was lower. This suggests that cattle may be more efficient in conserving methionine than rats, which appear to metabolize methionine similar to pigs and chickens.

Our results suggest that the regulation of methionine metabolism in the liver of cattle may be different than in other species. However, we are not able to definitively answer our initial question as to why cysteine did not spare methionine in cattle.

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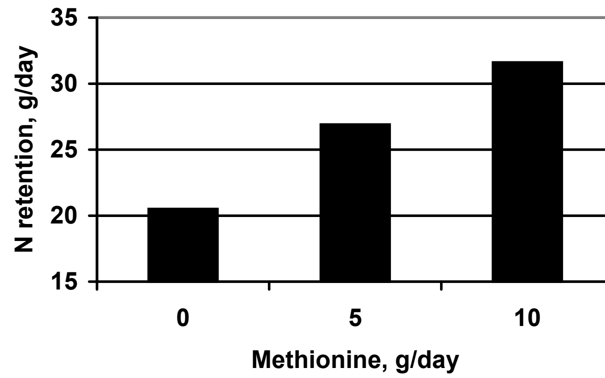

Figure 1. Effect of Methionine Supplementation on Nitrogen Retention of Growing Steers.

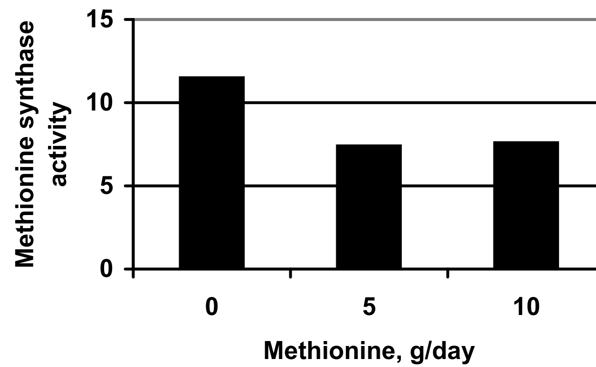

Figure 2. Effect of Methionine Supplementation on Methionine Synthase Activity in Liver of Growing Steers.

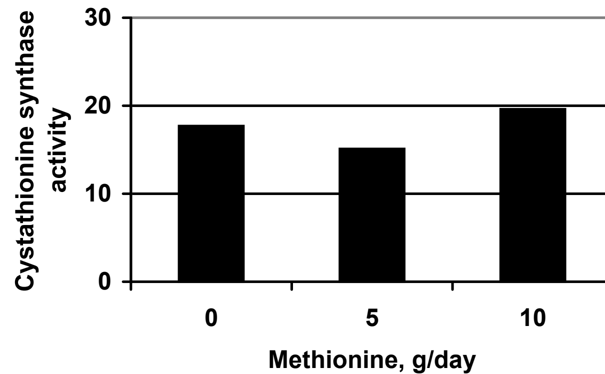

Figure 3. Effect of Methionine Supplementation on Cystathionine Synthase Activity in Liver of Growing Steers.

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EFFECT OF GLYCINE SUPPLEMENTATION ON SULFUR AMINO ACID USE IN GROWING CATTLE

B. D. Lambert, E. C. Titgemeyer and C. A. Löest

Summary

Previous research has suggested the possibility that the supply of glycine, a nonessential amino acid, might affect how efficiently cattle use methionine. This study was conducted to determine the role of glycine on methionine utilization in growing steers as well as how glycine might impact utilization of cysteine, an amino acid produced in the body from methionine. In Exp. 1, treatments were abomasal infusion of 2 or 5 g/day L-methionine and 0 or 50 g/day glycine in a factorial arrangement. Efficiency of methionine use was 27% in the absence of supplemental glycine, but 66% in its presence. Glycine supplementation by itself had little effect on protein deposition. In Exp. 2, treatments were abomasal infusions of 0 or 2.4 g/day L-cysteine and 0 or 40 g/day glycine in a factorial arrangement. Supplementation with cysteine in the absence of supplemental glycine did not change nitrogen balance. In fact, when glycine was supplemented alone, nitrogen retention decreased. However, when glycine and cysteine were supplemented together, nitrogen retention was increased. Thus, in the presence of supplemental glycine, it appears that cysteine can improve protein deposition, presumably by sparing methionine. Comparison of this and earlier studies suggests that B-vitamin status may play an important role in this response.

(Key Words: Glycine, Methionine, Growth.)

Introduction

Methionine is often the first limiting amino acid for growing cattle. Previous research has suggested that the supply of glycine, a nonessential amino acid, might affect how efficiently cattle use methionine. Methionine utilization is intertwined with metabolism of methyl groups because it serves as a primary methyl group donor as well as being an amino acid that is necessary for protein deposition. Glycine has the potential to either serve as a source of methyl groups or to deplete the supply of methyl groups available in the body. This study was conducted to determine the role of glycine on methionine utilization in growing steers as well as how glycine might impact utilization of cysteine, an amino acid that is produced in the body from methionine.

Experimental Procedures

Two separate experiments were conducted. In Exp. 1, four ruminally cannulated steers (290 lb initial body weight) were allotted for use in a 4 × 4 Latin square experiment, although only three actually completed the study. Steers were maintained in individual metabolism crates to allow for complete collection of feces and urine. Nitrogen retention was used as an indicator of lean protein deposition.

Treatments were infused directly into the abomasum and were either 2 or 5 g/day L-methionine and 0 or 50 g/day glycine in

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a factorial arrangement. Previous research shown that for cattle maintained under similar conditions, 2 g/day methionine was deficient and that steers would increase protein deposition when given additional methionine. By providing two levels of methionine both in the absence and presence of supplemental glycine, we could determine if the steers' response to methionine was impacted by glycine supply.

Steers received continuous abomasal supplements of folic acid, vitamin B_6, and vitamin B_{12} so that deficiencies would not confound results. Steers were fed 5.1 lb/day (dry matter basis) of a soybean hull-based diet (83% soyhulls, 8% wheat straw) twice daily. They received ruminal infusions of volatile fatty acids (180 g/day acetate, 180 g/day propionate, and 45 g/day butyrate) and abomasal infusions of 300 g/day dextrose to provide supplemental energy. To ensure that methionine was the first limiting amino acid for lean tissue deposition, a supplemental mixture containing 350 g/day of essential and nonessential amino acids was infused into the abomasum.

In Exp. 2, four ruminally cannulated steers (505 lb initial body weight) were used in a 4 × 4 Latin square design. Experimental conditions were similar to Exp. 1, except that the steers were fed 6.0 lb/day of diet and the supplemental amino acid mixture was reduced to 260 g/day. Treatments consisted of 0 or 2.4 g/day L-cysteine and 0 or 40 g/day glycine in a factorial arrangement. All steers received 2 g/day methionine in order to ensure that methionine was more limiting than cysteine, a prerequisite for response to cysteine supplementation. By evaluating responses to cysteine both in the presence and absence of supplemental glycine, we were able to determine if glycine impacted the ability of cysteine to spare methionine.

Results and Discussion

In Exp. 1, methionine supplementation increased N retention (Figure 1). When methionine was supplemented in the absence of glycine, N balance increased from 34.4 g/day to 40.9 g/day. This change would indicate an efficiency of methionine use of 27%. However, when methionine was supplemented in the presence of 50 g/day supplemental glycine, the methionine response was an increase from 33.6 to 49.5 g/day, an efficiency of methionine use of 66%. Thus, it appears that supplemental glycine led to improvements in the efficiency of methionine use. This suggests that glycine served as a source of methyl groups. Interestingly, glycine supplementation by itself had little effect on protein deposition by our steers.

In Exp. 2, supplementation with cysteine in the absence of supplemental glycine did not change nitrogen balance (Figure 2). In fact, when glycine was supplemented alone, nitrogen retention decreased ($P<0.05$). However, when glycine and cysteine were supplemented together, nitrogen retention increased (cysteine × glycine interaction; $P=0.01$). Thus, in the presence of supplemental glycine, it appears that cysteine can improve protein deposition, presumably by sparing methionine. The fact that responses to glycine supplementation alone were different between the two studies suggests that caution should be used in interpreting the data. Previously, we have observed responses to cysteine supplementation in the presence of supplemental glycine; all similar studies have been conducted with supplemental glycine. The only clear difference is that B-vitamin supplements were provided in this study but not in the previous work. Further work is needed to determine if vitamin status was responsible for the differing results. In any case, our results suggest that the nonessential amino acid, glycine, may be important in methionine metabolism.

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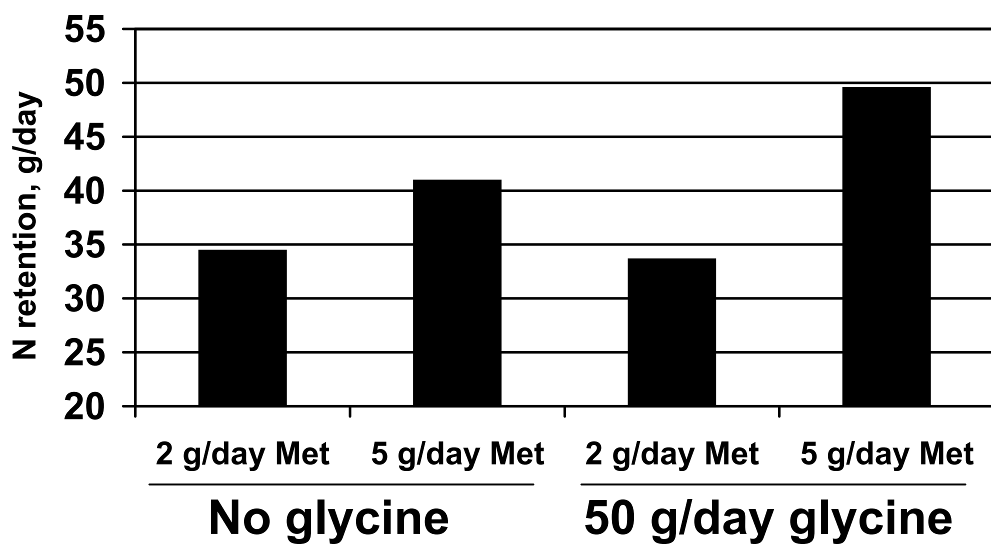

Figure 1. Effect of Methionine (Met) and Glycine Supplementation on Nitrogen Retention of Growing Steers (Exp. 1).

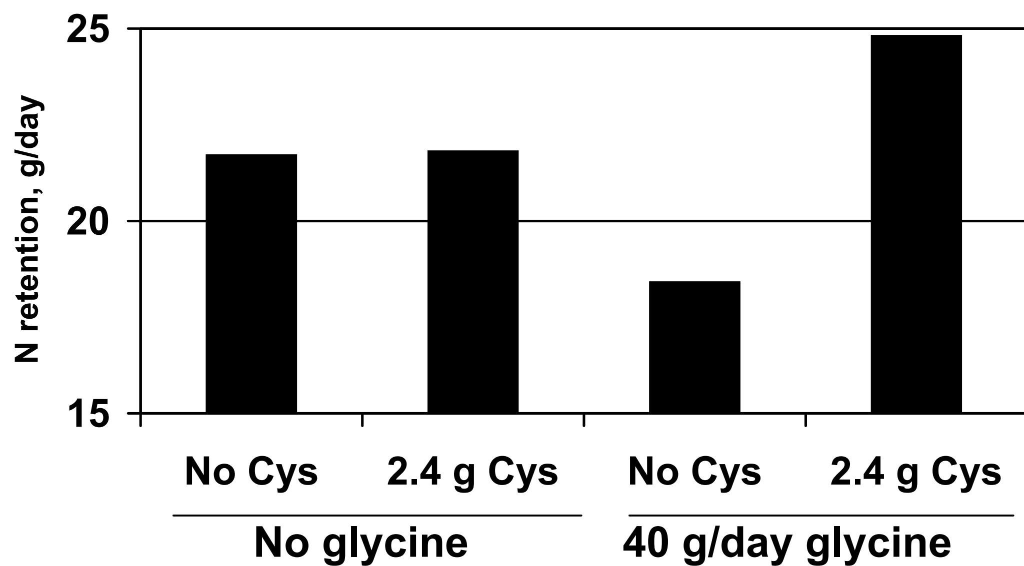

Figure 2. Effect of Cysteine and Glycine Supplementation on Nitrogen Balance of Growing Steers (Exp. 2).

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PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING STEERS FED DRIED, FULL-FAT CORN GERM

J. S. Drouillard, T. J. Kessen, M. J. Sulpizio, M. F. Spire[1], and R. T. Ethington[2]

Summary

Three hundred and fifty-eight crossbred beef steers (average initial weight 701 lb) were fed finishing diets containing 0, 5, 10, or 15% full-fat corn germ to evaluate effects on growth performance and carcass characteristics. Steers were placed into dirt-surfaced feedlot pens (12 to 16 head each) in December 2000 with a total of six pens per diet. Average daily gains during the 155-day finishing period were 2.83, 2.99, 3.01 and 2.93 lb/day for cattle fed 0, 5, 10, and 15% corn germ, respectively. Dry matter intakes decreased linearly ($P<0.05$) with increasing concentrations of full-fat corn germ in the diet. Relative to cattle fed no corn germ, efficiencies were improved by 8, 11, and 9% for cattle fed 5, 10, or 15% germ, respectively. Feeding corn germ also reduced the incidence of liver abscesses ($P<0.05$) compared to cattle fed the control diet. Dried, full-fat corn germ can be used successfully in cattle finishing diets to increase energy density and animal performance.

(Key Words: Corn Germ, Fat Supplementation.)

Introduction

Fats and oils are commonly added to cattle finishing diets to increase energy density and to improve efficiency of gain. However, use of liquid fats and oils is generally limited to operations with suitable equipment, such as pumps and heated storage tanks. Dried, full-fat corn germ may be a viable alternative to liquid fat sources when specialized handling and storage equipment is not available. Corn germ is a high-fat byproduct recovered during the production of corn sweeteners and(or) fuel ethanol. The wet germ is dried to a final moisture content of 3 to 5% and typically contains 46 to 54% fat and 12 to 15% protein (dry matter basis). Dried, full-fat corn germ is free-flowing and can be handled easily with conventional bins, augers, and pneumatic conveying systems. It has a bulk density of 22 to 26 lb/ft^3 and, as a result of its low moisture content, can be stored for extended periods without risk of oxidative rancidity. Our objectives were to measure the effects of dried, full-fat corn germ on growth performance and carcass attributes of cattle fed diets containing dry-rolled corn and wet corn gluten feed.

Materials and Methods

In December 2000, three hundred and fifty-eight crossbred yearling steers with an average initial weight of 701 lb were used in a feeding experiment conducted at the Kansas State University Beef Cattle Research Center in Manhattan. Steers were blocked by previous dietary regimen and assigned randomly, within blocks, to each of four dietary treatments (Table 1). They were fed in dirt-surfaced pens of 12 to 16

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animals each with a total of six pens per treatment. Pens provided approximately 175 ft^2 surface area per head. Using a common series of transition diets, steers were stepped up from a concentrate level of 60% to a final concentrate level of 97% (equivalent to the 0% germ diet, Table 1) over a period of 18 days. They were then weighed, implanted with Synovex Plus, returned to their pens, and placed onto their respective dietary treatments. Bunks were read at 7:00 a.m., and rations were delivered once daily at approximately 9:00 a.m. Feed deliveries were recorded daily, and compositional analyses of ration ingredients were performed weekly. Dry matter intake was corrected to reflect feed refusals that were removed from the bunks throughout the experiment. At the end of the 155-day finishing period, each pen was weighed prior to being transported to a commercial slaughter facility in Emporia, Kansas. Hot carcass weight and incidence of liver abscesses were recorded at slaughter. Yield grade, quality grade, marbling, incidence of dark cutters, 12th rib fat thickness, ribeye area, and percentage of kidney, pelvic, and heart fat were recorded following a 24-hour chill.

Results and Discussion

Growth performance, feed consumption, and carcass characteristics of steers fed varying levels of corn germ are shown in Table 2. Adding corn germ to the diet had a quadratic effect (P=0.02) on daily gain. The maximal rate of growth was achieved when germ was included at 10% of the diet dry matter and decreased slightly when additional germ was added. Feed intake decreased linearly (P=.02) as the proportion of germ in the diet increased. Efficiency improved dramatically (Linear, P<0.01; Quadratic P=0.04) with addition of germ. Relative to cattle fed no germ, gain efficiencies were improved by 8, 11, and 9% for cattle fed diets containing 5, 10, and 15% corn germ, respectively. Early in the experiment, feed intake was dramatically lower for cattle fed the high level (15%) of corn germ (Figure 1), suggesting that the shift from 0 to 15% germ on day 1 was too abrupt, and that a more gradual transition may have been beneficial. Steers ultimately acclimated to the high level of germ, and their intakes during the final 60 days were approximately equal to those of steers fed the other diets.

Adding corn germ to the diet also decreased incidence of liver abscesses. Cattle fed the control diet had 8.8% liver abscesses, whereas those fed diets containing germ were 2.3% or less. We would anticipate more liver abscesses when fat level in the diet increases due to the propensity for lower ruminal pH. Results of this study, however, are consistent with our observations in other experiments in which corn oil contributed significant amounts of lipid to the diet. This might be attributed either to effects of corn germ on feed intake, or to an effect of corn oil on bacteria that cause liver abscess.

Dressing percentage tended (P=0.08) to increase in a quadratic manner as the level of germ increased from 0 to 15%. Dressing percentage was greater when any level of germ was added to the diet. Adding corn germ also increased fat deposition, as indicated by changes in subcutaneous fat thickness; kidney, pelvic, and heart fat; and USDA Yield Grade. These factors indicate that cattle fed corn germ simply finish more quickly due to greater energy intake, and that the length of the finishing period should be adjusted accordingly.

In summary, including full-fat corn germ in the diets of finishing cattle provides a viable method for improving diet energy density, daily gain, and feed efficiency. Furthermore, it can be handled readily in conventional storage systems, and is relatively stable over extended storage intervals. Adding germ to finishing

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diets at 10% or less of dry matter can be done without incident. However, higher levels of inclusion may require gradual transitions to avoid exaggerated feed intake depression.

Table 1. Diet Composition (% of Dry Matter)

	Dried Full-Fat Corn Germ, % of Diet Dry Matter			
Ingredient	0	5	10	15
Dry-rolled corn	51.0	46.3	41.5	36.8
Wet corn gluten feed	35.0	35.0	35.0	35.0
Alfalfa hay	3.0	3.0	3.0	3.0
Full-fat corn germ, dried	0.0	5.0	10.0	15.0
Corn steep liquor	6.0	6.0	6.0	6.0
Dehulled soybean meal	0.79	0.53	0.27	-
Limestone	1.50	1.50	1.50	1.50
Salt	0.30	0.30	0.30	0.30
Vitamin/mineral premix[a]	2.39	2.39	2.39	2.39
Crude protein, actual %	13.0	13.0	13.1	13.1
Crude fat, actual %	3.9	6.2	8.4	10.7

[a]Formulated to provide 0.1 ppm cobalt, 10 ppm copper, 0.6 ppm iodine, 60 ppm manganese, 0.25 ppm selenium, 60 ppm zinc, 1200 IU/lb vitamin A, 300 mg/day Rumensin, and 90 mg/day Tylan.

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Table 2. Performance and Carcass Characteristics of Finishing Steers Fed Diets Containing 0, 5, 10, or 15% Dried Full-Fat Corn Germ

	Dried Full-Fat Corn Germ, % of DM				P-Value	
Item	0	5	10	15	Linear	Quadratic
Number of head (pens)	92(6)	91(6)	88(6)	87(6)	--	--
Initial weight, lb	701.3	703.7	694.3	706.3	0.83	0.40
Final weight, lb	1140.4	1166.4	1161.0	1161.1	0.17	0.16
Daily gain, lb (carcass adjusted) [a]	2.83	2.99	3.01	2.93	0.11	0.02
Dry matter intake, lb/day	18.80	18.34	18.04	17.80	0.02	0.71
Feed:gain[a]	6.63	6.13	5.99	6.06	<0.01	0.04
Liver abscess, %	8.8	2.2	2.1	2.3	0.02	0.05
Dressing percentage	61.25	61.81	61.89	61.69	0.14	0.08
Hot carcass weight, lb	718.4	734.9	731.4	731.5	0.17	0.16
12th rib fat thickness, in	0.31	0.33	0.35	0.36	0.04	0.81
Kidney, pelvic & heart fat, %	1.86	1.98	2.07	2.12	<0.01	0.43
USDA Choice & Prime, %	35.9	42.8	36.4	46.4	0.24	0.74
USDA Select, %	57.8	49.4	58.0	48.1	0.37	0.88
USDA Standard, %	5.3	4.5	5.6	5.5	0.85	0.86
Dark cutter, %	1.0	3.3	0.0	0.0	0.11	0.20
USDA Yield Grade	1.70	1.76	1.92	1.92	0.04	0.71

[a]Average daily gain and efficiency were determined using carcass adjusted final weights. Final live weight in these calculations was computed as hot carcass weight divided by a common dress of 63%

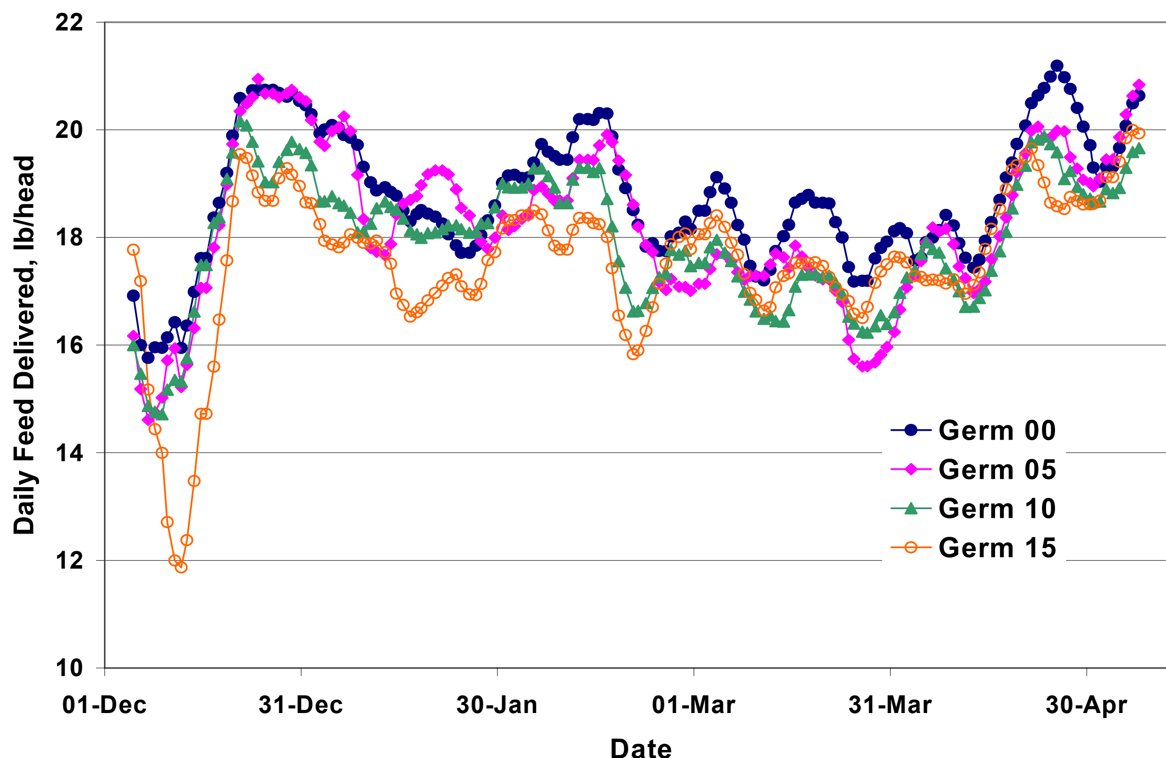

Figure 1. Daily Feed Deliveries for Yearling Steers Fed Diets Containing 0, 5, 10, or 15% Full-Fat Corn Germ.

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DAKOTA GOLD®-BRAND DRIED DISTILLER'S GRAINS WITH SOLUBLES: EFFECTS ON FINISHING PERFORMANCE AND CARCASS CHARACTERISTICS

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J. J. Sindt, S. P. Montgomery, J. N. Pike, T. J. Kessen,
M. J. Sulpizio, M. F. Spire[1], and J. J. Higgins[2]

Summary

A 153-day trial was conducted using 345 heifers to determine optimal level of Dakota Gold® dried distiller's grains with solubles (DDGS) in finishing diets based on steam-flaked corn. Diets contained six levels of DDGS: 0%, 15%, 30%, 45%, 60%, and 75%. DDGS affected average daily gain, final weight and hot carcass weight, all of which increased with 15% DDGS and then decreased as additional DDGS was added. Growth performance of heifers fed 30% DDGS was similar to those fed no DDGS. In general, heifers were overfinished, with 61% being Yield Grade 3 or greater and 83% grading Choice or Prime. Backfat tended to decrease with addition of DDGS, and kidney, pelvic, and heart fat and marbling scores tended to be greatest for intermediate levels of DDGS. Percentage of carcasses grading Choice or Prime tended to be lower for heifers fed 60 or 75% DDGS.

(Key Words: Dried Distiller's Grains with Solubles, Finishing Cattle, Performance.)

Introduction

Dakota Gold DDGS is a by-product of alcohol fermentation and can be made from corn, rye, or barley. The product is similar to corn gluten feed, except with DDGS, the remaining kernel fraction contains less gluten and more protein and oil. Distiller's grains can be fed either wet or dry, but the dried version is easier to handle. DDGS is an alternative to typical cereal grains in finishing cattle diets and in some cases may decrease acidosis and increase performance. DDGS is higher in fiber (43% NDF on a dry matter basis) than cereal grains, which can stabilize rumen pH and make cattle less prone to acidosis. We hypothesized that DDGS could be a good source of both energy and fiber in a finishing diet. This study was designed to identify the level of dietary inclusion that would optimize performance of cattle fed diets based on steam-flaked corn.

Experimental Procedures

Three hundred and forty-five crossbred heifers were used in a 153-day finishing trial. They were stratified by previous receiving treatment and randomly allocated to the six levels of DDGS (54 total pens with 9 pens per diet, 6 to 7 head per pen). Diets (Table 1) consisted of six levels (0%, 15%, 30%, 45%, 60%, and 75%) of Dakota Gold-brand distiller's dried grains with solubles.

Heifers were implanted with Component T-H® on day 1, and fed ad libitum amounts of their respective diet once daily. Finishing diets provided 300 mg Rumensin®, 90 mg Tylosin®, and 0.5 mg of melengesterol acetate per heifer daily.

[1]Food Animal Health and Management Center
[2]Department of Statistics

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Results and Discussion

Feedlot performance and carcass characteristics are shown in Table 2. Heifers started at a similar weight on all treatments, but DDGS affected final weight, hot carcass weight, and average daily gain ($P<0.05$). Cattle fed 0% or 30% DDGS gained at similar rates, and finished at similar weights. Heifers fed 15% DDGS had the best growth performance and addition of higher levels of DDGS to diets led to decreased performance. However, 12th rib fat thickness decreased as DDGS was added to the diet. Heifers in this experiment were overfinished, as evident in the large proportion of carcasses with a Yield Grade of 4 and 5, and with a USDA grade of Choice or Prime. Overall, 83% of the carcasses graded Choice or Prime. There was a tendency for heifers fed 60% or 75% DDGS to have a lower percentage of high-grading carcasses. Increasing level of DDGS did not affect the number of liver abscesses or the percent dark cutters.

Heifers on diets containing 15% DDGS finished at a heavier final weight and hot carcass weight, gained more weight per day, were more efficient, and had a higher percentage of cattle grading Prime. Growth of heifers fed 30% DDGS was similar to those fed no DDGS. Including DDGS at 45% or more tended to reduce performance and carcass grade.

Table 1. Diet Compositions (% of Dry Matter)

	Dried Distiller's Grains with Solubles[a]					
Item	0%	15%	30%	45%	60%	75%
DDGS[a]	-	15	30	45	60	75
Flaked corn	76.62	62.98	49.06	33.89	18.72	3.56
Ground corn	0.00	0.40	1.06	1.38	1.69	2.00
Alfalfa hay	10	10	10	10	10	10
Cane molasses	5	5	5	5	5	5
Dehulled soybean meal	3.01	1.43	0	0	0	0
Urea	1.21	1.06	0.79	0.67	0.55	0.43
Limestone	1.32	1.29	1.25	1.23	1.21	1.19
Salt	0.09	0.09	0.08	0.08	0.08	0.07
Medicated premix[b]	2.45	2.45	2.45	2.45	2.45	2.45
Vitamin/mineral premix[c]						
Crude protein	14.0	14.1	15.0	16.6	18.1	19.7

[a]Dakota Gold-brand dried distillers grains with solubles.

[b]Provided 300 mg monensin, 90 mg tylosin and 0.5 mg melengesterol acetate per heifer daily.

[c]Provided 1,200 IU/lb vitamin A, 0.05 ppm cobalt, 10 ppm copper, 0.62 ppm iodine, 60 ppm manganese, 0.30 ppm selenium, 10 ppm thiamin, and 60 ppm zinc.

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Table 2. Carcass and Performance Data

	Dried Distiller's Grains with Solubles[a]						
Item	0%	15%	30%	45%	60%	75%	SEM
No. of heifers	58	57	59	58	60	55	
Initial weight, lb	733	729	728	730	731	732	10.6
Dry matter intake, lb/day	16.40	17.03	16.74	16.51	16.36	15.45	0.12
Final weight, lb[b,c]	1063	1087	1063	1045	1042	1009	9.72
Carcass adjusted gain, lb/day[b,c]	2.19	2.37	2.21	2.10	2.05	1.85	0.19
Gain:feed[b]	0.134	0.138	0.132	0.127	0.125	0.121	0.037
Hot carcass weight, lb[b,c]	680	695	680	669	667	646	6.16
Dressing percentage	63.96	63.69	63.73	64.13	64.15	64.00	0.31
Ribeye area, in^2	11.4	11.7	11.8	11.7	11.2	11.5	0.27
Kidney, pelvic, & heart fat, %[c]	2.11	2.14	2.26	2.24	2.39	2.10	0.07
12th rib fat thickness, in	0.58	0.52	0.48	0.48	0.50	0.46	0.04
USDA Yield Grade							
Yield Grade 1, %	3	9	8	12	3	7	3.9
Yield Grade 2, %	34	30	32	31	29	36	6.4
Yield Grade 3, %	52	39	38	36	44	40	5.1
Yield Grade 4 & 5, %	10	22	22	21	24	18	7.2
Marbling Score[1,c]	Mt^{18}	Mt^{69}	Mt^{23}	Mt^{78}	Mt^{21}	Sm^{52}	30.5
USDA quality grade							
Prime, %`	15	29	13	23	20	8	5.3
Choice, %	73	61	79	58	55	63	6.2
Select, %[a]	9	10	7	20	25	26	6.0
Dark cutters, %	0.0	0.0	0.0	1.7	1.7	0.0	0.4
Liver abscesses, %	1.7	1.8	1.7	0.0	0.0	0.0	0.3

[a]Dakota Gold-brand dried distillers grains with solubles.
[b]Linear effect of diet ($P<0.05$).
[c]Quadratic effect of diet ($P<0.05$).
[1]Mt = Modest Sm = Small.

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STEAM-FLAKED CORN DIETS CONTAINING COMBINATIONS OF WET CORN GLUTEN FEED AND ALFALFA HAY: EFFECTS ON DIET DIGESTIBILITY AND RUMINAL CHARACTERISTICS

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S. P. Montgomery, J. N. Pike, T. B. Farran,
C. M. Coetzer, and J. J. Higgins

Summary

Twelve ruminally cannulated Jersey steers were used to measure digestibility and ruminal characteristics of steam-flaked corn based diets containing combinations of wet corn gluten feed (WCGF) and alfalfa hay (AH). Starch intake was lower (P<0.05), but neutral detergent fiber intake was higher (P<0.05) as AH and WCGF increased in the diet. Ruminal pH was increased by AH (linear, P<0.05) and tended (P<0.07) to increase with WCGF. Feeding higher levels of WCGF tended to increase passage rate (P=0.17) and decreased (P<0.05) total tract organic matter digestibility. Flaked corn diets containing at least 25% WCGF may contribute enough roughage to allow reduction of alfalfa hay levels.

(Key Words: Wet Corn Gluten Feed, Steam-Flaked Corn, Digestibility.)

Introduction

Roughage in modern cattle finishing diets is typically provided in small amounts (0 to 10% of dry matter). Roughages are often expensive due to their predisposition to shrink and their high cost per unit of energy. Due to its inherent fibrous characteristics, wet corn gluten feed (WCGF) has been used as a source of roughage in corn-based finishing diets. WCGF is also a good source of energy and is thought to lessen the propensity for acidosis when added to high-grain finishing diets. Our objective was to evaluate the effects on ruminal characteristics and diet digestibility when WCGF was used as a source of energy and as a replacement for alfalfa hay (AH) in steam-flaked corn (SFC) finishing diets.

Experimental Procedures

Twelve ruminally cannulated, mature Jersey steers (1290 lbs) were fed SFC-based diets containing 25 or 45% WCGF and 0, 2, or 6% AH in a 2 × 3 factorial design (Table 1). There were three 14-day periods. Each period consisted of 10 days for adaptation and 4 days for sampling. Steers were allowed *ad libitum* access to feed provided once daily. Chromic oxide (15 g) was hand mixed daily into individual diets on days 4 through 13 as a marker for diet digestibility. On day 11, a solution containing 3 g of cobalt-EDTA was pulse dosed through the ruminal cannula at 8:00 a.m. to estimate liquid passage and ruminal volume.

Fecal grab samples were collected three times daily on days 11 through 14 to estimate fecal output. Samples of ruminal fluid were collected beginning at 8:00 a.m. on day 11 and subsequently at 2, 4, 6, 8, 12, 18, and 24 hours after feeding.

Results and Discussion

Replacement of SFC with WCGF and AH caused starch intake to decrease (P<0.05), but neutral detergent fiber intake to increase (P<0.05; Table 2). The digestibilities of starch and fiber were similar among diets, but feeding 45% WCGF de-

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creased ($P<0.01$) organic matter digestibility, which was due to higher fiber and lower starch content of these diets (Table 1). Although additional WCGF decreased digestibility, it potentially created a more stable rumen environment, as it tended to lower the concentration of ruminal VFA ($P=0.13$) and increase pH ($P=0.08$; Table 3). Increasing dietary AH yielded quadratic responses ($P<0.05$) in concentrations of NH_3, total volatile fatty acids, and propionate (Table 3). These quadratic effects may be attributed to lower intakes for steers fed diets containing 25% WCGF and 2% alfalfa hay. Like WCGF, additional AH increased (linear, $P<0.05$) ruminal pH. Smaller additions of AH raised pH to a greater extent than larger additions of WCGF, implying that quantitatively AH, is the more effective roughage source. Furthermore, acetate:propionate ratio increased with levels of AH to a greater extent for cattle fed 25% WCGF than with cattle fed 45% WCGF, and this provided a WCGF × AH interaction ($P<0.05$). Liquid passage rate tended to be faster ($P=0.17$) when 45% WCGF was fed (Table 2). This faster rate of passage may partially explain the reduced digestibility of diets containing 45% WCGF.

Both WCGF and AH contribute value as roughage sources. Compared with AH, larger quantities of WCGF may be needed to provide equivalent roughage value, but digestibility may be reduced in diets containing high levels of WCGF. Feeding additional WCGF and AH may create a more favorable rumen environment. However, feeding at least 25% WCGF regardless of AH level appeared to provide adequate roughage to limit acidosis.

Table 1. Composition of Experimental Diets for Steers Fed Steam-Flaked Corn Diets Containing Combinations of Wet Corn Gluten Feed (WCGF) and Alfalfa Hay (AH; % of Dry Matter)

	25% WCGF			45% WCGF		
Item	0% AH	2% AH	6% AH	0% AH	2% AH	6% AH
Ingredient						
Flaked corn	65.3	63.6	60.4	48.3	46.3	42.4
Wet corn gluten feed	23.5	23.5	23.6	43.1	43.1	43.2
Alfalfa hay	-	1.9	5.8	-	2.0	5.9
Tallow	3.0	3.0	3.0	3.0	3.0	3.0
Premix[1]	2.5	2.6	2.6	2.5	2.5	2.6
Soybean meal	2.2	2.0	1.4	-	-	-
Urea	1.0	1.0	1.0	0.8	0.8	0.8
Limestone	1.7	1.6	1.5	1.7	1.6	1.5
Sodium chloride	0.3	0.3	0.3	0.3	0.3	0.3
Potassium chloride	0.4	0.4	0.3	0.3	0.3	0.2
Premix[2]	0.1	0.1	0.1	0.1	0.1	0.1
Dry matter, %	69.3	69.3	69.2	59.4	59.3	59.3
Organic matter, %	96.2	96.0	95.3	95.7	95.5	95.1
Starch, %	53.6	52.2	45.6	44.6	41.2	36.6
NDF, %	21.5	22.9	23.7	27.3	28.0	30.2
Crude protein, %	14.6	14.7	14.7	15.1	15.2	15.3
Calcium, %	0.68	0.65	0.63	0.72	0.71	0.65
Phosphorus, %	0.31	0.30	0.30	0.37	0.38	0.38

[1]Formulated to provide: 300 mg Rumensin and 90 mg Tylan daily.
[2]Formulated to provide: 1180 IU/lb vitamin A, and 0.1 ppm Co, 0.6 ppm I, 60 ppm Mn, 0.3 ppm Se, 60 ppm Zn, 10 ppm Cu, and 10 ppm thiamin.

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Table 2. Intake, Total Tract Apparent Digestibility, Ruminal Passage Rate, and Ruminal Volume of Steers Fed Steam-Flaked Corn Diets Containing Combinations of Wet Corn Gluten Feed (WCGF) and Alfalfa Hay (AH; % of Dry Matter)

	25% WCGF			45% WCGF			
Item	0% AH	2% AH	6% AH	0% AH	2% AH	6% AH	SEM
Intake, lb							
Dry matter	18.7	17.4	18.5	18.5	18.2	19.0	1.7
Organic matter	18.1	16.8	17.6	17.2	17.4	18.1	1.6
Starch[ab]	9.9	9.0	8.4	7.9	7.5	7.1	1.1
Neutral detergent fiber[ab]	4.2	4.2	4.4	5.1	5.3	5.7	0.42
Digestibility, %							
Organic matter[a]	87.5	87.2	87.5	84.7	85.5	87.0	0.73
Starch	98.3	98.1	98.1	98.4	97.6	97.5	0.72
Neutral detergent fiber	69.1	69.9	69.8	67.5	70.2	71.5	3.2
Fluid							
Passage rate, %/h	3.5	3.9	3.6	3.9	3.8	4.7	0.77

[a]Effect of level of WCGF ($P<0.01$).
[b]Linear effect of AH ($P<0.05$).

Table 3. Ruminal Fermentation Profiles of Steers Fed Steam-Flaked Corn Diets Containing Combinations of Wet Corn Gluten Feed (WCGF) and Alfalfa Hay (AH; % of Dry Matter)

	25% WCGF			45% WCGF			
Item	0% AH	2% AH	6% AH	0% AH	2% AH	6% AH	SEM
pH[a]	5.82	5.90	5.93	5.95	5.88	6.08	0.072
Acetate:propionate[b]	1.22	1.44	2.02	1.46	1.64	1.74	0.19
	----------	----------	---------- m*M*	----------	----------	----------	
NH_3[c]	6.5	8.4	7.9	6.5	9.9	4.3	2.2
Lactate	0.3	0.3	0.2	0.2	0.2	0.1	0.15
Total VFA[c]	110.7	95.8	118.3	105.7	100.1	100.0	8.1
Acetate	50.3	44.4	64.5	48.9	48.2	51.7	4.0
Propionate[c]	44.3	33.2	36.5	41.2	31.9	35.3	4.7
Butyrate	10.7	12.8	11.9	10.1	13.0	9.7	1.5

[a]Linear effect of AH ($P<0.05$).
[b]Linear effect of AH × WCGF ($P<0.05$).
[c]Quadratic effect of AH ($P<0.05$).

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IMPROVING THE UTILIZATION OF SOYBEAN HULLS BY CATTLE WITH DIGESTIVE ENZYME AND DIETARY BUFFER SUPPLEMENTATION

C. A. Löest, E. C. Titgemeyer, J. S. Drouillard,
B. J. Johnson, A. M. Trater, and B. D. Lambert

Summary

Four ruminally cannulated Holstein steers (749 lb) were used in a 4 × 4 Latin square experiment to evaluate the benefits of supplementing digestive enzymes and dietary buffers to a soybean hull-based diet fed to steers once daily at 15.4 lb/day (as fed basis). Treatments were arranged as a 2 × 2 factorial with factors being two levels (0 and 3 grams/day) of digestive enzymes and two levels (0 and 93 grams/day) of dietary buffers. Buffers and enzymes were thoroughly mixed with the soybean hull-based diet to provide a completely mixed ration. Digestive enzyme or buffer supplementation increased ($P \leq 0.06$) diet digestibilities of dry matter, organic matter, neutral detergent fiber, and acid detergent fiber. Addition of buffer also increased ($P \leq 0.06$) digestibilities of glucose, mannose, arabinose, xylose and galactose, whereas enzyme supplementation increased ($P = 0.03$) xylose digestibilities and tended to increase ($P = 0.10$) arabinose digestibilities. The addition of enzymes and buffer to the soybean hull-based diet did not alter passage of liquid or solids from the rumen and therefore cannot account for any of the responses in digestion. Also, ruminal pH was not altered when steers were supplemented with digestive enzyme and(or) buffer. The lack of response in pH to buffer was surprising, because the observed effect of buffer on fiber digestibilities would have been expected to be a result of a moderation of the ruminal pH. Results from this experiment demonstrated that both digestive enzyme and buffer supplementation improved the digestibility of soybean hull-based diet, and responses were greatest when both additives were supplemented together.

Introduction

Soybean hulls contain large amounts of potentially digestible fiber for cattle. However, their digestion may be less than expected when fed as a primary ingredient in forage-free diets. Research at Kansas State University has demonstrated that addition of alfalfa to soybean hull-based diets may improve digestibilities. However, these improvements were not due to a slower passage of soybean hulls through the gastrointestinal tract. Therefore, we hypothesized that the addition of roughage to soybean hull-based diets may have stimulated rumination and maintained a more favorable pH within the rumen for activity of microbes and digestive enzymes. This study evaluated the benefits of supplementing digestive enzymes and dietary buffers to diets containing soybean hulls as the primary ingredient.

Experimental Procedures

Four ruminally cannulated Holstein steers (749 lb initial body weight) were housed in individual tie-stalls and had free access to fresh water. The soybean hull-based diet (Table 1) was fed once daily at 15.4 lb/day (as fed basis). Dietary intakes were approximately 1.8% of the average

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initial body weight. The experimental design was a 4 × 4 Latin square. Treatments were arranged as a 2 × 2 factorial with factors being two levels (0 and 3 grams/day) of digestive enzymes and two levels (0 and 93 grams/day) of dietary buffers. The multi-enzyme complex (SAFIZYM FP; Lesaffre Development) was from the fungus *Trichoderma reseei* and included the enzyme activities, xylanase, beta-glucanase, galactomannase, and mannase. The buffer consisted of 0.5% of the diet dry matter as magnesium oxide and 1% as sodium bicarbonate. Buffers and enzymes were thoroughly mixed with the soybean hull-based diet to provide a completely mixed ration. Periods were 14 days, which allowed 8 days for adaptation to treatments, 5 days (days 9-13) for fecal collections (fecal bags) to measure digestibilities and passage rates, and 1 day for collection of ruminal fluid to measure ruminal pH. Ruminal passage rates of liquids and solids were determined by feeding pulse doses of liquid (chromium EDTA) and solid (ytterbium chloride) digesta markers and by measuring their concentrations in fecal samples taken once daily. Ruminal pH was measured from samples of ruminal fluid taken at 0, 3, 6, and 12 hours after feeding.

Results and Discussion

Diet digestibilities and ruminal passage rates are presented in Table 2. Feeding only digestive enzyme or buffer separately increased ($P \leq 0.06$) diet digestibilities of dry matter, organic matter, neutral detergent fiber, and acid detergent fiber. However, numerically these improvements were small. Addition of both digestive enzyme and buffer to the soybean hull-based diet tended to act synergistically (interaction; $P \leq 0.15$) and increased digestibilities of dry matter, organic matter, and neutral detergent fiber by 3.5%, and digestibilities of acid detergent fiber by 4.1% (Table 2). Acid detergent fiber is a measure of cellulose and lignin, whereas neutral detergent fiber also includes the hemicellulose fraction. Slightly greater improvements in the digestibilities of acid detergent fiber (4.1% increase) versus neutral detergent fiber (3.5% increase) suggest that the addition of the enzyme and buffer impacted the cellulose fraction of soybean hulls the most, although the digestibilities of individual sugars does not support this conclusion. Digestibilities of glucose, mannose, arabinose, xylose, and galactose increased ($P \leq 0.06$) in response to the addition of buffer to the soybean hull-based diet. Addition of the enzyme mixture increased ($P=0.03$) xylose digestibilities and tended to increase ($P=0.10$) arabinose digestibilities. However, numerically these improvements were small and reflect those for dry matter, organic matter, neutral detergent fiber, and acid detergent fiber. Supplementation with both enzyme and buffer tended to act synergistically (interaction; $P \leq 0.21$) and increased digestibilities of glucose and xylose by 5.2%. There was also a tendency (interaction; $P=0.15$) for the digestibilities of mannose to increase in response to the addition of both enzyme and buffer. Cellulose consists of chains of glucose molecules, whereas the major component of hemicellulose is xylose. Because improvements in digestibility were similar for both glucose and xylose, it does not appear that a specific cell wall structure was targeted by the addition of enzyme and buffer.

Previous research results demonstrated that addition of roughage to soybean hull-based diets increased digestibilities and ruminal passage rates. Addition of dietary buffers typically increases water intake, and therefore increases ruminal passage rates. However, the addition of enzymes and buffer to the soybean hull-based diet in this experiment did not alter passage of liquid or solids from the rumen (Table 2).

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Thus, changes in passage rate cannot account for any of the responses in digestion.

Differences in ruminal pH were not observed when steers were supplemented with digestive enzyme, buffer or a combination of both (Figure 1). For all treatments, ruminal pH decreased from approximately 6.5 at feeding to approximately 5.7 at 3 hours after feeding. The lack of change in pH in response to buffer addition was surprising, because improvements in fiber digestibilities due to the addition of buffer would have been expected to be a result of a moderation of the ruminal pH after feeding. Previous research has demonstrated that fiber digestion may be inhibited at ruminal pH below 6.0. However, it is possible that the effects of ruminal buffering with the addition of magnesium oxide and sodium bicarbonate is relatively short-lived and that decreases in ruminal pH may have been inhibited only during the first few hours after feeding and before the 3-hour sampling period. A tendency for greater improvements ($P \leq 0.15$) in diet digestibilities when both enzyme and buffer were added (Table 2) suggests that the beneficial effects of enzyme addition to the soybean hull-based diets may be dependent on ruminal buffering.

Our data indicate that both the addition of digestive enzyme and buffer improved the digestibility of a soybean hull-based diet. However, the response was greatest when buffer and enzymes were combined.

Table 1. Composition of the Soybean Hull-Based Diet

Item	% of Dry Matter
Ingredient	
Soybean hulls	95.5
Cane molasses	3.0
Calcium phosphate	0.5
Trace mineralized salt[a]	0.5
Urea	0.5
Nutrient	
Organic matter	92.5
Neutral detergent fiber	59.9
Acid detergent fiber	43.6
Crude protein	13.9
Glucose	33.9
Xylose	8.2
Mannose	5.3
Arabinose	4.4
Galactose	2.6

[a]Composition (g/100 g): NaCl (95 to 99), Mn (>0.24), Cu (>0.032), Zn (>0.032), I (>0.007), and Co (>0.004).

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Table 2. Effects of Digestive Enzyme and Dietary Buffer Supplementation on Digestibilities and Passage Rates

	Treatment[a]					*P*-value[b]		
Item	Control	Enzyme	Buffer	Enzyme + Buffer	SEM	E	B	E×B
Digestibility, %								
Dry matter	74.0	74.4	74.6	76.6	1.3	0.04	0.02	0.15
Organic matter	75.9	76.2	76.5	78.6	1.4	0.05	0.02	0.11
Neutral detergent fiber	77.2	77.6	77.7	79.9	1.8	0.04	0.03	0.10
Acid detergent fiber	74.7	74.9	75.4	77.8	2.1	0.06	0.02	0.09
Glucose	75.4	75.3	77.1	79.3	2.8	0.22	0.01	0.21
Mannose	97.4	97.4	97.6	97.8	0.18	0.21	0.01	0.15
Arabinose	90.0	90.4	90.5	91.5	0.77	0.10	0.06	0.44
Xylose	77.2	77.9	78.2	81.2	2.2	0.03	0.02	0.14
Galactose	91.4	91.6	92.3	92.2	0.49	0.83	0.06	0.66
Ruminal passage, %/hour								
Liquid	4.8	5.1	4.9	4.7	0.32	0.90	0.40	0.23
Solid	3.4	3.7	4.0	3.5	0.46	0.73	0.59	0.16

[a]Control = soybean hull-based diet; Enzyme = soybean hull-based diet plus enzyme addition; Buffer = soybean hull-based diet plus buffer addition; Enzyme + Buffer = soybean hull-based diet plus enzyme and buffer addition.
[b]E = effect of enzyme; B = effect of buffer; E×B = effect of an interaction between enzyme and buffer.

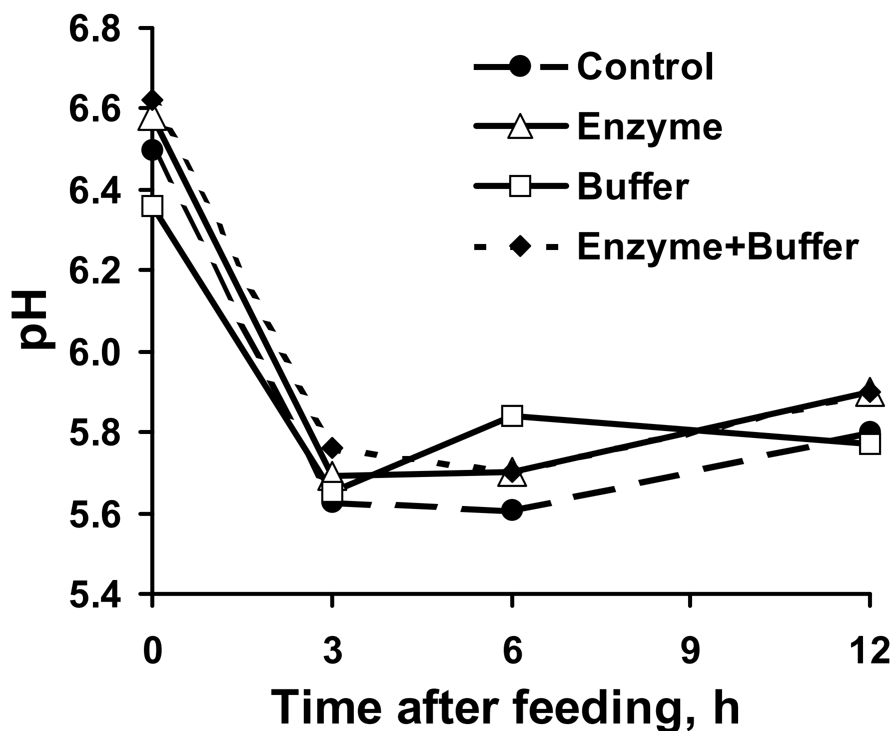

Figure 1. Effects of Digestive Enzyme and Dietary Buffer Supplementation on Ruminal pH.

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EFFECT OF HYDROGEN PEROXIDE ON PROTEIN DEGRADATION OF FEATHER MEAL

C. A. Löest, E. C. Titgemeyer, J. S. Drouillard, and C. M. Coetzer

Summary

Protein degradation of feather meal treated with hydrogen peroxide was evaluated using the *in situ* bag technique. Bags containing untreated feather meal or feather meal treated with 1.4, 2.5, 2.7, 5.0, or 7.0% hydrogen peroxide (g/100 g feather meal, as fed basis) at various pH and times of heating (55°C) were suspended in the rumen of a cannulated steer for 12 hours. Protein degradabilities of feather meal treated with 2.5 and 2.7% peroxide were only 12 to 19% greater than untreated feather meal, but feather meal treated with 5% peroxide had protein degradabilities 56 to 67% greater than untreated feather meal. Treatment of feather meal with 7% peroxide did not increase protein degradation further. Altering pH and heating (55°C) peroxide-treated feather meal for 30 or 120 minutes had only minor effects on protein degradability.

Introduction

Performance of feedlot cattle can be improved when high-grain diets are supplemented with rumen degradable, true protein sources. Protein sources that have low rumen degradation values, however, have little value for such cattle. This suggests that the protein supply to the small intestine is already adequate to meet the animal's postruminal requirements, and that responses to degradable, true protein are probably due to enhanced ruminal fermentation and consequently increased dietary energy utilization.

Feather meal, a by-product of the poultry industry, is high in crude protein (approximately 85%), but only a small fraction (30%) of this protein is degradable in the rumen. Increasing the ruminal degradability of feather meal protein and other high ruminal escape protein sources may improve their value in finishing diets for cattle.

Our objective was to evaluate the protein degradability of feather meal treated with hydrogen peroxide, using the *in situ* bag technique.

Experimental Procedures

Laboratory Experiments. Several laboratory experiments were conducted to evaluate the effect of hydrogen peroxide on rumen degradability of feather meal protein.

In Exp. 1, 10 g of 0, 4.0, 7.8, and 14.7 molar solutions of hydrogen peroxide were added to 100 g of feather meal (as fed basis). This allowed treatment of feather meal with 0, 1.4, 2.7, and 5.0% hydrogen peroxide (g/100 g feather meal), respectively.

In Exp. 2, 0, 5, 10, and 14 g of a 14.7 molar solution of hydrogen peroxide were mixed with 100 g of feather meal (as fed basis), which allowed treatment of feather meal with 0, 2.5, 5.0, and 7.0% hydrogen peroxide (g/100 g feather meal).

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In Exps. 3 and 4, the effects of pH and temperature on the peroxide treatment of feather meal were examined. Hydrochloric acid (6 normal) or sodium hydroxide (40% wt/wt solution) were used to adjust the pH of feather meal to approximately 3.5 or 10.5. The feather meal was then treated with 2.5% hydrogen peroxide. Feather meal that had been treated with 2.5 and 5.0% hydrogen peroxide was also incubated at 55°C for 30 and 120 minutes.

For all experiments, hydrogen peroxide and feather meal were mixed for approximately 5 minutes using a portable food mixer, and then allowed to stand for at least 12 hours before protein degradabilities were measured.

Protein Degradation Assay. The protein degradabilities of peroxide-treated and untreated feather meal samples were measured using the *in situ* bag technique. Duplicate polyester bags (2 × 4 inches; pore size = 50 μm), containing either untreated or peroxide-treated feather meal were sealed using an impulse heat sealer. Bags were then soaked in warm water before being suspended for 12 hours in the rumen of a cannulated Holstein steer fed a 50% concentrate diet. Bags were rinsed with water, then dried in a forced-air oven at 55°C, and analyzed for nitrogen.

Protein degradabilities were calculated as 100% minus the percent of the original nitrogen remaining after 12 hours in the rumen.

Results and Discussion

Although there were no large changes in protein degradation when feather meal was treated with 1.4% hydrogen peroxide, *in situ* protein degradabilities were 12 and 19% greater for feather meal treated with 2.5 and 2.7% hydrogen peroxide than for untreated feather meal (Figure 1; Exp. 1 and 2). Furthermore, feather meal treated with 5.0% hydrogen peroxide had protein degradabilities that were 67% (Exp. 1) and 56% (Exp. 2) greater than that of untreated feather meal.

Increasing the peroxide treatment to 7.0% of feather meal also improved *in situ* protein degradation by 55% when compared to untreated feather meal, but did not increase protein degradation above that resulting from treatment with 5.0% hydrogen peroxide.

Altering the pH of feather meal before treatment with 2.5% hydrogen peroxide resulted in small increases in protein degradation (Figure 2; Exp. 3).

Protein degradabilities of feather meal treated with 2.5 and 5.0% peroxide were also slightly higher when heated to 55°C for 30 and 120 minutes (Exp. 4). However, protein degradation of feather meal treated with 2.5% peroxide was not greatly altered by heat treatment.

Treating feather meal with optimum amounts of hydrogen peroxide (about 5%) increases ruminal protein degradability of feather meal, which may improve the value of feather meal in finishing diets for cattle.

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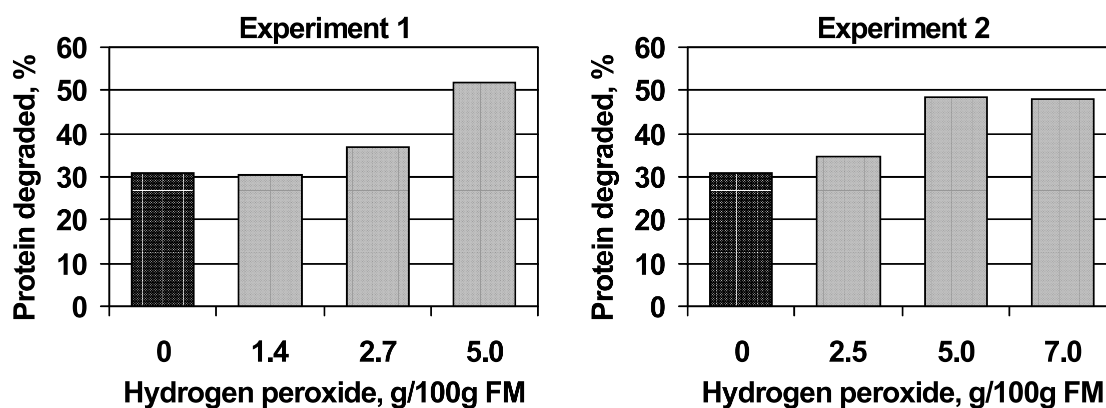

Figure 1. Effect of Hydrogen Peroxide on Protein Degradation of Feather Meal (FM).

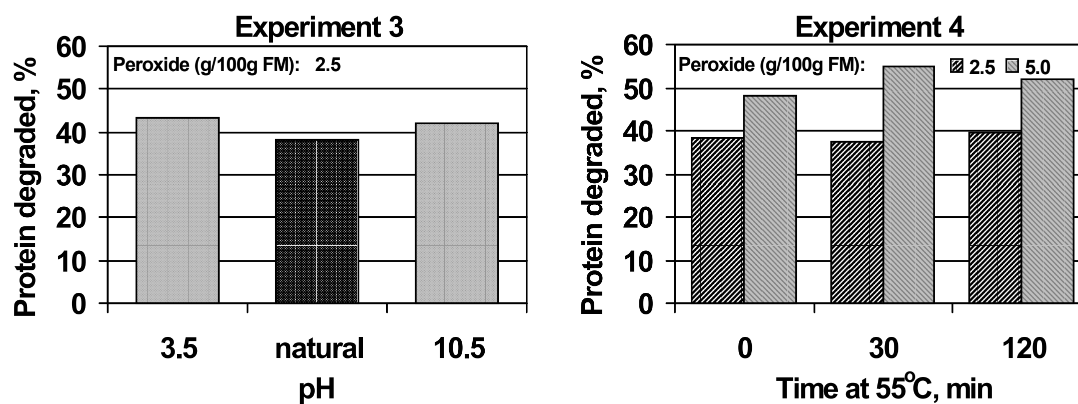

Figure 2. Effect of pH and Temperature on Feather Meal (FM) Treated with 2.5 and(or) 5% Hydrogen Peroxide (g/100 g FM).

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PEROXIDE TREATMENT OF FEATHER MEAL FOR FINISHING CATTLE

C. A. Löest, E. C. Titgemeyer, J. S. Drouillard, and C. M. Coetzer

Summary

Heifers (756 lb, 312 head) were used in a finishing study to evaluate the effects of peroxide-treated feather meal on animal performance and carcass characteristics. Diets contained 3.0% of peroxide-treated or untreated feather meal, and were fed ad libitum. Treatment of feather meal with hydrogen peroxide increased in situ protein degradabilities by 56%, but did not significantly alter feed intake or feed efficiencies. Although not statistically different, gains were 2.1% greater for heifers fed peroxide-treated feather meal. Hot carcass weights also averaged 6 pounds heavier for heifers fed diets containing peroxide-treated feather meal. Marbling tended to be lower, but carcasses grading USDA Choice tended to be higher for heifers fed diets containing peroxide-treated feather meal.

Introduction

Supplementation of high-grain diets with rumen-degradable, true protein can improve performance of finishing cattle, whereas adding ruminal escape protein is generally ineffective. This suggests that the metabolizable protein supplied by the basal diet is adequate. Improved performance in response to rumen degradable, true protein supplementation is likely due to improvements in dietary energy utilization rather than to metabolizable protein supply. Because feather meal is high in ruminal escape protein (70%), our objective was to find if increasing its ruminal degradation would improve its value in finishing diets.

Experimental Procedures

Three hundred twelve crossbred heifers (756 lb) were used in a randomized block design experiment to evaluate the effects of peroxide treatment of feather meal on animal performance and carcass characteristics. Heifers were individually weighed and allotted to one of three blocks based on weight and previous treatment and, within each block, were stratified by weight to one of eight pens (12 to 13 heifers per pen). Treatments were two finishing diets containing untreated or peroxide-treated feather meal (Table 1), which were fed to heifers once daily on an ad libitum basis. The three blocks of heifers were fed for 117, 127, and 159 days before final pen weights were obtained and heifers were shipped to a commercial slaughter facility.

Feather meal was treated by adding 14.3 lb of 35% feed-grade hydrogen peroxide solution to 100 lb of feather meal (as received basis) while being continuously mixed. This supplied approximately 5 grams of hydrogen peroxide per 100 grams of feather meal. After mixing for 15 minutes, the treated feather meal was allowed to cool by spreading it to a depth of 12 inches on a clean concrete surface.

Protein degradabilities were measured using an in situ bag technique. Duplicate polyester bags (5 × 10 cm; pore size = 50 μm), containing either no sample (blank) or 1.25 g of soybean meal (standard), feather meal, or peroxide-treated feather meal, were sealed using an impulse heat sealer

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and soaked in warm tap water before being suspended for 12 hours in the rumen of a cannulated Holstein steer fed a 50% concentrate diet. Bags were rinsed, dried in a forced-air oven at 55°C, and analyzed for nitrogen.

Results and Discussion

Chemical treatment of feather meal with hydrogen peroxide increased in situ protein degradability from 32% to 50%, a 56% increase. Replacement of untreated with peroxide-treated feather meal in the finishing diet of heifers had no effect on feed intakes (Table 2). Average daily gains, although not statistically different, were 2.1% greater for heifers fed diets containing peroxide-treated feather meal. Feed efficiencies were not greatly affected by treatment. Hot carcass weights for heifers fed the diets containing peroxide-treated feather meal were numerically, but not significantly, heavier (6 lb increase). Dressing percent was not different between diets. Kidney, pelvic and heart fat and twelfth rib back fat were not different between diets, but marbling tended to be lower (P=.16) for heifers fed peroxide-treated feather meal. The percentage of carcasses grading USDA choice also tended (P=.06) to be higher for heifers fed peroxide-treated feather meal diets, but carcasses grading USDA prime were numerically lower. As a result, there were no large differences in carcasses grading USDA choice or better.

Treating of feather meal with peroxide increased *in situ* protein degradability, and tended to improve performance and carcass characteristics of cattle.

Table 1. Ingredient and Nutrient Composition of the Finishing Diets

Item	% of Dry Matter
Ingredient	
Steam-flaked corn	81.61
Chopped alfalfa hay	7.00
Cane molasses	4.00
Feather meal	3.01
Bleachable tallow	2.00
Limestone	1.27
Urea	.55
Salt	.30
Potassium chloride	.15
Trace mineral mix [a]	.06
Rumensin-80 [b]	.02
Tylan-40 [c]	.01
Vitamin A premix [d]	.01
Nutrient, calculated	
Crude protein	13.0
Calcium	.65
Phosphorus	.28
Potassium	.65

[a]To provide (dry basis): 60 ppm Zn, 60 ppm Mn, 10 ppm Cu, 1.1 ppm Fe, .63 ppm I, .25 ppm Se, and .05 ppm Co to diet.
[b]To provide (dry basis): 30 g monensin per ton of diet.
[c]To provide (dry basis): 10 g tylosin per ton of diet.
[d]To provide (dry basis): 1200 IU vitamin A per lb of diet.

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Table 2. Effect of Peroxide-Treatment of Feather Meal on the Performance and Carcass Characteristics of Finishing Heifers

	Feather Meal		
Item	Untreated	Peroxide-treated	SEM
No. of heifers	156	156	-
Performance data			
Initial weight, lb	755	756	1.1
Final weight, lb[a]	1080	1088	5.4
Dry matter intake, lb/day	17.8	17.9	.21
Average daily gain, lb[a]	2.42	2.47	.041
Gain:feed[a]	.136	.138	.0023
Carcass Characteristics			
Hot carcass weight, lb	698	704	3.7
Dressing percentage	64.6	64.7	.12
Ribeye area, in^2	14.0	14.2	.16
Fat thickness, in	.41	.40	.015
KPH[b] fat, %	2.2	2.3	.047
Yield grade 1, %	19	16	2.6
Yield grade 2, %	37	40	3.7
Yield grade 3, %	36	41	4.0
Yield grade 4 & 5, %	8	4	1.8
Marbling score[c]	Sl^{66}	Sl^{47}	8.9
USDA Prime, %	8	3	2.2
USDA Choice, %	66	76	3.3
USDA Select, %	21	19	3.2
USDA Standard, %	5	2	1.1
Liver abscesses, %	5	6	1.9

[a]Computed by applying a 4% shrink to the final weights.
[b]KPH = kidney, pelvic & heart.
[c]Sl = Slight.

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VALIDATION OF A STEAM BASED POST-PROCESS PASTEURIZATION SYSTEM FOR CONTROL OF *LISTERIA MONOCYTOGENES* IN READY-TO-EAT ROAST BEEF

V. S. Gill, H. Thippareddi, R. K. Phebus,
J. L. Marsden, and C. L. Kastner

Summary

Listeria monocytogenes has been implicated in outbreaks of illness involving ready-to-eat (RTE) meat products, prompting researchers to look into intervention technologies to reduce or eliminate this risk. In our study roast beef was inoculated with a 5-strain cocktail of *Listeria monocytogenes*, vacuum-packaged, and then pasteurized at 205°F for 0, 2, 3 or 4 min in a Stork RMS-Protecon Post-Process Pasteurization System. More bacteria were killed as pasteurization time increased. Initial inoculum level was 5.8 $\log_{10}$ CFU/cm^2 of product surface area. Pasteurization for 2 min resulted in 2.5 to 2.7 $\log_{10}$ CFU/cm^2 reductions. Similar reductions were seen at 3 min. At 4 min pasteurization, *L. monocytogenes* decreased in roast beef by approximately 4.5 $\log_{10}$ CFU/cm^2; over 99.99% had been killed. The Stork steam based system is effective for reducing the risks of *L. monocytogenes* in RTE roast beef while providing acceptable quality characteristics.

(Key Words: Roast Beef, Post-Packaging, Ready-to-Eat, Steam-Based Pasteurization.)

Introduction

Listeria monocytogenes can contaminate cooked meat products between cooking and final packaging. Therefore, research is being focused on pasteurization of surfaces of cooked, ready-to-eat (RTE) meat products after packaging.

Both irradiation and thermal based pasteurization systems are being investigated. However, thermal based methods are easiest to implement because they do not require regulatory approval. Thermal systems, those based on saturated steam, appear to achieve the surface temperatures required to destroy *L. monocytogenes* in 1 to 4 min, without significantly affecting the sensory quality of the RTE meat products.

Our objective was to evaluate the effectiveness of the Stork RMS-Protecon Post-Process Pasteurization System in reducing or eliminating *L. monocytogenes* on RTE meat product surfaces after final packaging.

Experimental Procedures

Pre-cooked beef roasts (ca. 10 lb each) were stored at 40°F until pasteurization. Immediately before inoculation, beef roasts were cut into two equal halves. The resulting fresh-cut surfaces were labeled as "bottom" sides of the meat. The bottom sides were placed down to replicate retail conditions.

Five strains of *L. monocytogenes* were mixed with sterile 0.1% peptone water to achieve a final concentration of ca. 1×10^9 CFU/ml.

Beef roasts were placed on sterile stainless steel wire racks resting on a stainless steel trough. The inoculum was sprayed on both top and bottom surfaces by "misting" the mixed-strain inoculum in a "bio-containment" chamber. After inocu-

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lation the products were placed in a laminar flow cabinet for one hour at room temperature to allow microbial attachment. Then all products were vacuum-packaged in CNP 320 cook-in bags (Cryovac, Duncan, SC) and pasteurized at the Kansas State University Aseptic Processing Laboratory.

All inoculated beef roasts except unpasteurized (0 min) were surface pasteurized in the Stork RMS-Protecon Post-Processing Pasteurization System at 205°F for 2, 3 or 4 min. Immediately after pasteurization, products were immersed in an ice-water bath for 10 min before sampling.

Samples were taken from the top and bottom surfaces. The flat bottom surfaces were cored twice (7.36 in^2) and top surfaces were cored three times (11.04 in^2). Cores from each sampling location per product were combined with 0.1% sterile PW, serially diluted, plated on Modified Oxoid Agar MOX (Difco Laboratories, Detroit, MI) and incubated at 100°F for 24 h. Colonies were counted and reported as $\log_{10}$ CFU/cm^2. There were four replications for each treatment.

Results and Discussion

As pasteurization time increased, *Listeria* recovery decreased proportionally. Pasteurization for 2, 3, and 4 min resulted in reductions of 2.67, 3.57, and 4.48 $\log_{10}$ CFU/cm^2 on the top portion from an initial level of 5.98 $\log_{10}$ CFU/cm^2, and reduction of 2.51, 2.34, and 2.53 $\log_{10}$ CFU/cm^2 on the bottom portion from an initial level of 5.82 $\log_{10}$ CFU/cm^2. On the top surface, 3.30 log10 CFU/cm^2 survived 2 min of pasteurization, while 1.49 $\log_{10}$ CFU/cm^2 survived pasteurization for 4 min ($P \leq 0.05$). More *L. monocytogenes* survived 3 or 4 min of pasteurization on the bottom than the top surface ($P \leq 0.05$). Reducing a microbial population of 5 $\log_{10}$ CFU/cm^2 down to 2 $\log_{10}$ represents a reduction of 99.9%. the microbial population added to our samples through inoculation are much higher than would be seen under naturally-occurring circumstances.

The USDA-FSIS mandates a zero tolerance policy for *L. monocytogenes* (FSIS, 1989) in RTE meat and poultry products. The mortality rate for *L. monocytogenes* infection is about 33% because of the virulence of this organism. Exposure to even a single cell may cause septicemia, meningitis, and abortion in susceptible humans. Earlier studies have reported about 53% of samples testing positive for *L. monocytogenes* in vacuum packaged RTE sliced meat.

This study validates the effectiveness of a saturated steam-based post-processing system for reducing or eliminating *L. monocytogenes* on surfaces of RTE deli meat products. The Stork RMS-Protecon system can be integrated into the RTE meat product manufacturing process as a Critical Control Point to reduce or eliminate the risk of *Listeria monocytogenes* in these products.

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STEAM BASED POST-PROCESS PASTEURIZATION OF BEEF SALAMI FOR CONTROL OF *LISTERIA MONOCYTOGENES*

V. S. Gill, H. Thippareddi, R. K. Phebus, J. L. Marsden, and C. L. Kastner

Summary

We evaluated the destruction of *Listeria monocytogenes* on surfaces of artificially inoculated, vacuum-packaged beef salami by steam pasteurization (Stork RMA-Protecon Post-process Pasteurizer). Beef salami was inoculated with *L. monocytogenes* (initial concentrations of 4.36 $\log_{10}$ CFU/cm^2 at the end and 4.49 at the middle), then pasteurized at 185, 194, or 203°F for 2 or 4 min. Only about 0.11 $\log_{10}$ CFU/cm^2 (detection limit) *L. monocytogenes* survived after pasteurization at 203°F for 2 and 4 min, for a "kill rate" of over 99.99%. Post-packaging pasteurization reduces the threat of *L. monocytogenes* on the surfaces of cooked meat products.

(Key Words: Post-Processing Pasteurization, Beef Salami, *Listeria monocytogenes*.)

Introduction

Listeria monocytogenes, an important cause of foodborne diseases in humans, contaminates a variety of meats. It can easily aerosolize, making it easy to spread, and can survive and grow at refrigeration temperatures.

Irradiation and thermal-based pasteurization are being investigated to reduce its risk in ready-to-eat (RTE) meats. Because cooking during production of RTE meats eliminates most harmful pathogens, research is focusing on post-packaging pasteurization. Our objective was to evaluate the effectiveness of the Stork Post-process Pasteurizer in reducing or eliminating *L. monocytogenes* on the surface of packaged RTE meat.

Experimental Procedures

Five strains of *L. monocytogenes* (101 M, 108 M, 109, serotype 4c ATCC, and 3 ATCC) were diluted to produce a mixed inoculum concentration of about 1×10^9 CFU/ml.

Retail packages (300 g) of beef salami were procured and stored at 40°F until pasteurization. Beef salami was placed on a sterile stainless steel wire rack held in a stainless steel trough in a "biocontainment" chamber, and was mist inoculated with the 5-strain *L. monocytogenes* inoculum. The inoculated products were placed in a laminar flow cabinet for one hour at room temperature to allow microbial attachment.

All inoculated products were then vacuum-packaged and pasteurized at the Kansas State University Aseptic Processing Laboratory. Inoculated packages were surface pasteurized in a Stork RMS-Protecon Post-Packaging Pasteurization Chamber for either control, 2, or 4 min at 185, 194, or 203°F.

Immediately after pasteurization, all packages were immersed in ice water for 10 min, then sampled. Packages were surface sampled by removing the casings from the end (1.5 cm) caps from both sides and

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combining both end caps from one sausage to give the "end" sample. The rest of the casing served as the middle sample.

The end and middle samples from beef salami were diluted with 0.1% sterile peptone water (PW), stomached for 2 min, serially diluted in PW and plated on Modified Oxoid Agar (MOX) (Difco Laboratories, Detroit, MI) and incubated at 98.6°F for 24 h. Colonies were counted and reported as $\log_{10}$ CFU/cm^2. Three replications were performed for each treatment.

Results and Discussion

Mean inoculum levels were 4.26 $\log_{10}$ CFU/cm^2 for end and 4.49 for middle portions. Pasteurization of salami at 185°F for 2 min reduced surface *L. monocytogenes* by about 3.65 (end) and 3.18 (middle) $\log_{10}$ CFU/cm^2, while pasteurization at 185°F for 4 min reduced *L. monocytogenes* by 4.26 $\log_{10}$ CFU/cm^2 for both end and middle portions. Pasteurization at 194°F for 4 min achieved similar results. Only 0.11 $\log_{10}$ CFU/cm^2 (detection limit) *L. monocytogenes* were recovered from middle and end surfaces of salami pasteurized at 203°F for 2 and 4 min, representing a "kill rate" of over 99.99%.

STORK Steam Pasteurization Unit in the KSU Aseptic Processing Laboratory.

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MICROBIAL FLORA OF COMMERCIALLY PRODUCED VACUUM PACKAGED, COOKED BEEF ROAST

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Summary

Commercially produced vacuum packaged, fully cooked, microwaveable beef roasts from four producers were purchased from local retail markets. Salt concentration, pH, water activity (a_w), and percent moisture, fat and protein were determined. Samples of both package juice and homogenized beef plus juice were analyzed for the presence of aerobic, anaerobic and lactic acid bacteria and clostridia-type organisms. The cooked beef products had pH values from 5.82 to 6.19, water activity of 0.992 to 0.997, and contained 0.34 to 1.07% salt, 61.89 to 72.39% moisture, 4.29 to 18.21% fat and 15.92 to 20.62% protein. No growth was detected in juice for aerobic, anaerobic or lactic acid bacteria or clostridia-type organisms. Combined beef and juice had less than 2 CFU/g for aerobic, anaerobic or lactic acid bacteria or clostridia-type organisms. Cooking and chilling schedules used in the manufacture of the four products we evaluated in this study limited survival and outgrowth of microorganisms.

(Key Words: Microbial Flora, Vacuum Packaged, Cooked Beef.)

Introduction

Demand for beef in the United States is on the rise. Contributing to this increased demand is the development of heat-and-serve beef entrees. These vacuum packaged, cooked, then chilled in the package beef products are meeting consumer demand for convenience and high quality, with minimal preparation time. Use of microwaveable beef entrees reduces meal preparation time to less than 10 minutes. In 2000, sales of heat-and-serve beef products, such as beef pot roast, reached $84 million.

Beef roasts that are vacuum packaged, cooked, then chilled in the package have the advantage of extended shelf life since cooked product is not re-exposed to spoilage organisms. During heat treatment of extended shelf life, refrigerated foods, vegetative cells are destroyed but spores can survive. Little or no preservative is used in the manufacture of these products and refrigeration is required to ensure product safety. Temperature abuse occurs in the food distribution chain, as well as by consumers. Potential temperature abuse, along with vacuum packaging that creates an anaerobic environment, makes these types of foods a potential risk from spore forming bacteria such as *Clostridium botulinum* and *C. perfringens*.

Microwaveable beef roast (pot roast) is the most common retail heat and serve product. Our objective was to determine the microbial flora and compare pH, salt concentration, water activity, moisture, fat and protein content of different commercially available beef roast heat and serve products.

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Experimental Procedures

Commercially produced retail beef roast heat-and-serve products from four manufacturers were purchased locally. Each manufacturer was assigned a code: A, B, C, or D. For each manufacturer's product, three sets of duplicate packages, each set bearing a different code date, were selected with one exception. Only packages bearing the same lot number were available for supplier A. Product was transported from the retail store to the lab in an insulated cooler, and stored at 40° F for not more than two weeks, at which time all testing was completed.

Product samples were analyzed for the presence of aerobic, anaerobic and lactic acid bacteria and clostridia-type organisms. Salt concentration, pH, water activity and moisture, fat and protein content were determined. Data were analyzed using proc GLM, and mean separation was done with Fisher's least significant difference (LSD) test (SAS, 1999). Significance level was $P<0.05$.

Results and Discussion

No aerobic or anaerobic microorganisms, lactic acid bacteria or clostridia-type organisms were detected in juice from the beef roast packages (Table 1). Similarly, less than two (estimated) colony forming units/g (CFU/g) of these organisms were detected when combined cooked beef and juice were sampled, regardless of manufacturer. Meat is an ideal growth medium for microbes because it is high in moisture and nitrogen, supplies ample amounts of minerals and growth factors, and has a favorable pH of 5.6 or higher. Intrinsic properties (Table 2) indicated some differences ($P<0.05$) among manufacturers, but each product would provide a good substrate for growth if bacteria were present. Thorough cooking must have been used by the four manufacturers to significantly reduce or eliminate microorganisms, and subsequent chilling, distribution and refrigerated retail display was adequate to prevent outgrowth of spores that may have been present.

Because the seasoned beef roast products were vacuum packed and cooked, all the natural juices were retained in the packages, leading to the high moisture and water activity results (Table 2). Salt content was 0.34%, 0.43% and 0.54% in three of the products and 1.07% in the fourth. Considering the high moisture content of these products, the ability of the low salt content to serve as an antimicrobial was limited. Even salt levels of 2-3% in products with moisture contents above 60% do not provide a significant preservative effect. The ingredient statements for these products indicated that no acidulants were added to the products (Table 3). The beef roasts had a pH range of 5.82 to 6.19. Three products had similar fat contents ($P>0.05$) but sample A contained three times more fat, at 18.21%. That was the product that was not available after the first set of samples had been purchased and only one sample was available for chemical analysis. It was a whole muscle product and may have contained seam fat not found in other samples. It may also not be truly representative of the manufacturer's normal product because, based on the nutritional panel on this sample, the fat content should have been 10.7 % $\pm$ 2.1%.

Manufacturing, chilling, distribution and retail display for the cooked beef roast products from all four manufactures resulted in less than 2 CFU/g of aerobic, anaerobic and lactic acid bacteria and clostridia-type organisms. This indicates that the cooking and chilling protocols used limited survival and outgrowth of the microorganisms we measured. Our results are consistent with the good safety record for products of this type.

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Table 1. Microbial Counts (CFU/g) for Commercially Available Vacuum Packaged, Cooked Beef Roasts from 4 Manufacturers

Product	Manufacturer	Aerobic Plate Count	Anaerobic Plate Count	Clostridia-type Organisms	Lactic Acid Bacteria
Juice	A	NG[1]	NG	NG	NG
	B	NG	NG	NG	NG
	C	NG	NG	NG	NG
	D	NG	NG	NG	NG
Beef and Juice	A	<2 est.[2]	<2 est.	<2 est.	<2 est.
	B	<2 est.	<2 est.	<2 est.	<2 est.
	C	<2 est.	<2 est.	<2 est.	<2 est.
	D	<2 est.	<2 est.	<2 est.	<2 est.

[1]NG=no growth.
[2]est.=estimate.

Table 2. pH, Salt Concentration, a_w, and Proximate Analysis of Commercially Available Vacuum Packaged, Cooked Beef Roast from 4 Manufacturers

Company	pH	% Salt	% Fat	a_w [1]	% Moisture	% Protein
A	6.19^{a}	0.34^{c}	18.21^{a}	0.994^{a}	61.89^{a}	18.56^{c}
B	6.00^{b}	1.07^{a}	4.29^{b}	0.997^{a}	72.39^{b}	15.92^{d}
C	5.82^{c}	0.54^{b}	5.38^{b}	0.996^{a}	70.81^{b}	20.62^{a}
D	6.04^{b}	0.43^{c}	6.30^{b}	0.992^{a}	71.00^{b}	19.63^{b}

^{a,b,c,d}Means in the same column with a different superscript letter differ ($P<0.05$).
[1]Water activity.

Table 3. Combined Ingredient List for 4 Commercially Prepared Beef Roast Products and Number Who Used Each

Ingredient	Number of Products Containing Ingredients	Ingredient	Number of Products Containing Ingredients
Salt	4	Caramel Color	4
Sweeteners	4	Disodium inosinate	2
Hydrolyzed protein	3	Disodium guanylate	2
Garlic	2	Beef tallow	2
Onion	3	Starch	2
Sodium lactate	1	Sodium phosphate	2
Monosodium glutamate	1	Gums	1
Flavoring	2	Spices or extracts	3

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USE OF ORGANIC ACIDS FOR CONTROL OF *CLOSTRIDIUM PERFRINGENS* IN COOKED VACUUM-PACKAGED GROUND BEEF PRODUCTS SUBJECTED TO SUBSTANDARD COOLING PROCEDURES

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Summary

This study determined the ability of *Clostridium perfringens* spores to germinate and grow after different organic acid treatments in vacuum packaged cooked ground beef subjected to substandard (slow) cooling. Meat samples were inoculated with a three-strain cocktail of *C. perfringens* spores (ATCC 10388, NCTC 8238, and NCTC 8239), then vacuum-packaged, cooked in a water bath to 167°F internal temperature, and held 20 min. The water bath temperature was then lowered to 130°F, and samples were cooled from 130°F to 45°F over 18 hr. Samples were taken after inoculation, after cooking, and after cooling. In the event of substandard cooling, sodium citrate at 2 or 4.8% or sodium lactate at 4.8% will control *C. perfringens* growth, with 4.8% sodium citrate showing the best inhibition.

(Key Words: *Clostridium perfringens*, Cooked Ground Beef, Organic Acids.)

Introduction

Between 1983 and 1992, *Clostridum perfringens* caused 8.94% of all reported food bacterial outbreaks, and 4.77% of total estimated cases of bacterial disease in the United States. Changing lifestyles have increased use of pre-cooked, vacuum-packaged food. In such products, competitive normal microflora, which serve as "spoilage indicators," are destroyed. Thus, pathogen contamination can be present even though the product looks and smells normal.

Clostridium perfringens is a heat resistant, spore-forming bacteria that can survive the mild heat treatments used for ready-to-eat meats. Such mild heating may even serve to "activate" spores, allowing them to germinate and multiply, especially if the product is cooled slowly after cooking. To prevent this potential health hazard, the USDA requires that the relative growth of *C. perfringens* should not exceed one $\log_{10}$ (a 10× increase) in meat and poultry products. In 1993, the Food and Drug Administration (FDA) recognized that inadequate cooling was a major food safety problem and recommended that all foods should be cooled from 140°F down to about 40°F in 6 hr or less, but did not require changes in the operating performance of refrigerators. Because of the possibility of inadvertently chilling pre-cooked food too slowly, several additives have been examined as a way to protect against foodborne pathogens such as *C. perfringens*.

Our purpose was to assess the use of certain food grade organic acids and their salts as added protection against *C. perfringens* growth brought on by an inadequate cooling.

Experimental Procedures

Ground beef from the lean inside round (1/8 inch grind) was obtained from the

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Kansas State University Meat Laboratory, and formulated to an industrial recipe; 10% water, 1.5% sodium chloride, and 0.5% tri-sodium phosphate were added and mixed in a Hobart mixer. Generic sodium citrate at pH 5.6, sodium citrate adjusted to pH 5.0 (Ingredients Solutions Inc., Searsport, Maine), and sodium lactate (Purac, Lincolnshire, Illinois) were used at concentrations of 2% and 4.8%. Sodium acetate and sodium diacetate (Niacet Corporation, Niagara Falls, New York) were used at a 0.25% concentration.

Strains of *C. perfringens* (NCTC 10388, 8238, and 8239) were obtained from the Kansas State University Food Microbiology Laboratory culture collection. An equivalent proportion of spores from each strain were mixed and added to ground beef to get a three-strain cocktail inoculum of 2 $\log_{10}$ cfu/g of meat Samples of prepared ground beef (25 g) were placed in 2 × 3 inch plastic bags, vacuum packaged to a negative pressure of 1000 millibars and heat sealed. The bags were fully submerged and cooked in water at 167°F for 20 min, then chilled from 130°F to 45°F over an 18 hr period; a rate of cooling slower than FDA recommendations.

Samples were taken after inoculation, after cooking, and after the 18-hr cooling period. Fifty ml of 0.1% sterile peptone water was added to each sample and macerated in a Stomacher Lab-blender™ for 2 min. Decimal serial dilutions were prepared in 0.1% peptone water. Total cell counts were obtained by pouring (in duplicate) 1 ml samples into Fung's Double Tubes using tryptose-sulfite agar without egg yolk. Tubes were incubated at 99°F for 8 to 10 hr before assessment of growth.

Results and Discussion

The effects of the different organic acid treatments (mean of two replications) on *C. perfringens* outgrowth are shown in Table 1. Controls showed a 2 $\log_{10}$ growth (from 1.61 to 3.87 $\log_{10}$ CFU/g) between inoculation and the completion of slow cooling. Similar 1.5 to 2 $\log_{10}$ growth was noted in the presence of 0.25% sodium acetate or sodium diacetate. With 2% sodium lactate, *C. perfringens* increased from 1.96 $\log_{10}$ to 2.58 $\log_{10}$ CFU/g. For all other treatments (sodium citrate at 2% and 4.8% at pH 5.6, and pH 5.0, and sodium lactate at 4.8%) viable *C. perfringens* cells decreased by 0.5 to almost 1 $\log_{10}$. Sodium lactate at 4.8% was the most effective growth inhibitor with a 0.96 $\log_{10}$ CFU/g reduction.

Table 1. Log_{10} CFU/g of the Total *Clostridrium perfringens* Cells in Ground Beef

	Percent Added	After Inoculation	After Heating	After Slow (18 Hr) Cooling
Sodium citrate, pH 5.6	2	1.78	2.36	1.35
Sodium citrate, pH 5.6	4.8	1.77	2.29	1.18
Sodium citrate, pH 5.0	2	1.84	2.10	1.08
Sodium citrate, pH 5.0	4.8	1.92	2.51	1.17
Sodium lactate	2	1.96	2.39	2.58
Sodium lactate	4.8	2.49	2.31	1.53
Sodium acetate	0.25	1.90	2.43	4.04
Sodium diacetate	0.25	1.96	2.35	3.40
Control		1.61	2.50	3.87

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SALMONELLA SPP. RISK ASSESSMENT FOR COOKING OF BLADE TENDERIZED PRIME RIB

J. W. Wendelburg, D. L. Lambert, C. L. Kastner, R. K. Phebus, H. Thippareddi, and J. L. Marsden

Summary

Prime rib is generally prepared by cooking to low temperatures for long times to attain the desired tenderness and juiciness. Destruction of *Salmonella* spp. in blade tenderized prime rib was examined by following cooking procedures commonly used by chefs. Beef ribs (boneless) were inoculated with *Salmonella* spp. to attain initial surface levels of about 5.75 $\log_{10}$ CFU/cm^2. The ribs were blade tenderized (one pass) using a Ross blade tenderizer. Each was split into two equal sections. One half was cooked to a target internal temperature of 110 and the other half to 120°F, then tempered at room temperature for up to 60 min and placed in a holding oven (120°F) for up to 120 min. Reductions of 4.54 and 4.80 $\log_{10}$ CFU/g were attained for roasts removed from the oven at 110 and 120°F, respectively. Even though prime rib preparation utilizes very low cooked product temperatures, the long cooking time and tempering period result in substantial process lethality and a safe final product.

(Key Words: Blade Tenderization, *Salmonella*, Prime Rib Cookery.)

Introduction

The meat industry must provide product quality and uniformity, especially with regard to tenderness. Blade tenderization is an effective method of meat tenderization. However, this process can translocate surface bacteria into the muscle. This research was done to determine the effectiveness of cooking/holding protocols on reducing *Salmonella* spp. populations that may contaminate the interior of prime rib as a result of translocation due to blade tenderization.

Experimental Procedures

Fifteen boneless beef ribs (roast ready, NAMP 110) were surface-inoculated (fat side) to a target contamination level of 10^7 *Salmonella* spp./cm^2. A five strain cocktail of *Salmonella* spp., used in all investigations, was applied by a light mist of the inoculum onto the exterior meat surfaces. After 30 min, one set of ribs was blade tenderized (Ross C700M, Midland, VA, fat side up) using one pass, with the unit's conveyor moving 1.25 inches forward and 0.5 inches laterally between each blade cycle. The 448 blades of the tenderizer produce 32 incisions per square inch. Product was held at 40°F until cooking (about 1 h). A Type T thermocouple was inserted into the geometric center of each roast through the side and roasts were cooked in a conventional kitchen oven at 375°F to a specific end-point temperature of either 110 or 120°F. Upon reaching the end-point temperature, the product was removed from the oven and tempered at room temperature for 0, 30 or 60 min, then held at 120°F for 0, 60 or 120 min.

Microbiological samples were obtained after blade tenderization, again immediately after

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removal from the oven or after 60 min of tempering, and a third sample after 60 or 120 min of holding at 120°F subsequent to the 60 min tempering. A 1.0 × 1.0 × 1.0-inch section was excised (parallel to the blade channels), from the geometric center of the roast for each treatment. The samples were placed in plastic bags and immersed in an ice water bath to bring the meat temperature down quickly. These samples were microbiologically analyzed for *Salmonella* spp.

Surviving *Salmonella* spp. populations were counted by direct plating on Xylose Lysine De-oxycholate Agar (XLD) and modified Xylose Lysine De-oxycholate Agar (mXLD).

Bacterial population reduction was based on a comparison to inoculated but uncooked control roasts receiving the same processing treatment. If a specific cooking time/temperature reduced the inoculated *Salmonella* spp. to below the detection level of direct plating, stored samples were enriched according to modified USDA protocols. Four replications of the experiment were performed with duplicate roasts being cooked and analyzed for each cooking treatment within replications.

Results and Discussion

Cooking prime ribs to 110 and 120°F internally with subsequent holding at 120°F for 1 h reduced *Salmonella* spp. by 4.54 and 4.80 $\log_{10}$ CFU/g, respectively, from initial levels of 5.76 $\log_{10}$ CFU/g. Internal temperatures reached during cooking were not expected to result in a high level of destruction of *Salmonella* spp., but microbial cells on the surface of the prime rib would be exposed to higher, lethal temperatures.

Combined tempering and holding at 120°F (Table 1) showed the most reduction with 60 min tempering followed by 120 min holding and resulted in a safe final product.

Table 1. *Salmonella* spp. Reductions Attained by Cooking Prime Rib to Internal Temperatures of 110 or 120°F (Pooled Data), Tempering (T) at Ambient Temperature and Holding (H) for Various Periods at 120°F

Tempering (min) at Room Temperature	Holding (min) at 120°F	Reduction $\log_{10}$ CFU/g
0	0	3.87
30	0	5.02
60	0	4.47
60	60	4.72
60	120	5.29

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GARLIC, COLD STORAGE AND HEATING EFFECTS IN CONTROLLING *ESCHERICHIA COLI* O157:H7 IN GROUND BEEF

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M. C. Hunt, and C. L. Kastner

Summary

This research evaluated the effect of garlic, cold storage and heating on *Escherichia coli* O157:H7 in ground beef patties. Ground beef (20% fat) inoculated with *E. coli* O157:H7 to an initial inoculum level of 8 $\log_{10}$ CFU/g, was mixed with 0.5, 1.0 and 1.5% garlic powder (wt/wt). Samples were stuffed into 1 inch diameter test tubes and incubated at 40°F for 24 hr. Tubes were heated to internal temperatures of 125, 130, 135, 140, 145, 155 and 160°F, and *E. coli* O157:H7 was enumerated. Garlic addition lowered *E. coli* O157:H7 survival in ground beef heated to 150 and 155°F, and no organisms were found in beef heated to 160°F. This slight effect may enhance safety of ground beef, but is not a substitute for cooking ground beef to 160°F.

(Key Words: Ground Beef, *E. coli* O157:H7, Garlic, Cooked Temperature.)

Introduction

Enterohemorrhagic *Escherichia coli* O157:H7 is a foodborne pathogen for which a zero-tolerance in ground beef is established by the United States Department of Agriculture. Serious outbreaks of illness due to *E. coli* O157:H7 have been associated with consumption of raw or undercooked ground beef.

In addition to their flavoring properties in food, spices have been studied for their antimicrobial properties. Garlic may be a strong antimicrobial agent against foodborne pathogens such as *E. coli* O157:H7. The objective of this study was to determine the effects of garlic, cold storage and heating in controlling *E. coli* O157:H7 in ground beef.

Experimental Procedures

Five strains of *E. coli* O157:H7 (ATCC 35150, 43889, 43894, 43895 and 51657) were grown in Brain Heart Infusion slants (BHI) at 100°F for 24 hr and kept at 38°F until use. Cultures were transferred to BHI broth, incubated at 100°F for 24 hr and centrifuged at 5,000 × g for 15 min. The resulting cell pellet was diluted with 0.1% peptone water and mixed to make a cocktail solution for inoculation into ground beef.

Cocktail solutions (30 ml) were added to 2,000 g of ground beef (20% fat) to achieve an initial inoculum level of ca. 8 $\log_{10}$ CFU/g, and mixed thoroughly for 2 min. Inoculated ground beef was mixed 2 more min after garlic powder (0, 0.5, 1.0 and 1.5% w/w) was added. Samples were stuffed into 1 in. diameter test tubes (average sample weight, 26.4 g) and incubated at 38°F for 24 hr.

Ground beef samples in the test tubes were heated in a water bath to reach an internal temperature of 125, 130, 135, 140, 145, 150, 155 or 160°F. Samples were immediately removed from the hot water

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bath, placed into an ice bath, then homogenized in 100 ml of 0.1% peptone water for 2 min using a stomacher. Serial dilutions were made using 0.1% peptone water. The enumeration of *E. coli* O157:H7 was performed on Tryptic Soy Agar (TSA), MacConkey Sorbitol Agar (MSA), 202 Agar, TSA-MSA Agar and TSA-202-Agar, TSA-MSA Agar and TSA-202 Agar incubated at 100°F for 24 hr.

Results and Discussion

The initial level of *E. coli* O157:H7 was about 8.0 $\log_{10}$ CFU/g at 125°F internally. With cooking to 140°F or hotter, the number of *E. coli* O157:H7 was reduced, reaching an undetectable level at 160°F (Figure 1).

At temperatures of 145°F and below, garlic had no effect on *E. coli* O157:H7 (Figure 1). However, at 150°F *E. coli* O157:H7 was reduced to 2.9 $\log_{10}$ CFU/g in control samples and to 2.5 and 2.3 $\log_{10}$ CFU/g in 1.0 and 1.5% garlic samples, respectively. At 155°F the control samples contained 1.7 $\log_{10}$ CFU/g while 1.0 and 1.5% garlic samples contained 1.4 and 1.2 log CFU/g of *E. coli* O157:H7, respectively. Our results show that added garlic powder modestly reduced *E. coli* O157:H7 concentrations, but only when the internal cooking temperature was 150°F or higher.

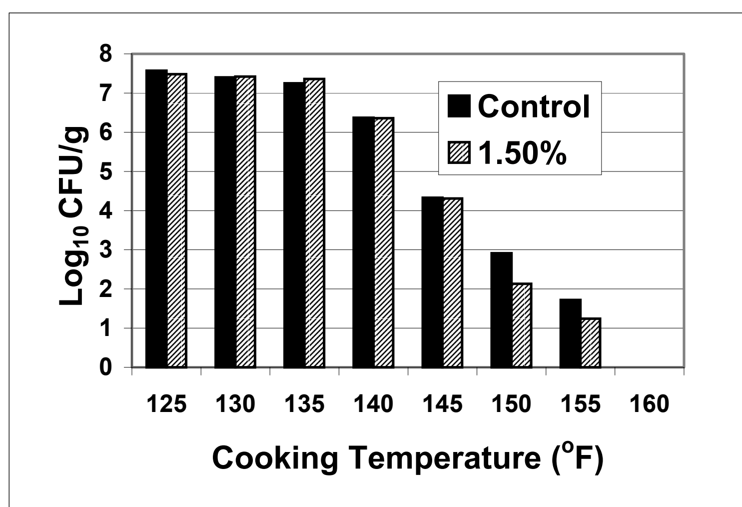

Figure 1. *E. coli* O157:H7 Survival at Various Cooking Temperatures, With and Without 1.5% Added Garlic Powder.

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DAKOTA GOLD®-BRAND DRIED DISTILLER'S GRAINS WITH SOLUBLES IN FINISHING CATTLE DIETS: A PREHARVEST STRATEGY AGAINST ACID RESISTANT *ESCHERICHIA COLI* AND COLIFORMS?

C. M. Gordon, R. K. Phebus, J. S. Drouillard, H. Thipppareddi, D. L. Lambert, K. Kerr, N. Pike, J. J. Sindt, and J. J. Higgins[1]

Summary

Trial 1. Finishing beef heifers (345 head) were used in a 153-day finishing trial to evaluate the effects of feeding six levels of Dakota Gold®-brand dried distiller's grains with solubles (DDGS): 0%, 15%, 30%, 45%, 60%, 75% (dry basis), on the number of acid resistant *E. coli* and coliforms. Fecal grab samples were taken on day 65 and day 100, 2 and 20 hours after feeding, and were analyzed for acid resistant *E. coli* and total coliforms, as well as pH and VFA. There was a significant linear increase in fecal pH with increased DDGS at both 2 and 20 hours postfeeding ($P<0.05$). Total coliforms and acid resistant *E. coli* at 2 and 20 hours postfeeding were not affected by dietary treatment ($P>0.05$). Total fecal VFAs were not affected by dietary treatment or hour sampled after feeding ($P>0.05$)

Trial 2. Trial 2 was conducted on ruminally fistulated Jersey steers (18 head) using three levels of DDGS (0%, 30%, 75%). Rumen and fecal grab samples were taken after 4-week adaptation periods on three occasions after every animal had been on each level of the diet and had been sampled. Fecal and rumen samples were taken 2, 4, 6, 8, 12,18, and 24 hours post-feeding. Both fecal and rumen pH were unaffected by dietary treatment, yet an hour effect was noted. Dietary treatment had no effect ($P>0.05$) on *E. coli* or total coliforms cultured from rumen fluid or feces.

(Key Words: *E. coli,* Finishing Cattle, Dakota Gold Brand Dried Distiller's Grains with Solubles.)

Introduction

Recent food safety research has focused on pre-harvest intervention to reduce *E. coli* contamination. Methods such as vaccination, competitive exclusion, and diet have been proposed as strategies to prevent *E. coli* from contaminating the food supply. Studies have used various fiber sources to reduce numbers of acid resistant *E. coli* shed in cattle feces prior to slaughter. Feeding a fiber source such as hay before slaughter has been proposed as a method to reduce prevalence of acid resistant *E. coli.*

Dakota Gold dried distillers grain with solubles (DDGS) is higher in fiber (43% NDF, DM basis), fat, and protein as compared to cereal grains. Also, DDGS undergoes heating, creating Maillard products that can inhibit the growth of pathogenic microorganisms. We hypothesized that the high fiber content plus the Maillard products could reduce rumen and fecal acid-resistant coliforms, including *E. coli*.

Experimental Procedures

Trial 1. Three hundred sixty-three crossbred heifers (average wt 729 lb) were fed diets with six levels of DDGS (0, 15, 30, 45, 60 and 75%, DM basis) throughout a 153-day finishing experiment. Diet compositions are shown in Table 1. Heifers

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were stratified by previous treatment and randomly allocated to the six diets (54 total pens with 9 pens per diet, 6-7 head per pen). Fecal samples were aseptically obtained from heifers on days 65 and 100 (nine animals per diet, 54 animals daily), at 2 hours and 20 hours postfeeding. Samples of feces were incubated for 15 minutes in a citric acid/sodium phosphate buffer solution at pH 2, 4, and 7 to ascertain total and acid-resistant coliforms and *E. coli*. The samples in the pH 2 and pH 4 buffers were neutralized with sterile 1 M NaOH and placed on ice. Serial dilutions were made with each sample in 0.1% sterile peptone water, plated onto Petrifilm™ plates, incubated for 24 hours at 99°F and enumerated.

Trial 2. Eighteen ruminally fistulated Jersey steers were used in a 3 × 3 Latin square experiment. Steers were fed diets containing 0%, 30%, or 75% Dakota Gold-brand dried distiller's grains for a 16-week period (Table 2). Rumen and feces samples were obtained aseptically from each steer after a four-week adaptation period for each level at 2, 4, 6, 8, 12, 18, and 24 hours postfeeding. The fecal and rumen samples were processed in the same manner as the fecal samples from study 1.

Results and Discussion

Trial 1. Total VFA concentration in the feces was not affected (P>0.05) by dietary treatment or time sampled postfeeding (Figure 1). However, propionate levels were numerically higher at 20 hours post-feeding than at 2 hours postfeeding. Fecal pH was not affected by dietary treatment or sampling time (P>0.05), but increased linearly as DDGS increased (Figure 2). Diet did not affect either *E. coli* or total coliforms at pH 2, 4, or 7; however, more organisms were recovered at 2 hours post-feeding versus 20 hours postfeeding (Table 3). This suggests that dietary fiber may not be the diet component to be studied, since varying levels of DDGS had no significant effect on acid-resistant *E. coli* or total coliforms, fecal pH, or total VFAs. Sampling time had a significant effect, as *E. coli* and total coliforms were almost a half a $\log_{10}$ less at 20 hour postfeeding than at 2 hours postfeeding, demonstrating that results for an acid-resistance study can be affected by sampling time.

Trial 2. Neither fecal pH nor rumen pH were affected by dietary treatment, but pH increased with time after feeding (P<0.05; Figure 3). Fecal *E. coli* had a treatment by hour interaction (P<0.05). When pH 2 buffer was used to establish the presence of acid-resistance organisms, we found an effect of diet but this effect may have been related to unequal consumption in diets. Sampling time was again affected (Table 4), but, this could be related to differences of feed consumption. The first three time periods were sampled in succession and the cattle were not consuming as much because they may have been stressed by sampling. Neither rumen *E. coli* nor total coliforms were affected by dietary treatment or sampling time (P>0.05). The lower rumen pH could have killed many of the *E. coli* and total coliforms before reaching the hindgut, but the surviving organisms were acid tolerant and possibly grew in the neutral pH of the hindgut. The exact component of diet that affects acid-resistant *E. coli* and coliforms was not identified in this study.

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Table 1. Diet Compositions (% of Dry Matter)

	Dried Distiller's Grains with Solubles[a]					
Item	0%	15%	30%	45%	60%	75%
DDGS[a]	-	15	30	45	60	75
Flaked corn	76.62	62.98	49.06	33.89	18.72	3.56
Ground corn	0.00	0.40	1.06	1.38	1.69	2.00
Alfalfa hay	10	10	10	10	10	10
Cane molasses	5	5	5	5	5	5
Dehulled soybean meal	3.01	1.43	0	0	0	0
Urea	1.21	1.06	0.79	0.67	0.55	0.43
Limestone	1.32	1.29	1.25	1.23	1.21	1.19
Salt	0.09	0.09	0.08	0.08	0.08	0.07
Medicated premix[b]	2.45	2.45	2.45	2.45	2.45	2.45
Vitamin/mineral premix[c]	0.09	0.09	0.08	0.08	0.08	0.07
Crude protein	14.0	14.1	15.0	16.6	18.1	19.7

[1]Dakota Gold-brand dried distillers grains with solubles.

[a]300 mg Monensin, 90 mg Tylosin and 0.5mg MGA.

[b]KSU Beef TM Mix.

Table 2. Diet Composition (Dry Basis, Trial 2)

	Dried Distillers Grains with Solubles[1]		
Item	0%	30%	75%
DDGS[a]	-	30	75
Flaked corn	76.62	49.06	3.56
Ground corn	0.00	1.06	2.00
Alfalfa hay	10	10	10
Cane molasses	5	5	5
Dehulled soybean meal	3.01	0	0
Urea	1.21	0.79	0.43
Limestone	1.32	1.25	1.19
Salt	0.09	0.08	0.07
Medicated premix[b]	2.45	2.45	2.45
Vitamin/mineral premix[c]	0.09	0.08	0.07

[1]Dakota Gold-brand dried distillers grains with solubles.

[a]KSU Beef TM Mix.

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Table 3. Trial 1. Effects of Time After Feeding on Fecal *E. coli* and Coliforms

Item	2 Hours	20 Hours
Fecal E. coli	--Log_{10} CFU/G--	--Log_{10} CFU/g--
Buffer Treatment		
pH 2[1]	2.62	1.87
pH 4	5.90	5.48
pH 7	6.35	6.07
Fecal Total Coliforms	--Log_{10} CFU/g-	--Log_{10} CFU/g--
Buffer Treatment		
pH 2[1]	2.65	1.89
pH 4	5.98	5.64
pH 7	6.40	6.26

[1]Sampling time effect ($P<0.05$).

Table 4. Trial 2. Fecal and Rumen *E. coli* and Total Coliforms

	Dried Distillers Grains with Solubles[1]			P-Value	
Item	0%	30%	75%	Linear	Quadratic
Fecal *E. coli*		Log_{10} CFU/g			
Buffer Treatment					
pH 2[2]	3.24	2.78	2.75	0.67	0.03
pH 4	5.57	5.22	5.62	0.14	0.40
pH 7	6.77	5.91	6.22	0.34	0.00
Fecal Total Coliforms		Log_{10} CFU/g			
Buffer Treatment					
pH 2[2]	3.38	2.86	2.79	0.55	0.02
pH 4	5.80	5.40	5.72	0.25	0.13
pH 7	6.90	6.05	6.35	0.14	0.00
Rumen *E. coli*		Log_{10} CFU/mL			
Buffer Treatment					
pH 2	1.80	1.35	1.41	0.18	0.16
pH 4	3.54	2.66	2.72	0.12	0.16
pH 7	4.02	3.14	3.16	0.09	0.10
Rumen Total Coliforms		Log_{10} CFU/mL			
Buffer Treatment					
pH 2	1.87	1.39	1.49	0.21	0.15
pH 4	3.64	2.83	2.98	0.11	0.15
pH 7	4.15	3.39	3.41	0.11	0.16

[1]Dakota Gold-brand dried distillers grains with solubles.
[2]Hour effect ($P<0.05$).

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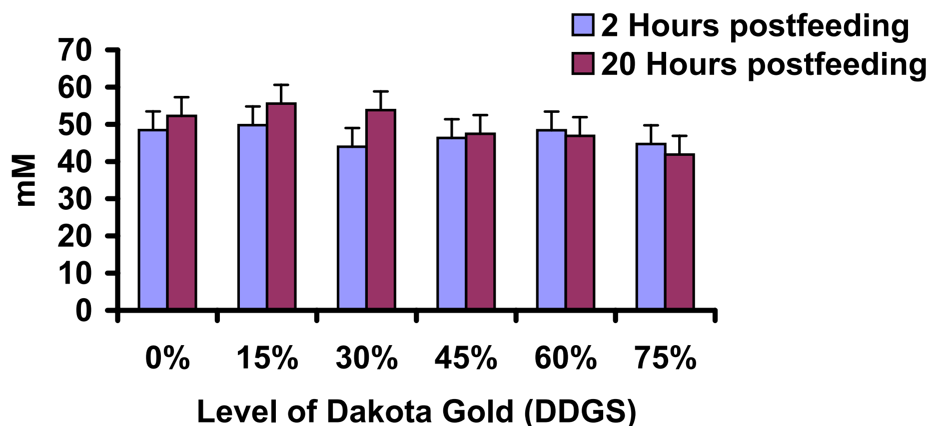
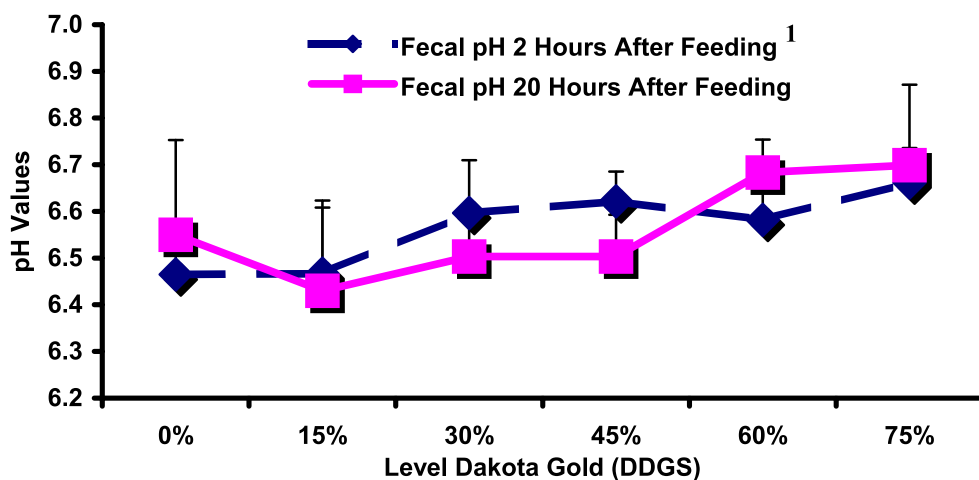


Figure 1. Total VFAs For Varying Levels Of Dakota Gold DDGS For 2 and 20 Hours Postfeeding (Trial 1).



[1]Linear Effect (P< 0.05) of % DDGS.

Figure 2. Fecal pH at 2 and 20 Hours After Feeding Heifers Varying Levels of Dakota Gold Dried Distiller's Grains With Solubles (Trial 1).

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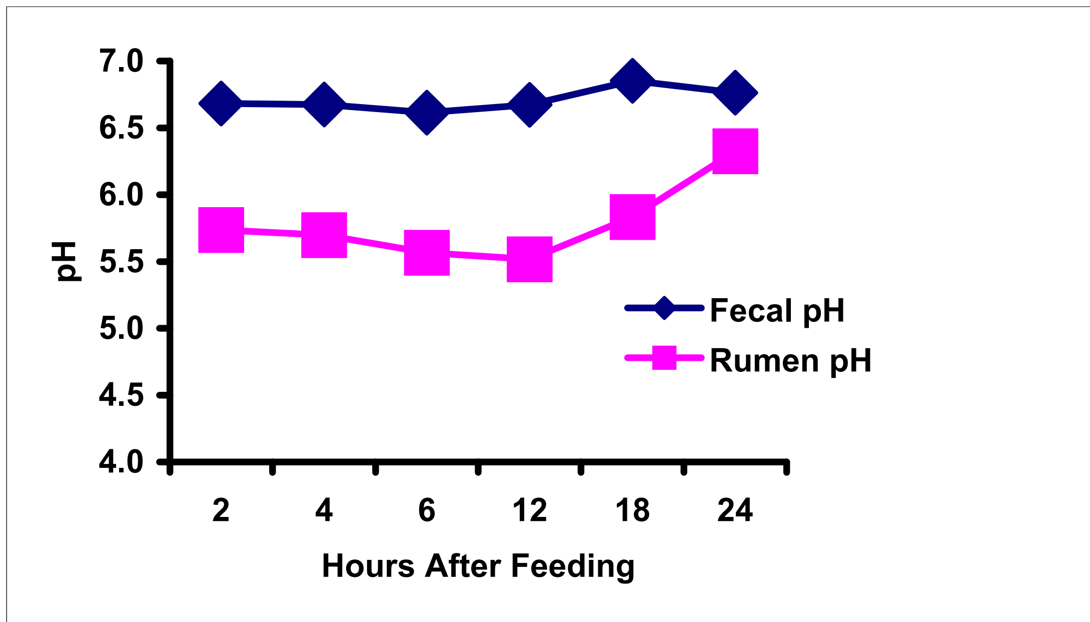
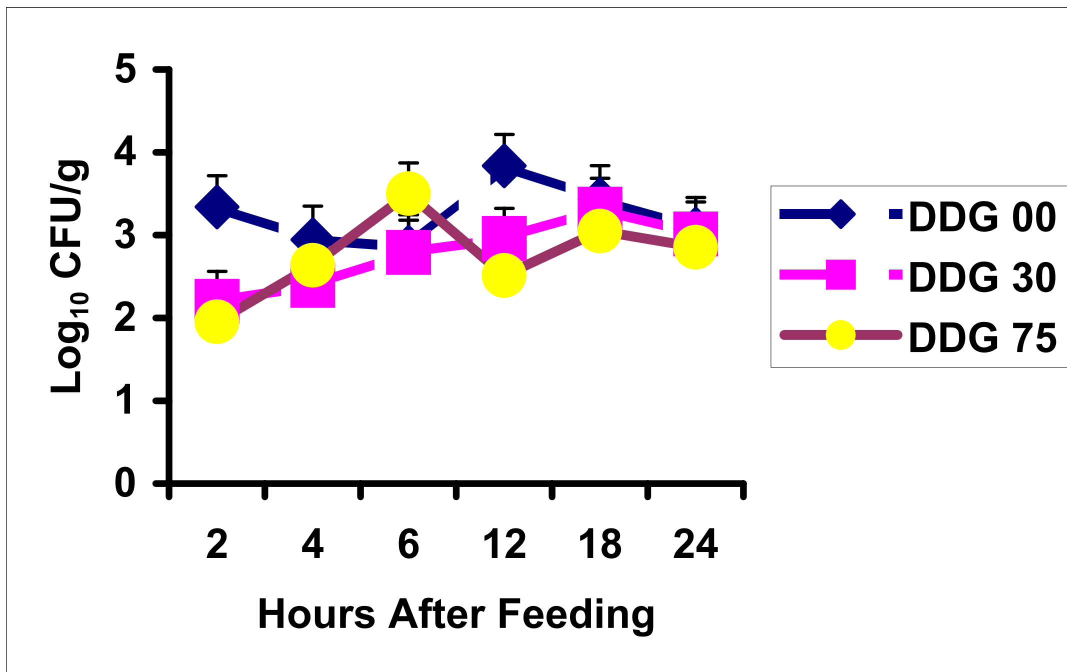


[1]Hour effect, quadratic with regards to diet (P<0.05) SEM= .073
[2]Hour effect, quadratic with regards to diet and time (P<0.05) SEM = .077

Figure 3. Fecal[1] and Rumen[2] pH over a 24 Hour Period (Trial 2).



Quadratic effect (P<0.05)

Figure 4. Acid-Resistant Fecal *E. coli* (Trial 2).

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IMPACTS OF FOOD SAFETY ON BEEF DEMAND

T. L. Marsh[1] *and N. E. Piggott*[2]

Summary

This study investigates whether food safety incidents involving beef, pork, and poultry, and the accompanying publicity have impacted United States meat demand. Beef demand is modeled as a function of beef prices, competing meat prices, meat expenditures, and food safety. Food safety indices are constructed separately for beef, pork, and poultry.

Statistical tests reveal significant effects of food safety incidents on beef demand. The effect of an additional beef food safety incident on beef demand is negative, implying a detrimental impact on beef consumption. Spillover effects of pork and poultry safety incidents are positive and improve beef demand, revealing substitution away from pork and poultry towards beef. In other words, food safety incidents involving beef decrease beef demand and those involving pork or poultry increase beef demand. Overall, the demand responses to food safety incidents are small when compared to price effects and to previously reported estimates on health effects, such as information relating to beef and cholesterol.

(Key Words: Beef Demand, Food Safety, Spillover Effects.)

Introduction

Food safety concerns in the United States have increased dramatically in the past decade. Contaminated meat products can result in serious risk to consumers, and can cause disease outbreaks due to such pathogens as *Listeria monocytogenes*, *Escherichia coli* O157:H7 (E. coli), and *Salmonella*. Food safety problems are not isolated to the United States, as evidenced by the highly publicized outbreaks of Bovine Spongiform Encephalopathy (BSE) in Europe. The potential impacts of food safety incidents on consumer demand for meat products include effects on the demand for the contaminated commodity, as well as spillover effects for other meat commodities.

Experimental Procedures

Food safety indices were constructed separately for beef, pork, and poultry by searching the top 50 English-language newspapers from 1982 to 1999, using the academic version of the Lexis-Nexis search tool. Keywords searched were food safety or contamination or product recall or outbreak or salmonella or listeria or *E. coli* or trichinae or staphylococcus or food-borne. From this information base, the search was narrowed to collect beef, pork, and poultry

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information separately by using additional terms a) beef or hamburger, b) pork or ham, and c) chicken, turkey, or poultry, respectively. The newspaper articles were then counted to construct quarterly beef, pork, and poultry media indices.

To accurately assess meat demand shifts as a result of changes in media reports, meat demand was estimated in a systems model quarterly over the 1982 to 1999 period. The meat demand system accounted for prices of competing meats, total consumer expenditures on meat, food safety, and seasonality. Specifically, the beef equation included beef, pork, and poultry prices; total expenditure on meat; beef, pork, and poultry food safety indices; and seasonality and time trend variables.

Results and Discussion

Figure 1 shows the beef, pork, and poultry media article count quarterly from 1982 to 1999. The number of reported food safety articles for each series remained small, trending slowly upward from 1982 to 1988. From 1988 and through 1999 the number of articles increased markedly with some dramatic peaks dominated by the beef series. The beef series exhibits the highest mean and most variation in the number of articles, with a mean of 162.8 and standard deviation of 223.4. The poultry series has a mean of 151.3 and standard deviation of 126.8. The pork series has a mean of 41.9 and standard deviation of 40.9. The maximum number of reported articles per quarter for beef was 1158 in 1996, 571 for poultry in 1997, and 241 for pork in 1999. Not surprisingly, peaks in the beef series relate to such critical events as BSE concerns in 1990 and 1996 and *E. coli* outbreaks in 1993 and 1997.

Results from the meat demand system provide important insight and implications for beef producers and the beef industry. First, beef demand is inelastic with respect to beef price. From 1982 to 1999, on average, beef quantity demanded declined 0.91 percent for a 1 percent increase in beef price. Response of beef demand to competing pork and poultry price changes is less than one tenth of the response to beef price. Beef demand is highly responsive to changes in per capita meat expenditures. The beef demand model indicates that beef demand increases 1.06 percent for a 1 percent increase in per capita meat expenditures. This implies that beef demand mirrors meat expenditures, which is in turn directly related to disposable income.

Second, consumers perceive an increase in food safety articles about beef as an indicator of a decrease in "quality" of beef products. This leads to individuals consuming less beef. From 1982 to 1999, beef demand decreased on average 0.0004 percent for a 1 percent increase in beef food safety articles. Although this average response seems small, it is important to point out that the number of articles on beef safety increased from 110 in quarter three of 1995 to a high of 1158 in quarter two of 1996. During this period, the 1053 percent increase in number of articles translated to a dramatically larger decrease in beef demand. Alternatively, spillover effects of pork and poultry food safety articles were beneficial to beef, as consumers perceived increased pork or poultry food safety reports in newspapers to indicate a decrease in the "quality" of pork or poultry products and, as a result, they reallocated expenditure towards beef. The demand model indicates beef demand increases 0.0005 percent for a 1 percent increase in

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pork food safety articles. The corresponding increase for poultry articles is .0008.

Overall the demand responses to food safety incidents are small, especially compared to price effects and expenditure, and compared to previously published estimates of health related issues relating to cholesterol. Nevertheless, policy-makers and other participants in the U.S. meat industry need to understand the adverse effects of food safety publicity on beef demand, and spillover effects among competing meats.

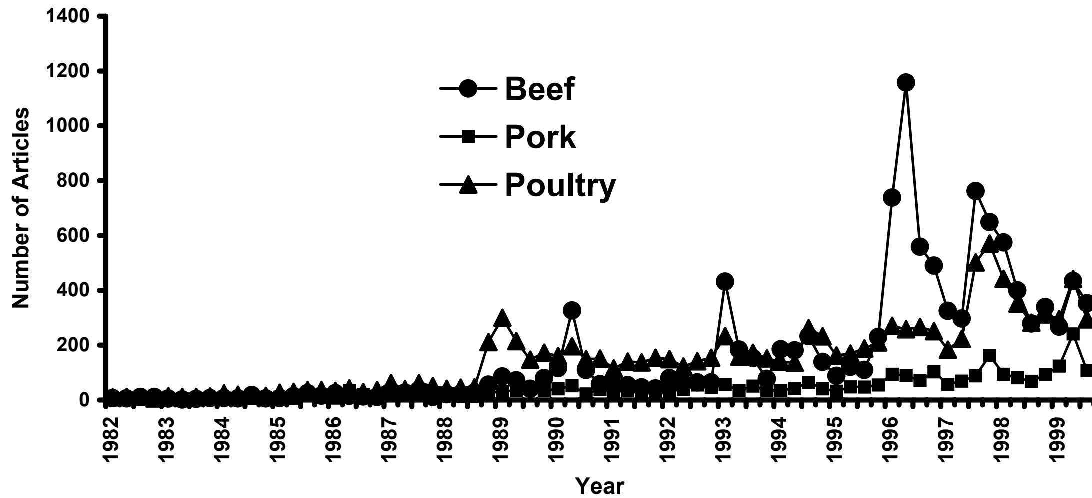

Figure 1: Beef, Pork, and Poultry Food Safety Media Articles 1982-1999.

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TEMPERATURE MANAGEMENT TO MINIMIZE GROUND BEEF AEROBIC AND LACTIC ACID BACTERIA GROWTH

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D. H. Kropf, and K. A. Hachmeister

Summary

Increasing storage and display temperature and time of ground beef significantly increased microbial counts but lean level had no effect. Prolonged storage at abusive temperatures (48°F) caused up to 90% unacceptable chubs and aerobic bacteria counts as high as 7.7 $\log_{10}$ CFU/g, which would render chubs unsatisfactory for further processing, packaging and sale. Thus, ground beef chubs should be stored at 32°F. and as briefly as possible to minimize pre- and post-display microbial counts. Maintaining both optimal storage and display temperatures is critical because combining abusive storage and display conditions resulted in the greatest microbial growth. Shelf life and wholesomeness benefits from maintaining cold (32°F) storage and display temperatures are clearly demonstrated.

(Key Words: Ground Beef Microbiology, Cold Chain Management.)

Introduction

Cold temperature is the most critical factor for suppressing microbial growth and maintaining shelf life and wholesomeness. Coarse ground beef is commonly packaged in chubs, which increases shelf life but creates conditions favoring lactic acid bacteria rather than aerobic microflora. Prolonged chub storage can result in a "sour" odor due to production of lactic acid, whereas subsequent regrinding and packaging for display favors growth of aerobic bacteria. When bacterial counts reach 7 to 8 $\log_{10}$ CFU/g, the resulting microbial end products yield offensive odors that cause consumers to declare the meat spoiled and unwholesome. Currently, ground beef chubs delivered to retailers contain approximately 2 to 4 $\log_{10}$ CFU/g. However, suboptimal temperature control may rapidly increase microbial counts. This project assessed the benefits of cold (32°F) storage and display temperatures, and shorter storage times. This project is unique because it simulated "real world" conditions.

Experimental Procedures

Coarse-ground beef chubs (10 lbs each) of three fat/lean blends (7/93, 19/81, and 27/73) were shipped at 32°F to the Kansas State University Meat Lab. Chubs then were stored for six days at 32°F before randomly assigning one chub per lean level per replication to each of 12 possible combinations of storage temperature (32°, 40°, and 48°F) and storage time (0, 4, 8, and 12 days). There were three replications.

After storage (prior to re-grinding), each chub was evaluated for surface discoloration, objectionable odors, excessive purge, and gas pockets. Chubs were considered objectionable if they had either dark green or black spots on the surface, moderately strong off odors, >1 cup purge, or gas pockets of >4 inch^2. The percentage of unacceptable chubs per treatment com-

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bination that would be discarded prior to grinding was recorded. However, unacceptable chubs were still re-ground and displayed. Each chub was mixed by hand, re-ground, and approximately one pound of ground beef was placed on a Dri-Loc pad on a tray that was overwrapped with polyvinyl chloride (PVC) film. After packaging, one package per chub per fat level per replication was assigned to each of four display treatments [no-display (initial counts), and display at 32°, 40°, and 48°F]. Ground beef was displayed continuously for 48 hours in open-topped display cases under 150 foot candles of Philips Ultralume 30 fluorescent light. The 32ºF case had two defrost cycles/day, the 40ºF case had 1, and the 48ºF case had no defrost cycles.

Samples were analyzed for aerobic plate counts and lactic acid bacteria prior to and after display at assigned temperatures. Dry-rehydrateable 3M Aerobic Plate Count Petrifilm™ was incubated at 95±1°F for 48 hours and lactic acid bacteria counts were analyzed using MRS agar in a 20% CO_2 incubator for 48 hours at 95±1°F. Microbial analyses were done in triplicate and averaged.

The experimental design consisted of four main effects: lean level (n=3), storage temperature (n=3), storage time (n=4), display treatment (n=4) and their interactions analyzed over three replications. Main effects and all possible interactions were analyzed using the Mixed procedure of the Statistical Analysis System (SAS, 2000). Main effects, interactions, and least square means were considered significant at $P<0.05$.

Results and Discussion

Table 1 shows the combined effects of each storage temperature, storage time, and display temperature on aerobic and lactic acid bacteria counts and chub loss. In general, storage and display at 32°F resulted in the lowest microbial counts. Following 0 day storage at 32°F with display at 32°F resulted in an increase of only 0.1 $\log_{10}$ CFU/g for aerobic bacteria and a 0.4 $\log_{10}$ CFU/g decrease in lactic acid bacteria. Conversely, combinations involving 48°F consistently resulted in high counts. Prolonged (12 days) storage at 48°F resulted in predisplay chub loss of 90% and aerobic and lactic acid bacteria counts as high as 7.6 and 6.6 $\log_{10}$ CFU/g, respectively. For chubs stored for 12 days at 40°F, 10% were considered unacceptable at grinding.

Storage of ground beef chubs at 32° and 40°F resulted in aerobic bacteria counts that were similar but less than with storage at 48°F, whereas lactic acid bacteria numbers increased with each increase in storage temperature. Storage for 0 and 4 days resulted in similar pre-display counts for lactic acid bacteria, but less than after 8 and 12 days, which were similar.

Following all storage treatments (32°, 40°, and 48°F), display at 32° and 40°F resulted in aerobic bacteria counts that were statistically similar, whereas display at 32°F consistently resulted in less microbial growth than display at 48°F. Following storage and display at 48°F, aerobic bacteria counts reached 8.3 $\log_{10}$ CFU/g and often resulted in putrid off odors.

After 0 and 4 days of storage, display at 32° and 40°F resulted in lactic acid bacteria counts that were similar, but less than at 48ºF. Following eight days of storage, display at 32°F slightly increased growth of lactic acid bacteria, whereas 48 hours of display at 40° and 48°F significantly increased growth.

Considering that the average retail display temperature is 40°F, aerobic bacteria

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counts (APC) of ground beef commercially displayed for 48 hours may range from 4.0 to 8.0 $\log_{10}$ CFU/g (Table 1). Storage of ground beef chubs resulted in a 1 $\log_{10}$ increase in APC after 8 days of storage and a 2.8 $\log_{10}$ increase after 12 days. Combining elevated storage and display temperatures (48°F) and prolonged storage periods (12 days) greatly increased bacterial growth. Conversely, insuring that brief but cold storage is followed by cold display will minimize microbial growth, decrease off odors, and increase shelf life.

Storage and display at 48°F results in ground beef that is obviously spoiled, as demonstrated by putrid off odors and gas pockets. However, maintaining cold temperatures throughout storage and display insured low microbial counts, and prevented off odors, gas pockets, product loss, and sales loss. The results clearly demonstrate that 32°F temperatures are essential to suppress microbial growth, maximize shelf life, and should enhance profitability.

Table 1. Combined Effects of Storage and Display on Aerobic, Lactic Acid Bacteria, and Chub Loss of Ground Beef

	Storage Temperature (°F)											
	32				40				48			
	Display Treatment (°F), 48 Hrs											
Storage Time (d)	Pre-display	32	40	48	Pre-display	32	40	48	Pre-display	32	40	48
A. Aerobic bacteria counts ($\log_{10}$ CFU/g)												
0	4.0	4.1	4.2	5.2	4.0	4.1	4.2	5.2	4.0	4.1	4.2	5.2
4	5.0	5.6	5.0	5.7	5.1	5.5	6.1	5.9	6.0	6.0	6.6	6.7
8	4.8	5.5	6.3	6.7	5.0	6.7	6.8	6.9	7.7	7.6	7.4	7.8
12	6.2	6.9	7.3	7.9	6.8	7.7	8.0	8.0	7.6	8.0	8.2	8.3
B. Lactic acid bacteria ($\log_{10}$ CFU/g)												
0	4.0	3.6	3.9	5.4	5.0	3.6	3.9	5.4	4.0	3.6	3.9	5.4
4	4.0	4.5	4.7	5.4	3.7	4.8	5.5	5.9	4.8	5.6	5.9	6.4
8	4.5	4.9	6.0	6.0	5.2	5.8	6.6	6.7	6.6	7.0	7.1	7.2
12	4.4	5.4	5.9	6.5	5.6	6.7	6.7	6.8	6.9	7.2	7.6	7.5

C. Chub loss after storage (%)[a]

Storage	Storage Temperature (°F)		
Time (d)	32	40	48
0	0	0	0
4	0	0	0
8	0	0	30
12	0	10	90

[a]Rejection based on extreme black surface discoloration, objectionable odors, >1 cup purge, and gas pockets >4 $inch^2$.

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MAXIMIZING DESIRABLE GROUND BEEF COLOR WITH COLD STORAGE AND DISPLAY TEMPERATURES

R. A. Mancini, M. C. Hunt, D. H. Kropf, K. A. Hachmeister, D. E. Johnson[1], S. Fox[2]

Summary

This study evaluated the combined effects of storage temperature, storage time, display temperature, display time, and fat level on ground beef color. Storage at 32°F minimized discoloration during display compared to storage at 40° and 48°F. Storage up to 12 days at 32°F did not affect ground beef color stability, whereas prolonged storage at 40° and 48°F increased discoloration dramatically. When storage was at 32°F, sales loss was 0.4%, compared to 62% at 48°F. Fat level did not influence discoloration. The use of 32°F during storage and display is essential for maximizing ground beef color life.

(Key Words: Ground Beef Color, Cold Chain Management, Discoloration.)

Introduction

Discoloration, defined as a change in ground beef color from bright-red to brown, results in consumer rejection, reduced shelf life, and decreased profit. Even though discoloration is inevitable, it is slowed by cold storage and display temperatures. A recent national retail survey found that the average display case temperature was 40°F. Our objectives were to evaluate the combined effects of storage temperature, storage time, display temperature, display time, and fat level on ground beef color.

Experimental Procedures

Coarse ground beef chubs (10 lb each) of 3 fat/lean blends (7/93, 19/81, and 27/73%) were shipped to the Kansas State University Meat Lab at 32°F. All chubs were stored for 6 days at 32°F before randomly assigning one chub per lean level per replication, to each of 12 storage temperature (32°, 40°, or 48°F) and storage time (0, 4, 8, and 12 days) combinations for each of 3 replications.

Following storage, each chub was mixed by hand and ground once through a 1/8 inch plate. After grinding, approximately one pound of ground beef was placed on a Styrofoam tray with a Dri-Loc pad and packaged with polyvinyl chloride (PVC) film. One package per chub per fat level per replication was displayed continuously for 48 hours at either 32°, 40°, or 48°F in one of three open-top display cases under 150 foot candles of Philips Ultralume 30 fluorescent light. The 32ºF case had two defrost cycles/day, the 40ºF case had one, and the 48ºF case had no defrost cycles.

Ground beef surface color was evaluated at 0, 24, and 48 hours of display by seven trained panelists. Initial color (0 hour) was evaluated 30 minutes after the meat was ground and packaged. Evaluation was on a five-point color scale (1=very bright cherry red, 2=bright cherry red, 3 = slightly dark red to tannish red, 4 = moderately grayish/tan to brown, and 5 = tan to brown) in increments

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of 0.5. Borderline color acceptability was considered to be a score of 3.5.

The statistical design consisted of 5 main effects: fat level (n=3), storage temperature (n=3), storage time (n=4), display temperature (n=3), and display time (n=3), and their interactions. Data were analyzed over 3 replications using the Mixed procedure of the Statistical Analysis System (SAS, 2000). Least square means for significant interactions were separated ($P<0.05$).

Results and Discussion

Storage and/or display at 40º and 48ºF accelerated ground beef discoloration (Figure 1). Storage at 32ºF resulted in brighter-red initial bloomed color than storage at either 40º or 48ºF. Storage at 32ºF also maintained this more desirable color during display, whereas longer storage times had more adverse effects at warmer temperatures. Failing to use cold display temperatures accelerated discoloration dramatically (Table 1).

When 32ºF storage was coupled with 32ºF display, display time effects were so minimal that at no point during the 48-hour display did color become unacceptable. However, utilizing only cold storage temperatures and allowing warmer display temperatures negated the benefits of 32ºF storage. In general, as storage temperature and display temperature increased, discoloration during display was accelerated. Changes in discoloration due to lean level were relatively small.

The normal level of sales loss (i.e. price discounts and profit loss due to discoloration) was assumed to be 6% at 40°F. Reducing the storage and display temperatures from 40° to 32°F reduced the sales loss to 0.4% (Figure 2). Increasing the storage and display temperatures to 48°F was estimated to increase sales loss to 31%. Increasing the storage time to 12 days at 48°C resulted in estimated sales losses of 62%. However, sales losses for 8 and 12 days of storage at 48°F may be underestimated because those chubs had high microbial counts, extreme surface discoloration, off odors, and/or gas pockets; rendering them unsuitable for grinding and display.

Use of 32°F was far superior to storage and display at 40° and/or 48°F. Thus, to maximize color life and profit, 32°F during storage and display is strongly recommended. Failure to select and maintain 32°F will accelerate discoloration dramatically and increase sales losses. Except at 32°F, increasing storage time was detrimental to color. Thus chub storage should be as brief as possible. Ground beef fat level had minor effects on discoloration.

These results overwhelmingly suggest that the use of cold temperatures (32°F) during both storage and display of ground beef maximizes shelf life and profit.

Table 1. Relative Rates of Color Loss for Ground Beef Displayed for 48 Hours Compared to Those Stored at 32°F for 0 Days Prior to Display at 32°F. Rates Larger than 1.0 Indicate Increased Discoloration Compared to Optimum Conditions

	Storage Temperature (°F)					
	32			48		
Storage	Display Temperature (°F)					
Time (d)	32	40	48	32	40	48
0	1.0	1.9	2.7	1.0	1.9	2.7
4	1.1	1.7	2.7	1.3	1.4	2.1
8	1.4	1.9	2.9	2.4	2.9	3.2
12	1.3	1.8	2.8	3.8	6.4	7.2

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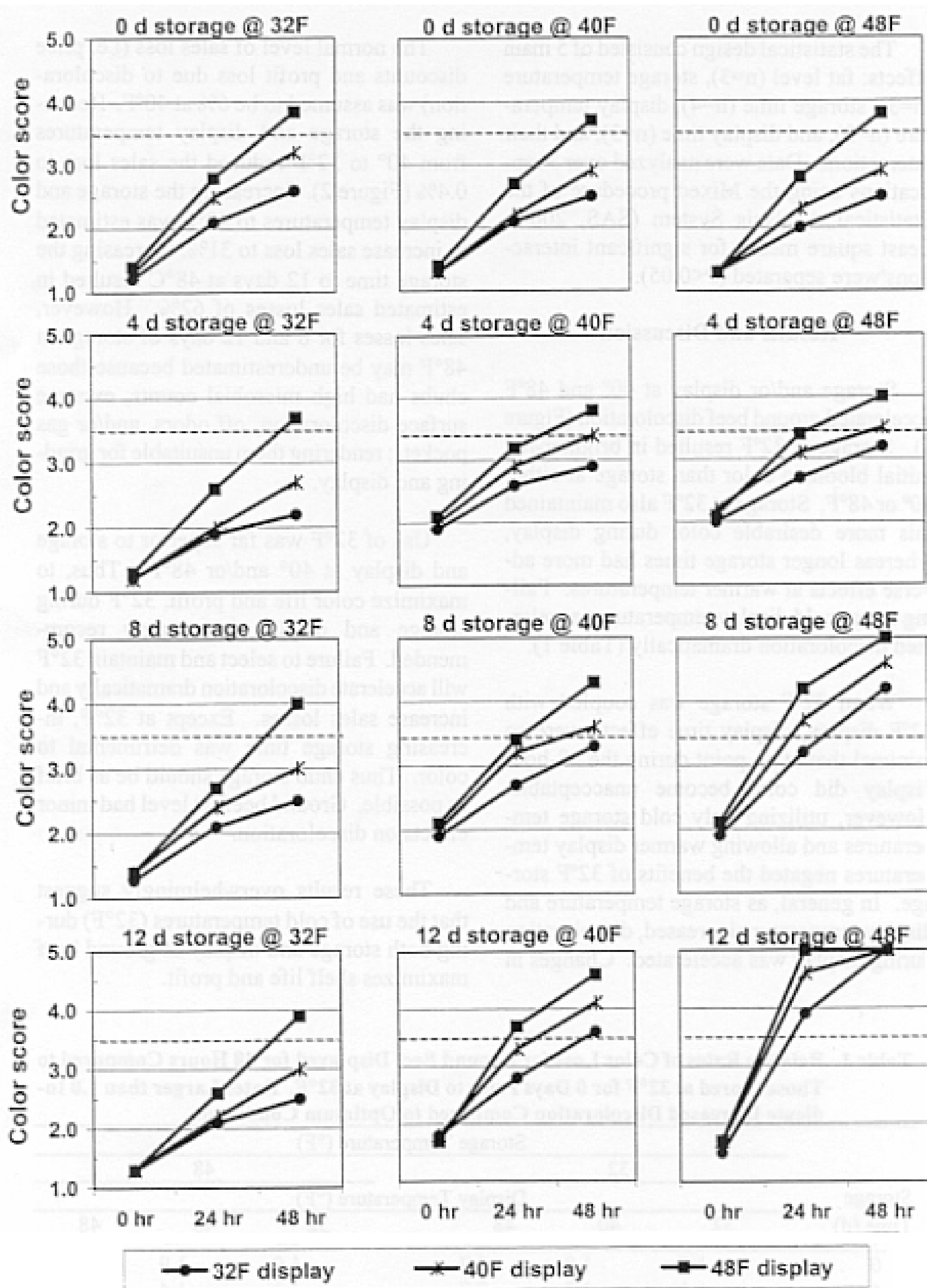

Figure 1. Effect of Temperature and Time of Storage and Display on Visual Color Score. Visual color scale: 1=very bright cherry red; 3.5=unacceptable slightly dark red; 5=brown.

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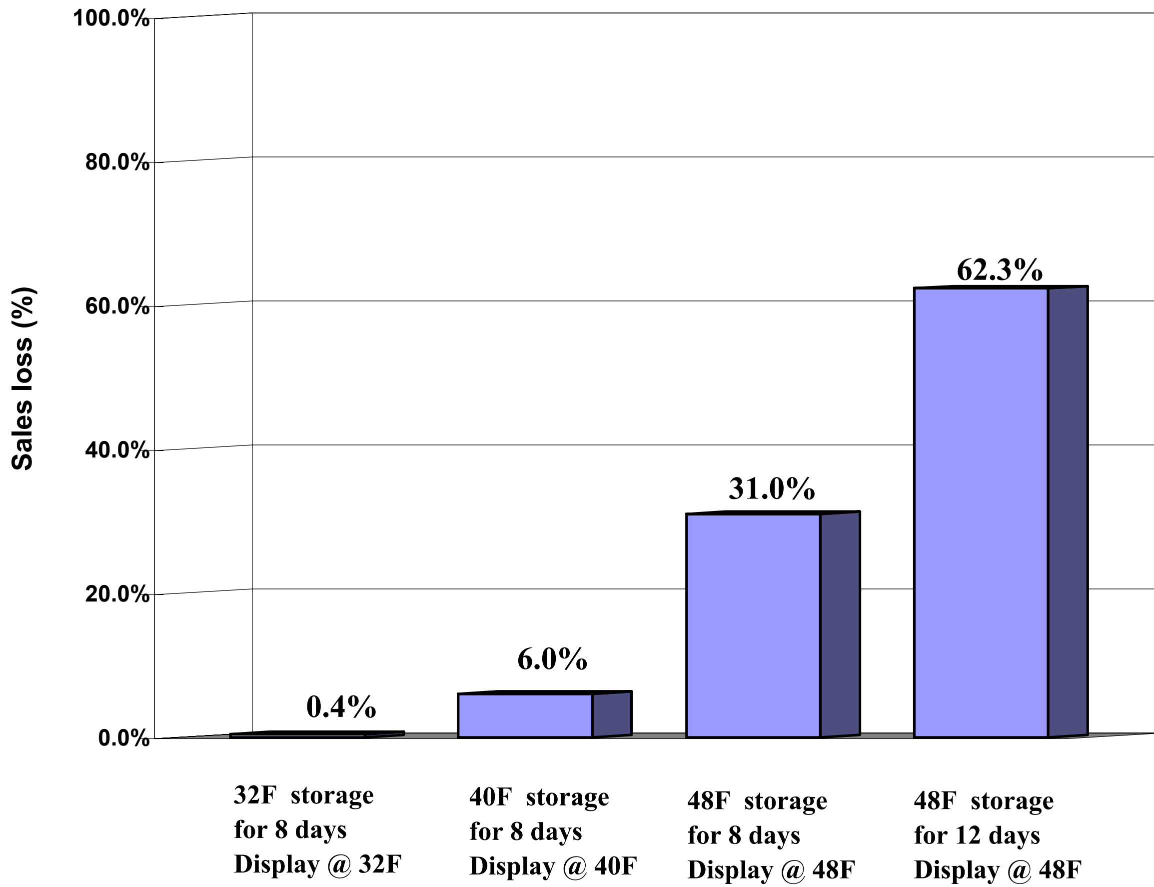

Figure 2. Effects of warm temperatures and prolonged storage times on sales loss of ground beef.

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THE EFFECT OF DAKOTA GOLD®-BRAND DRIED DISTILLER'S GRAINS WITH SOLUBLES OF VARYING LEVELS ON SENSORY AND COLOR CHARACTERISITICS OF RIBEYE STEAKS

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Summary

We evaluated the effect of varying levels of Dakota Gold®-brand dried distiller's grains with solubles (DDGS) on meat quality characteristics including sensory traits and display color stability. Rib cuts from heifers from a 153-day feeding trial were selected randomly so that each level of DDGS had 10 steaks in a seven-day retail display color study, and 10 steaks that were cooked for evaluation by a trained sensory panel. Color reflectance value L* (lightness) exhibited an interaction (P<0.05) between diet and day, as well as a quadratic effect (P<0.05). Diet had no effect on a* (redness) or b* (yellowness) values, but a* and b* for all treatments decreased with longer display (P<0.05). A trained sensory panel detected small but significant (P<0.05) linear improvements in myofibrillar tenderness and overall tenderness as DDGS increased. The effect on sensory traits or display color stability were too small to warrant the feeding of DDGS to improve these traits.

(Key Words: Color, Sensory, Dakota Gold Dried Distiller's Grains with Solubles.)

Introduction

Dakota Gold-brand dried distiller's grain with solubles (DDGS) is a corn by-product of alcohol production. Starch has been removed, so fiber, fat, and protein have been concentrated, and it is well suited as an alternative ingredient in typical cereal grain-based diets for finishing cattle. DDGS also contains antioxidants including tocopherols (vitamin E), melanoidin (brown pigments formed during drying) and a unique fatty acid profile. These differences from conventional cattle diets led us to determine if adding Dakota Gold-brand DDGS in varying levels to diets of finishing heifers would impact meat quality attributes such as sensory and display color stability of beef steaks.

Experimental Procedures

Wholesale ribs were taken from heifers fed six different levels of Dakota Gold-brand DDGS (0, 15, 30, 45, 60 and 75%) during a 153-day finishing trial. Sixty rib cuts (10 per diet treatment) were deboned, vacuum packaged, and aged for two weeks. After aging, ribs were cut into six, 1-inch-thick steaks. Steaks for sensory analysis were vacuum packaged and stored at -40º F until used. Steaks for the display study were immediately put onto Styrofoam trays on absorbent Dri-Loc pads, and wrapped in polyvinyl chloride film. Steaks were displayed in a 35ºF case using Philips Ultralume 30 fluorescent lights at 150 foot candles. Reflectance was measured with a HunterLab Miniscan XE Spectrophotometer. CIE L*a*b* values for illuminant A and percent reflectance from 400 to 700 nm at 10 nm increments were measured. Each steak was scanned at three locations on the longissimus dorsi muscle and measurements were averaged. Hue angle, saturation index, and 630/580 nm ratios were calcu-

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lated. Scans were taken at 0, 3, and 7 days, with steaks being rotated around the case twice daily. Digital pictures were taken on day 1 and day 7 for visual comparison.

Sensory analysis was conducted by a professional panel at Kansas State's Sensory Analysis Center. All panelists were oriented twice on flavor, texture, and aroma attributes, which they scored for each steak on an 8 point scale to the nearest 0.5. Steaks were thawed and cooked on a Wells charbroiler to a target internal temperature of 160ºF, measured with internal thermocouples. Steaks were trimmed of external fat, then cut into equal size cubes and assigned a random number. Initially, six steaks were tested per day, each steak representing a treatment, but after two days, panelists evaluated 12 samples a day, with each treatment being represented twice. Panelist's scores were analyzed by SAS using a mixed model for differences among the diets.

Results and Discussion

Color is the first quality element that a consumer observes. It may be the sole motive behind the purchase of one steak over another. Ideally, the heme pigment in a steak is in the oxymyoglobin form and is visually perceived to be a bright cherry red color. If oxidation occurs, metmyoglobin, a brown pigment, forms, and the steak will be perceived as being of less desirable quality. Oxygen, lipid oxidation, presence of antioxidants, and microbial contamination can all effect which pigment is observed. We used the CIE L*a*b* instrumental color system to measure color change over time (Table 1). The L* value (lightness) exhibited a treatment by day interaction ($P<0.05$) with a quadratic effect ($P<0.05$). A dietary effect was not found for a*(redness) or b*(yellowness), but these decreased with longer display ($P<0.05$). Over the 7-day display period, steaks slowly turned less red, which is the usual pattern of discoloration. Hue angle was not affected by diet ($P>0.05$), but the increase with longer display confirms the discoloration.

Trained sensory panel evaluation found differences ($P<0.05$), in myofibrillar tenderness and overall tenderness (Table 2). Myofibrillar tenderness showed a linear improvement as DDGS increased ($P<0.05$). Overall tenderness showed a similar linear trend. Other sensory attributes—connective tissue amount, juiciness, flavor intensity, and off flavor intensity—were not different ($P>0.05$). As none of these levels of Dakota Gold-brand DDGS had an effect on fat oxidation as measured by thiobarbituric acid reactive substances (TBARS), the lack of consistent flavor differences was expected ($P>0.05$). Neither were there differences due to DDGS levels in other off flavors, such as metallic, rancid oil, organ, sour, serumy, earthy, and grassy. Our panelists are trained to detect differences the average consumer would not be able to detect. Therefore, the small improvements we observed in sensory traits and display characteristics are too small to warrant feeding DDGS on that basis alone.

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Table 1. Color Data for Steaks In a 7-Day Retail Display Study

	Dried Distiller's Grains with Solubles[a]								
Item	0%	15%	30%	45%	60%	75%	SEM	Linear	Quadratic
Day 0									
L*[1]	45.7	45.8	46.9	45.7	45.0	44.0	0.86	0.13	0.02
a*[2]	31.9	32.3	31.9	32.7	32.1	31.9	1.06	0.17	0.28
b*[2]	24.1	24.7	24.4	25.4	24.4	23.8	0.74	0.53	0.47
Saturation[2]	39.9	40.7	40.1	41.4	40.3	39.8	1.18	0.24	0.32
Hue Angle[2]	37.5	37.4	37.4	37.7	37.4	36.6	1.42	0.06	0.32
630/580[2]	6.2	6.4	6.2	6.5	6.4	6.6	0.30	0.80	0.10
Day 3									
L*[1]	45.0	45.2	46.1	45.5	45.3	43.0	0.86	0.13	0.02
a*[2]	28.0	29.0	27.1	27.0	26.5	28.3	1.06	0.17	0.28
b*[2]	21.2	22.0	20.9	20.9	20.4	21.8	0.74	0.53	0.47
Saturation[2]	35.1	36.4	34.2	34.2	33.5	35.7	1.18	0.24	0.32
Hue Angle[2]	37.4	37.2	37.4	36.7	37.5	37.2	1.42	0.06	0.32
630/580[2]	4.6	4.8	4.3	4.2	4.1	4.9	0.30	0.80	0.10
Day 7									
L*[1]	44.6	44.8	46.0	45.7	45.4	42.9	0.86	0.13	0.02
a*[2]	19.5	18.8	17.6	16.3	15.0	16.9	1.06	0.17	0.28
b*[2]	16.3	15.6	15.9	15.1	14.6	16.1	0.74	0.53	0.47
Saturation[2]	25.5	24.4	23.8	22.3	21.0	23.5	1.18	0.24	0.32
Hue Angle[2]	41.5	40.4	42.0	41.8	44.2	44.6	1.42	0.06	0.32
630/580[2]	2.6	2.5	2.2	2.0	1.8	2.3	0.30	0.80	0.10

[a]Dakota Gold-brand dried distillers grains with solubles.
[1]Diet × Day interaction (P<0.05).
[2]Day interaction (P<0.05).

Table 2. Sensory Panel Evaluations of Ribeye Steaks from Heifers Fed Diets Containing Varying Levels of Dakota Gold Brand DDGS

	Dried Distiller's Grains with Solubles[1]								
Items[2]	0%	15%	30%	45%	60%	75%	SEM	Linear	Quadratic
Myofibrillar Tenderness	6.35[c]	6.58[ab]	6.43[b]	6.64[ab]	6.74[a]	6.62[ab]	0.100	0.008	0.330
Juiciness	6.22	6.18	6.26	6.35	6.33	6.28	0.120	0.225	0.583
Flavor Intensity	6.42	6.61	6.51	6.65	6.68	6.50	0.100	0.199	0.033
Connective Tissue Amount	6.93	7.19	7.11	7.11	7.16	7.17	0.090	0.076	0.226
Overall Tenderness	6.26[b]	6.72[a]	6.55[a]	6.66[a]	6.76[a]	6.76[a]	0.110	0.001	0.135
Off-Flavor Intensity	7.70	7.67	7.57	7.66	7.68	7.54	0.090	0.155	0.948
TBARS[3]	0.06	0.07	0.07	0.07	0.07	0.07	0.004		

[1]Dakota Gold-brand dried distillers grains with solubles.
[2]1=extrememly tough, dry, bland, abundant connective tissue, extremely tough, or intense; 8=extremely tender, juicy, intense, no connective tissue, tender, none.
[3]Thiobarbituric acid reactive substance, expressed as ppm of malonaldehyde.
[a,b]Means within same row without common superscript are different (P<0.05).

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EFFECTS OF TALLOW AND GROUND FLAXSEED ON SENSORY AND COLOR CHARACTERISTICS OF RIBEYE STEAKS[1]

H. J. LaBrune, J. S. Drouillard, K. A. Hachmeister, D. H. Kropf, and M. E. Dikeman

Summary

Forty-eight ribeye steaks from steers fed diets containing steam-flaked corn (SFC), steam-flaked corn with tallow (SFC/Tallow), or steam-flaked corn with rolled flaxseed (Flax) were used to evaluate the effects of dietary fat on sensory traits, retail display color stability, and fatty acid composition. Steaks from Flax-fed steers had increased deposition of alpha linolenic acid (C18:3n3, an omega-3 fatty acid; $P<0.01$) and developed a detectable off-flavor ($P<0.05$) when compared to those of cattle fed SFC and SFC/Tallow. There were no differences in tenderness, juiciness, or flavor intensity ($P>0.10$) among the three treatments. Steaks from cattle fed SFC retained a desirable color longer than those from cattle fed Flax ($P<0.05$) which may be attributable to premature lipid oxidation in steaks from cattle fed Flax. This study suggests that altering the fat in the diet may affect flavor and color stability of the meat. Feeding flaxseed can effectively alter composition of carcass tissues to yield beef that is high in omega-3 fatty acids, which may lead to premature lipid oxidation.

(Key Words: Flaxseed, Omega-3 Fatty Acids, Alpha-Linolenic Acid, Sensory Traits.)

Introduction

Flaxseed is a rich source of alpha linolenic acid, an essential omega-3 fatty acid. Notable effects of omega-3 fatty acids include improved immunity, reduced risk of coronary heart disease, and modulation of blood glucose. The estimated daily requirement for omega-3 fatty acids in adult humans is 1 gram. Increasing concentrations of omega-3 fatty acids in beef would provide an alternative means of meeting this requirement. Our objective was to determine if including flaxseed in finishing diets would alter muscle fatty acid composition, and affect retail display life and sensory characteristics of the meat.

Experimental Procedures

Forty-eight steers were housed at the Kansas State Beef Cattle Research Center and fed finishing diets containing steam-flaked corn (SFC), SFC plus 4% tallow, or SFC plus 10% rolled flaxseed (equivalent to 4% added lipids). After slaughter the rib was removed from each carcass and aged in vacuum packages for 21 days at 37°F. One-inch steaks were cut from the posterior end of the rib, and were used for analysis of fatty acid oxidation (TBARS; thiobarbituric acid reactive substances), sensory characteristics, retail display color stability, and fatty acid composition.

Plasma collected from steers 14 days prior to slaughter was analyzed for fatty acids by gas chromatography. Fatty acid content of the longissimus muscle also was determined following extraction of lipids from the muscle tissue. Assessment of

[1]This research was supported by a grant from the North Dakota Oilseed Council.

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color change during retail display was determined by L* a* b* values utilizing a HunterLab Miniscan spectrophotometer (Hunter and Associates, Reston, VA). The L* value is a measure of lightness (0 = black to 100 = white), the a* value measures green (-60) to red (60), and the b* value measures blue (-60) to yellow (60). The hue angle measures discoloration from red toward yellow. The reflectance ratio 630 nm/580 nm is a measure of color deterioration, with larger numbers indicating a more desirable red color. The saturation index represents the vividness of the color, with higher numbers indicating a more vivid, less dull color.

Steaks were thawed and cooked to 160°F in a Blodgett modified broiler oven. Cooked steaks were cut into ½ × ½ × 1 inch pieces for evaluation and scored on a scale of 1 to 8 for tenderness, flavor, juiciness, connective tissue content, and flavor intensity, where 8 is desirable and 1 is undesirable. Products were evaluated independently for various flavor and texture attributes by seven panelists.

Results and Discussion

Feeding Flax to cattle increased the proportion of linoleic acid (C18:2) in rib steaks compared to feeding SFC ($P<0.10$; Table 1). Alpha linolenic acid (C18:3n3) also was higher for steaks from cattle fed Flax compared to those from cattle fed SFC or SFC/TALLOW ($P<0.01$). This has potentially important implications for human health because consumption of alpha linolenic acid can decrease cholesterol levels, reduce the risk of cardiovascular disease and stroke, and alleviate inflammation associated with certain forms of arthritis.

Feeding Flax yielded increased plasma levels of alpha linolenic acid ($P<0.05$; Table 2) to 276 μg/ml compared to 13 for SFC and 34 for SFC/Tallow. No difference in C18:3n6 resulted from the diets ($P>0.10$). Steers fed SFC/Tallow had higher plasma content of C16:0 and C16:1 when compared to Flax and SFC ($P<0.05$).

Sensory panel overall tenderness, juiciness, and flavor intensity were not different among treatments (Table 3). However, steaks from steers fed Flax had a more pronounced off-flavor ($P<0.02$). This could be due to incorporation of alpha linolenic acid from the Flax into the muscle, and its subsequent oxidation. Some of the off flavors were described as metallic, rancid, cardboard, sour, and slightly bitter, all suggestive of lipid oxidation.

Instrumental reflectance values for color analysis of rib steak longissimus (L*, a*, and b*) after a 7-day display are presented in Table 4. Lightness (L*) measures were not different among treatments. On day 7, SFC and SFC/Tallow retained the red color better than Flax ($P<0.05$), and steaks from cattle fed SFC had a more vivid color appearance than steaks from cattle fed Flax ($P<0.05$), but were not different than steaks from steers fed SFC/Tallow ($P>0.05$). Retail display life of steaks from cattle fed the Flax diet was shorter than that of steaks from cattle SFC and SFC/Tallow, as evidenced by changes in the 630/580 nm ratio.

Feeding Flax to finishing cattle increases omega-3 fatty acids in muscle and may have application for producing value added beef products. However, supplementation with antioxidants, such as vitamin E, may be necessary to prevent premature lipid oxidation and to promote longer retail display life.

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Table 1. Long Chain Fatty Acids in Ribeye Steaks

	SFC[e]	SFC/Tallow	FLAX	SEM
C14:0	4.6	4.6	5.0	.54
C14:1	1.1	1.2	1.2	.18
C15:0	.7	.7	.8	.10
C15:1	1.1	1.3	1.5	.25
C16:0	33.4	25.5	30.4	3.62
C16:1	2.9	4.9	3.6	.65
C17:0	1.2	1.8	1.3	.19
C17:1	1.4	1.3	0.8	.18
C18:0	7.4	11.3	10.2	1.32
C18:1	37.9	38.0	32.3	4.25
C18:2	6.3[a]	6.6[ab]	8.4[b]	.86
C18:3	0.2[c]	0.2[c]	2.1[d]	.12

[1]Values expressed as a percent of fat content.
[a,b]Means in a row with unlike superscripts are different ($P<0.10$).
[c,d]Means in a row with unlike superscripts are different ($P<0.01$).
[e]Steam-flaked corn.

Table 2. Long Chain Fatty Acids in Plasma[1]

	SFC[e]	SFC/Tallow	FLAX	SEM
C14:0	16.9	17.8	11.7	2.97
C14:1	1.7[cd]	2.5[c]	0.0[d]	1.00
C15:0	13.7[cd]	14.0[c]	9.4[d]	1.88
C15:1	1.9[d]	7.9[cd]	10.3[c]	3.10
C16:0	185.4[a]	257.5[b]	198.8[a]	14.26
C16:1	2.8[a]	20.0[b]	5.5[a]	2.40
C17:1	11.6	14.5	7.2	2.83
C18:0	1466.6	1406.1	908.0	409.97
C18:1n9	256.4	94.3	248.6	96.23
C18:1n9c	217.0	200.2	120.1	43.52
C18:2	1212.2	1287.4	1317.7	102.40
C18:3n6	13.7	20.4	7.4	3.18
C18:3n3	12.9[a]	33.8[a]	275.6[b]	19.20

[1]Values expressed as μg fatty acid/mL plasma.
[a,b]Means in a row with unlike superscripts are different ($P<0.05$).
[c,d]Means in a row with unlike superscripts are different ($P<0.10$).
[e]Steam-flaked corn.

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Table 3. Sensory Panel Evaluation of Ribeye Steak Longissimus Muscle from Cattle Fed Diets Containing SFC, SFC/Tallow, and Flax

	Diets			
Item	SFC[e]	SFC/Tallow	Flax	SEM
Myofibrillar tenderness	6.58	6.59	6.55	.122
Juiciness	6.11	5.82	5.78	.271
Flavor intensity	5.81	5.96	5.94	.076
Connective tissue amount	7.36	7.39	7.25	.094
Overall tenderness	6.70	6.73	6.65	.120
Off flavor intensity	7.69[a]	7.64[a]	7.36[b]	.083
TBARS[c]	.10[a]	.09[a]	.16[b]	.021

[a,b]Means within same row without common superscripts differ ($P<0.02$).
[c]Thiobarbituric acid ractive substances, expressed as mg of malonaldehyde/1000 grams of longissimus muscle.
[e]Steam-flaked corn.

Table 4. Color Profiles on Day 7 of Display for Longissimus Steaks from Cattle Fed SFC, SFC/Tallow, or Flax

	Diets			
Item	SFC[c]	SFC/Tallow	Flax	SEM
L*	45.2	44.2	45.1	.59
A*	26.6[a]	25.6[ab]	22.9[b]	.91
B*	20.9	20.6	19.6	.50
Hue Angle	38.3[a]	38.9[a]	41.0[b]	.61
Saturation Index	33.9[a]	32.8[ab]	30.2[b]	1.00
630/580	4.1[a]	3.9[ab]	3.3[b]	.21

[a,b]Means within same row without common superscripts differ ($P<0.05$).
[c]Steam-flaked corn.

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SURFACE ROUGHENING DURING SLICING REDUCES IRIDESCENCE

T. E. Lawrence, M. C. Hunt, and D. H. Kropf

Summary

We evaluated surface roughening during slicing as a way to decrease iridescence of pre-cooked cured beef bottom round, inside round, and eye of round roasts. Using a textured slicing blade surface decreased iridescence intensity and the area of iridescence compared to the control (smooth surface). Iridescence intensity and percentage of iridescent area was greatest in the eye of round, followed by the inside bottom round. Iridescence (both intensity and percentage of area) in sliced meat products can be reduced by using a meat-slicing blade with a textured face.

(Key Words: Beef, Iridescence.)

Introduction

Iridescence, an unnatural rainbow-like color array, is often present in pre-cooked meats such as corned beef, ham, and pastrami. Consumers find this visually unappealing and may falsely associate a green or orange-red iridescent sheen with old or unwholesome meat products. Limited research has concluded that iridescence in cooked cured beef is caused by light diffraction by the meat surface microstructure. Using a dull slicer blade has been shown to cause less iridescence than a sharp blade and perpendicular cut muscle exhibits more iridescence than diagonally cut fibers. Our objective was to determine the effects of surface roughening during slicing on the iridescence of cooked cured beef products.

Experimental Procedures

Pre-cooked, vacuum-packaged corned beef inside round, eye of round, and bottom round were obtained (4 of each) from a commercial processor. Fine or medium textured sandpaper with adhesive backing was attached to the blade of a commercial meat slicer while a smooth slicer blade served as a control. The sandpaper was attached approximately 1/8 in. from the cutting edge of the blade, allowing the sharp edge to initialize the cut. For each treatment, three cross-sections from the interior portion of each muscle were sliced approximately 1/4 in. thick. Slices were placed on white foam trays, and wrapped in oxygen permeable heat shrinkable PVC film (23,250 cc $O_2/m^2/24$ hr).

Approximately 2 h after slicing, each slice was evaluated visually for iridescence intensity (0=no iridescence, 1=very slight iridescence, 2=slight iridescence, 3= moderate iridescence, 4=strong iridescence, 5= very strong iridescence) and percentage of surface area covered by iridescence (0=no iridescence, 1=1 to 20%, 2=21 to 40%, 3=41 to 60%, 4=61 to 80%, 5=81 to 100%) to the nearest 0.5 point by nine experienced panelists. All 12 pre-cooked muscle samples exhibited iridescence.

Panelist scores for each slice were averaged to give one score per slice. The three slice scores within a surface treatment and muscle combination were repeated measures and therefore averaged to give one score per treatment combination. Data

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for iridescence intensity and percentage iridescent area were analyzed as four replications of a two-way treatment structure in a completely randomized design. Main effects for surface treatment and muscle as well as their interaction were tested by analysis of variance. When significant at the 5% level, mean values were separated using Duncan's multiple range test.

Results and Discussion

Compared to the control (smooth slicing blade) both fine and medium sandpaper surface roughing treatments reduced the intensity of iridescence (*P*=0.0054) and the percentage of surface area covered by iridescence (*P* = 0.0038; Table 1) suggesting that physical disruption by surface roughening reduced iridescence. However, no differences were found between the two blade textures.

Significant differences for iridescence intensity and iridescent area were found among the bottom round, inside round, and eye of round muscles (Table 1). Iridescence was most pronounced in eye of round and least in bottom round, with the inside round being intermediate. Within bottom round muscles, iridescence occurred most frequently in the ischiatic head. The muscle differences are most likely due to the angle of slicing. The eye of round muscle was sliced more perpendicular to the muscle fiber direction than the inside round, and the bottom round was the least perpendicular.

Our results support development of slicing blades with a textured face that could be used by the industry to reduce the costly problem of iridescence in slices of cooked beef.

Table 1. Mean Panelist Scores[1] for Sandpaper Treatment and Muscle Main Effects

Item	Iridescence[1] Intensity	Iridescent Area[2]
n	12	12
SE	.233	.195
Surface roughing treatment		
Control	2.83[y]	2.48[y]
Fine	1.73[x]	1.51[x]
Medium	1.75[x]	1.46[x]
P-value	.0054	.0038
Muscle		
Bottom round	1.22[x]	1.07[x]
Inside round	1.94[y]	1.80[y]
Eye of round	3.14[z]	2.58[z]
P-value	.0011	.0013

[1]Iridescent intensity: 1=very slight, 2=slight, 3=moderate.
[2]Iridescent area: 1=1 to 20%, 2=21 to 40%, 3=41 to 60%.
[x,y,z]Means in the same main effect and column with unlike superscripts differ ($P<0.05$).

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Cattlemen's Day 2002

WILL BLADE TENDERIZATION DECREASE IRIDESCENCE IN COOKED BEEF *SEMITENDINOSUS* MUSCLE?

E. Obuz and D. H. Kropf

Summary

Ten beef *semitendinosus* muscles were divided into three sections, which were randomly assigned to one of three blade tenderization treatments (control-zero, one, or two times). Blade-tenderized muscles were cooked in a forced-air convection oven at 325° to 145°F and held for 1 min. Cooked muscles were chilled overnight at 38°F and sliced by a sharp knife. Panelists (n=19) evaluated iridescence intensity on a five-point scale (0=no iridescence, 5=very strong) and extent of iridescence (0=no iridescence, 5=81-100% affected area). Blade tenderization decreased ($P<0.05$) iridescence intensity from 2.37 to 2.02 and extent of iridescence from 2.18 to 1.83 (control zero vs. two passes). Cooking loss increased ($P<0.05$) with blade tenderization (30.4% control, 32.6% one pass, 33.7% two passes). Blade tenderization has a moderate effect on reducing iridescence.

(Key Words: Iridescence, Beef, Blade Tenderization.)

Introduction

Color, an important characteristic of any meat, is an indication of freshness, appropriate storage temperature, adequate processing, and wholesomeness. Deviations from proper meat color may result in consumer rejection and decrease the value of meat products. Iridescence, an unnatural rainbow-like or multi-colored appearance, is caused by optic diffraction by meat microstructure. Consumers may confuse iridescence with microbial discoloration, resulting in product rejection.

Blade tenderization is a mechanical method used to improve meat tenderness by disrupting muscle structure. Since iridescence is a structural problem, blade tenderization might reduce or eliminate it. The objective of this study was to investigate the effects of blade tenderization on iridescence of cooked beef *semitendinosus* muscle.

Experimental Procedures

Ten USDA Select grade beef *semitendinosus* muscles were divided into three portions. Blade tenderization treatment (control (OX), one time (1X) or two times (2X)) was randomly applied to portions from each muscle using a blade tenderizer (Model T7001, Ross Industries, Midland, Virginia). Blade tenderization was accomplished by inserting the long direction of muscle parallel to the conveyor belt (parallel to muscle fibers) but perpendicular to needles. The first pass had muscle with the deep portion on top. For blade tenderization (2X) the muscle was rotated 90° after the first pass and passed through with muscle fiber direction again parallel to the conveyor belt. After blade tenderization, each muscle was cooked in a forced-air convection oven held at 325° to 145°F internally and held for 1 min. Cooking loss was evaluated on each sample. Cooked muscles were chilled overnight at 38°F, sliced perpendicular to muscle fiber direction

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with a sharp knife and each slice was individually vacuum-packaged in a polyethylene-nylon-polyethylene film. A group of experienced panelists (n=19) evaluated iridescence intensity and extent of iridescence on each sample. The iridescence intensity was evaluated on a five-point scale (0=no iridescence, 1=very slight, 2-slight, 3=moderate, 4=strong, 5=very strong iridescence). The extent of iridescence was also evaluated on a five-point scale (0=no iridescence, 1=1 to 20%, 2=21 to 40%, 3=41 to 60%, 4=61 to 80%, 5=81 to 100% affected area).

The statistical design was a completely randomized block. The data were analyzed by SAS using PROC MIXED procedure. When significant at $\alpha<0.05$, mean values were separated by Fisher's Least Significant Difference method.

Results and Discussion

Blade tenderization (two passes) reduced iridescence intensity (P=0.013) (Table 1). Both one and two passes reduced extent of iridescence (P=0.003). Blade tenderization increased the cooking loss because blades opened the meat surface. Previous work found that muscles sliced with a dull blade exhibited less iridescence than those sliced with a sharp blade, suggesting that iridescence could be reduced by physical alteration of the meat surface. Our results confirm this effect, although reductions in iridescence were moderate.

Table 1. Mean Panelist Scores for Blade Tenderization and Cooking Loss

Blade Tenderization	Iridescence Intensity[1]	Extent of Iridescence[2]	Cooking Loss (%)
0X (control)	2.37[a]	2.17[a]	30.4[a]
1X	2.27[a]	1.84[b]	32.6[a,b]
2X	2.02[b]	1.83[b]	33.7[b]

[1]0 = none, 5 = very strong iridescence.
[2]0 = none, 5 = 81 to 100% affected area.
[a,b,c]Means in a column sharing the same letter are not different (P>0.05).

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EFFECTS OF COOKING BEEF MUSCLES FROM FROZEN OR THAWED STATES ON COOKING TRAITS AND PALATABILITY

E. Obuz and M. E. Dikeman

Summary

We used an electric belt grill to cook steaks from two muscles; outside round (*biceps femoris*), and loin strip (*longissimus lumborum*) from both frozen and thawed states. The color values L* and a*, Warner-Bratzler shear force (WBSF), juiciness, flavor, connective tissue amount, and overall tenderness did not differ (P>0.05) between steaks cooked from frozen and thawed states. Thawed steaks cooked faster and had less cooking loss. The *biceps femoris* had higher WBSF than *longissimus* and was rated less tender by trained panelists. Color values L*, a*, or b* did not differ (P>0.05) among the muscles. The *biceps femoris* needed more time to cook and had greater cooking loss than *longissimus*.

(Key Words: Cooking, Belt Grill, Frozen or Thawed Steaks.)

Introduction

Freezing preserves meat quality for a number of months with insignificant changes in product size, shape, texture, color, and flavor. However, freezer burn, discoloration, dehydration, rancidity, drip loss, and bleaching might occur, depending upon freezing conditions, storage time, packaging, and thawing procedures. When meat is thawed at room temperature, the risk of growth of spoilage and pathogenic microorganisms increases. Therefore, cooking meat directly from the frozen state might offer advantages of less drip loss and reduced risk of microbial growth.

Previous research suggests that cooking yield and palatability were not affected by the physical state of meat at the start of cooking, but meat cooked from the frozen state required more cooking time. On the contrary, some researchers have reported greater cooked yield, improved tenderness, and higher juiciness ratings for beef cooked from the frozen state. To rationalize these differences, the objectives of our study were to evaluate the effects of cooking two beef muscles from either the frozen or thawed state on cooking traits and palatability.

Experimental Procedures

Sub-primals from a commercial processing plant were aged 19 days postmortem at 34°F, then frozen. We sawed one-inch thick steaks from 20 outside rounds (NAMP 171B), and 20 loin strips (NAMP 170) from USDA Choice carcasses. Steaks were numbered from 1 to 12 for each outside round or loin strip to identify anatomical location. Steak #10 was cooked from the thawed state, while steak #11 was cooked directly from the frozen state on an electric belt grill (TBG-60 Magigrill, MagiKitch'n, Inc., Quakertown, PA) at 200°F. All steaks were cooked to 158°F internally. Cooking loss and cooking time were recorded for each steak. We measured the color values L*, a*, and b* (Illuminant A) on each steak 3 hr after cooking.

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After cooked steaks were refrigerated overnight (39°F), we removed six cores (0.5 inch in diameter) parallel to muscle fiber orientation and sheared each core once using an Instron Universal Testing Machine. A 110-lb load cell and 10 inches/min cross-head speed were used. We cooked steaks in a similar manner for sensory evaluation. Trained panelists (n=6) evaluated palatability attributes on an 8-point scale for myofibrillar tenderness, juiciness, flavor, overall tenderness, and connective tissue amount (1=extremely tough, dry, bland, extremely tough, and abundant; 8=extremely tender, juicy, intense, tender, and none). We analyzed the data in two ways. Paired t-tests were used to distinguish effects of cooking from frozen vs. thawed state on cooked color, cooking time, cooking loss, Warner-Bratzler shear force, and sensory properties. To analyze muscle effects, we used one-way analysis of variance for a completely randomized design.

Results and Discussion

No differences (P>0.05) in L* (lightness), a* (redness), WBSF, juiciness, flavor, connective tissue amount, or overall tenderness were found between steaks cooked from the frozen or thawed states (Tables 1 and 2). However, frozen steaks required more cooking time (P<0.01), had higher cooking loss (P<0.01), lower b* values (less yellow) (P<0.05), and lower myofibrillar tenderness scores (less tender) (P<0.05) than thawed steaks (Tables 1 and 2). The biceps femoris required more time to cook (P<0.05), had more connective tissue (P<0.01), less intense flavor score (P<0.05), higher WBSF (P<0.05), and lower tenderness scores (P<0.01) than the longissimus (Tables 1 and 2). Cooking from the frozen state offers some advantages because thawing is much faster, drip loss does not occur, and the risk of microbial growth associated with slow thawing should be reduced. However, higher cooking losses and a greater energy requirement for cooking might outweigh these advantages.

Table 1. Warner-Bratzler Shear Force, Cooking Time, Cooking Loss, and Cooked Color Values for *Biceps femoris* and *Longissimus lumborum* Steaks Cooked from Frozen or Thawed State

Source of Variation	WBSF (lb)	Cooking Time (min)	Cooking Loss (%)	L*	a*	b*
Muscle						
Biceps femoris	10.58	11.37	31.04	58.16	19.54	20.58
Longissimus lumborum	9.28	10.78	28.94	56.77	19.49	20.25
P-value	0.025	0.013	0.07	0.15	0.97	0.65
State						
Frozen	10.12	13.13	32.96	57.87	18.97	19.67
Thawed	9.75	9.02	27.03	57.05	20.06	21.15
P-value	0.52	<0.0001	<0.0001	0.40	0.40	0.049

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Table 2. Sensory Panel Values[a] for *Biceps femoris* and *Longissimus lumborum* Steaks Cooked from Frozen or Thawed State

Source of Variation	Myofibrillar Tenderness	Connective Tissue Amount	Juiciness	Flavor Intensity	Overall Tenderness
Muscle					
Biceps femoris	4.63	3.90	5.35	5.59	4.00
Longissimus lumborum	5.58	6.81	5.23	5.81	5.84
P-value	<0.0001	<0.0001	0.64	0.012	<0.0001
State					
Frozen	4.93	5.31	5.24	5.73	4.80
Thawed	5.28	5.40	5.34	5.68	5.04
P-value	0.024	0.65	0.68	0.42	0.10

[a]Eight point scale for myofibrillar tenderness, juiciness, flavor intensity, connective tissue amount and overall tenderness where: 1=extremely tough, dry, bland, abundant and tough and 8=extremely tender, juicy, intense, non and tender.

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EFFECTS OF COLD SHORTENING AND COOKING RATE ON BEEF TENDERNESS

D. A. King, M. E. Dikeman, T. L. Wheeler[1], C. L. Kastner, and M. Koohmaraie[1]

Summary

A study was conducted to determine if excised, cold-shortened muscle improves in tenderness with refrigerated aging. Changes in muscle tenderness due to cooking rates were also evaluated. Beef ribeye and shoulder clod muscles from the left side of 12 carcasses were removed 45 min postmortem and placed in an ice bath to induce cold shortening. Corresponding muscles from the right side were chilled conventionally on the intact side. One-inch steaks from these muscles were either frozen at 24 hours or aged for 14 days at 40ºF before being cooked and analyzed. Steaks were analyzed raw, or cooked to 160ºF internally in a oven at 200 (SLOW) or 500°F (FAST). Sarcomere length (degree of contraction), tenderness, and the extent of degradation of structural proteins were measured. Rapid chilling caused severe muscle contraction, which had a dramatic toughening effect. At 24 hours, the cold-shortened muscle showed less protein degradation than conventionally chilled muscle. After aging 14 days, tenderness had improved and protein degradation had occurred in both cold-shortened and conventional muscles, but degradation was still less in cold-shortened muscles. The improvement in tenderness and the increase in protein degradation from 1 to 14 days were equal between cold-shortened and conventional chilling treatments but the cold-shortened muscles remained tougher. FAST cooking resulted in greater cooking losses and greater sarcomere shortening than SLOW cooking. Cooking rate did not affect the tenderness of ribeye steaks, but SLOW cooking improved the tenderness of shoulder clod steaks that are higher in connective tissue. Extreme chilling conditions, which induce cold shortening, may reduce protein degradation beyond the effect of shortening. Although aging improved the tenderness of cold-shortened muscles, they remained tougher than their conventionally chilled counterparts.

(Key Words: Beef Tenderness, Cooking Rate, Cold Shortening.)

Introduction

Degree of contraction affects the tenderness of muscle. Without skeletal restraint, muscles exposed to cold will enter rigor in a contracted state, a condition called cold shortening. Previous reports as to whether or not aging would improve tenderness of cold-shortened muscle are mixed. Some researchers have suggested that the greater overlapping of proteins in contracted muscle blocks access to proteins by the calpain enzyme system. Some earlier research has indicated that protein in cold-shortened muscle degrades at a rate similar to normal muscle. Therefore, we evaluated the effect of aging on tenderness and extent of protein degradation in normal and cold-shortened muscle. In addition, the beef industry needs to more effectively utilize muscles from the round and chuck. One muscle with potential for greater use is the *triceps brachii*, commonly sold as part

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of the shoulder clod. Because of the demand for more pre-cooked products, we were interested in the effects of cooking rates on ribeye and shoulder clod muscles as well as the heating rate effect on tenderness of cold-shortened muscle.

Experimental Procedures

Twelve Charolais-Angus crossbred heifers from a local feeder were harvested in the Kansas State University Meat Laboratory. Approximately 45 min after death, *longissimus* (ribeye) and *triceps brachii* (shoulder clod) muscles were removed from the left side and placed in an ice bath to cause cold shortening. The right side was chilled intact and corresponding muscles were removed after 24 hours (conventional chill).

All muscles were cut into one-inch thick steaks. Steaks were either frozen at 1 day or aged 14 days at 40°F. Some steaks were analyzed raw, others after cooking to 160º F internally in a gas-fired, forced-air convection oven set at either 200 or 500° F. The sarcomere length (extent of contraction) and the extent of protein degradation were measured on all steaks. For cooked steaks, cooking losses were recorded. Steaks were chilled for 24 hours before six, half-inch cores were removed and tenderness was measured using Warner-Bratzler shear force. Analysis of variance was used to identify differences between treatments.

Results and Discussion

Our cold shortening treatment produced severe contraction; the shoulder clod and ribeye muscles shortened 34 and 29%, respectively (Table 1). Rapid chilling and the resulting cold shortening decreased desmin degradation and increased Warner-Bratzler shear force, but did not affect cooking losses (Table 2). A number of structural proteins, including desmin, are degraded by the calpain enzyme during aging. Desmin degradation is thought to play a role in tenderization and is also believed to indicate the extent of degradation of other proteins. Cold shortening reduced desmin degradation by 30.5% vs. 40.9% for conventional muscles. Desmin degradation increased in all steaks, conventioal or cold-shortened, between day 1 and day 14 of aging (Table 3). Chilling and aging treatments did not interact, indicating that the change in desmin degradation between day 1 and day 14 was not affected by chilling treatment. Thus, the difference in protein degradation between chilling treatments occurred during the first 24 hours postmortem.

Table 1. Average Sarcomere Length of Beef Ribeye and Shoulder Clod Steaks

Muscle	Treatment	Sarcomere Length (μm)
Ribeye	Conventional	1.8^{x}
Ribeye	Cold-shortened	1.3^{z}
Shoulder clod	Conventional	2.1^{w}
Shoulder clod	Cold-shortened	1.4^{y}
SEM		0.03
P>F		<0.01

^{w,x,y,z}LS means lacking a common superscript letter differ (P<0.05).

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Table 2. Desmin Degradation, Warner-Bratzler Shear Force, and Cooking Loss of Beef Ribeye and Shoulder Clod Steaks

Treatment	Desmin Degraded[a] (%)	WBSF[b] (kg)	Cooking Loss (%)
Chilling Effect			
Conventional	40.9[z]	10.6y	26.0
Cold-shortened	30.5[x]	22.1[z]	25.2
SEM	2.6	0.62	0.55
P>F	<0.01	<0.01	0.23
Aging Effect			
1 day	--	17.2[z]	24.9
14 day	--	15.0[y]	26.2
SEM	--	0.55	0.55
P>F	--	<.01	0.06

[a]Determined by comparing samples to an at death standard.
[b]Warner-Bratzler shear force.
[y,z]LS means within a column and main effect lacking a common superscript letter differ (P<0.05).

Cold-shortened muscles were much tougher than muscles chilled on the carcass (Table 2). Warner-Bratzler shear force of both cold-shortened and conventionally chilled muscles decreased with aging (Table 3). The lack of an interaction between chilling treatment and aging treatment for shear force indicated that the increase in tenderness from 1 to 14 days was equal for both chilling rates. However, aging did not diminish the toughening effect of cold shortening. Cooking losses were not affected by chilling rate, but aging tended to increase cooking losses (Table 2).

Cooking reduced sarcomere lengths of conventional by chilled samples (Table 4), with FAST cooked steaks having the greatest sarcomeres shortening. Cooking also shortened sarcomeres of the cold-shortened muscle, but there was no difference due to cooking rate. Cooking rate had no effect on the extent of protein (desonin degradation (Table 5), but raw ribeye steaks underwent more degradation than FAST cooked steaks.

FAST cooking caused greater cooking losses than did SLOW cooking (Table 5). This difference was much greater in the ribeye than in shoulder clod steaks. However, shoulder clod steaks had greater cooking losses at both cooking rates than the ribeye steaks. Cooking rate did not affect WBSF of the ribeye steaks. When the shoulder clod steaks were cooked FAST, they were equal in Warner-Bratzler shear force to the ribeye steaks, but when cooked SLOW, were more tender than ribeye steaks. Shoulder clod has more connective tissue and SLOW cooking likely minimized the negative effects of heating on the connective tissue that occurs with FAST cooking.

Table 3. Desmin Degradation and Warner-Bratzler Shear Force Values for Beef Ribeye and Shoulder Clod Muscles

Chilling Treatment	Aging (days)	Desmin Degraded[a] (%)	WBSF[b] (kg)
Conventional	1	28.7	11.21
Conventional	14	53.1	9.7
Cold shortened	1	16.5	23.4
Cold shortened	14	44.6	20.3
SEM		2.97	0.71
P>F		0.35	0.13

[a]Determined by comparing samples to an at death standard.
[b]Warner-Bratzler shear force.

Table 4. Sarcomere Length of Beef Ribeye and Shoulder Clod Steaks as Affected by Chilling Rate and Cooking at Either 200 or 500°F

Shortening Treatment	Cooking Treatment	Sarcomere Length (μm)
Conventional	Raw	2.0[v]
Conventional	Fast[a]	1.8[x]
Conventional	Slow[b]	1.9[w]
Cold shortened	Raw	1.4[y]
Cold shortened	Fast[a]	1.3[z]
Cold shortened	Slow[b]	1.3[z]
SEM		0.02
P>F		<0.01

[a]Cooked in a forced-air convection oven with thermostat set at 500°F.
[b]Cooked in a forced-air convection oven with thermostat set at 200°F.
[v,w,x,y,z]LS means lacking a common superscript letters differ (P<0.05).

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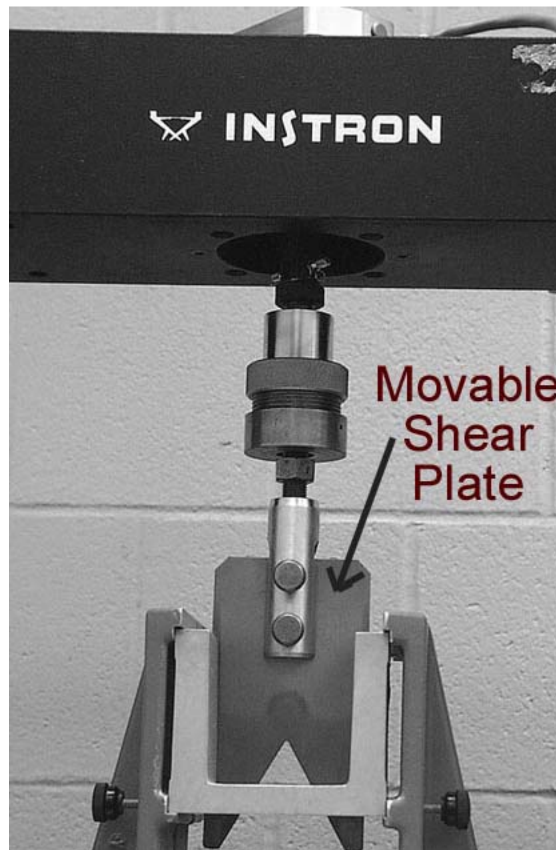
Table 5. Average Desmin Degradation, Warner-Bratzler Shear Force, and Cooking Losses of Beef Ribeye and Shoulder Clod Steaks Analyzed Raw or After Cooking at Either 200 or 500°F

Muscle	Cooking Treatment	Desmin Degraded[a] (%)	WBSF[b] (kg)	Cooking Loss (%)
Ribeye	Raw	40.1[y]	--	--
Ribeye	Fast[c]	31.8[z]	16.5[z]	27.1[y]
Ribeye	Slow[d]	34.3[yz]	16.8[z]	19.8[x]
Shoulder clod	Raw	33.2[yz]	--	--
Shoulder clod	Fast[c]	35.5[yz]	16.8[z]	29.7[z]
Shoulder clod	Slow[d]	40.3[y]	14.6[y]	25.7[y]
SEM		3.29	0.71	0.74
P>F		0.03	0.03	0.02

[a]Determined by comparing samples to an at death standard.
[b]Warner-Bratzler shear force.
[c]Cooked in a forced air convection oven with thermostat set at 500°F.
[d]Cooked in a forced air convection oven with thermostat set at 200°F.
[x,y,z]LS means within a column lacking a common superscript differ ($P<0.05$).



Warner-Bratzler Shear: A ½-inch core of meat is placed in the inverted "V" notch of the movable shear plate. The shear plate moves downward, and the Instron testing machine records the amount of force required to shear the core.

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EFFECTS OF END-POINT TEMPERATURE, REHEATING, HOLDING TIME, AND HOLDING TEMPERATURE ON BEEF TENDERNESS

E. Obuz and M. E. Dikeman

Summary

We cooked steaks from two muscles; outside round (*biceps femoris*), and strip loin (*longissimus lumborum*) with an electric belt grill. *Biceps femoris* steaks had higher Warner-Bratzler shear force (WBSF), connective tissue force (WB C-force), and myofibrillar force (WB M-force) values than *longissimus lumborum* steaks. Holding *biceps femoris* steaks at 144°F after cooking increased WB C-force ($P<0.05$) and WB M-force ($P<0.01$) as compared to holding them at 135°F. Holding *biceps femoris* steaks for 15 min decreased shear force by 12%, whereas the decrease was only 3% from holding for 30 min, likely because more moisture was lost with the longer holding time. Reheating had the only significant effect on *longissimus lumborum* steaks' WB measures because low collagen content of this muscle is not affected by holding time or temperature.

(Key Words: Cooking, Belt Grill, Shear Force.)

Introduction

Cooking meat can tenderize connective tissue due to collagen solubilization and can toughen myofibrillar proteins (muscle cells) due to water loss. Tenderness will decrease with increased end-point temperature. To optimize tenderness, the influence of low-temperature/long cooking time has been investigated. In other research, meat became more tender and cooking losses decreased with lower cooking temperatures. Additionally, post-cooking holding time at 135-140°F internally was correlated ($r^2 = 0.53$) with tenderness. Minimum shear force values (maximum tenderness) were reported after heating eye round (*semitendinosus*) cores and holding to 140-147°F for 30-60 min. Holding meat below the collagen shrinkage temperature (≈149°F) should benefit tenderness because collagen solubilization will occur before collagen shrinkage has a negative effect. However, at the same time, dehydration may cause toughening. Therefore, our objectives were to study the effects of endpoint temperature, reheating, holding time, and holding temperature on beef tenderness.

Experimental Procedures

Sub-primals from a commercial processing plant were aged for 19 days postmortem at 34°F, then frozen and held at –20°F. We sawed one-inch thick steaks from 24 outside rounds (NAMP 171B), and 24 strip loins (NAMP 170) from USDA Choice carcasses. Steaks were numbered from 1 to 12 for each outside round or strip loin to identify anatomical location. Paired steaks (#3 to 8) were cooked on an electric belt grill (TBG-60 Magigrill, MagiKitch'n, Inc., Quakertown, PA) at 200°F to internal temperatures of either 129 or 138°F, then held in a water-bath at 135 or 144°F (to allow for a post-cooking temperature rise of about 5°F) for 0, 15, or 30 min. One

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steak from each pair was immediately reheated on the electric- belt grill to 158°F.

Steaks were held overnight at 39°F before we removed six round cores (0.5 inch diameter) parallel to muscle fiber orientation. Each core was sheared once using an Instron Universal Testing Machine. A 110-lb load cell and 10 inches/min cross-head speed were used. WBSF, WB M-force, and WB C-force values were calculated from the shear curves obtained from Instron software. The statistical design was a split-split plot. Treatment differences were evaluated by Statistical Analysis System software using the PROC MIXED procedure.

Results and Discussion

For cooking loss (Tables 1 and 2), an interaction for holding temperature × holding time was found for *biceps femoris*. At a holding temperature of 135°F no difference was noted between a 15 or 30 minute holding time, but at 145°F the longer holding time caused increased cooking loss.

Both muscles had an interaction between reheating and holding time effects on cooking loss. In *longissimus* muscle with no reheating, increasing holding time increased cooking loss, but when muscles were reheated, a longer holding time did not affect cooking loss.

The reheating × holding temperature interaction showed increased cooking loss with both reheating and with warmer holding temperature. In summary, all three variables—holding time, holding temperature and reheating—can increase cooking loss.

For *biceps femoris* steaks, WBSF, WB M-force, and WB C-force increased with higher holding temperature. Holding *biceps femoris* steaks for 15 min decreased shear force by 12%, whereas the decrease was only 3% for 30 min holding time. This was likely caused by greater moisture loss with longer holding time. Reheating *biceps femoris* steaks increased WBSF and WB M-force, but did not significantly change WB C-force (Table 1). WB C-force was always higher than WB M-force for *biceps femoris* steaks, while the opposite was true for *longissimus lumborum* steaks. With *longissimus lumborum* steaks, reheating increased WBSF and WBM-force, but did not influence WB C-force. This is because of the low collagen content of the *longissimus lumborum*.

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Table 1. Effects of Holding Temperature, Holding Time, and Reheating on WBSF, WB M-Force, WB C-Force, and Cooking Loss for Biceps Femoris Steaks

Source of Variation	WBSF (lb)	WB M-Force (lb)	WB C-Force (lb)	Cooking Loss (%)
Holding temperature (°F)				
135	8.40[a]	5.41[a]	7.35[a]	16.88
144	9.88[b]	6.89[b]	9.13[b]	21.29
P- value	0.054	<0.0001	0.026	<0.0001
Holding time (min)				
0	9.61[b]	5.90	8.95[b]	14.14
15	8.50[a]	5.96	7.48[a]	20.17
30	9.31[a,b]	6.58	8.25[a,b]	22.94
P-value	0.038	0.14	0.02	<0.0001
Holding temperature/holding time				
135/0	9.28	5.5	8.45	13.13[a]
135/15	7.57	5.08	6.09	17.95[c]
135/30	8.34	5.7	7.48	19.55[c]
144/0	9.97	6.29	9.48	15.14[b]
144/15	9.42	6.86	8.88	22.39[d]
144/30	10.25	7.48	9.02	26.33[e]
P-value	0.28	0.31	0.19	0.0007
Reheating				
No	8.71[a]	5.72[a]	8.25	16.81
Yes	9.55[b]	6.58[b]	8.23	21.35
P-value	0.016	0.004	0.98	<0.0001
Reheating × holding time				
No/0	9.04	5.04	8.51[a,c,d]	10.75[a]
Yes/0	10.21	6.73	9.42[b,d]	17.52[b]
No/15	7.96	5.57	7.30[a]	17.66[b]
Yes/15	9.02	6.36	7.66[a]	22.68[c]
No/30	9.15	6.53	8.91[b,c]	22.04[c]
Yes/30	9.46	6.64	7.61[a]	23.84[c]
P-value	0.43	0.07	0.047	0.0003
Reheating × holding temp				
No/135	7.85	4.91	7.22	13.95[a]
Yes/135	8.95	5.94	7.48	19.81[b]
No/144	9.59	6.53	9.28	19.69[b]
Yes/144	10.16	7.22	8.98	22.88[c]
P- value	0.53	0.53	0.44	0.007

[a,b]Within columns, means sharing the same letter are not significantly different (P>0.05).

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Table 2. Effects of Holding Temperature, Holding Time, and Reheating on WBSF, WB M-Force, WB C-Force, and Cooking Loss for Longissimus Lumborum Steaks

Source of Variation	WBSF (lb)	WB M-Force (lb)	WB C-Force (lb)	Cooking Loss (%)
Holding temperature (°F)				
135	5.81	5.35	4.66	17.74
144	5.70	5.43	4.84	20.13
P- value	0.70	0.77	0.60	0.027
Holding time (min)				
0	5.70	5.13	4.64	14.03
15	5.74	5.39	4.64	20.25
30	5.79	5.65	4.97	22.53
P-value	0.90	0.36	0.48	<0.0001
Holding temperature/holding time				
135/0	5.85	5.13	4.77	13.61
135/15	5.81	5.39	4.73	18.68
135/30	5.74	5.32	4.47	20.94
144/0	5.54	5.10	4.51	14.45
144/15	5.70	5.21	4.53	21.82
144/30	5.83	5.98	5.48	24.13
P-value	0.54	0.39	0.11	0.20
Reheating				
No	2.39[a]	4.91[a]	4.53	16.78
Yes	2.83[b]	5.87[b]	4.97	21.09
P-value	<0.0001	0.0006	0.07	<0.0001
Reheating × holding time				
No/0	5.17	4.49	4.29	11.20[a]
Yes/0	6.23	5.74	4.97	16.86[b]
No/15	5.30	5.06	4.40	18.26[c]
Yes/15	6.20	5.72	4.88	22.23[e]
No/30	5.32	5.17	4.88	20.88[d]
Yes/30	6.25	6.14	5.08	24.19[f]
P-value	0.90	0.60	0.72	0.04
Reheating × holding temp				
No/135	5.30	4.88	4.44	15.13[a]
Yes/135	6.29	5.79	4.88	20.35[c]
No/144	5.21	4.91	4.60	18.43[b]
Yes/144	6.16	5.96	5.08	21.83[d]
P- value	0.85	0.79	0.95	0.02

[a,b]Within columns, means sharing the same letter are not significantly different (P>0.05).

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EFFECTS OF FREEZING AND LOCATION WITHIN THE BEEF *LONGISSIMUS* MUSCLE (STRIP LOIN STEAK) ON TENDERNESS

R. R. Timm, J. A. Unruh, M. E. Dikeman, M. C. Hunt, J. E. Boyer, Jr.[1], and J. L. Marsden

Summary

Twenty-four USDA Select strip loins (IMPS 180) were aged (32°F) until 14 days postmortem and fabricated into *longissimus* muscle (strip loin) steaks (1-in. thick). Then, steaks were either cooked or stored at –20°F for an additional 17 days before they were thawed and cooked. Cores and sensory panel samples were removed from the medial, center, and lateral sections of each steak and locational identify maintained. In addition, a random composite of cubes from an entire steak was used for a sensory panel evaluation. Previously frozen steaks had lower Warner-Bratzler shear force (WBSF) values, less cooking loss, and a shorter cooking time than fresh (non-frozen) steaks; however, no difference was found for combined thawing and cooking loss. Cores from the medial section of steaks had lower WBSF values than cores from the center section. A sensory panel found that the medial section was more tender than the lateral section and had less detectable connective tissue than the center or lateral sections or samples taken at random. The center and random treatments were juicer than the lateral section. Highest correlations between sensory panel tenderness and WBSF were obtained when the medial and lateral sections were averaged (r=–0.74, r=–0.69) and when all three sections were averaged (r=–0.70, r=–0.69) for fresh and frozen WBSF steaks, respectively. Freezing lowered WBSF values and the medial section of the steak was the most tender. An awareness of these results and potential procedural artifacts must be considered when handling and sampling steaks, and interpreting results.

(Key Words: Beef, *Longissimus* dorsi, Freezing, Steaks, Tenderness.)

Introduction

Previous work in our laboratory has shown that pork tenderness can be improved by freezing. Additional benefits of freezing are longer storage periods, better product control, and more flexibility in inventory. Many researchers have found differences in tenderness between the lateral and medial sections of the *longissimus* muscle, but have disagreed which section is most tender. If such differences actually exist, they must be accounted for in order for tenderness measurements to be accurate. Our objectives were to determine effects of location within the *longissimus* muscle, and effects of freezing, on WBSF and sensory panel attributes.

Experimental Procedures

Twenty-four USDA Select strip loins (IMPS 180) from a commercial packing facility (2 days postmortem) were stored at 32 ± 2°F until 14 days postmortem. Loins were trimmed of external fat, faced, and fabricated into seven 1-in.thick *longissimus* muscle steaks, starting at the anterior end. One steak was randomly assigned to fresh (non-frozen) WBSF, one to frozen WBSF, and five steaks to sensory panel evaluation. Steaks assigned to the fresh WBSF treatment were immediately weighed and cooked after aging. All

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other steaks were vacuum packaged and stored at −20°F for 17 days until analysis. Frozen WBSF steaks were thawed for 27 hours at 37°F before they were weighed, removed from the bag, and reweighed to determine thawing loss. In addition, cooking time and weight after cooking were recorded and percentage of cooking loss for both WBSF treatments was calculated.

All steaks were cooked to 158°F internally in a Blodgett dual-air-flow convection gas oven preheated to 325°F. Steak temperature was monitored using a 30-gauge, type T thermocouple inserted into the geometric center of each steak. Steaks for WBSF were then stored overnight at 37°F. Following refrigeration, six ½-in. diameter cores were taken parallel to muscle fibers. Two cores each were taken from the medial, center, and lateral portions of each steak. Cores were sheared perpendicular to muscle fiber orientation using an Instron Universal Testing Machine with a WBSF attachment.

Sensory panel steaks were thawed for 24 to 36 hours at 37°F and cooked using the same procedures as for WBSF steaks. Cooked steaks were trimmed of epimysial connective tissue and any remaining external fat, cut into ½ × ½ in. × steak thickness cubes and placed in pre-heated double boilers. The random treatment contained a composite of random cubes from an entire steak. The medial, center, and lateral sections from four steaks were identified and separated. The center portion consisted of a 2-in. section centered at the point where the medial and lateral muscle fibers conjoin.

Sensory evaluation was conducted in individual booths having a mixture of red and green lighting. Duplicate samples for each treatment were presented to experienced panelists in a statistically randomized order. All treatments within a single loin were evaluated during a session. Samples were evaluated for five sensory attributes using an eight-point numerical scale and scored to the nearest 0.5. Traits assessed were: myofibrillar tenderness (1 = extremely tough, 8 = extremely tender), juiciness (1 = extremely dry, 8 = extremely juicy), beef flavor intensity (1 = extremely bland, 8 = extremely intense), connective tissue amount (1 = abundant, 8 = none), and overall tenderness (1 = extremely tough, 8 = extremely tender).

All data were analyzed as a randomized complete block design in which loin served as the blocking factor. Data for WBSF were analyzed in a split plot design with fresh and frozen treatments as the main plots and location within the *longissimus* (random, medial, center, and lateral) as the subplots. Means were separated by least significant differences when respective F-tests were significant, using appropriate error terms for split plot analyses (Mixed procedures of SAS, 2000). Mixed procedures of SAS (2000) were used to determine sensory panel treatment differences and means were separated ($P < 0.05$) using least significant differences. Correlations were determined using the Corr procedure of SAS (2000).

Results and Discussion

Previously frozen steaks had lower ($P<0.05$) WBSF values, less cooking loss, and a shorter cooking time than fresh (non-frozen) steaks (Table 1). However, no difference ($P=0.95$) was found for total loss (combination of cooking loss and drip loss). The improved tenderness due to freezing may be attributed to ice crystal formation causing myofibrils to rupture, connective tissue to stretch, and/or some proteolysis. The shorter cooking time for previously frozen steaks may be because drip loss was removed prior to cooking, resulting in less evaporative loss during cooking.

The medial section had lower ($P<0.05$) WBSF values than the center section and tended to have lower ($P=0.09$) WBSF values than the lateral section (Table 2). Further-

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more, sensory panel myofibrillar and overall tenderness scores were higher (more tender; P<0.05) for the medial section than the lateral section. Connective tissue amount scores were also higher (less detectable connective tissue; P<0.05) for the medial section compared to the center section, lateral section, and random treatment. Also, the center section had higher (P<0.05) connective tissue scores than the lateral section. *Longissimus* muscle juiciness scores were higher (more juicy; P<0.05) for the center and random treatments when compared to the lateral section. Differences in tenderness between the medial and lateral sections of the *longissimus* may be partially attributed to the muscle's shape, chill rate, and function. Typically, the medial section of the *longissimus* steak is wider and has more mass than the lateral section. During carcass chilling, the lateral section may chill faster than the medial, causing slower glycolysis, as evidenced by occasional occurrences of cold toughening. Also during cooking, the narrower lateral section may reach a higher endpoint cooking temperature than the wider medial section.

Fresh WBSF values were correlated to sensory panel overall tenderness scores for the medial (r=–0.66), center (r=–0.52), lateral (r=–0.73), and an average of medial and lateral (r=–0.74) locations. Average fresh WBSF values were also correlated to overall tenderness scores (r=–0.70). Frozen WBSF values were also correlated to overall tenderness scores (r=–0.62, –0.58, –0.69, –0.69) for medial, lateral, average of medial and lateral, and average of all three locations, respectively. For the random treatment, fresh WBSF was not correlated to sensory panel overall tenderness for many locations or location combinations within the *longissimus*, but all locations of frozen WBSF were moderately correlated (ranging from r=–0.47 to r=–0.54) to sensory panel overall tenderness.

Location within the *longissimus* is important when correlating sensory panel tenderness and WBSF, because of tenderness variability. Overall, highest correlations between sensory panel and fresh WBSF values were obtained when the medial and lateral sections were averaged, with the center portion excluded, or when all three sections were averaged. This trend was also found when sensory panel tenderness and WBSF values of steaks that were previously frozen were correlated, although some correlations were lower. Because of tenderness variation within a steak, random location source of cubes during sensory panels resulted in lower correlations between WBSF and sensory panel tenderness. To achieve high correlations between sensory panel tenderness and WBSF, steaks should be divided into specific sections and values for all sections averaged. This study confirms the importance of location identification of samples and uniform handling throughout the course of any experiment.

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Table 1. Effects of Freezing on Warner-Bratzler Shear Force (WBSF), Cooking Loss, Drip Loss, Total Loss, and Cooking Time for Longissimus Muscle Steaks

Item	Fresh[a]	Frozen[b]	SE
WBSF, kg	4.37^{z}	3.83^{y}	0.21
Cooking loss, %	27.65^{z}	24.70^{y}	0.69
Drip loss, %	-----	2.98	-----
Total loss, %	27.65	27.71	0.71
Cooking time, min	31.25^{z}	28.21^{y}	1.07

[a]Steaks were cooked at 14 days postmortem
[b]Steaks were frozen at 14 days postmortem and stored for an additional 17 days before cooking
[yz]Means within a row with different superscript letters differ ($P < 0.05$)

Table 2. Effects of Location Within the Longissimus Muscle on Warner-Bratzler Shear Force (WBSF) Force and Sensory Panel Attributes

	Location[a]				
Trait[b]	Medial	Center	Lateral	Random[c]	SE
WBSF, kg	3.84^{y}	4.34^{z}	4.11^{yz}	-----	0.22
Myofibrillar	5.74^{z}	5.54^{yz}	5.31^{y}	5.54^{yz}	0.15
Connective Tissue	6.61^{z}	6.42^{y}	6.23^{x}	6.37^{xy}	0.11
Juiciness	5.62^{yz}	5.68^{z}	5.43^{y}	5.63^{z}	0.08
Flavor Intensity	5.82	5.88	5.79	5.86	0.05
Overall Tenderness	5.93^{z}	5.69^{yz}	5.45^{y}	5.69^{yz}	0.15

[a]Steaks were divided into medial, center, and lateral locations
[b]Sensory traits were evaluated on an eight-point scale; (myofibrillar tenderness, 1=extremely tough, 8=extremely tender; connective tissue amount, 1=abundant, 8=none; juiciness, 1=extremely dry, 8=extremely juicy; flavor intensity, 1=extremely bland, 8=extremely intense; overall tenderness, 1=extremely tough, 8=extremely tender)
[c]Cubes were randomly chosen from the entire steak
[xyz]Means within a row with different superscript letters differ ($P < 0.05$)

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MECHANICAL FORCE MEASURES ON UNCOOKED BEEF *LONGISSIMUS* MUSCLE CAN PREDICT TENDERNESS OF STRIP LOIN STEAKS

R. R. Timm, J. A. Unruh, M. E. Dikeman,
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J. E. Boyer, Jr.[1], and J. L. Marsden

Summary

We investigated mechanical force measurements on uncooked *longissimus* muscle as a means to predict Warner-Bratzler shear force (WBSF) and trained sensory panel tenderness (SPT) of cooked strip loin steaks. Uncooked steaks from 24 USDA Select strip loins (IMPS 180) were evaluated at 2 and 14 days postmortem using plumb bob and needle probe devices attached to an Instron Universal Testing Machine. Cooked steaks aged 14 days were then evaluated for WBSF and SPT. Regression models to predict SPT from needle probe and plumb bob measurements individually taken at 2 days postmortem had R^2 of 0.54 and 0.51, respectively. Combining needle probe and plumb bob measurements resulted in an R^2 of 0.76; however, when quadratic terms for both variables were in the model, R^2 was 0.80. Regressing needle probe and plumb bob measurements at 2 days postmortem with WBSF produced R^2 of 0.51 and 0.45, respectively. When linear terms of both probes were combined, R^2 improved to 0.77. An equation to predict WBSF including both the linear and quadratic terms of needle probe and plumb bob measurements resulted in R^2 of 0.84. Using plumb bob and needle probe combined on uncooked *longissimus* muscle at 2 days postmortem can predict cooked WBSF and SPT of strip loin steaks aged for 14 days.

(Key Words: Beef, *Longissimus dorsi*, Instrument, Tenderness.)

Introduction

Tenderness is the most important factor of beef palatability, and consumers are willing to pay a premium for tender beef. In 1995, the National Beef Quality Audit listed inadequate tenderness as the second most important concern of the beef industry. The USDA currently uses marbling as the primary predictor of beef palatability but often it does not accurately sort carcasses for tenderness, especially in intermediate marbling scores (Slight and Small). Despite many attempts, researchers have not developed a mechanical method for use on uncooked meat that will successfully predict cooked meat tenderness. In a preliminary study, we found the force required to insert a plumb bob into uncooked steaks at 14 days postmortem was correlated (r=-0.48) to SPT. Therefore, our objective was to further investigate two mechanical methods applied to *longissimus* muscle of uncooked USDA Select steaks to predict cooked WBSF and SPT.

Experimental Procedures

Twenty-four USDA Select strip loins (IMPS 180) were obtained at 2 days postmortem from a commercial slaughter facility. Loins were trimmed of external fat, faced, and two *longissimus* muscle steaks

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were fabricated from the anterior end of each strip loin. The first uncooked steak (1 in.) was used for the plumb bob measurement and the second (2 in.) was assigned to the needle probe assessment. The remaining strip loin was vacuum packaged and stored at 32 ± 2°F. At 14 days postmortem, the strip loins were further fabricated into steaks, starting at the anterior end. The first steak (2 in.) was assigned to the needle probe measurement and the remaining steaks (1 in.) were randomly assigned to plumb bob measurement (one steak), sensory panel evaluation (three steaks), and WBSF (one steak). Sensory panel steaks were then vacuum packaged, frozen, and stored at –20°F. Uncooked steaks at 2 and 14 days postmortem were evaluated immediately after fabrication with the needle probe and plumb bob. Steak temperature at 2 days postmortem was 41 ± 2°F and at 14 days postmortem was 36.8 ± 1°F.

A brass plumb bob (model 27446, Hempe Manufacturing Co., Inc., New Berlin, WI) was attached to an Instron Universal Testing Machine with a 50-kg compression load cell using a crosshead speed of 250 mm/min. The plumb bob had an angle of 20°, a diameter ranging from zero to 1.38 in., and was 3.8 in. long. Uncooked steaks (1 in.) were positioned on an aluminum plate (4.1 × 3.9 × 0.5 in.) that had a 27º hole in the center (tapering from 0.87 to 0.63 in. in diameter). The plumb bob traveled 2.7 in. and penetrated the steak to a point where the diameter of the plumb bob at the top of the steak was 1 in. Plumb bob steaks were probed once each in the medial, center, and lateral sections, and peak force required for penetration was recorded.

A multi-needle probe was modified such that two rows of three needles each were attached to a 1 × 3 in. plate; rows were 1 in. apart and needles within a row were 0.75 in. apart. Each needle was 2.75 in. long and had a diameter of 0.12 in. with a 10° sharpened point. The needle probe was attached to an Instron Universal Testing Machine with a 50-kg compression load cell using a crosshead speed of 250 mm/min. Uncooked steaks (2 in.) were positioned on an aluminum plate (4.1 × 3.9 × 0.5 in.). The probe traveled 1.75 in., allowing it to penetrate 1.5 in. into each steak. Steaks were probed once in the medial and lateral sections. Peak force required for penetration was recorded.

Steaks for WBSF were cooked to a 158ºF endpoint internally in a Blodgett forced-air convection gas oven preheated to 325ºF. Steak temperature was monitored using a 30-gauge, type T thermocouple inserted into the geometric center of each steak. Following refrigeration overnight at 37ºF, six ½-in. diameter cores were taken parallel to muscle fiber orientation. Two cores were taken from each of the medial, center, and lateral sections of each steak. Cores were sheared perpendicular to muscle fiber orientation using an Instron Universal Testing Machine with a WBSF V-blade attachment. A 50-kg compression load cell and a crosshead speed of 250 mm/min were used.

Sensory panel steaks were thawed for 24 to 36 hours at 37ºF and cooked using the same procedures as for WBSF steaks. Cooked steaks were trimmed of epimysial connective tissue and any remaining external fat, cut into ½ × ½ in. × steak thickness cubes, and placed in preheated double boilers. Medial, center, and lateral sections were evaluated separately and averaged. The center section consisted of a 2-in. × steak width section centered at the point where the medial and lateral muscle fibers conjoin. Sensory panels were conducted in individual booths having a mixture of red and green lighting. Duplicate samples for each steak section were presented to panelists in a statistically randomized order.

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Samples were evaluated for overall tenderness using an 8-point scale (1=extremely tough, 8=extremely tender) and scored to the nearest 0.5.

Correlations were determined using the CORR procedure of SAS (2000). Regression models were developed to predict trained SPT and WBSF values from the plumb bob, needle probe, and their respective quadratic terms. Preliminary models were selected using the PROC RSQUARE procedure (SAS, 2000) and final models were developed using the PROC REG procedure (SAS, 2000). Models were selected based on the best combination of R^2, root mean square error, and model simplicity.

Results and Discussion

Means, SD, and ranges for plumb bob, needle probe, WBSF, and SPT measurements are presented in Table 1. At 14 days postmortem, the plumb bob and needle probe values were higher than at 2 days postmortem, probably because the 14-day steaks were approximately 4.1ºF colder, resulting in a firmer muscle and higher probe values. Plumb bob measurements at 2 days postmortem were correlated to SPT (r=−0.71) and WBSF (r=0.78). In contrast, plumb bob values at 14 days postmortem were not correlated ($P>0.05$) to SPT or WBSF. Needle probe values at 2 days postmortem were correlated to SPT (r=−0.74) and WBSF (r=0.67). Needle probe values at 14 days postmortem were correlated to SPT (r=−0.61) and WBSF (r=0.53).

Regression models to predict SPT from needle probe and plumb bob measurements individually had R^2 of 0.54 and 0.51, respectively (Table 2). By combining independent needle probe and plumb bob measurements, the R^2 increased to 0.76, and when quadratic terms for both variables were in the model, the R^2 value was 0.80.

Utilizing needle probe and plumb bob measurements individually at 2 days postmortem to predict WBSF values resulted in R^2 of 0.45 and 0.51, respectively. By combining linear terms of both probes, the R^2 improved to 0.77. Including both the linear and quadratic terms for needle probe and plumb bob measurements to predict WBSF had an R^2 of 0.84.

We speculate that although needle probe and plumb bob measurements in preliminary regression models were both found to predict tenderness, each probe might have a different mode of action that when combined contributes to the improved prediction. We postulate that the plumb bob may have applied both compression and tensile strength forces to the connective tissue matrix and may have caused muscle fibers or bundles to separate. We speculate that the needle probe may measure more of the muscle fiber component of tenderness. Because of their small diameters, the needle probes may be piercing through the muscle bundles, thus measuring the strength needed to separate the muscle fibers.

The combination of needle probe and plumb bob measurements at 2 days postmortem can accurately predict WBSF and SPT on steaks aged 14 days. Future development and refinement may provide a method to accurately predict cooked meat tenderness from fresh uncooked muscle. Potentially, subprimal cuts or intact carcasses could be sorted into tenderness categories, with premiums for guaranteed tender steaks.

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Table 1. Plumb Bob and Needle Probe Values of Uncooked Steaks, and Sensory Panel Tenderness (SPT) and Warner-Bratzler Shear Force (WBSF) Values of Cooked Steaks

Trait	Day[a]	Mean	SD	Minimum	Maximum
Plumb bob, kg	2	3.62	0.56	2.75	5.24
	14	4.34	0.60	3.32	5.7
Needle probe, kg	2	2.96	0.69	1.36	4.47
	14	3.08	0.67	1.65	4.58
WBSF, kg	14	4.50	1.21	2.33	8.33
SPT[b]	14	5.4	1.0	3.5	6.8

[a]Steaks evaluated at 2 or 14 days postmortem.

[b]Sensory panel tenderness evaluated on an 8-point scale (1=extremely tough, 8=extremely tender).

Table 2. Multivariate Regression Equations Predicting Sensory Panel Tenderness and Warner-Bratzler Shear Force of Cooked Steaks Aged for 14 Days Using Plumb Bob (PB) and Needle Probe (NP) Measurements Taken at 2 Days Postmortem

			Parameter Estimate				
Item	R^2	Intercept	PB	PB^2	NP	NP^2	Root MSE[a]
Sensory Panel Tenderness							
	0.54	8.63			-1.08		0.69
	0.51	10.07	-1.28				0.72
	0.76	11.02	-0.89		-0.79		0.52
	0.58	6.70			0.33	-0.24	0.68
	0.51	10.03	-1.26	-0.003			0.74
	0.76	10.97	-0.89		-0.76	-0.005	0.53
	0.79	18.15	-4.52	0.47	-0.91		0.49
	0.80	18.32	-5.24	0.58	-0.09	-0.15	0.49
Warner-Bratzler Shear Force							
	0.45	0.99			1.19		0.92
	0.51	10.07	-1.28				0.77
	0.77	-2.57	1.33		0.76		0.61
	0.47	2.38			0.17	0.17	0.93
	0.70	10.24	-4.57	0.81			0.70
	0.78	-4.59	1.45		1.96	-0.21	0.61
	0.79	4.55	-2.28	0.47	0.64		0.59
	0.84	4.99	-4.22	0.75	2.83	-0.40	0.54

[a]Root mean square error.

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Cattlemen's Day 2002

EFFECTS OF INJECTION MARINATION WITH VARIOUS CALCIUM SOURCES AND MOLAR CONCENTRATIONS ON DISPLAY COLOR LIFE, TENDERNESS, AND MICROBIAL INHIBITION OF BEEF LOIN STEAKS

T. E. Lawrence, M. E. Dikeman, M. C. Hunt, C. L. Kastner, and J. L. Marsden

Summary

Beef strip loins were assigned to one of 11 treatments that included injection marination (10% by weight) with three calcium salts at three molar concentrations, a distilled water control, and a non-marinated control. The effects of calcium salt and concentration were tested for retail display color life, tenderness and sensory traits, and microbial growth. Calcium lactate marinated steaks had longer color life and less microbial growth than those treated with calcium chloride or calcium ascorbate. Increasing molar concentration (.1*M* to .2*M* to .3*M*) caused faster color deterioration, and did not significantly improve microbial inhibition. All calcium treatments improved tenderness; however, calcium chloride treatments induced off-flavors. Considering a whole system approach that accounts for color life, microbial inhibition, shear force, and sensory traits, we recommend injecting beef longissimus with 10% of a .1*M* solution of calcium lactate, and do not recommend other calcium salts or concentrations.

Introduction

Numerous researchers have cited the benefit of injecting beef and lamb with calcium chloride to improve tenderness. Despite the improvement in tenderness, calcium chloride has caused bitter, metallic, and livery off-flavors. In addition, calcium chloride injected muscle is often darker and discolors faster than untreated muscle. No research has been published on the injection of calcium ascorbate to improve tenderness, and only one report exists on the use of calcium lactate. Our objective was to investigate the effects of calcium ascorbate, calcium chloride, and calcium lactate at three molar concentrations on beef loin steak color life, shear force and sensory traits, and microbial inhibition.

Experimental Procedures

At 40 hours postmortem, USDA Select beef strip loin subprimals (n=26) were trimmed of all external fat and accessory muscles, and cut into three equal sections. Loin sections were randomly allocated to one of the following treatments: injection (10% by weight), of calcium ascorbate, lactate or chloride, each at .1, .2 or .3*M*; 10% distilled water, and a non-marinated control. Each loin section was vacuum packaged, tumbled for 15 minutes, and stored at 32°F until 14 days postmortem.

At 14 days postmortem, two 1-inch steaks for shear force and sensory panel evaluations, and two 0.75-inch steaks, one for simulated retail display and the other for initial microbial assessment, were cut from each loin section. Shear force and sensory panel steaks were vacuum packaged, and frozen until evaluations began. Retail display steaks were placed on white foam trays and overwrapped with oxygen permeable PVC film (23,250 $cc/m^2/24$ h). Steaks were displayed for three days at 37°F under 150 foot candles of Philips Ultra-lume™ fluorescent lighting in a retail

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display case and visually evaluated by trained color panelists at 0 (before display), 24 and 48 hr using a scale of 1 = very bright cherry red, 2 = bright cherry red, 3 = slightly dark red to tannish red, 3.5 = borderline acceptable, 4 = moderately grayish tan to brown, 5 = tan to brown. Shear force and sensory panel steaks were cooked on a MagiKitch'n electric belt grill set at 242°F, to 158°F internally. Half-inch diameter cores were taken parallel to muscle fiber orientation with a mechanical coring device, and cores were sheared once through the center by a V-notch Warner-Bratzler shear attachment connected to an Instron Universal Testing Machine. Sensory panel steaks were evaluated for myofibrillar and overall tenderness (1 = extremely tough, 8 = extremely tender), juiciness (1 = extremely dry, 8 = extremely juicy), flavor intensity (1 = extremely bland, 8 = extremely intense), connective tissue amount (1 = abundant, 8 = none), and off-flavor intensity (1 = abundant, 8 = none). Two surface cores (1.0 inch diameter, ~1/8 inch thick) were aseptically cut from the microbiological samples, added to 99 ml of 0.1% peptone buffer, and stomached for 2 minutes. Initial (at start of display) and final (after 5 days of display) samples were plated at 1, 10^{-1}, 10^{-2}, and 10^{-3} in duplicate on Aerobic Plate Count Petrifilm™ and incubated for 48 hours at 96°F. Microbiological growth was counted and converted to $\log_{10}$ colony forming units per cm^2.

The treatment structure was a 3 × 3 factorial (3 calcium salts × 3 molar concentrations) with negative (non-marinated) and positive (distilled water) controls. The design structure was an incomplete block design. Loin was the blocking factor and one-third of a loin was the experimental unit. The statistical model included the fixed effect of treatment, and the random effects of loin and location within loin (anterior, middle, posterior). Treatment means were generated and separated when significant (P<0.05). In addition, single degree of freedom contrasts were used to test the main effects of calcium salt and molar concentration.

Results and Discussion

Color deterioration varied with calcium source and molar concentration (Figure 1). The vertical dotted line represents the color limit of consumer acceptance; to the right of the line is unacceptable meat color. Color of calcium ascorbate injected steaks was unacceptable or approached unacceptability at 0 time (P<0.05). Regardless of calcium salt, injection of a .3*M* solution usually caused a less (P<0.05) desirable color than a .2*M* or .1*M* solution. Treatments with the most acceptable color were .1*M* calcium chloride, .1*M* calcium lactate, and distilled water, all of which had color scores <2.5 after 48 hours of display. Ascorbic acid can have both antioxidant and prooxidant effects. Apparently all levels of calcium ascorbate that we tested encouraged pigment oxidation. The increasing level of color deterioration (oxidation) due to molar concentration is likely due to an increased level of metal ions (calcium), which donate free electrons to oxidation reactions.

As expected, all calcium treatments reduced shear force values by 24.3 to 41.6%, compared to the non-marinated control (Table 1). In addition, calcium marination improved myofibrillar and overall tenderness compared with both controls, and connective tissue amount scores compared with the non-marinated control. Because longissimus muscle was used throughout this experiment, differences in sensory connective tissue scores are likely not real differences, but perceived differences based on variation in myofibrillar toughness. Juiciness scores were not different across treatments. Beef flavor intensity scores were highest for calcium lactate and lowest for calcium chloride treatments.

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Off-flavor intensity scores were poorest for .3*M* calcium chloride (often characterized as bitter, metallic, sour, soapy, and astringent), followed by .2*M* calcium chloride and .3*M* calcium ascorbate.

All calcium sources initiated calcium-induced tenderization. Even the lowest molar concentration met the minimum requirement for calpain enzyme activation. Furthermore, calcium salts other than calcium chloride improved tenderness.

Initial aerobic plate counts were similar among treatments; however, all counts except for .2*M* calcium lactate increased (P<.05) after 5 days of simulated retail display (Table 2). Beef loin steaks treated with .3*M* calcium lactate, .2*M* calcium chloride, or .2*M* calcium lactate had lower (P<0.05) counts than steaks treated with .1*M* calcium chloride, .2*M* calcium ascorbate, or .3*M* calcium chloride. Because there is no consistent pattern, it is difficult to recommend a specific calcium source or concentration based on microbial characteristics. Based on the data presented here, to improve beef longissimus tenderness and palatability traits without having a detrimental effect on display color life, we recommend injection with a 10% solution of 0.1*M* calcium lactate.

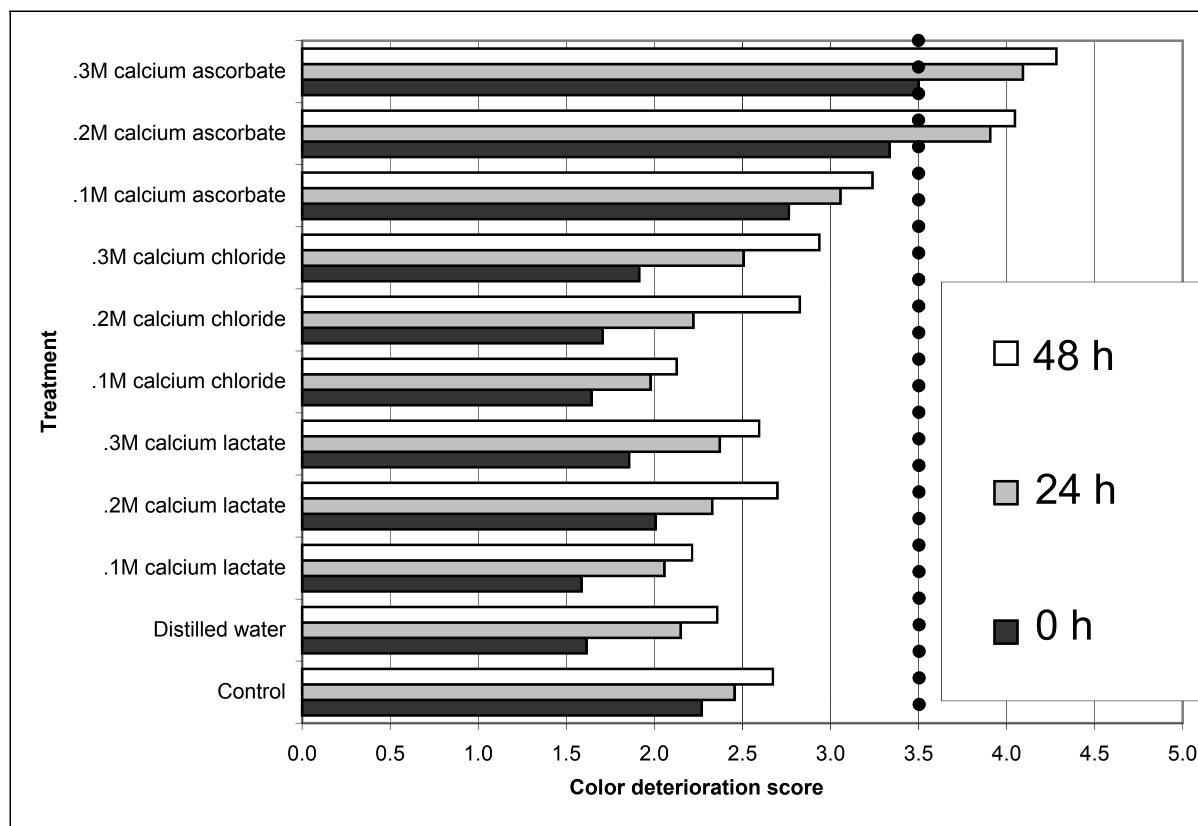

Figure 1. Visual Color Scores of Calcium Marinated Beef Loin Steaks.

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Table 1. Warner-Bratzler Shear Force (lbs) and Sensory Panel Scores of Loin Strips Injected with Three Calcium Salts at Three Molar Concentrations

Treatment	Warner-Bratzler Shear Force	Myofibrillar Tenderness	Juiciness	Beef Flavor Intensity	Connective Tissue Amount	Overall Tenderness	Off-Flavor Intensity
.3*M* Calcium ascorbate	5.48 [a]	6.51 [d]	5.32 [a]	4.82 [a b c]	7.40 [d]	6.69 [d]	5.81 [b]
.2*M* Calcium ascorbate	6.15 [a b]	6.01 [b c d]	5.32 [a]	4.90 [b c]	6.98 [b c]	6.20 [b c d]	6.89 [c]
.1*M* Calcium ascorbate	6.65 [a b]	5.81 [b]	4.83 [a]	4.95 [b c]	6.99 [b c]	6.09 [b]	7.23 [c]
.3*M* Calcium chloride	5.87 [a b]	6.36 [c d]	5.11 [a]	4.50 [a]	7.32 [c d]	6.62 [c d]	4.87 [a]
.2*M* Calcium chloride	6.38 [a b]	5.93 [b c]	5.03 [a]	4.69 [a b]	7.07 [b c d]	6.15 [b c]	6.13 [b]
.1*M* Calcium chloride	6.80 [a b]	5.80 [b]	5.13 [a]	5.05 [b c]	7.05 [b c d]	6.11 [b]	7.01 [c]
.3*M* Calcium lactate	6.35 [a b]	6.41 [c d]	5.22 [a]	5.02 [b c]	7.19 [c d]	6.59 [b c d]	7.41 [c]
.2*M* Calcium lactate	6.71 [a b]	6.06 [b c d]	5.29 [a]	5.18 [c]	7.21 [c d]	6.34 [b c d]	7.40 [c]
.1*M* Calcium lactate	7.10 [b]	5.88 [b c]	5.22 [a]	5.16 [c]	7.06 [b c d]	6.17 [b c]	6.93 [c]
Distilled water	8.55 [c]	5.00 [a]	4.94 [a]	4.92 [b c]	6.77 [b]	5.28 [a]	7.41 [c]
Control	9.38 [c]	4.70 [a]	5.07 [a]	5.02 [b c]	6.31 [a]	5.00 [a]	7.44 [c]

[a,b,c,d,e]Within a column, means with a common superscript letter do not differ ($P<0.05$).

Table 2. Aerobic Plate Counts ($\log_{10}$ CFU/cm^2) of Marinated Beef Loin Steaks Initially and after 5 days of Simulated Retail Display

Treatment	Initial	Final
.3*M* Calcium ascorbate	1.31 [y]	2.91 [a b c d, z]
.2*M* Calcium ascorbate	1.41 [y]	3.47 [c d, z]
.1*M* Calcium ascorbate	0.90 [y]	2.96 [a b c d, z]
.3*M* Calcium chloride	1.32 [y]	3.71 [d, z]
.2*M* Calcium chloride	0.94 [y]	2.15 [a, z]
.1*M* Calcium chloride	1.53 [y]	3.28 [b c d, z]
.3*M* Calcium lactate	1.14 [y]	2.13 [a, z]
.2*M* Calcium lactate	1.36 [y]	2.18 [a, y]
.1*M* Calcium lactate	1.46 [y]	2.37 [a b, z]
Distilled water	1.11 [y]	2.61 [a b c, z]
Control	1.60 [y]	2.19 [a, y]

[a,b,c,d]Within a column, means with a common superscript letter do not differ ($P<0.05$).
[y, z]Within a row, means with a common superscript letter do not differ ($P<0.05$).

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MYOFIBRILLAR STRUCTURAL CHANGES CAUSED BY MARINATION WITH CALCIUM PHOSPHATE OR CALCIUM CHLORIDE AND SODIUM PYROPHOSPHATE

T. E. Lawrence, A. T. Waylan, and C. L. Kastner

Summary

Ultrastructural changes were studied in beef eye of round muscle after 120 hours marination in 0.5, 0.75, or 1.0% calcium phosphate (CaPO) or 2, 4, or 6% calcium chloride or 1% sodium pyrophosphate (CaCl+NaPO) solutions. Increasing the concentration of CaPO caused decreasing myofibril width and increasing myofilament degradation. Increasing the concentration of CaCl+NaPO caused increasing loss of I-band material. Marination of beef eye of round muscle in calcium phosphate or calcium chloride + sodium pyrophosphate solutions caused denaturation of myofibrillar proteins likely due to marinating solution acidity.

(Key Words: Marinades, Muscle Structure.)

Introduction

Variability in meat tenderness is a major quality defect of current beef production practices. Marination can add various ions to muscle to alter pH and ionic strength, ultimately affecting the degree of muscle fiber disruption. Injecting beef and lamb muscles with calcium chloride ($CaCl_2$) improves tenderness through the activation of calcium-dependent proteases as well as a salting-in of the calcium ions, causing degradation of Z-disk proteins (desmin and nebulin), titin, C-protein, troponin-I, troponin-T, and tropomyosin. Phosphate compounds increase water-holding capacity by increasing negative charge electrostatic repulsion, and improve tenderness by dissociating actomyosin. Each of these can lead to improved tenderness. Our objective was to investigate changes in the ultrastructure of beef caused by marination in either calcium phosphate or calcium chloride-sodium pyrophosphate solutions.

Experimental Procedures

We used the eye of round muscle from one side of a commercially fed and slaughtered beef animal. At 40 hours postmortem, the muscle was sliced into 1-inch steaks perpendicular to muscle fiber orientation. These steaks were further sliced into small muscle samples with final dimensions of .2 inch × .4 inch × 1.0 inch. The longitudinal axis of the muscle fibers coincided with the long axis of the small tissue samples. Three calcium phosphate ($Ca(H_2PO_4)_2$) solutions (0.50, 0.75, and 1.0% calcium phosphate monobasic), 3 calcium chloride ($CaCl_2$) + sodium pyrophosphate ($Na_2H_2P_2O_7$) solutions (2, 4, and 6% calcium chloride plus 1% disodium pyrophosphate), and a no liquid, unmarinated control were utilized to test the effects of marination on the small muscle samples. Each tissue sample was placed in a 15 ml conical polystyrene centrifuge tube to which 10 ml of a single marination solutions was added deionized water. The pH of each marination solution was

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also recorded. After 120 hours of marination, final sample pH was determined by homogenizing five samples per treatment in their respective solutions and measuring pH of the homogenate. After marination, three samples were randomly selected from each treatment for transmission electron microscopy. Microscopy samples (.04 inch × .04 inch × .11 inch) were cut from the muscle blocks using a razor blade, fixed in 3% gluteraldehyde - 0.1*M* sodium cacodylate for three hours under slight agitation on an orbital shaker, rinsed three times in 0.1*M* sodium cacodylate - 0.1*M* sucrose, and post-fixed in 1% osmium tetroxide - 0.1*M* sodium cacodylate for 2 hours (1 hour in ice, 1 hour at room temperature). Samples were then rinsed three times with distilled water, dehydrated using a graded acetone series (50, 70, 80, 90, 100, 100, 100%), infiltrated with resin, placed in embedding molds, and heated (140°F) for 48 hours to polymerize the resin. Thin sections were cut using glass knives on an ultramicrotome and mounted on 250-mesh copper grids before electron micrographs were taken. pH data were analyzed as a one-way treatment structure in a repeated measures experimental design. Marination solution was the between-subject treatment factor and the initial and after marination measurements were the within-subject repeated measures. Differences among treatments and between repeated measures were tested and separated when significant ($P<0.05$).

Results and Discussion

Increasing concentrations of calcium phosphate (CaPO) or calcium chloride-sodium pyrophosphate (CaCl+NaPO) decreased solution pH (Table 1). Calcium phosphate is an acidulant used in the baking industry, therefore the low pH was expected. However, the low pH of the CaCl+NaPO solutions was unexpected. Apparently, both calcium chloride and sodium pyrophosphate dissociated, then the calcium complexed with the pyrophosphate, liberating hydrogen ions and decreasing solution pH.

Measurements of pH (Table 1) indicated the control increased ($P<0.05$) in pH unmarinated while the 0.75 and 1.0% CaPO and all CaCl+NaPO treatments decreased ($P<0.05$) in pH. No significant difference between initial and final pH was detected for the 0.5% CaPO treatment. Muscle tissue pH of each treatment was similar initially; however, a stepwise decrease in tissue pH after marination was noted as CaPO or CaCl+NaPO concentration increased, reflecting the acidic properties of the calcium phosphate and calcium chloride solutions and loss of muscle tissue buffering capacity.

Figures 1 through 7 illustrate the myofibrillar structure of *semitendenosis* muscle samples subjected to each of the 7 treatments. In Figure 1 (control) the Z-lines were intact and clearly defined. The A-bands and I-bands had no noticeable degradation and the H-zone was detectable. Overall, sarcomere components had clear definition and were aligned in a systematic manner. In Figure 2 (0.50% CaPO), only slight degradation of Z-lines was detected as noted by a few gaps or breaks. The Z-lines were less intact and less in register than the control and the H-zone was still detectable. A noticeable loss of Z-line stability seen in Figure 3 (0.75% CaPO), indicates significant structural degradation. The Z-lines were in less register at the lower concentration and wavy appearance had increased. The H-zone was not well defined, indicating less structural integrity amongst the myosin filaments. In Figure 4 (1.0% CaPO) increased Z-line degradation occurred compared to the 0.75% CaPO treatment. The H-zone was barely detectable and the Z-lines were in disarray, indicating significant structural alteration. In addition, both the 0.75% and 1.0% CaPO

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treatments caused narrowing of the myofibrils compared to the negative control, likely due to the loss of water caused by acid denaturation of the myofilaments and the sarcoplasmic reticulum. The 2% CaCl + 1% NaPO treatment (Figure 5) caused the Z-lines and H-zones to lose some structural order. However, the H-zone and I-bands were clearly identifiable. In Figure 6, muscle samples marinated in 4% CaCl + 1% NaPO had partially degraded Z-lines due to their loss of order and appearance of multiple gaps or breaks. In addition, less I-band material was seen, indicating increased degradation of actin filaments. Muscle marinated in 6% CaCl +1% NaPO (Figure 7) also showed many gaps and loss of Z-line order. The I-band was less visible, suggesting more structural alteration of I-band material from this treatment.

Our original hypothesis was that low concentrations of calcium phosphate would dissociate in water, yielding free calcium and phosphate. Free calcium was anticipated to enhance calpain activity, thereby increasing structural degradation of the myofibrillar component, while the phosphates would bind water. However, even low concentrations of calcium phosphate dissociated poorly in water. Calpain activity was likely not enhanced because of the poor dissociation of the marination compounds as well as the low pH of the marination solutions. A synergism was expected to exist between calcium chloride and sodium pyrophosphate, but they apparently dissociated and calcium complexed with pyrophosphate, thereby decreasing pH. We suggest that degradation evident in the micrographs resulted from acid denaturation of myofibrils and possibly from increased activity of cathepsin enzymes.

Beef eye of round marinated in a calcium phosphate or calcium chloride - sodium pyrophosphate solution showed myofibrillar protein structural changes when compared to non-marinated controls. The changes were likely the result of acid denaturation of proteins. In applied practice, we do not recommend the use of calcium phosphate or calcium chloride-sodium pyrophosphate solutions for marination of beef.

Table 1. pH of Marination Solutions and Eye of Round Tissue Samples Initially and 120 Hours after Marination in Calcium Phosphate or Calcium Chloride + Sodium Pyrophosphate Solutions (S.E.=0.067)

Marination Treatment	pH Solution	Initial pH	Final pH
Untreated control	----	5.42^{b}	$5.67^{a,t}$
0.50% Calcium phosphate	4.53	5.38^{a}	$5.43^{a,u}$
0.75% Calcium phosphate	4.37	5.39^{a}	$5.16^{b,v}$
1.00% Calcium phosphate	4.30	5.47^{a}	$4.94^{b,w}$
2% Calcium chloride + 1% Sodium pyrophosphate	2.90	5.44^{a}	$3.55^{b,x}$
4% Calcium chloride + 1% Sodium pyrophosphate	2.71	5.25^{a}	$3.21^{b,y}$
6% Calcium chloride + 1% Sodium pyrophosphate	2.39	5.43^{a}	$2.83^{b,z}$

^{a,b}Means within a row with different superscripts differ (*P*<0.05).
^{t,u,v,w,x,y,z}Means within a column with different superscripts differ (*P*<0.05).

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Effect of Treatment on Muscle Structure

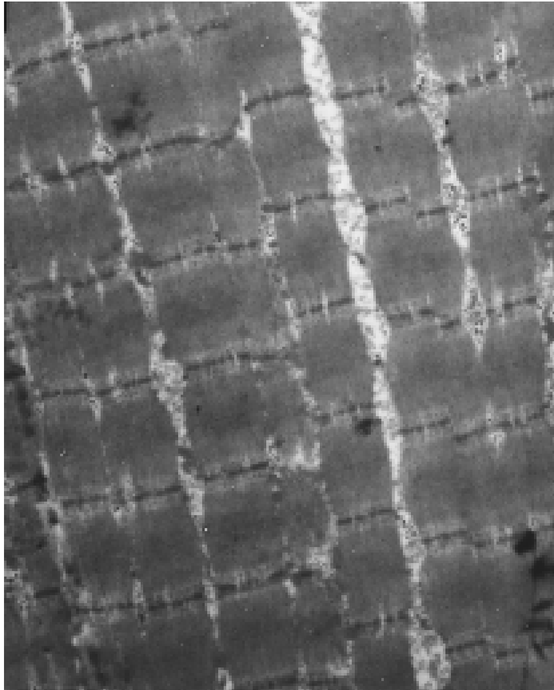

Figure 1. Control

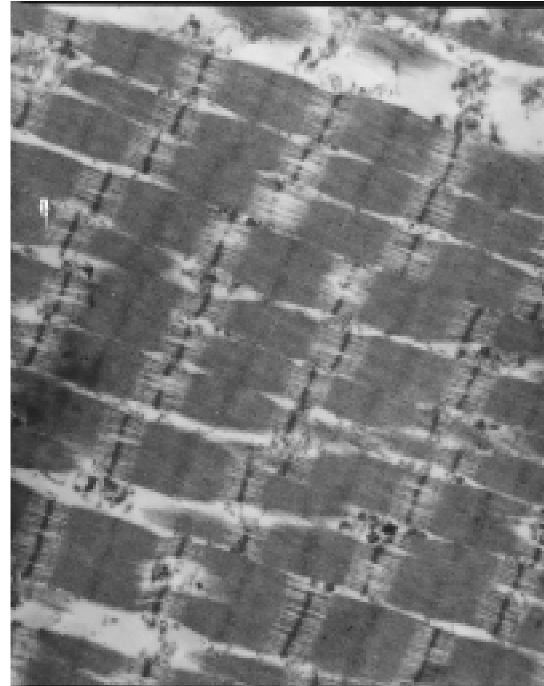

Figure 2. 0.50% Calcium phosphate

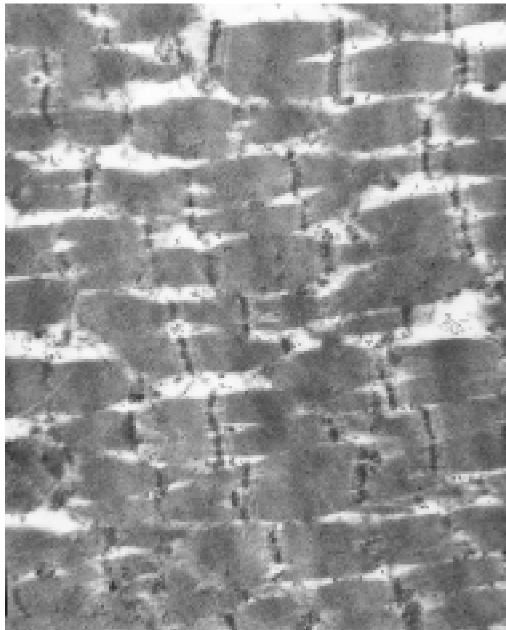

Figure 3. 0.75% Calcium phosphate

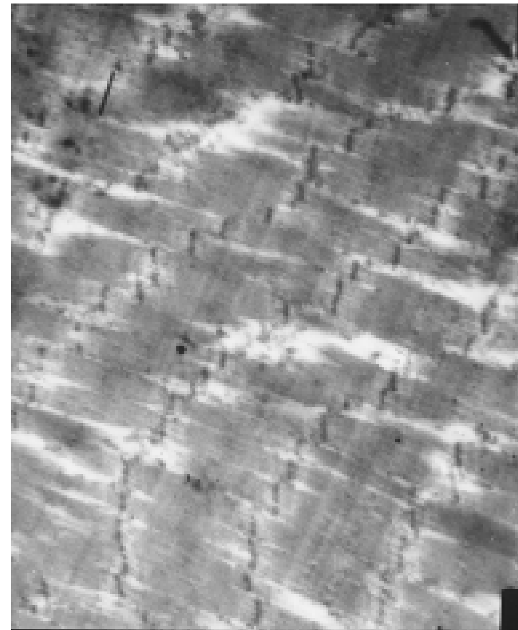

Figure 4. 1.0% Calcium phosphate

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Effect of Treatment on Muscle Structure

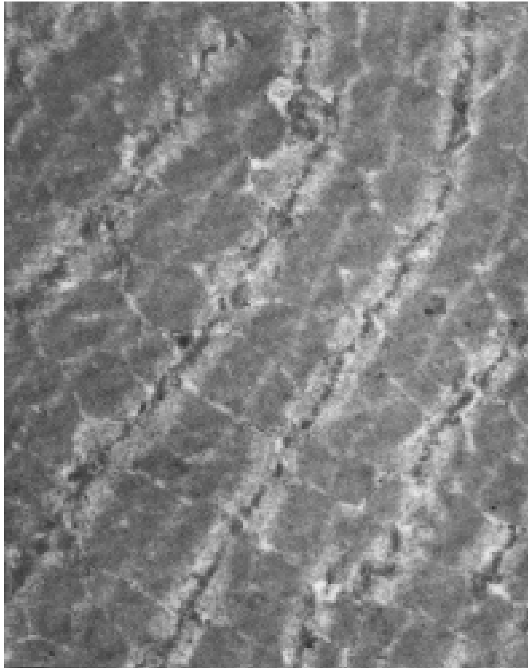

Figure 5. 2% Calcium chloride + 1% Sodium pyrophosphate

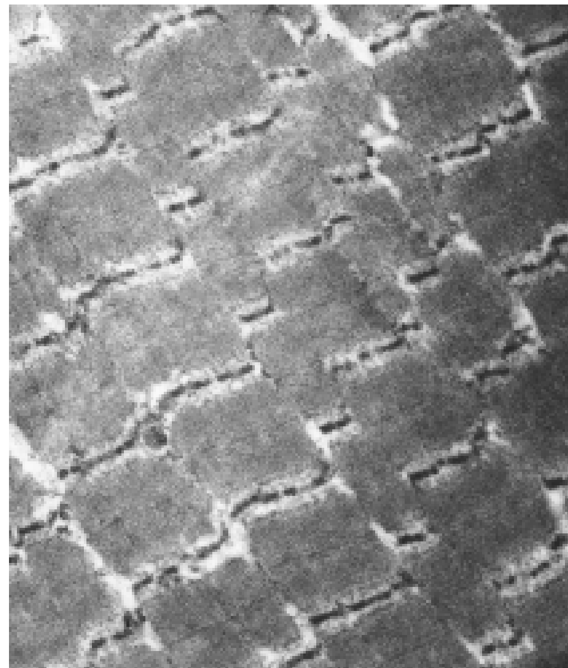

Figure 6. 6.4% Calcium chloride + 1% Sodium pyrophosphate

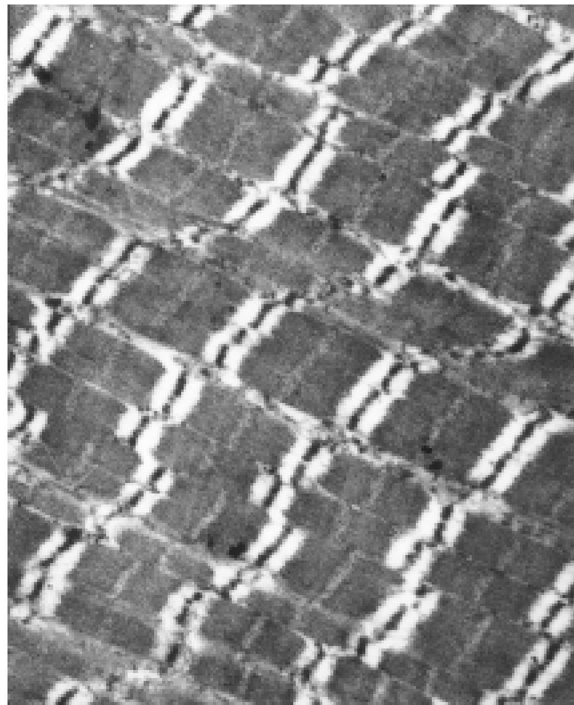

Figure 7. 6% Calcium chloride + 1% Sodium pyrophosphate

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COMPARISON OF THE BEEF EMPIRE DAYS INDEX WITH CARCASS PRICING FOR RANKING BEEF CARCASSES

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R. D. Jones[1]*, and D. E. Schafer*

Summary

Our study evaluated the effectiveness of the Beef Empire Days carcass index in ranking beef carcasses compared to rankings based on carcass prices. Two price sets were used: the average prices between January 1998 and June 2001, and a short-range price determined from the average prices between April and September of 2001. Additionally, carcass data from the top live-placing cattle were compared to the data of the highest indexing carcasses. The live show judges were very accurate in selecting for ribeye size. However, they selected cattle that were fatter, but did not marble as well as the high indexing carcasses. Changes that might improve the index are identified. However, the Beef Empire Days index ranked carcasses moderately well compared to the pricing system.

(Key Words: Beef Carcass Ranking, Prices.)

Introduction

In 1992, the Beef Empire Days Committee and Kansas State University developed an index system to rank beef carcasses based on how well they fit a specific industry target. The target, and point deductions for missing the target, were based on industry priorities at that time. Since 1992, slight modifications have been made to the index as needed. However, no comparison has been made between the index rankings and price rankings of carcasses.

Value-based marketing of cattle has become much more common since 1992. Today, a large proportion of slaughter cattle are sold on a carcass value basis. Prices are negotiated between the producer and processor and usually have premiums and discounts based on carcass weights, quality and yield grades, and factors that reduce carcass value. This study evaluated the ability of the live show judges to select cattle that scored well in the index. Additionally, we wanted to see how well the Beef Empire Days Index reflects beef carcass prices in industry trade.

Experimental Procedures

USDA yield and quality factors and Beef Empire Days index values were obtained for the 641 steers and 494 heifers entered in the 1998, 1999, 2000, and 2001 Beef Empire Days contests. We compared the carcass data from the 25 steers and 15 heifers that placed high in the live show each year to the data of the 25 steer and 15 heifer carcasses that had the highest indexes in that same year. Analysis of variance was used to determine if differences existed in the characteristics between the top live placings and the top carcass placings.

Prices were calculated for each carcass based on the base prices ± premiums and discounts reported by USDA. A long-

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range price structure was determined from the average prices reported during the time period from January 1998 through June of 2001 (Table 1). A short-range price was determined using the average prices from April to September of 2001 (Table 2). The price for low Choice, yield grade 3 carcasses was used as the base. That value and the Choice-Select spread were obtained one day each week from the USDA Beef Carcass Price Equivalent Index Value report. The premiums and discounts for carcasses deviating from the base were determined one day each week from the USDA National Weekly Direct Slaughter Cattle-Premiums and Discounts report. The Spearman correlation between the Beef Empire Days index values and carcass prices was calculated. Additionally, correlations between rankings produced by these two systems were evaluated.

The Beef Empire Days index starts with 100 points and is based on an optimum range of hot carcass weight, fat thickness, ribeye area, kidney, pelvic and heart fat, and quality grade. Cattle with values for a trait outside the optimum range have points deducted based on how far outside the optimum range they are. A relatively large deduction is made for Select versus the low Choice grade, but higher quality grades are rewarded minimally.

Results and Discussion

The average carcass data of the highest placing individuals from the live and carcass shows are presented in Table 3. The live judges attempt to select cattle that produce "ideal" carcasses and are useful to all segments of the beef cattle industry. No difference was found in the live weights of the cattle selected live compared to the highest indexing animals. However, the live judges selected animals that dressed higher than those that yielded the top ranking carcasses.

Highest placing live cattle had more fat cover, higher yield grades and less marbling than the highest indexing carcasses. Remarkably, the ribeye areas were almost identical between the individuals selected in the live and carcass shows.

Spearman correlation coefficients measure the relationship between rankings based on Beef Empire Days index and rankings based on prices. Spearman correlations of 0.69 and 0.71 indicate that rankings from the different methods agree moderately well. Additionally, of the 100 highest indexing carcasses, 33 were among the 100 with the highest long-range prices, and 70 were among the 100 carcasses with the highest short-range prices.

An examination of the Beef Empire Days index would not be complete without examining the current industry situation and determining if the targets set by the index in 1992 need to be changed. In the early 1990's, reducing fat and improving quality were top priorities. A comparison of the 1991 and 2000 National Beef Quality Audits (NBQA) show that the 2000 audit had a slightly higher proportion of Select carcasses and of yield grade 1 and 2 carcasses. Additionally, the average fat thickness had decreased slightly, but other carcass traits had not really changed.

According to industry interviews in the NBQA—2000, excessive fat is still a primary concern. Therefore, the heavy emphasis on cutability should be maintained in the index. A significant increase in demand for "premium Choice" and Prime carcasses has occurred since 1992. The NBQA—2000 indicated that insufficient marbling is still among the top five industry concerns. Therefore, we suggest that the point bonuses for carcasses grading premium Choice or Prime should be increased.

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The Beef Empire Days index is applied differently to steer and heifer carcasses, primarily because of the long-standing belief that heifers cannot compete with steer carcasses. However, previous data from the contests indicate that heifers are slightly fatter than their steer counterparts, but are also more muscular at the same carcass weight. Furthermore, steer and heifer carcasses are not priced differently in the industry. Therefore, we suggest that the same index be applied to both steer and heifer carcasses.

Finally, the range in carcass weights considered optimum in the Beef Empire Days index system is extremely narrow (50 pounds). In industry, the range of acceptable (no discounts) weights is about 350 to 400 pounds, which leads to too much variability for carcass ranking. However, the 50 pound optimum range in the Beef Empire Days index system penalizes a large number of carcasses that are desirable by industry standards. Initially, the narrow optimum weight range was established to decrease variability in subsequent retail cuts. This is partially corrected by the ribeye area adjustment for carcasses with especially large ribeyes. However, we suggest that the range of acceptable hot carcass weights be increased.

Table 1. Average Carcass Prices ($/cwt) by USDA Quality and Yield Grades with Discounts for Outliers from January 1998 to June 2001

Yield Grade	Prime	Choice +/0	Choice-	Select	Standard
1	119.09	114.92	113.45	105.54	95.61
2a	117.99	113.82	112.35	104.44	94.51
2b	117.95	113.78	112.31	104.40	94.47
3a	117.05	112.88	114.41	103.50	93.57
3b	116.75	112.58	111.11	103.20	93.27
4	101.12	96.95	95.48	87.57	77.64
5	95.94	91.77	90.30	82.39	72.46

Miscellaneous Discounts		Outweight Discounts	
Bullock/Stag	-25.90	400-500	-21.83
Hardbone	-22.88	400-550	-17.64
Dark Cutter	-28.90	950-1000	-16.14
		1000+	-22.20

[a]Trimmer half of yield grades 2 & 3; [b]Fatter half of yield grades 2 & 3.

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Table 2. Average Carcass Prices ($/cwt) by USDA Quality and Yield Grades with Discounts for Outliers from April to June 2001

Yield Grade	Prime	Choice +/0	Choice-	Select	Standard
1	127.19	122.54	121.08	110.97	103.88
2a[a]	125.73	121.08	119.62	109.51	102.42
2b[b]	125.21	120.56	119.10	108.99	101.90
3a	124.06	119.41	117.95	107.84	100.75
3b	123.96	119.31	117.85	107.74	100.65
4	110.98	106.33	104.87	94.76	87.67
5	104.41	99.76	98.30	88.19	81.10

Miscellaneous Discounts		Outweight Discounts	
Bullock/Stag	-22.33	400-500	-24.00
Hardbone	-24.57	400-550	-15.14
Dark Cutter	-27.50	950-1000	-9.23
		1000+	-18.26

[a]Trimmer half of yield grades 2 & 3.

[b]Fatter half of yield grades 2 & 3.

Table 3. Least Squares Means for Carcass Traits of Highest Placing Steers and Heifers Selected by Live Evaluators or the Beef Empire Days Carcass Index from the 1998, 1999, 2000, and 2001 Beef Empire Days Contests

	Steers		Heifers	
	Live	Carcass	Live	Carcass
Live weight (lbs)	1212	1207	1102	1107
Hot carcass weight (lbs)	780[a]	763[b]	712	705
Fat thickness (in.)	0.50[a]	0.37[b]	0.50[a]	0.37[b]
Ribeye area (in^2)	14.5	14.3	14.6	14.5
KPH (%)	1.7	1.6	1.8[a]	1.7[b]
Yield grade	2.4[a]	2.1[b]	2.1[a]	1.8[b]
Marbling	Slight 80[a]	Small 50[b]	Small 00[a]	Small 60[b]
Beef Empire Days Index	68.16[b]	102.23[a]	69.71[b]	99.11[a]

[a,b]LS means within a trait and sex class lacking common superscripts differ ($P<0.05$).

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FERTILITY OF HEIFERS AFTER SYNCHRONIZATION OF ESTRUS USING GnRH, $PGF_{2\alpha}$, AND PROGESTERONE (CIDR)

A. M. Richardson, S. K. Johnson[1], B. A. Hensley
T. J. Marple, and J. S. Stevenson

Summary

Our objectives were to determine fertility of heifers after estrus synchronization using $PGF_{2\alpha}$ preceded by either progesterone, GnRH, or both. Beef (n = 193) and dairy (n = 246) heifers were assigned randomly to three treatments: 1) 50 µg of GnRH and a used intravaginal progesterone-releasing insert were administered on day −7, followed by 25 mg of $PGF_{2\alpha}$ on day −1, and CIDR removal on day 0 (CIDR + GnRH + PGF); 2) the same as 1) but without the GnRH (CIDR + PGF); and 3) the same as 1) but without the CIDR (GnRH + PGF; modified Select Synch). Rates of estrus detection were lower in dairy than in beef heifers, and greater in heifers treated with the CIDR. In dairy heifers, conception and pregnancy rates were greatest in the CIDR + PGF treatment, followed by the CIDR + GnRH + PGF and GnRH + PGF treatments. The opposite trend was observed among treatments in beef heifers. All estrus-synchronization treatments produced acceptable estrus detection and pregnancy rates.

(Key Words: Estrus, Heifers, CIDR-B, Fertility.)

Introduction

The importance of dairy and beef heifers as future replacements cannot be overstated. Estrus can be synchronized either by shortening the luteal phase with $PGF_{2\alpha}$ or by artificially extending the luteal phase with progestins. The "gold standard" for synchronizing estrus in beef heifers is the MGA + PGF protocol (feed 0.5 mg of melengesterol acetate [MGA] per day for 14 days and then inject $PGF_{2\alpha}$ 17-19 days later). The major disadvantage of that protocol is its long duration (31-33 days) before insemination begins.

Introduced in the early 1980's, the CIDR-B device (Controlled Internal Drug Release; InterAg, Hamilton, NZ) is an intravaginal insert that provides controlled release of exogenous progesterone. Similar to using MGA, behavioral estrus and ovulation are suppressed during treatment with the CIDR. But unlike MGA, fertility is normal at the first estrus after CIDR treatment. Short-term treatment with the CIDR produced tight synchrony of estrus, but conception rates were variable and related to treatment duration.

Our objectives were to determine estrual characteristics and fertility of heifers after synchronization using $PGF_{2\alpha}$ preceded by either progesterone, GnRH, or both.

Procedures

Holstein heifers (n = 246) averaged 13 ± 0.1 months of age (12 to 20 months) and weighed 886 ± 4 lb (754 to 1236 lb) prior to treatment. Sixteen replications of the treat-

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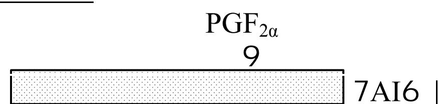
ments (ranging from 6 to 29 heifers per replication) were conducted between November 1998 and August 2001.

Beef heifers at the Manhattan location (April 2001) consisted of purebred Angus, Herefords, and Simmentals. Average age was 14 ± 0.1 mo (12 to 15 mo). Beef heifers at Hays (April 2001) were Angus crosses and averaged 13 ± 0.1 mo (11 to 15 mo) of age. Only one beef heifer was less than 12 mo of age at the initiation of treatments.

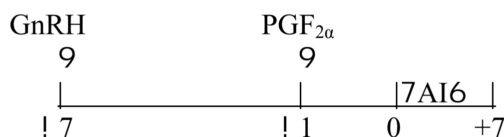
Heifers were assigned randomly to three treatments (Figure 1): 1) 50 µg of GnRH (injected i.m., Cystorelin, Merial, Iselin, NJ) and a used intravaginal progesterone-releasing insert (CIDR-B, InterAg, Hamilton, NZ) were administered on day −7, followed by 25 mg of $PGF_{2\alpha}$ (i.m., Lutalyse, Pharmacia Animal Health, Kalamazoo, MI) on day −1, and CIDR removal on day 0 (CIDR + GnRH + PGF); 2) the same as 1) without the GnRH (CIDR + PGF); and 3) the same as 1) without the CIDR (GnRH + PGF; modified Select Synch).

CIDR+GnRH+PGF:

CIDR+PGF:



GnRH+PGF:



CIDR in place

Figure 1. Experimental Protocols.

Blood samples were collected for later analyses of progesterone concentration. Prepubertal heifers had only low (<1 ng/mL) concentrations of progesterone on days −7, −1, and 0.

Beef heifers were observed for estrus multiple times during daylight hours beginning the day of $PGF_{2\alpha}$ injection. Dairy heifers had HeatWatch patches attached for continuous detection of estrus. All heifers were examined for pregnancy once between 27 and 34 days after insemination by transrectal ultrasonography. Rates of estrus detection (number of heifers detected in estrus during 7 days after $PGF_{2\alpha}$), conception (number of pregnant heifers divided by number of heifers inseminated), and pregnancy (number of pregnant heifers after synchronized insemination divided by the number of heifers treated) were calculated. Intervals from injection of $PGF_{2\alpha}$ to visual observation of estrus were determined. Measures of estrus-detection rate, conception rate, pregnancy rate, and interval from $PGF_{2\alpha}$ to estrus, were analyzed using a model consisting of treatment, group (beef vs. dairy), and their interaction.

Results and Discussion

Summarized in Table 1 are the estrus-detection rates of the dairy and beef heifers. The rates varied from 74 to 91% and were greater ($P<0.05$) in both heifer groups treated with the CIDR. The estrus detection rates tended ($P=0.07$) to be lower for prepubertal heifers (61%) than for cycling heifers (85%) and less ($P=0.06$) for all heifers that had low progesterone levels (no corpus luteum) (69%) than for heifers with high progesterone levels (corpus luteum present) (86%). Average interval from $PGF_{2\alpha}$ to estrus was greater ($P<0.01$) for both CIDR treatments (3 ± 0.1 days) than for the GnRH + PGF treated heifers (2.2 ± 0.1 days). In addition, estrus-detection rates were 10% greater ($P<0.05$) in beef than dairy heifers.

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Distribution of estrus after $PGF_{2\alpha}$, based on continual surveillance of the dairy heifers by the HeatWatch system, is illustrated in Figure 2. More ($P<0.01$) dairy heifers in the CIDR + PGF (67%) and CIDR + GnRH + PGF (75%) treatments began estrus between 48 and 71 hours after $PGF_{2\alpha}$ than those in the GnRH + PGF treatment (40%). In contrast, more ($P < 0.05$) heifers in the GnRH + PGF treatment began estrus between 24 and 47 hours (44%) after $PGF_{2\alpha}$ than in other treatments (<10%). The peak in estrus expression was confined to a 24-hour period for those heifers treated with the CIDR compared to those receiving only GnRH before $PGF_{2\alpha}$.

In Figure 3, the pattern of estrus expression of the beef heifers (based on multiple daily visual observations during daylight hours) was similar to that of the dairy heifers (Figure 2). Most of the beef heifers showed estrus on day 2 after $PGF_{2\alpha}$. More ($P < 0.01$) beef heifers in the CIDR + PGF (74%) and CIDR + GnRH + PGF (74%) treatments were in estrus on day 2, whereas fewer ($P < 0.05$) heifers in the GnRH + PGF treatment (44%) were detected on day 2.

Average heifer group conception rates varied little, from 54 to 59%, but a treatment × group interaction ($P<0.05$) was detected (Table 1). This interaction carried over to pregnancy rates as well. In the dairy heifers, conception and pregnancy rates were greatest in the CIDR + PGF treatment and least in the GnRH + PGF treatment, whereas those in the CIDR + GnRH + PGF treatment were intermediate. In contrast, conception and pregnancy rates in the CIDR + PGF treatment were the least in beef heifers, and those in the CIDR + GnRH + PGF and GnRH + PGF treatments were similar.

These data provide evidence that administration of progesterone for only 7 days before $PGF_{2\alpha}$ produced superior conception and pregnancy rates in dairy heifers. But for beef heifers, an injection of GnRH may be necessary at the time of CIDR insertion to maximize conception and pregnancy rates.

We cannot explain the difference between beef and dairy heifers in their response to these treatments. We can only speculate that perhaps the progesterone in the CIDR was able to prevent formation of persistent follicles in dairy heifers whose corpus luteum regressed early after CIDR insertion. In beef heifers, without the GnRH injection, the CIDR + PGF did not produce acceptable fertility. Likewise, for the GnRH + PGF in dairy heifers, level of fertility observed was not acceptable.

We anticipate that the CIDR will provide a viable alternative treatment protocol of short duration compared to the MGA (14 days of feeding) + PGF (injected 17 to 19 days after MGA) protocol for synchronizing estrus in beef heifers.

Note: The administration of progesterone via a CIDR as described in this study has not been approved by the United States Food and Drug Administration. It is anticipated to be market-available late in 2002.

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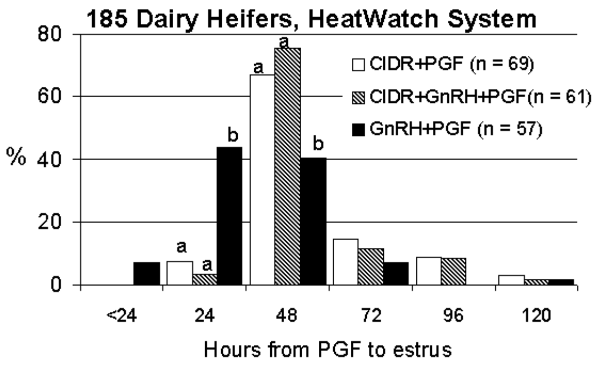

Figure 2. Percentage Distribution of Estrus After $PGF_{2\alpha}$. Continuous Surveillance by HeatWatch System. [a,b]Different (P<0.01) within interval

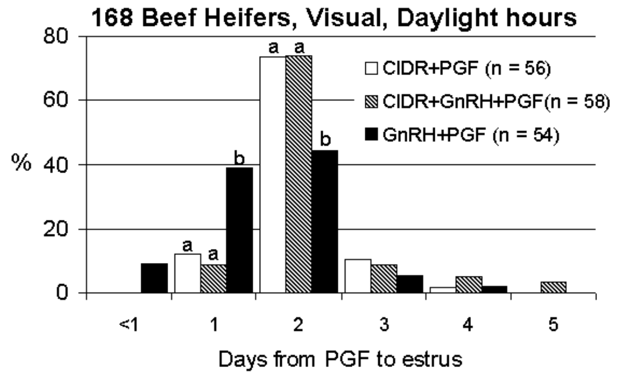

Figure 3. Percentage Distribution of Estrus After $PGF_{2\alpha}$. Visual Observation, Daylight Hours. [a,b]Different (P<0.01) within day.

Table 1. Reproductive Traits of Dairy and Beef Heifers in Response to CIDR, CIDR+GnRH, or GnRH

		Treatment[a]			
Item	Group	CIDR + $PGF_{2\alpha}$	CIDR+GnRH + $PGF_{2\alpha}$	GnRH + $PGF_{2\alpha}$	Group Avg.
No. of heifers					
	Beef	64	64	65	193
	Dairy	83	81	83	247
	Total	147	145	148	
Estrus-detection rates[b], %					
	Beef	89	91	83	88
	Dairy	86	79	74	79
	Total	87	84	78	
Conception rates[c], %					
	Beef	46	59	59	54
	Dairy	69	58	48	59
	Total	59	58	53	
Pregnancy rates[c], %					
	Beef	41	53	49	48
	Dairy	59	46	35	47
	Total	51	49	41	

[a]See Figures 2 and 3 for description of treatments.
[b]Effects of group (P<0.05) and CIDR (P<0.05).
[c]Treatment × group interaction (P<0.05).

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TIMED-INSEMINATION OF BEEF HEIFERS USING COSYNCH WITH ONE OR TWO INITIAL INJECTIONS OF GnRH

D. M. Grieger, C. D. Holladay and D. R. Eborn

Summary

Our purpose was to determine if giving an additional injection of GnRH to beef heifers synchronized with the Cosynch protocol would increase pregnancy rate to timed A.I. Eighty yearling beef heifers received an injection of GnRH, 7 days before receiving an injection of PGF (Cosynch). One half of the heifers were also given an injection of GnRH 14 days prior to the PGF injection (2×GnRH-Cosynch). All heifers were given a GnRH injection 2 days after PGF and inseminated at that time. Pregnancy rate for the 2×GnRH-Cosynch group (40%) was not different than that for the Cosynch group (50%) and was actually numerically lower. This trial suggested that an additional injection of GnRH 1 week prior to the Cosynch protocol was not beneficial in increasing the pregnancy rate of heifers to timed A.I.

(Key Words: Heifers, AI, Estrous Synchronization, GnRH, $PGF_{2\alpha}$.)

Introduction

Research at Kansas State University and other locations has shown that using combinations of GnRH and prostaglandin $F_{2\alpha}$ (PGF) to synchronize estrus in lactating beef cows results in pregnancy rates ranging from 40 to 60 percent after timed A.I. Using these same protocols in heifers, however, usually results in low pregnancy rates, partly because some heifers have not achieved puberty at the onset of the breeding season. In an effort to increase the number of heifers that respond to a GnRH/PGF/timed-A.I. synchronization system (Cosynch), we conducted an experiment using an additional injection of GnRH 2 weeks prior to PGF.

Experimental Procedures

Eighty crossbred yearling beef heifers received an injection of GnRH (100 μg of Cystorelin®; Merial Ltd., Iselin, NJ) on day –7 and an injection of PGF (25 mg of Lutalyse®; Pharmacia & Upjohn, Kalamazoo, MI) on day 0 followed by a second injection of GnRH on day 2. All heifers were inseminated 48 hours after PGF, when an additional injection of GnRH was given. This estrus/ovulation synchronization protocol is known as the "Cosynch" protocol. Half of the heifers (n=40) were given a preliminary injection of GnRH on day –14. This treatment is referred to as "2×GnRH-Cosynch". Pregnancy was determined in all heifers 30 days after insemination using transrectal ultrasonography.

Results and Discussion

The experimental design and results are shown in Figure 1. The pregnancy rate was not different between the 2×GnRH-Cosynch (40%) and the Cosynch treatments (50%). Therefore, we concluded that an additional injection of GnRH 2 weeks prior to PGF did not increase cyclicity and timed-AI pregnancy rate in this small group of heifers.

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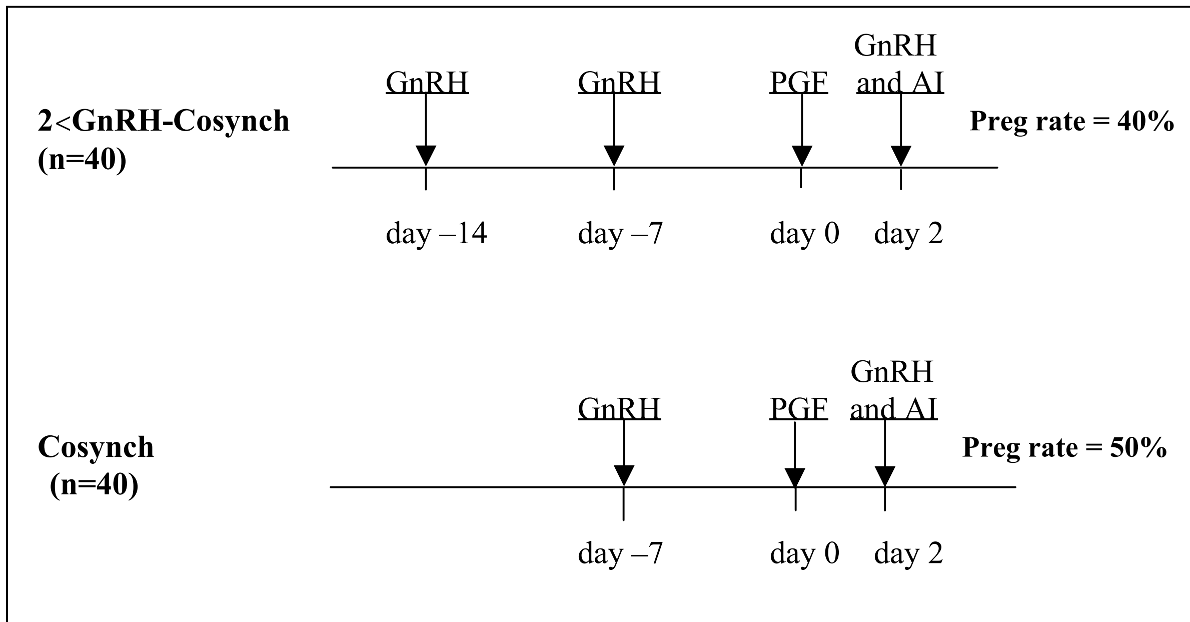

Figure 1. Synchronization Treatments and Pregnancy Rates for 2<GnRH-Cosynch vs. Cosynch in Yearling Heifers.

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TIMED INSEMINATION OF SUCKLED BEEF COWS AFTER OVULATION SYNCHRONIZATION WITH COSYNCH + CIDR

S. K. Johnson[1], K. R. Harmoney[2], and J. S. Stevenson

Summary

Lactating beef cows (n=360) were synchronized using the Cosynch procedure; 100 µg of GnRH (day −7) followed in 7 days by 25 mg of $PGF_{2\alpha}$ (day 0). A used intravaginal progesterone insert (CIDR-B) was inserted on day −7 and removed at the time of $PGF_{2\alpha}$ administration. Cows were assigned to a 2 × 2 factorial arrangement of four treatments: 1) insemination beginning at 48 vs. 60 hours after $PGF_{2\alpha}$ and 2) administration of a second, 100 µg injection of GnRH or an equivalent volume of saline immediately after timed AI. Timed AI at either 48 or 60 hours after $PGF_{2\alpha}$ in a Cosynch + CIDR protocol was equally effective. Administration of GnRH at timed AI improved conception in all cycling cows and in some noncycling cows, depending on their progesterone status.

(Key Words: Ovulation Synchronization, Beef Cows, Timed AI, GnRH, CIDR.)

Introduction

Pregnancy rates to timed AI of 40 to 50% are reported for the Cosynch synchronization protocol; a GnRH injection on a Monday, $PGF_{2\alpha}$ on the following Monday, and GnRH plus timed AI on Wednesday (48 hours after $PGF_{2\alpha}$). Cosynch was adapted from the Ovsynch protocol developed earlier for dairy cows in which AI is performed 16 hours after the second GnRH injection.

In general, beef herds have more problems than dairy herdswith cows that are anestrus prior to the beginning of the breeding season and estrus synchronization. We also know that the interval between $PGF_{2\alpha}$ injection and estrus is longer in cycling than anestrous cows. Incorporation of an intravaginal progesterone insert (CIDR) into the Cosynch protocol is beneficial because it prevents heat expression prior to $PGF_{2\alpha}$ (first day of the breeding season). However, it may also prolong the onset of estrus. Thus, breeding 48 hours after $PGF_{2\alpha}$ in the Cosynch + CIDR protocol may not be optimal in beef herds.

GnRH is given at timed AI to initiate an LH surge. This GnRH injection may not be necessary to achieve acceptable pregnancy rates when the CIDR is used. The benefit of GnRH at timed AI may depend on whether or not the cow has resumed normal estrous cycles before $PGF_{2\alpha}$, and on the interval between $PGF_{2\alpha}$ and timed AI.

Experimental Procedures

In the spring of 2001, lactating beef cows from two Kansas herds were studied (Table 1). Purebred Angus, Simmental, and Hereford cows (n=146) were used at the Kansas State University Purebred Beef Unit (PBU) in Manhattan and crossbred Angus cows (n=214) were used at the Agriculture Research Center in Hays (ARCH). One ovula-

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tion-synchronization protocol (Cosynch) was used in which all cows were administered (day −7)100 μg of GnRH (i.m., Factrel7, Fort Dodge) followed in 7 days (day 0) by 25 mg of $PGF_{2\alpha}$ (i.m.; Lutalyse7, Pharmacia Animal Health). A used intravaginal progesterone insert (CIDR-B) was inserted on day −7 and removed at the time of $PGF_{2\alpha}$ administration (Figure 1). Cows were blocked by breed, calving date, and parity and assigned randomly to a 2 × 2 factorial arrangement of four treatments: 1) insemination beginning at either 48 or 60 hours after $PGF_{2\alpha}$; and 2) a second, 100-μg injection of GnRH or an equivalent volume of saline immediately after timed AI. Therefore, the four treatments were: 48+saline, 48+GnRH, 60+saline, and 60+GnRH.

Blood samples were collected on days −14, −7, 0, and before timed insemination for later analysis of progesterone. Cows with serum progesterone concentrations ≥1 ng/mL on day −14 and/or day −7 were assumed to have resumed normal estrous cycles (cycling), whereas cows with progesterone concentrations <1 ng/mL on both days −14 and −7 were classified as noncycling. Pregnancy rate after the timed insemination was determined 35-36 days after timed AI via transrectal ultrasonography.

Results and Discussion

Pregnancy rates were not different in cows inseminated at 48 or 60 hours after $PGF_{2\alpha}$ (80/179 [45%] vs. 87/181 [48%], respectively). This was true regardless of whether cows were classified as cycling or noncycling before the initiation of treatments (Figure 2). Lack of differences in pregnancy rates between the 48 and 60 hour groups indicates a fairly broad window for optimal timing of insemination.

Administration of GnRH after timed AI tended ($P = 0.12$) to increase pregnancy rates compared to administration of saline (90/178 [51%] vs. 77/182 [42%], respectively). Cycling cows receiving GnRH had greater pregnancy rates than those receiving saline (51% vs. 38%, respectively, Figure 3). Pregnancy rates were similar for cows not cycling at the beginning of the breeding season, regardless of GnRH or saline treatment.

Cycling cows with concentrations of progesterone ≥1 ng/ml on day 0 (indicating the presence of a corpus luteum) and those with concentrations of progesterone <1 ng/ml at insemination (corpus luteum regressed in response to $PGF_{2\alpha}$) had greater ($P<0.05$) pregnancy rates when they received GnRH compared to saline-injected controls (49/86 [57%] vs. 36/93 [39%], respectively).

Treatment with GnRH vs. saline at insemination did not influence pregnancy rates in noncycling cows with progesterone ≥1 ng/ml on day 0 and progesterone <1 ng/ml at insemination (24/51 [47%] vs. 28/49 [57%], respectively). Noncycling cows with concentrations of progesterone deviating above baseline on day 0 by 0.4 to 0.9 ng/mL had greater ($P<0.05$) pregnancy rates if GnRH (vs. saline) was given at insemination (10/16 [63%] vs. 5/19 [26%], respectively). This small increase in progesterone was likely due to the presence of the CIDR alone and not due to the presence of luteal tissue. Thus, noncycling cows that ovulated in response to the first GnRH injection do not seem to benefit from GnRH at timed AI. In contrast, GnRH given at timed AI benefitted those noncycling cows that did not respond to the first injection of GnRH but had enough progesterone from the CIDR so that when the CIDR was removed an ovulatory follicle developed.

Benefits of GnRH at timed AI seem to depend on cycling status and the stage of cycle when treatment is initiated. Trying to predict the proportion of cows cycling or the proportion at various stages of the cycle prior

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to synchronization is not practical. Thus, a producer's decision to use GnRH at timed AI may depend on the added value of earlier pregnancies, cost of GnRH, and some estimation of the proportion of cows cycling. Another way to view the GnRH injection given at timed AI is as added insurance on the existing investment in the synchronization protocol. Knowledge of which "types" of cows seem to benefit from various treatments may help us design better treatments in the future.

Timed AI at either 48 or 60 hours after $PGF_{2\alpha}$ in a Cosynch + CIDR protocol was equally effective. Administration of GnRH at timed AI improved conception in all cycling cows and also in some noncycling cows, depending on their progesterone status.

Table 1. Characteristics of Herds in Study

Herd	No.	BCS[1]	Days Postpartum[2]	% Cycling[3]	No.	BCS	Days Postpartum	% Cycling
PBU[4]	100	5.5 ± .1	69 ± 1.5	80	46	5.0 ± .1	93 ± 3.0	72
ARCH[5]	214	4.3 ± .1	60 ± 1.5	46				

[1]Body condition score assessed at the onset of the breeding season. [2]Days postpartum at the onset of the breeding season. [3]Percentage of cows that had resumed estrous cycles since calving based on elevated serum progesterone concentrations during 10 days prior to the Cosynch + CIDR protocol. [4]Kansas State University Purebred Beef Unit, Manhattan. [5]Agriculture Research Center, Hays.

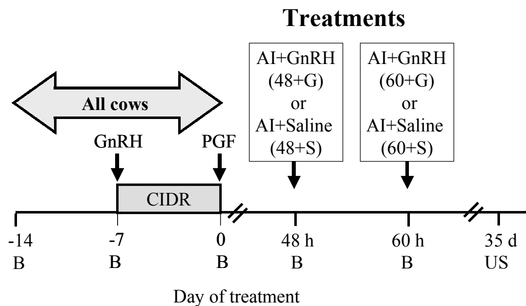

Figure 1. Experimental Protocols: B = Blood Sample, US = Ultrasound Pregnancy Diagnosis.

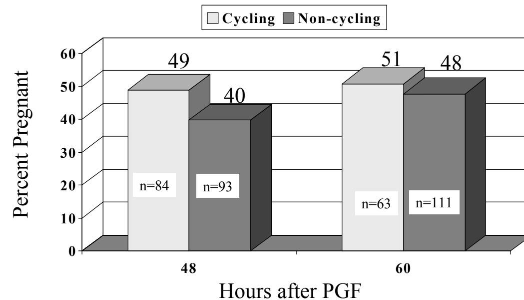

Figure 2. Effect of Time of Insemination on Pregnancy Rates.

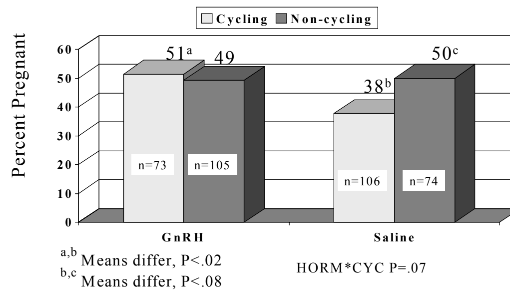

Figure 3. Effect of GnRH or Saline at Timed AI on Pregnancy Rates.

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PRACTICAL ASPECTS OF BEEF CARCASS TRACEABILITY IN COMMERCIAL BEEF PROCESSING PLANTS USING AN ELECTRONIC IDENTIFICATION SYSTEM

J. R. Davis and M. E. Dikeman

Summary

The use of an electronic identification (EID) system in slaughter facilities holds great potential as a tool for animal and carcass traceability, if used as part of a comprehensive carcass tracking system. However, the correct association of each carcass with its individual EID tag number may be hindered at several points during the slaughter process. For 2,994 cattle slaughtered in 14 lots and bearing button-type, full duplex EID ear tags, 113 (3.92%) had non-functional tags, 16 (0.53%) had no tag, and 37 extra head were introduced accidentally into one of our lots. Of the 2,994 carcasses, 71 (2.37%) were railed out for further trimming, 8 (0.27%) were retained for further inspection, 3 (0.10%) were condemned, and 1 carcass fell from the rail. For the plant in which data were collected, the hot-carcass scale operator ultimately had the responsibility for assuring that lots of carcasses accurately represented lots of cattle slaughtered. Although the current systems in some plants may be adequate for cattle traded on a live basis, they may not insure exact matching of live animals and their respective carcasses.

(Key Words: Electronic identification, Traceability, Beef cattle, Beef carcasses)

Introduction

Increased producer ownership through slaughter has revealed a need for accurate animal and carcass traceability from the standpoints of carcass merit, carcass payment, and meat safety. Current protocols in many commercial beef processing plants, however, are inadequate to accurately trace carcasses back to individual live animals. Electronic identification (EID) use in slaughter facilities has shown great promise as a tool for traceability, if used as part of a comprehensive carcass tracking system.

For most slaughter floors, it is somewhat naive to assume that individual ear tags will always be read and matched exactly with carcass identification numbers. Potential exists for the sequence of carcasses moving through the slaughter floor to be altered from the sequence in which animals were slaughtered by one or more head per lot. Cattle may be temporarily railed out of the carcass sequence if they require additional trimming, fall from the rail, or are retained. The hot-carcass scale operator must keep track of carcasses railed out of and returned to the carcass sequence, a system that is not infallible. Also, lots may be accidentally mixed in holding pens. Cattle may be re-associated with their lot only if each animal in that lot bears a common tag.

Our objectives were to conduct a field evaluation of EID system tags, and evaluate the carcass tracking capabilities in a large commercial beef slaughter plant.

Experimental Procedures

In a 1-month period during the fall of 2001, we followed 2,994 cattle slaughtered

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in a large commercial beef plant. Cattle were slaughtered in 14 lots ranging in size from 99 to 311 head, with an average of 214 head. All cattle were originally identified with a full-duplex, button-type EID ear tag. Because no error during tag reading was tolerable, tags were collected sequentially from cattle at slaughter and returned to Kansas State University to be read. During tag collection, incidence and location within kill sequence of animals missing tags were recorded, and incidences of non-functional tags were recorded during tag reading. Each carcass was identified with a sequentially numbered "kill order tag" applied as early as possible during the skinning process. We also recorded the incidence of lots of cattle mixed together by plant employees in the holding pens.

At a point following carcass splitting, and before the hot-carcass scale, USDA personnel inspect carcasses. Should any carcass need further trimming, the carcass may be railed out of the sequence of carcasses crossing the kill floor and re-inserted after trimming and USDA inspection. Records were kept of carcasses that were railed-out and carcasses from cattle slaughtered in other lots that were railed in. Records were also kept of carcasses that fell from the rail, were retained, or were condemned.

Results and Discussion

This field evaluation is not a tag endorsement; therefore, brand names are omitted. The tags used in this study were full-duplex, button-type EID ear tags. The other predominant type of EID tag is a half-duplex tag. Functionally, the two types of tags differ in their reported read range and speed of reading. Full-duplex tags read faster (50-60 milliseconds versus 70-80 milliseconds), but have roughly half the read range of half-duplex tags (2.8 ft. versus 5 ft.). Tags using either full or half-duplex technology are manufactured by competing companies. We were informed by the company using half-duplex technology that the 3.92% tag failure rate in our study was quite high as compared to half-duplex technology, but we have not seen any data to this effect.

Sixteen of the 2,994 cattle (0.53%) were missing ear tags. In 1 of the 14 lots, an additional 37 head of cattle not belonging with our lot were mixed with our lot by errors in the holding pens. These cattle had no common lot tag and were virtually indistinguishable from our cattle. The only means of identifying our cattle was by their EID tag. Had one of our cattle been missing a tag, we would not have known which one it was. We were fortunate that this occurred within the last 10 head of our lot and that none of our remaining cattle had missing tags. Mixing of cattle in the holding pens is fairly rare, but it happens. In most instances, only one or two animals will jump a fence, and will either be returned to their lot or identified with a series of marks on the hide.

Carcasses will normally arrive at the hot-carcass scale in the same sequence as that in which the animals entered the kill floor originally. However, two events may alter this. The first (and least frequent) is when a carcass falls from the rail. Carcasses seldom fall prior to the hide pulling station, but worn trolleys and feeble tendon attachments may be stressed to the point of failure by the downward hide puller. Fallen carcasses must be trimmed extensively and tediously inspected by USDA inspectors. The single carcass that fell in our study was in the center of the kill floor, away from visual contact by Kansas State personnel. Therefore, neither the hot-carcass scale operator nor we were aware of the fallen carcass until some time later.

The other (and most common) event that may alter the carcass sequence is when a carcass is railed-out because it did not get

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split, requires additional trimming, or is retained. Seventy-one carcasses (2.37%) in our study were railed out for further trimming and/or splitting prior to inspection. A carcass may be retained for veterinary inspection if any physiological attribute is suspect. Following inspection, there are two outcomes: passed or condemned. We had eight carcasses (0.27%) retained for veterinary inspection. Three of these eight (0.10% of total cattle) were condemned, resulting in a "0" value for hot carcass weight and no payment to the owner.

At the time of this study, the plant in which we worked did not have the capability to read EID tags. It would have been impossible to trace a carcass from an animal slaughtered on any given day back to the live animal without additional efforts of carcass data collectors. The various events that occurred on the kill floor and in the holding pens limited the amount of certainty with which an animal could be traced back, even to the lot of animal origin. This will often have little monetary impact to a producer, especially if there are no dropped or condemned carcasses in the lots immediately before and after a producer's lot. However, it would result in errors in matching carcass data to specific animals.

Results of this study are not intended to blame processors for impropriety. Neither do they excuse any inability to pay a producer on a grade and yield basis for the exact cattle delivered to the plant. The grand implication is that not all processing plants offer the same level of service. Some plants are very technologically adept and have a higher capacity for carcass traceability than others. Producers who intend to sell cattle on a grade and yield basis must take it upon themselves to become informed and learn the capabilities of the plant that will slaughter their cattle.

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FACTORS AFFECTING THE PRICE PAID FOR SPRING-YEARLING BULLS

T. T. Marston, D. W. Moser, and L. E. Wankel

Summary

Many factors are considered when commercial cow/calf producers buy bulls. Breeding system needs and breeder's preference determine which breed of bull will be purchased at a multi-breed sale. Our analysis of prices paid for bulls tested and sold through the Kansas Bull Test Station indicates that bull consigners' reputations and marketing techniques influence the price received for bulls at such an event. Individual performance and genetic potential are other areas of interest to bull buyers. Buying habits and prices indicate that commercial cow/calf operations use different traits, depending on the breed, to enhance their cowherd's production.

Introduction

Commercial cow/calf producers are provided a multitude of performance, genetic, and ancestral information on which to base their herd bull purchases. The number of traits reported by breed associations over the past 20 years has increased, but it is not known what specific information commercial bull buyers utilize. Certainly, independent selection is needed to optimize the production of differing cowherds. However, understanding the importance of specific information is useful to both the commercial cow/calf industry and to the bull suppliers. Information from the last four Kansas Bull Test sales was used to determine the monetary value of the information.

Experimental Procedure

Data were combined for Kansas Bull Test sales from 1997 through 2000. Information included in the analysis was taken directly from the sale catalog and compared to the purchase price of 678 spring-born, yearling bulls. Breeds included in the analysis were: Angus, Simmental, Charolais, Hereford, Gelbvieh and Red Angus. The data were fitted to a regression model, and independent variables were removed in a stepwise procedure until all remaining variables approached significance ($P<.20$). Phenotypic appearance probably affected the selling price, but it could not be estimated from the catalog information and therefore became part of the regression model's error term.

Results and Discussion

Independent variables included in the final model explained 71.5% of the variation in the auction prices. Significant differences in breed ($P<.01$) and sale year ($P<.03$) were noted. Table 1 shows the mean value of bulls by breed and year. Our data indicate a general trend for the price of bulls to increase over the four years. Variation among breeds indicated that bull buyers changed buying habits, depending upon which breed was being auctioned. The breeder of each bull was assigned an identification number that was included in the regression analysis. This allowed the model to evaluate whether a particular breeder had a price advantage within a particular breed of bulls. The model indicated

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that the consignor within each breed significantly affected price (P<.01). The range in prices received indicates that consignors should place major emphasis on developing excellent reputations and promotion/marketing skills.

The individual bull's performance was important. Buyers preferred older bulls born within the spring calving season. They paid $3.53 ± 1.02 for each added day of age. Actual birth weight, average daily gain during the 112-day test, and weight per day of age were also significant factors (P<.01). As birth weight increased, a bull's worth was decreased $14.97 ± 2.89 per pound. High performance cattle were rewarded monetarily as $379 ± 115 and $869 ± 172 was paid, respectively, for each additional pound of average daily gain (ADG) and weight per day of age (WDA). The Kansas Bull Test calculates and reports an individual test index composed of the average ADG and WDA ratios within respective breeds. Bull buyers used the test index to price bulls. Interestingly, adjusted 205-day and yearling weights did not affect a bull's value.

Ultrasound measurements were reported for back fat, ribeye area, and marbling score. Table 2 summarizes the influence that those measurements had on purchase prices. Buyers paid premiums for heavy muscled, higher marbling bulls. However, the buyers discounted bulls that were fat externally.

Genetic predictions for growth and management are best expressed through EPDs. Buyers utilized birth weight, weaning weight, and milk EPDs within breeds to determine their purchases (Table 3). Angus, Gelbvieh, and Hereford bull buyers gave substantial premiums for low birth weight EPD bulls. However, Charolais, Red Angus and Simmental bull buyers did not place as much emphasis on birth weight EPDs. Angus and Simmental consignors were rewarded for greater weaning weight EPDs while other breeds were not. Yearling weight EPD was not significant to KBT bull buyers. Hereford bulls with greater milk EPDs commanded greater prices than their contemporaries, but other breed buyers showed little interest in milk EPD values. These data indicate that buyers select bulls differently, depending on which breed is being purchased. It may also indicate that buyers come to the auction with a predetermined need for replacement genetics that are specific to their operation's need and breeding system.

Our results indicate that buyers emphasized individual animal performance (birth weight, ADG, WDA) and EPDs for birth and weaning weight more than they did measurements or EPDs for yearling weight and milk production.

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Table 1. Average Prices Paid for Spring Yearling Bulls

	Year			
Breed	1997	1998	1999	2000
Angus				
Price, $	1322	1627	1665	1684
No. of head	99	72	68	66
Charolais				
Price, $	958	1843	1340	1509
No. of head	54	55	40	23
Gelbvieh				
Price, $	1163	1346	1258	1514
No. of head	8	12	6	11
Hereford				
Price, $	785	1993	1528	1925
No. of head	17	7	10	4
Red Angus				
Price, $	--	2000	1479	1383
No. of head	0	1	12	9
Simmental				
Price, $	1138	1435	1549	1471
No. of head	34	33	39	31
All Breeds				
Price, $	1151	1613	1530	1585
No. of head	212	147	175	144

Table 2. Influence of Ultrasound Measurements on Spring-Yearling Bull's Purchase Price

Measurement	Price Adjustment/Unit of Measure	SE	P value
Backfat, 0.1 in.	-49	29	.08
Ribeye area, sq in.	54	17	.01
Marbling score[a]	69	35	.05

[a]CPEC marbling score scale used: 4 = Slight 00, 5 = Small 00.

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Table 3. The Value Paid for EPDs

Item	$ Price Adjustment /1 lb EPD	SE	P value
Angus EPD			
Birth weight	-150	24	.01
Weaning weight	18	4	.01
Milk	3	6	.65
Charolais EPD			
Birth weight	-42	34	.22
Weaning weight	-2	8	.80
Milk	8	10	.46
Gelbvieh EPD			
Birth weight	-115	67	.81
Weaning weight	1	10	.91
Milk	0	17	.99
Hereford EPD			
Birth weight	-64	33	.05
Weaning weight	-5	13	.73
Milk	50	14	.01
Red Angus EPD			
Birth weight	-20	82	.81
Weaning weight	-8	21	.72
Milk	9	20	.65
Simmental EPD			
Birth weight	-50	35	.16
Weaning weight	17	10	.08
Milk	0	14	.98

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ALTERNATIVE REPLACEMENT HEIFER INVESTMENT STRATEGIES

J. Fanning[1], T. Marsh[1], and R. Jones[1]

Summary

The effects of beef cow herd inventory management strategies on net income were evaluated in a historical simulation of a representative Kansas beef-cow herd. Constant inventory, counter-cyclical, and dollar-cost averaging strategies were compared to an optimal heifer replacement strategy. Results indicate that price and inventory signals can be used to time replacement heifer acquisition to improve profitability of the average Kansas producer.

(Key Words: Replacement Heifer, Market Timing, Cattle Cycle, Economics.)

Introduction

Cost and timing of replacement heifer investment is an important factor in cow-calf producer profitability. "What to pay?" and "when to buy or retain?" depend on the specific strategy chosen to acquire or retain replacement heifers. Kansas cattle producers face both profitable and unprofitable periods within a cattle cycle. In addition to cyclical cattle prices, costs of production are important determinants of net revenues. Breakeven costs determine the crossover between profitable and unprofitable years in the cattle cycle.

Timing is also important for a cost-minimizing producer. Replacement heifers either retained or acquired toward the end of the high-price phase of the cattle cycle often produce calves during the low-price phase, implying that these heifers may be less profitable over their productive life. Conversely, replacements placed in service just prior to, or at the beginning of, the high-price phase of the cattle cycle tend to yield above average profits.

Recently, inventory management strategies have been recommended that are not necessarily profit-maximizing, but none of these strategies fully utilize price information. The objective of this study was to compare alternative inventory management strategies relative to a profit maximizing or optimal cow inventory and replacement strategy for a representative Kansas producer.

Experimental Procedures

A dynamic optimization model was formulated to simulate replacement strategies and enterprise profits, based on historical input costs (feed, labor, utilities, interest, etc.), calf and cull cow prices, and historical production measures (weaning weight, weaning percent, cull rate, and death loss). A Kansas beef-cow enterprise was simulated for the 1975-1999 period under 1) constant inventory, 2) counter-cyclical inventory and 3) dollar-cost averaging replacement investment strategies. These strategies are then compared to an *economically optimal* replacement investment strategy. The *economically optimal*

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replacement strategy maximized the Net Present Value (NPV, the discounted value of the stream of future net incomes plus the salvage value of the cow-herd) of net income and ending inventory value of the cow herd for the study period. A *constant inventory* strategy assumes the number of cows and replacements in the herd are held constant over time. The *counter-cyclical* strategy alters bred cow inventory inversely with U.S. January 1 beef-cow inventory; when the U.S. inventory increases 1%, the producer decreases his inventory 1%. The *dollar-cost averaging* strategy retains the same dollar value of replacement heifers each year. The beginning cow-herd for each strategy consisted of 100 bred females. Inventory levels are constrained to no more than 120 hd. In addition to comparing replacement strategies from 1975 to 1999, optimal inventory levels are predicted using 2001 Federal Agricultural Policy Research Institute (FAPRI) price projections through 2010.

Results and Discussion

Using the NPV of investment as the criteria of comparison from 1975 to 1999, *dollar-cost averaging*, with a NPV of $116.32/hd over the 25-year simulation period, outperformed *constant inventory* and *counter-cyclical inventory* management strategies by $30.34/hd and $31.78/hd, respectively.

The NPV was heavily impacted by the value of the herd at the end of the study period. Thus an alternative comparative measure such as annual net income, is likely more useful in evaluating the differences between strategies. Using average Gross Domestic Product deflated net income as the criteria from 1975 to 1999 instead of NPV, the *counter-cyclical* management strategy with average real net income of $8.95/hd is $4.03/hd more than *constant inventory* and $0.51/hd more than the *dollar-cost* strategy. Figure 1 shows the Gross Domestic Product deflated income levels of the alternative strategies in comparison to the *economically optimal* replacement strategy. Profit maximizing with *economically optimal* heifer replacement yielded a NPV of $284.69 and average real net income of $26.10/hd, which outperformed the other strategies.

Bred cow inventories over time from the alternative strategies are presented in Figure 2. The *economically optimal* strategy maximized or minimized inventory during profitable or unprofitable periods of the cattle-cycles, adjusting replacements (purchased or raised) according to price signals (Figure 3). The alternative strategies invested in replacements each year, regardless of price and inventory signals. The *economically optimal* bred cow inventory fluctuated greatly compared to the inventory management strategies studied. The effect of ill-timed investment in replacement females of the alternative strategies is to reduce long-run net returns.

These results suggest there is potential to improve profitability by using heifer replacement strategies that incorporate price and fundamental signals. However, practical implementation of variable-rate replacement management strategies requires resource flexibility. For example, the *economically optimal strategy* requires that another enterprise, such as a stocker enterprise, be available to utilize the forage not consumed by the liquidated cowherd, or that this forage be rented out. It is also important to acknowledge that the *optimal* solution is unattainable because perfect foresight of prices is not possible. Nevertheless, the *optimal* strategy sheds light on the decision criteria.

Interestingly, the profit maximizing strategy with optimal replacement began retaining replacement heifers when the U.S. cow inventory began liquidation and the percent change in steer calf price increased. Enough heifers were retained or purchased each year to attain or maintain

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the maximum herd size until price and inventory signals indicate the top of the cattle cycle is approaching. At the top of the price cycle, the *optimal* strategy no longer kept any replacements if (1) the percent change in U.S. beef cow inventory increased significantly (about 1.5%) or became positive and (2) the percent change in steer price was less than its three year moving-average. Re-simulating the model using these two ad hoc decision rules resulted in average real net income of $19.10/hd, which is only $7/hd less than the optimal strategy, and still surpassed the counter-cyclical strategy in average real net income by $10.15/hd, further emphasizing the role of price and inventory signals in decision making. This specific ad hoc decision rule is only valid for a producer with costs equal to that of the average Kansas producer. Therefore, it is essential that individual producers evaluate their specific cost situation before deriving enterprise- specific criteria.

Ignoring price signals in the *dollar-cost-averaging*, *counter-cyclical*, and *constant-inventory* strategies limits net returns for the average Kansas producer. The results of this study suggest a cost minimizing cow-calf producer can benefit from incorporating output and input price signals into the timing and rate of their heifer replacement decisions. Projections of optimal inventories, using 2001 FAPRI price projections, indicate that the average Kansas cow-calf producer should maintain full inventory levels until 2005. Of course, replacement projections are only as reliable as price projections and need to be continuously updated to refine production plans.

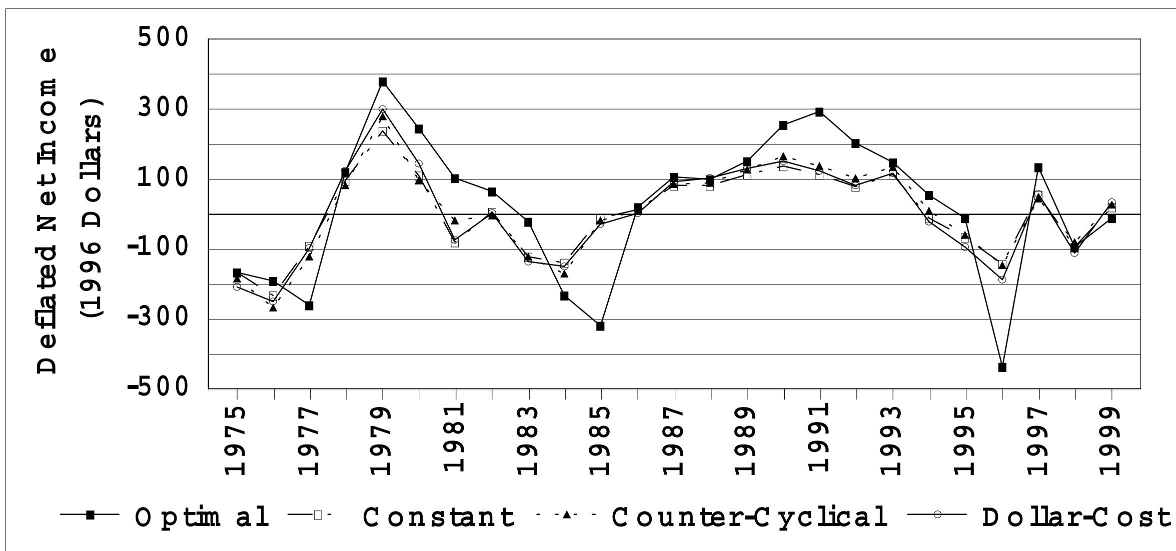

Figure 1. Real Net Income for Alternative Replacement Strategies.

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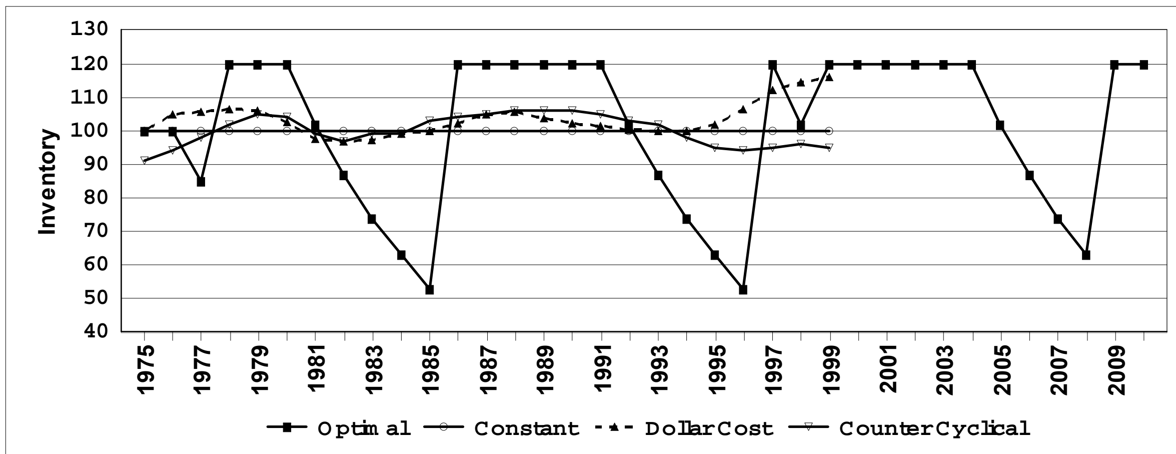

Figure 2. Bred Cow Inventory Levels of Alternative Inventory Management Strategies.

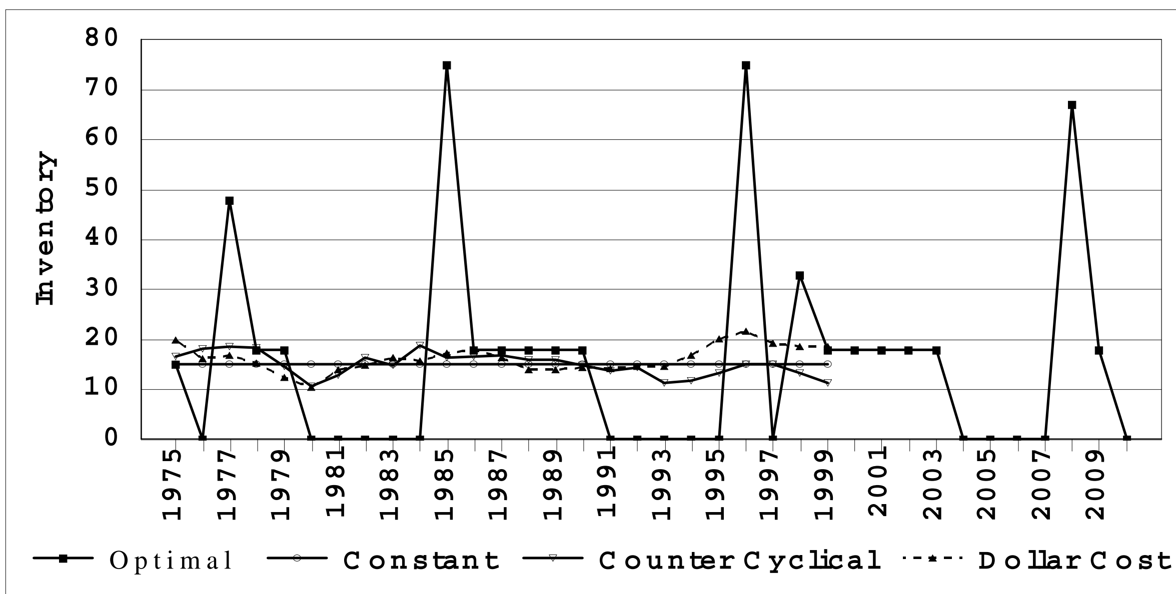

Figure 3. Bred Heifer Inventory Levels of Alternative Replacement Investment Strategies.

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EFFECTS OF WEATHER ON AVERAGE DAILY GAIN AND PROFITABILITY

D. R. Mark[1] and T. C. Schroeder[2]

Summary

The effect of several weather conditions on average daily gain (ADG) and profits is quantified for typical steers and heifers fed in commercial feedyards in Western Kansas from 1980 to 1999. ADG predictions for particular pens of cattle are often used to plan marketing dates and calculate break-even purchase prices. Weather is known to influence cattle performance, and expected weather conditions can be used to improve ADG predictions. Effects on ADG and profits from combinations of, and interactions between, temperature, precipitation, humidity, and wind speed were analyzed. The influence of these weather conditions was allowed to differ by sex, placement weight, and placement month. Results indicate that performance and profits of lightweight placements are more sensitive to temperature and precipitation changes than are heavier weight calves. Above average temperature tends to reduce cattle performance during the summer and increase it for cattle fed during the winter.

(Key Words: Cattle Performance, Average Daily Gain, Cattle Feeding Profits, Temperature, Weather.)

Introduction

Cattle feeding budgets rely on predicting average daily gain (ADG) for steers placed on feed at various weights and times of year. Typically, historical averages and feedyard manager experience are used to forecast ADG for particular pens of cattle. Historical averages of cattle performance are based on season-average weather conditions. Deviations from normal or average weather conditions lead to better or worse cattle performance. Anticipating how, and to what degree, various weather conditions impact cattle performance is essential for cattle feeders to consider in break-even budgeting.

Changes in cattle performance resulting from favorable or adverse weather conditions generally affect profits. Cattle feeders must understand how weather affects cattle feeding profits when making production and risk-management decisions. For example, investment in facilities to reduce cold weather stress in winter can have the opposite effect during the summer. Performance and profit gains from such facilities during winter-feeding periods may be offset by reductions in performance and profit for summer feeding.

Previous research has concentrated on how short-term and unique weather events affect performance of individual or small groups of cattle over short time periods. In this study, we examine how average weather conditions during conventional feeding periods impact performance and profitability of typical feedlot cattle.

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Experimental Procedures

Two commercial feedyards in southwestern Kansas provided data for 17,715 pens of steers and heifers (over 2.3 million head) placed on feed from January 1980 to November 1999. The data included information on ADG, cattle purchase and sale prices, feeding cost of gain, and dates on feed. Using this information, profit for each pen was calculated. Daily weather records were obtained from the Kansas Weather Data Library for locations that were in close geographical proximity to the two feedyards. Weather variables were computed based on the daily weather records for each pen of cattle to describe the environmental conditions (e.g., temperature, precipitation, wind speed, humidity) during the time the pen of cattle was on feed. Statistical models were then estimated to quantify the effect of weather variables on cattle feeding performance and profit.

The average ambient air temperature during the feeding period was used to identify effects of cattle's thermal environment on performance. Optimal cattle feeding performance generally occurs when temperature is between 40 and 60 degrees Fahrenheit. When temperatures are colder, maintenance energy increases, and when they are hotter feed consumption declines, resulting in less weight gain. Temperature variability can further reduce cattle performance. Cattle performance is also affected by precipitation, which can increase stress on cattle by creating muddy pen conditions and wet, matted hair coats. Cattle response to temperature and precipitation is likely to be more pronounced at the beginning and end of the feeding period, which is accounted for in the model. Environmental stress at the beginning of the feeding period comes at a time when cattle are stressed from shipping and are most susceptible to respiratory diseases. Weather stress at the end of the feeding period can also reduce performance. Wind speed influences the extent to which cattle become stressed from thermal conditions, i.e., high wind speed exacerbates the affect of cold temperatures in the winter whereas it relieves heat stress in the summer. High humidity levels also can increase heat stress on feedlot cattle. Wind speed and relative humidity levels were used to measure the effect of cold and heat stress on performance.

Results and Discussion

The effects of weather on ADG and profit differed by cattle sex, placement weight, and placement month. A 1-degree higher average temperature over the feeding period improved ADG for average pens of lightweight steer and heifer placements by 0.01 and 0.02 lbs/day, respectively, and increased profits by $0.40/head and $0.48/head. The effect of temperature was nonlinear and had numerous interaction terms. Therefore, for example, these results cannot be multiplied by 5, for a 5-degree temperature differential. Heavyweight placements had smaller changes in profits from a 1-degree temperature change.

The average change in ADG and profits across pens of steers placed at 700-799 lbs in each month associated with a one-degree higher average temperature during each cattle placement month are depicted in Figures 1 and 2. The standard deviation lines are included in the figures to demonstrate the variation in estimates of the magnitude of changes in ADG. For example, Figure 1 shows that ADG increases 0.01 lbs/day on average if the average temperature over the feeding period increases by 1 degree (i.e., was 1 degree higher than during the previous year for the same time period) for steers placed on feed in January. A 1-degree increase in average feeding period temperature results in an increase in ADG between -0.004 and 0.023 lbs/day 68% of the time for January placements.

For steers placed on feed from March through June, a higher average temperature

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generally caused ADG to decrease, corresponding to summer feeding periods with seasonally highest temperatures. ADG declined by over 0.01 lbs/day and profits decreased more than $0.20/head for May steer placements if temperature was 1 degree higher. Variability in the change in ADG and profits from a change in average temperature was greatest for steers fed during the summer months. Higher average temperatures over the entire feeding period resulted in higher ADG and profit per head for cattle placed on feed in the late summer/early fall because they were on feed during the typically coldest time of the year (winter and early spring).

A 1% increase in the percent of days with cold stress (low temperatures and high wind speeds) reduced profits by approximately $0.15/head for average cattle fed during the winter. For cattle fed during the summer, a 1% increase in the percent of days with heat stress (high temperature, high humidity, and low wind speed) lowered profits for the average pen of cattle by $1.00/head. Precipitation during the first 3 weeks and last 3 weeks of a feeding period adversely affected profitability by about $0.60 to $0.70/head, depending upon cattle weight and season of the year.

Cattle feeding performance and profits were most influenced by temperature, temperature variability, heat stress, and precipitation, especially at the beginning and end of the feeding period. During cold months, increasing temperature is beneficial, whereas higher temperature tends to be detrimental during warmer periods. Steers and heifers placed at light weights were influenced more by temperature and precipitation relative to heavyweight placements. Results indicate that cattle perform better and realize higher profits when weather conditions remain relatively stable over the feeding period.

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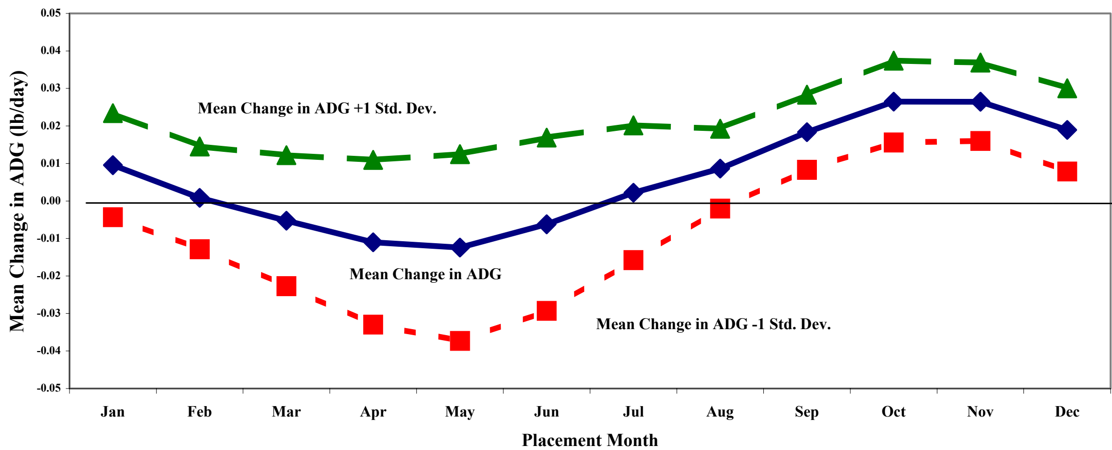

Figure 1. Predicted Change in ADG over the Feeding Period Resulting from a 1 Degree Increase in Average Temperature Compared to the Previous Year, by Placement Month. (Steers placed at 700-799 lbs in Western Kansas, 1980-1999.)

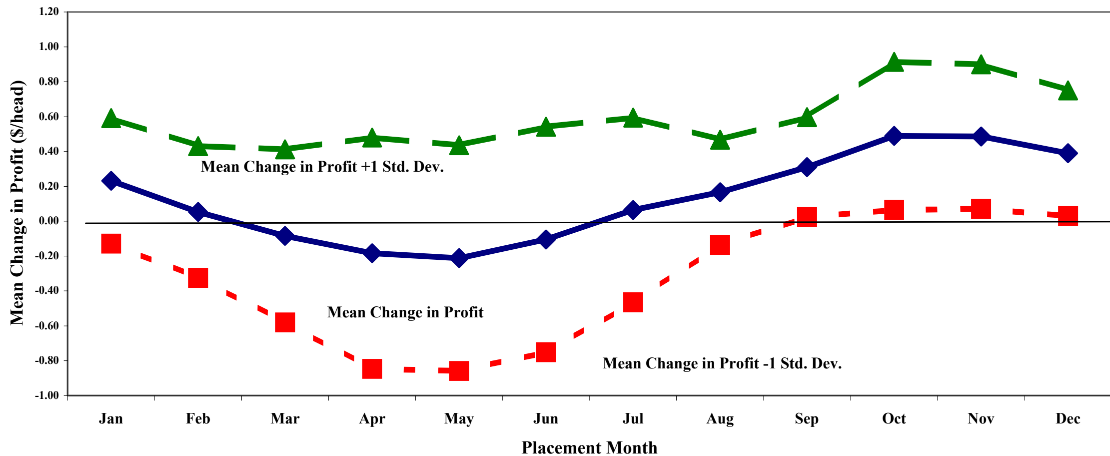

Figure 2. Predicted Change in Profit Per Head Over the Feeding Period Resulting from a 1 Degree Increase in Average Temperature Compared to the Previous Year, by Placement Month. (Steers placed at 700-799 lbs in Western Kansas, 1980-1999.)

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ECONOMIES OF SCALE IN KANSAS BEEF COW-CALF PRODUCTION

L. Stryker[1], M. Langemeier[1], and R. Jones[1]

Summary

Cow-calf producers must learn to control those aspects of production that are under their management. Quantity of beef produced and the cost of maintaining the breeding herd from conception to weaning are two examples of variables over which an individual operator has control. Therefore, it is important for managers to know their cost of production and, in turn, the relationship of quantity produced to cost. Our study found that for a 1% increase in quantity of beef produced, total cost increased by only 0.88%, suggesting economies of scale.

(Key Words: Cow-Calf, Total Cost, Economies of Scale.)

Introduction

There has been a trend in the beef cattle industry to associate larger operations with least-cost production. While farms becoming larger does not guarantee decreased average cost of production, it is important for operators to know the optimal size for their operation. Quantity of beef produced and the cost incurred in the production of that beef are two variables over which managers have substantial control. That is why it is important for producers to know their costs of production, and how changes in farm structure (size) would affect them.

Our objective was to evaluate the relationship between total cost of production and pounds produced for beef cow-calf producers in Kansas. Findings should be helpful in the development of long-term herd management goals.

Experimental Procedures

Total cost data from the Kansas Farm Management Association database were utilized for the analysis. The data consisted of an average of five years (1995-1999) of total cost for 97 different cow-calf enterprises in Kansas, as well as corresponding quantities of beef produced. Output consisted of the total pounds of beef produced, including weaned calves and culled breeding stock. Table 1 presents summary statistics on output and average cost of production for the sample. Producers' output ranged from 14,193 to 220,001 pounds of beef. Input cost included labor, feed, capital, fuel and utilities, veterinary expenses, miscellaneous, and opportunity cost. Cost items were adjusted using the implicit-price deflator for personal consumption expenditures to account for inflation. Cost items were then summed to arrive at total cost.

Regression analysis was used to estimate the relationship between total cost and output. Estimated cost resulting from the regression coefficients was plotted against output to detect economies of scale.

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Results and Discussion

The regression resulted in an R^2 of 0.915, indicating a strong relationship between pounds produced and total cost. Regression results demonstrate that, on average, total cost increased by 0.88% for each 1% increase in quantity produced: output increased at a greater rate than total cost, signifying the existence of economies of scale.

Figure 1 reveals that average cost decreases while quantity of beef produced increases, which also indicates the existence of economies of scale. As pounds of beef produced per year increased from 10,000 to 60,000 lbs, estimated average cost per lb declined from $1.12 to $0.91, illustrating the cost advantages of increasing the quantity produced in these relatively small herds. These operations may have cost synergies associated with producing beef and crops that we did not capture in our study. They might also have capital or labor constraints that prevent them from capitalizing on the economic benefits of increased quantity of production. Average cost begins to level out after 60,000 pounds of beef produced, but there is still a slight decrease in average cost for higher output levels.

The opportunities for capitalizing on economies of scale are apparently more pronounced for smaller operations. Producers, especially very small producers, can use these results to judge whether they are fully utilizing their resources. Cow-calf managers considering herd expansion should first carefully evaluate their individual cost of production, and then, perhaps, incorporate these results into the decision process.

Table 1. Summary Statistics for a Sample of Kansas Beef Cow-Calf Farms (1995-1999)

Variable	Average	Minimum	Maximum	Standard Deviation
Number of cows (hd)	122.38	26	491	245.42
Total cost ($)	62,744	11,436	168,978	36982
Pounds beef produced	71,182	14,193	220,001	45320
Average costs ($/lb)	0.9284	0.6033	1.7913	0.1957

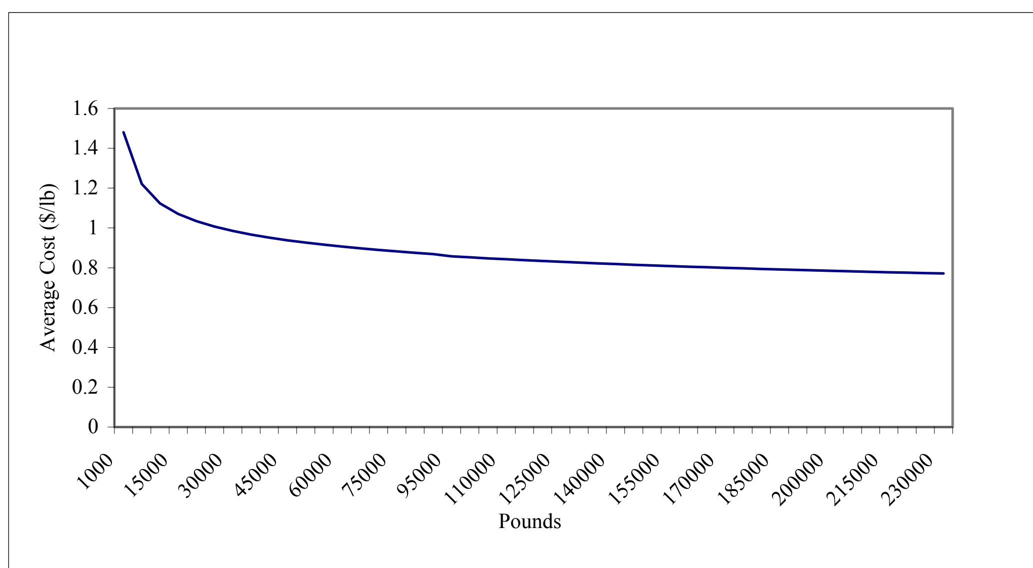

Figure 1. Average Cost Curve for a Sample of Kansas Cow Producers 1995-1999.

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EFFICIENCY DIFFERENCES IN KANSAS BEEF COW-CALF PRODUCTION

L. Stryker[1], R. Jones[1], and M. Langemeier[1]

Summary

For the beef industry to be economically competitive with other meat industries, it is essential that individual producers strive for the most efficient, highest quality, least cost production possible. A sample of 26 Kansas beef cow-calf enterprises from the Kansas Standardized Performance Analysis database (SPA) was used to measure efficiency differences among producers, as well as factors contributing toward these differences. On average, farms were 86% technical, 69% economic, and 58% overall efficient. Thus, our results suggest that output could be increased by 14% with optimal technology use, and cost could be decreased by 42% if farms were fully economically efficient.

(Key Words: Cow-Calf, Efficiency, Profitability, SPA.)

Introduction

While there are many aspects of cow-calf production that are beyond the control of the manager, such as weather, death loss, prices, and some aspects of performance, cost of production is one area in which the manager has substantially more control. In order for a producer to increase their competitive position relative to others in the industry, it is critical that operators be aware of their own production costs. With this information, differences between farms that are efficient, and those that are not efficient can be evaluated for changes that might be advantageous for an individual operation. The use of a detailed enterprise analysis, such as SPA, can be useful for producers to evaluate their production and financial position. The following analysis determines characteristics that distinguish relatively efficient producers from those who are less efficient, while investigating the dependence of efficiency measures on various production and financial management factors.

Experimental Procedures

Twenty-six observations from the KS SPA database, representing 13 Kansas counties and production years 1997-2000 were used for this analysis. Herd sizes in the database ranged from 39 to 300 head, with an average of 158. The average farm in the sample derived approximately 50% of total farm income from cow-calf operations.

Detailed records of inputs, outputs, and cost of production were needed for efficiency analysis. Output was measured as the pounds of calf weaned from exposed females. The four inputs examined were feed, grazing, veterinary, and other. Use of management and labor was not examined in this study due to the lack of a consistent assessment of these factors. Grazing cost included all cost attributed to grazing, such as pasture rent (or opportunity cost of owned pasture), fertilizer, and spray for pastures. Feed cost represented all feed cost other than pasture, such as minerals, grain, harvested forages, and supplements. Veterinary cost included all expenses associated with the welfare of the animal other than nutritional inputs, and

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included items such as veterinary services and pharmaceuticals. The other cost category included all costs not included in the first three expense groups, such as interest, depreciation, and miscellaneous costs.

A series of mathematical programs was used to determine the technical, allocative, economic, scale, and overall efficiencies of operations. Technical efficiency measures how well the operation utilized cutting-edge technology in their production process. Allocative efficiency determines how well the farm purchased inputs; at the best price and in the right proportions. Economic efficiency is computed by multiplying technical efficiency by allocative efficiency. Scale efficiency measures whether the farm produced at the optimal size of operation. Overall efficiency is computed by multiplying economic efficiency by scale efficiency. Overall inefficiency is a result of either sub-optimal use of technology and inputs in the production process, or scale inefficiency. Farms with the lowest per unit cost of production are overall efficient. Efficiency measures for each individual producer were computed on a relative scale of 0 to 100%.

Correlations were calculated between overall efficiency, and production and economic variables. In addition, characteristics that differed between the top and bottom overall efficient groups of producers were revealed through t-tests. A simple regression was also estimated to determine the actual effect of cost on overall efficiency.

Results and Discussion

Table 1 presents the statistical summary of cost, gross revenue, and other important operation characteristics for most and least efficient producers. Forty-six percent of farms were technically efficient. The average technical efficiency rating was 96% for the top half of producers and 76% for the bottom half. Approximately one quarter of the farms had allocative and economic efficiency ratings greater than 90%, while half had scale efficiency ratings greater than 90%. Only 3 out of the 26 farms had overall efficiency ratings greater than 90%. Figure 1 presents efficiency results measuring output (lb) and corresponding cost per unit of output ($/lb). The farm that was overall most efficient (both economic and scale efficient) in the analysis had a production cost of $0.5542/lb and 75,174 lb of production and is located at the minimum cost point on the graph (signified with arrow). Farms that have higher cost and fall on either side of the overall efficient farm in Figure 1 were either not using optimal technologies in production, not allocating their inputs efficiently, or were not producing at the optimal size (75,174 lb). The wide range of efficiency results demonstrates the potential for improvement that exists in cow-calf production.

Simple regression analysis resulted in a significant relationship between total cost and overall efficiency, with each 1% increase in total cost per pound produced decreasing overall efficiency by 0.98%. Regression results suggested that 70.6% of the variability in overall efficiency is explained by changes in total cost ($/lb).

Further results found gross revenue ($/lb) was negatively related to overall efficiency, indicated by the top efficiency group having lower gross revenue ($/lb) than bottom efficiency producers. This result suggests that to increase profitability one should try to cut cost rather than to increase gross revenue per pound. Total, grazing, veterinary, and other cost all were higher for the less efficient producers; however, other cost had the strongest negative association with overall efficiency. This suggests that controlling economic cost such as interest, depreciation, and herd replacement cost, is the key to efficiency.

Other factors that differed between top and bottom overall efficient producers included weaning weights of steers and heifers, and pounds weaned per exposed female,

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which were all higher for the top efficiency group. This result emphasizes the importance of production more than many previous studies, but indicates that top producers are achieving efficient weight gains at low cost each year. It should be noted, however, that rainfall amounts were lower for the bottom efficiency group, suggesting that some inefficiency might have been due to resulting forage shortages.

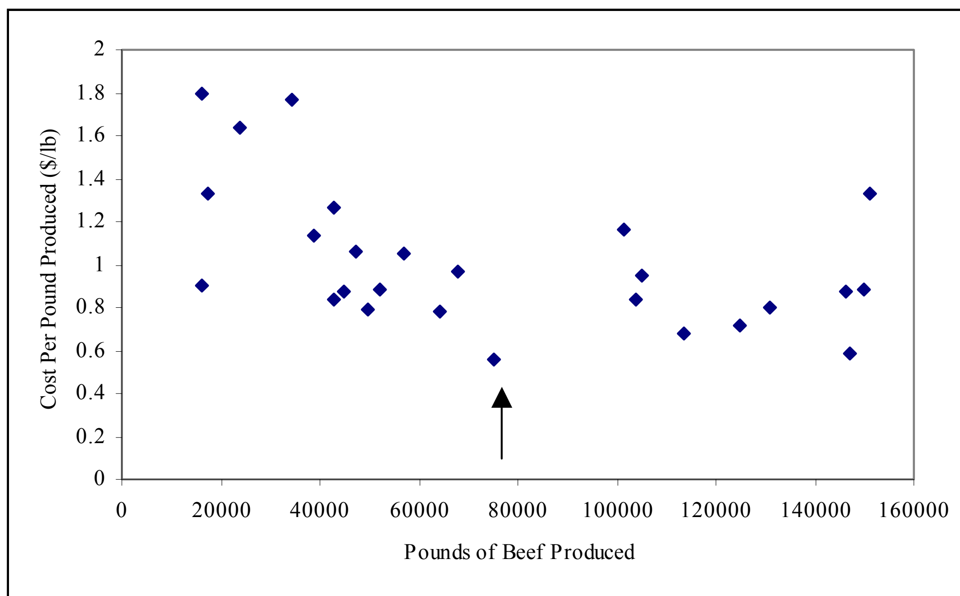

Figure 1. Kansas Beef Cow-Calf Average Cost of Production.

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Table 1. Top and Bottom Efficient Producer Results

Variables	Bottom 1/2 Mean	Top 1/2 Mean	P Value	Correlation Coefficient
Technical efficiency	0.76	0.96	0.0016	0.61*
Allocative efficiency	0.76	0.85	0.1268	0.57*
Economic efficiency	0.57	0.81	0.0014	0.80*
Scale efficiency	0.76	0.91	0.0085	0.53*
Overall efficiency	0.42	0.74	0.0000	1.00*
Real gross revenue ($/lb)	1.13	0.83	0.0019	-0.64*
January 1 inventory (hd)	155	160	0.8751	0.30
% Revenue from cow-calf	62.77%	45.85%	0.1353	-0.13
Total cost ($/lb)	1.23	0.80	0.0003	-0.78*
Feed cost ($/lb)	0.30	0.27	0.5253	-0.24
Grazing cost ($/lb)	0.32	0.24	0.0441	-0.34
Veterinary cost ($/lb)	0.08	0.05	0.1661	-0.41*
Other cost ($/lb)	0.53	0.24	0.0001	-0.81*
Net base transfer cost ($/lb)	-0.01	0.03	0.2692	0.36
Total cost ($/cow)	482.67	406.97	0.0452	-0.49*
Feed cost ($/cow)	108.86	137.83	0.3888	0.11
Grazing cost ($/cow)	140.51	126.70	0.6516	0.06
Vet cost ($/cow)	29.73	25.37	0.6462	-0.21
Other cost ($/cow)	203.58	113.20	0.0023	-0.70*
Average weaning weight (lb)	481.46	561.92	0.0122	0.57*
lb weaned /exposed female (lb)	421.62	497.92	0.0087	0.53*
lb calf weaned (lb)	67366	83705	0.3737	0.43*
Rainfall (in)	20.88	29.62	0.0050	0.44*

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PREVALENCE OF *MYCOPLASMA BOVIS* IN BOVINE PNEUMONIA AND ARTHRITIS

J. C. Nietfeld[1] and T. Yeary[1]

Summary

Samples from cattle with pneumonia and/or arthritis were cultured for *Mycoplasma*. When requested, the *Mycoplasma* isolates were further identified to species by polymerase chain reaction or restriction fragment length polymorphism. The records of all cases where mycoplasma testing was performed were examined and other infectious agents known to cause pneumonia or arthritis were recorded. *Mycoplasma* species were isolated from 85% of the lung samples and 69% of the joint samples. Eighty-four percent of the 81 *Mycoplasma* isolates that were further identified were *M. bovis*, which clearly made it the most common pathogenic agent identified in samples from cattle with pneumonia and/or arthritis. *M. bovis* appeared to play an important role in feedlot pneumonia and was the most common cause of arthritis. Unfortunately, treatment and prevention options are currently either ineffective or their effectiveness is unknown.

(Key Words: Bovine, Pneumonia, Arthritis, *Mycoplasma bovis*.)

Introduction

Pneumonia is the most common and serious disease problem that affects beef cattle. Bacteria such as *Mannheimia* (*Pasteurella*) *haemolytica*, *Pasteurella multocida*, and *Haemophilus somnus*, and viruses such as infectious bovine rhinotracheitis virus, bovine virus diarrhea virus, parainfluenza type 3 virus, and bovine respiratory syncytial virus, acting independently or in association with one another, are considered to be the major causes of bovine pneumonia. *Arcanobacterium* (*Actinomyces*) *pyogenes* is frequently isolated from chronically infected lungs, but it is usually thought to invade after another agent has damaged the lungs. Recently, there has been considerable interest in *Mycoplasma bovis* as a cause of pneumonia and arthritis that fails to respond to treatment. The purpose of this project was to first determine the frequency of isolation of *Mycoplasma* species, especially *M. bovis*, from bovine lung and joint samples submitted to the Kansas State University Veterinary Diagnostic Laboratory, and second to compare that frequency to the frequency for which other respiratory pathogens were identified.

Experimental Procedures

The records of bovine cases submitted between May1999 and December 2001 in which mycoplasma testing was performed were examined and the results recorded. Culture for *Mycoplasma* spp. was by inoculation onto Friis agar and by inoculation into Friis broth followed by subculture onto agar. Agar plates were examined between 2 and 10 days after inoculation for *Mycoplasma* colonies. When requested by the

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submitting veterinarian or owner, *Mycoplasma* isolates were identified to species by polymerase chain reaction (PCR) using species-specific primers or by restriction fragment length polymorphism of the DNA product obtained by PCR using genus-specific primers. Identification of other bacteria was by routine culture procedures, and identification of viruses was by fluorescent antibody staining and/or virus isolation.

Results and Discussion

Mycoplasma were isolated from 157 of 185 (84.9%) lung samples and from 82 of 119 (68.9%) joint samples (Table 1). In cases where both lung and joint samples were included in the same submission (*Mycoplasma* isolation was not requested for both types of samples in all cases), 27 of 30 (90.0%) lung samples and 28 of 37 (75.7%) joint samples were culture positive. Of the 81 *Mycoplasma* isolates identified as to species, 68 (83.9%) were *M. bovis*. There were six isolates of *M. arginini*, one each of *M. alkalesence*, *M. bovirhinis*, and *M. canadense*, and four that were not further identified after the PCR indicated they were not *M. bovis.* In 7 of the 13 cases where a non-*M. bovis* species was identified, *M. bovis* was also isolated from the sample. Other pathogens that were identified are listed in Table 1.

Mycoplasma species easily were the most common agents isolated from lung and joint samples from cattle with pneumonia and arthritis, and 84% of the isolates that were further identified were *M. bovis*. In many cases, pneumonic lungs contained no identifiable pathogen, except *Mycoplasma*, and a large majority of joint samples were culture-negative except for *Mycoplasma*. A 1980 study from California reported that *Mycoplasma* species were isolated from 86% of the lungs from 500 feedlot cattle, and that 76% of the isolates that were identified were *M. bovis* alone or in combination with another *Mycoplasma*. Recently, *M. bovis* has been touted as an emerging disease of cattle and associated with the presence of multiple abscesses in the lungs of cattle with chronic bronchopneumonia. Examination of our records revealed that *M. bovis* was present in lungs from cattle with acute bronchopneumonia, chronic bronchopneumonia without abscesses, and acute interstititial pneumonia, as well as cases of chronic bronchopneumonia with abscesses. Our results, as well as the earlier report from California, indicate that *M. bovis* is common in the lungs of cattle dying of all types of pneumonia, and most likely it is not an emerging disease, but one that over the years has been underdiagnosed.

Most *Mycoplasma* species that have been isolated from cattle lungs do not cause any disease when put back into cattle. After infection with only *M. bovis*, most cattle do not become visibly sick, but the organism causes a small amount of lung damage from which *M. bovis* can be isolated for months. Perhaps more importantly, *M. bovis* increases the severity of pneumonia caused by *Mannheimia* (*Pasteurella*) *haemolytica* and *Pasteurella multocida*, especially if the calves are infected with *M. bovis* before infection with other bacteria. Several people have found that on arrival at a feedlot, a large majority of cattle already have been exposed to *M. bovis*. After a month on feed, almost all feedlot cattle have been exposed, and after exposure most animals remain infected for months. Therefore, almost all cattle in most feedlots are infected with *M. bovis*, and one would expect to isolate the organism from a large proportion of pneumonic lungs, regardless of the cause of the pneumonia. This makes it very difficult be certain of the role of *M. bovis* in bovine pneumonia, but many veterinarians and researchers feel that it plays an important role, probably by increasing the severity of other respiratory infections.

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After infection of the respiratory tract, *M. bovis* usually invades the blood, from which it can be isolated for several days. Usually calves clear the organism from their blood without further problems, but occasionally *M. bovis* settles in the joints and causes arthritis. Lung damage, regardless of the cause, provides an excellent environment for growth of *M. bovis* and results in pockets with high numbers of organisms. These act as reservoirs from which *M. bovis* can invade the blood and infect joints, where it is a proven cause of arthritis. Unfortunately, treatment, even with antibiotics that are effective in killing *M. bovis* in the laboratory, usually do not cure the lameness. Vaccines are available, but their effectiveness is not known. Because *M. bovis* is so common, it is not feasible to try to buy *M. bovis*-free cattle. The best preventative for mycoplasma arthritis in cattle appears to be doing everything possible to prevent pneumonia caused by other agents, and when it occurs to treat it early and limit the severity of the pneumonia. More research is required to fully understand and control *M. bovis*.

Table 1. Numbers of *Mycoplasma* Species and Other Pathogens Isolated from Lungs and Joints of Cattle

	Source of Isolate	
Agent	Lungs (n=185)	Joints (n=119)
Mycoplasma species	157	82
Mannheimia haemolytica	66	1
Pasteurella multocida	72	4
Haemophilus somnus	34	1
Arcanobacterium pyogenes	23	7
Salmonella spp.	4	
Streptococcus spp.		5
Chlamydophila (*Chlamydia)*		1
Bovine virus diarrhea virus	5	
Bovine respiratory syncytial virus	4	

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A STUDY OF THE CHEMICAL AND MICROBIAL CHANGES IN WHOLE-PLANT CORN SILAGE DURING FERMENTATION AND STORAGE: EFFECTS OF PACKING DENSITY AND SEALING TECHNIQUE

M. E. Uriarte-Archundia,
K. K. Bolsen, and B. E. Brent

Summary

The objectives of this study with whole-plant corn silage were to determine the effects of forage density after packing, and sealing technique on yeast and mold populations; and to examine the relationship between the microbial and chemical changes in the silages during the fermentation process and storage period. Whole-plant corn was harvested at 80% milkline (36% DM) and ensiled at three densities (D): D1, 23.2; D2, 33.2, and D3, 43.3 lb/ft^3. Half of the silos for each density were sealed immediately after filling (S, sealed) and the other half of the silos were sealed 48 hours after filling (DS, delayed seal). The experiment was arranged in a completely randomized design with treatments being combinations of two factors: three densities (D1, D2, D3), and two sealing techniques (S, DS). There were two 3-quart capacity PVC laboratory silos per treatment. Silos were opened after 150 days, and the chemical and microbial compositions of the silages determined. Silage pH and lactic acid content were indicative of an efficient preservation. Yeast and mold populations at day 0 were high, and most of the yeasts were lactate-assimilating yeasts (LAY). LAY populations at day 0 were high, with values of 5 $\log_{10}$ colony forming units (CFU) per g of fresh material. Low packing density and delayed sealing resulted in higher LAY populations ($P<0.01$).

(Key Words: Corn Silage, Aerobic Deterioration, Packing Density.)

Introduction

Aerobic deterioration of silage is a complex process and probably depends on the establishment and/or survival of aerobic spoilers during the fermentation and storage phases. If the levels of microorganisms responsible for deterioration are high, aerobic stability is likely to be short regardless of the chemical constituents.

The factors influencing deterioration include oxygen (amount and exposure time), composition of the microbial population, substrate type and quantity (e.g., water soluble carbohydrates and organic acids), stage of maturity at harvest, density of the silage, ambient temperature, and temperature of the silage mass. Better packing and more rapid sealing are generally thought to improve aerobic stability of a silage. Inadequate sealing allows air to penetrate and/or remain entrapped in the ensiled material for long periods and subsequent nutrient losses can be considerable.

Research has shown that silages with at least 5 $\log_{10}$ CFU yeasts per g were very susceptible to aerobic spoilage. This critical value for yeast numbers depends on the condition that the yeast population is made up principally of lactate-utilizing organisms. Such yeasts can initiate deterioration in all types of silage exposed to air.

The objectives of this study with whole-plant corn silage were to determine how forage density after packing, and delayed sealing influence yeast and mold

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populations; and to examine the relationship between the microbial and chemical changes in the silages during fermentation and storage.

Experimental Procedures

Whole-plant corn was harvested at 80% milkline (36% DM) on September 21, 1999. It was precision chopped to approximately 12 mm, ensiled in laboratory silos and stored for 150 days at ambient temperature. Whole-plant corn silage was ensiled at three fresh matter densities: D1, 23.2; D2, 33.2, and D3, 43.3 lb/ft^3. Half of the silos for each density were sealed immediately after filling (S = sealed) and the other half of the silos were sealed 48 hours after filling (DS = delayed seal).

The laboratory silos were 3-quart polyvinyl chloride (PVC) laboratory silos. Two silos from each treatment were opened and sampled for chemical and microbial analyses at days 1, 3, 7 and 150. The experiment was arranged in a completely randomized design with two replications, and treatments being combinations of two factors: three densities (D1, D2, D3), and two sealing techniques (S, DS).

Results and Discussion

The chemical composition of the corn silages after 150 days of storage is shown in Table 1. Silage pH and lactic acid content were indicative of an efficient preservation. No effects of packing density and sealing technique were observed on pH and lactic acid. The microbial composition of the corn silages after 150 days of storage is presented in Table 2. Yeast and mold populations at day 0 were high, and most of the yeasts were lactate-assimilating (LAY). LAY populations at day 0 were high, with values of 5 $\log_{10}$ CFU per g of fresh material.

Low packing density and delayed sealing both resulted in higher LAY populations. LAY in delayed sealed silages were higher than in their sealed counterparts, 7.65 vs. 6.02 $\log_{10}$ CFU per g of fresh material (Figure 1). LAY population was highest in the D1 silages (7.18 $\log_{10}$ CFU per g of fresh material) and lowest in the D3 silages (6.41) (Figure 2), which generally agrees with other researchers who have compared LAY and packing density.

Results of our study show the importance of air to yeast growth during the fermentation and storage phases. Both low packing density and delayed sealing resulted in higher LAY populations. Silage management practices that eliminate air, including both effective sealing and high packing density, should enhance aerobic stability by reducing the number of microorganisms responsible for aerobic deterioration.

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Table 1. Chemical Composition and pH of the Corn Silages Before ensiling (day 0) and After 150 Days of Storage

	DM (%)		pH		Lactic Acid[1]	
	Day		Day		Day	
Treatment	0	150	0	150	0	150
D1S	35.8	36.9	5.6	4.2	0.2	6.5
D1DS	35.8	33.8	5.6	4.2	NA	4.7
D2S	35.8	NA	5.6	NA	0.6	5.9
D2DS	35.8	24.1	5.6	4.1	NA	5.6
D3S	35.8	35.2	5.6	4.1	NA	NA
D3DS	35.8	33.5	5.6	4.1	NA	3.9

[1]Percent of the silage DM.

Table 2. Microbial Composition ($\log_{10}$ CFU per g of fresh material) of the Corn Silages Before Ensiling (day 0) and After 150 Days of Storage

	Y and M[1]		LAY[2]		LAB[3]	
	Day		Day		Day	
Treatment	0	150	0	150	0	150
D1S	6.0	7.3	NA	NA	6.7	6.7
D1DS	5.7	5.7	5.7	5.7	7.9	6.9
D2S	NA	NA	NA	5.5	NA	NA
D2DS	5.5	5.5	NA	NA	6.2	8.0
D3S	NA	NA	NA	NA	7.2	7.2
D3DS	5.7	3.4	5.6	5.6	8.6	8.6

[1]Yeast and mold.
[2]Lactate-assimilating yeast.
[3]Lactic acid bacteria.

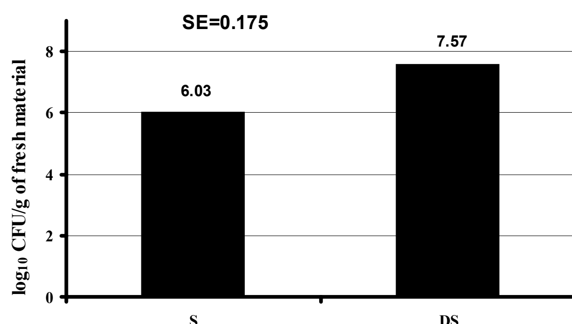

Figure. 1. Lactic Acid-Assimilating Yeast Populations in the Corn Silages After 150 Days of Storage. Effect of Sealing Technique.

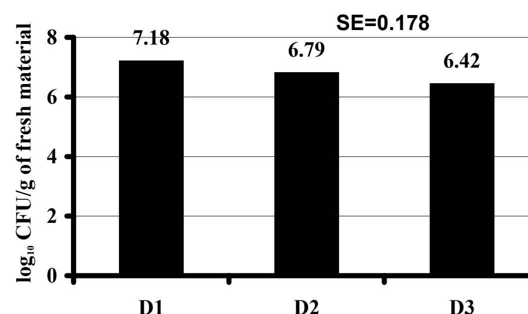

Figure 2. Lactic Acid-Assimilating Yeast Populations in the Corn Silages After 150 Days of Storage. Effect of Packing Density.

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A STUDY OF THE CHEMICAL AND MICROBIAL CHANGES IN WHOLE-PLANT CORN SILAGE DURING EXPOSURE TO AIR: EFFECTS OF A BIOLOGICAL ADDITIVE AND SEALING TECHNIQUE

M. E. Uriarte-Archundia
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Summary

The objectives of this study with whole-plant corn silage were to determine the effects of a biological additive and sealing technique on yeast and mold populations; and to examine the relationship between the microbial and chemical changes in the silages during exposure to air. Whole-plant corn was harvested at 80% milkline (36% DM), and ensiled at a density of 35 lb of fresh matter/ft^3. Half of the pre-ensiled forage was treated with a biological additive (A) (Sil-All 4×4, Alltech, Inc.); the other half of the pre-ensiled forage was the untreated control (C). Half of the silos in the A and C groups were sealed immediately after filling (S=sealed) and the other half of the silos were sealed 48 hours after filling (DS=delayed seal). Treatments consisted of combinations of the two factors: additive (A and C) and sealing technique (S and DS). There were three, 5-gal capacity, laboratory silos per treatment. Silos were opened after 150 days, and the chemical and microbial compositions and aerobic stability of the silages determined. All four silages were moderately stable during exposure to air. The C, DS silage was the first to show a rise in temperature, which occurred after 65 hours. The two DS silages were 48 hours less stable than their S counterparts, and the two A silages were 24 hours more stable than their C counterparts. Deterioration of the silages during exposure to air was accompanied by an increase in temperature and pH, a decrease in lactic acid content, and a rapid increase in the lactate-assimilating yeast population. Treatment with a biological additive significantly improved aerobic stability, and delayed sealing reduced the aerobic stability of silages.

(Key Words: Corn Silage, Inoculant, Aerobic Deterioration, Sealing.)

Introduction

Efficient forage preservation as silage requires minimizing losses during the aerobic, fermentation, storage, and feedout phases. While the efficiency of the fermentation phase has been improved, the same cannot be said about aerobic stability during the feedout phase. This improvement in silage quality, which prevented the production of butyric acid and minimized the amount of acetic acid during the fermentation phase, increased the risk of aerobically unstable silages. These volatile fatty acids (VFAs) possess antimycotic activity, and thus inhibit the growth of yeasts and molds upon exposure to air during the feedout phase. In general, well-preserved silages are considered more prone to aerobic deterioration than their poorly-preserved counterparts. The addition of homofermentative lactic acid bacteria (LAB) has improved silage quality by promoting fast and efficient production of lactic acid, which results in a rapid pH decrease. However, aerobic stability has often been less for homolactic compared to heterolactic silages.

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The objectives of this study with whole-plant corn were to determine the effects of a biological silage additive and sealing technique on yeast and mold populations; and to examine the relationship between the microbial and chemical changes in the silages during exposure to air.

Experimental Procedures

Whole-plant corn was harvested at 80% milkline (36% DM) on September 21, 1999. It was precision-chopped to approximately 12 mm, ensiled in laboratory silos, and packed at a density of 35 lb of fresh matter/ft^3. Half of the pre-ensiled forage was treated with a biological additive (A) (Sil-All 4×4 supplied by Alltech, Inc.), which contained a mixture of bacteria (*Streptococcus faecium*, *Pediococcus acidilactici*, *Lactobacillus plantarum*, *Bacillus pumulis*) and enzymes (cellulase, hemicellulase, amylase, and pentosanase). The other half of the pre-ensiled forage was the untreated control (C). Half of the silos in the A and C groups were sealed immediately after filling (S=sealed), and the other half were sealed 48 hours after filling (DS=delayed sealed). The laboratory silos were 5-gal capacity plastic pails. Treatments consisted of combinations of the two main effects: additive (A and C) and sealing technique (S and DS).

The silos were opened after 150 days. All three replicates from each treatment were composited and mixed, and 2.2-lb pooled samples for each treatment were placed in 1.7-gal capacity polystyrene foam containers. There were 10 containers per treatment. Silages were exposed to air for 4 days. Thermocouples were placed in the center of the silage in each container, and temperature of silages was recorded daily at 6:00, 12:00, 18:00, and 24:00 h. Ambient room temperature was kept constant at 75°F ± 1.5. A silage was considered aerobically unstable when the temperature raised 2.7°F above room temperature. Two containers of each treatment were removed on days 1 through 4, and two samples were taken for chemical and microbial analyses.

Results and Discussion

The chemical composition of the corn silages after 150 days of storage and a 4-day exposure to air is shown in Table 1. Silage pH and lactic acid concentration were indicative of an efficient preservation. Exposure of the silages to air led to an increase in pH and a decrease in lactic acid content in the delayed seal silages ($P<0.01$).

All four silages were moderately stable during the exposure to air period (Figure 1). Extremely good aerobic stability was observed in the two sealed silages. The two DS silages were 48 hours less stable than their S counterparts, and the two A silages were 24 hours more stable than their C counterparts.

The microbial composition of the corn silages after 150 days of storage and a 4-day exposure to air is presented in Table 2. Additive and sealing technique had no significant effects on yeast and mold or lactic acid bacteria populations. Aerobic deterioration of the two delayed seal silages was accompanied by an increase ($P=0.06$) in the lactic acid assimilating yeast population.

Treatment with a biological additive significantly improved aerobic stability, but the mechanism of action was not evident. Delayed sealing after the silos were filled reduced the aerobic stability of the silages.

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Table 1. Chemical Composition and pH of the Four Corn Silages Before ensiling (day 0) and After Exposure to Air (day 4)

	DM (%)		pH		Lactic Acid[1]	
	Day		Day		Day	
Treatment	0	150	0	150	0	150
Control						
S	35.1	36.1	3.7	3.9	5.5	4.0
DS	33.8	32.9	3.7	8.0	3.3	0.3
Additive						
S	33.0	35.0	3.5	3.6	5.9	4.9
DS	32.5	32.2	3.6	7.2	5.5	1.5

[1]Percent of the silage DM.

Table 2. Microbial Composition ($\log_{10}$ CFU per g of fresh material) of the Corn Silages Before (day 0) and After Exposure to Air (day 4)

	Y and M[1]		LAY[2]		LAB[3]	
	Day		Day		Day	
Treatment	0	150	0	150	0	150
Control						
S	NA	9.2	NA	8.2	5.6	8.4
DS	2.9	9.7	2.8	9.4	3.6	8.0
Additive						
S	NA	9.1	NA	7.0	NA	7.9
DS	5.1	8.6	2.5	8.7	NA	NA

[1]Yeast and mold.
[2]Lactate-assimilating yeast.
[3]Lactic acid bacteria.

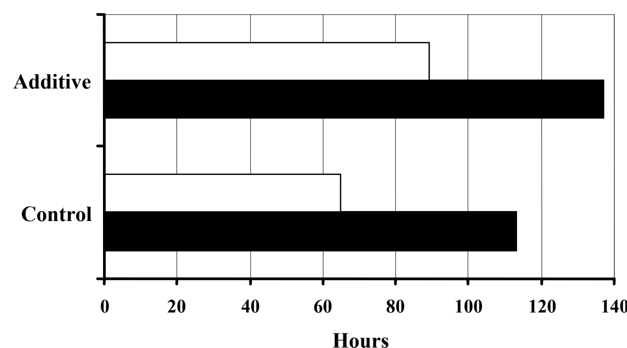

Figure 1. Hours to the Initial Rise in Temperature for the Four Corn Silages During Exposure to Air. ■ Sealed, □ Delayed seal

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EFFECT OF LEGUME PERSISTENCE IN ENDOPHYTE-INFECTED TALL FESCUE PASTURES ON FORAGE PRODUCTION AND STEER PERFORMANCE

L. W. Lomas[1], J. L. Moyer[1], and G. L. Kilgore[2]

Summary

A total of 135 steers grazed high-endophyte tall fescue pasture in 1998, 1999, and 2000 that had been previously interseeded with either lespedeza, red clover, or ladino clover during 1995, 1996, and 1997. Legume cover, forage dry matter production, grazing steer performance, and subsequent feedlot performance were measured. Pastures interseeded with ladino clover produced higher stocker gains in 1998 and more available forage and legume cover in all 3 years than those interseeded with lespedeza or red clover. Legume treatment had little effect on subsequent finishing performance. Results of this study indicate that lespedeza and red clover should be seeded every year and ladino clover at least every 2 years in endophyte-infected tall fescue pasture in order to provide sufficient legume to improve performance of grazing cattle.

(Key Words: Grazing, Tall Fescue, Endophyte, Legumes, Interseeding, Finishing.)

Introduction

Cattlemen with high-endophyte tall fescue pastures can either tolerate low gains from their cattle, seek to improve animal performance by destroying existing stands of fescue and replacing them with endophyte-free fescue or other forages, or interseed legumes into existing pastures to reduce the adverse effects of endophyte on animal performance. Previous research at the Southeast Agricultural Research Center has shown that performance of stocker steers grazing high-endophyte tall fescue improved significantly when 'Regal' ladino clover was broadcast on the pastures in late winter, and that interseeding ladino clover into existing stands of high-endopyte tall fescue produced higher grazing gains than interseeding lespedeza or red clover. This study was conducted to compare legume persistence, forage production, grazing performance, and subsequent feedlot performance of stocker steers grazing high-endophyte tall fescue pastures that had been previously interseeded with ladino clover, lespedeza, or red clover.

Experimental Procedures

Pastures. Nine 5-acre pastures located at the Parsons Unit of the Kansas State University-Southeast Agricultural Research Center on a Parsons silt loam soil were used in a randomized complete block design containing three replications. The pastures of established (>5-yr) 'Kentucky 31' tall fescue had more than 65% infection rate with the endophyte, *Neotyphodium coenophialum* (formerly called *Acremonium coenophialum*). Pastures were fertilized in September 1998, 1999, and 2000 with 16-40-40 lb/a of N-P_2O_5-K_2O. Pastures were treated in early spring of

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1994 with 3 tons/acre of ag lime (62% effective calcium carbonate). Three legumes were seeded in late February 1995 with a no-till drill. Three pastures each received 4 lb/acre of Regal ladino clover, 12 lb/acre of 'Kenland' red clover, or 15 lb/acre of 'Marion' striate lespedeza. Pastures were seeded again in mid-March of 1996 and early March of 1997 with the same respective legumes that were planted in 1995, except that Korean rather than Marion lespedeza was planted. Seeding rates in 1996 were 6 lb/acre of Regal ladino clover , 13 lb/acre of Kenland red clover, or 17 lb/acre of Korean lespedeza. Seeding rates in 1997 were 4 lb/acre of Regal ladino clover, 12 lb/acre of Kenland red clover, or 14 lb/acre of Korean lespedeza.

Available forage was determined at the initiation of grazing and periodically during the season with a disk meter calibrated for tall fescue. Three exclosures (15-20 ft^2) were placed in each pasture; total production was estimated from three readings per exclosure, and available forage was determined from three readings near each cage. Legume canopy coverage was estimated from the percentage of the disk circumference that contacted a portion of the canopy.

Grazing Steers. In 1998, 1999, and 2000, 45 mixed-breed steers were weighed on consecutive days, stratified by weight, and allotted randomly to the nine pastures. Grazing was initiated on April 1 in 1998, March 30 in 1990, and April 4 in 2000. Initial steer weights were 573 lbs in 1998, 565 lbs in 1999, and 553 lbs in 2000. Cattle were treated for internal and external parasites prior to being turned out to pasture and later were vaccinated for protection from pinkeye. Steers were fed 2 lb of ground grain sorghum per head daily and had free access to commercial mineral blocks that contained 12% calcium, 12% phosphorus, and 12% salt. One steer was removed from one of the lespedeza pastures in 1998, one from one of the ladino clover pastures in 1999, and one from one of the red clover pastures in 2000 for reasons unrelated to experimental treatment. Pastures were grazed continuously at a stocking rate of 1 head/acre. Grazing was terminated and steers were weighed on November 9 and 10 (223 days) in 1998, November 3 and 4 (218 days) in 1999, and November 7 and 8 (218 days) in 2000.

Following the grazing period, cattle were shipped to a finishing facility and fed a diet containing 80% ground milo, 15% corn silage, and 5% supplement (dry basis). Steers were implanted with Synovex S® on days 0 and 84 of the finishing period. Cattle grazed during 1998, 1999, and 2000 were fed a finishing diet for 154, 140, and 111 days, respectively. They were slaughtered in a commercial facility and carcass data were collected.

Results and Discussion

Pastures. Available forage dry matter of the pastures for 1998, 1999, and 2000 is presented in Figures 1, 2, and 3, respectively. Available forage dry matter was higher in pastures that had been interseeded with ladino clover than in those with lespedeza in all 3 years, and higher than those with red clover in 1999 and 2000.

Legume canopy coverage for 1998, 1999, and 2000 is presented in Figures 4, 5, and 6, respectively. Greater legume coverage was maintained in each of the 3 years in pastures that were previously interseeded with ladino clover than in those with red clover or lespedeza. However, legume coverage declined each year with only an average of 1.3% remaining in ladino clover pastures in 2000.

Cattle Performance. Grazing and subsequent finishing performance of steers grazing fescue pastures in 1998, 1999, and

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2000 that had been previously interseeded with the various legumes are presented in Table 1. Results are listed by year for each legume treatment, since there was a significant (P<0.05) treatment × year interaction. In 1998, steers grazing pastures interseeded with ladino clover gained 33.3% more (P<0.05) and 20.4% more (P<0.05) than those grazing pastures interseeded with lespedeza and red clover, respectively. Gains of steers grazing pastures interseeded with lespedeza or red clover were similar (P>0.05). In 1999 and 2000, grazing gains among legume treatments were similar (P>0.05).

Legume treatment during the grazing phase had no effect on subsequent finishing performance or carcass parameters except steers that grazed pastures interseeded with red clover in 1998 gained 9.1% more (P<0.05) than those that grazed pastures interseeded with ladino clover. This may have been compensatory gain, as cattle that grazed pastures interseeded with ladino clover gained more (P<0.05) than those grazing pastures interseeded with red clover during the grazing phase. Finishing performance of steers that had previously grazed pastures interseeded with lespedeza or red clover were similar (P>0.05). Overall gains from the beginning of the grazing phase through the end of the finishing phase were similar between legume treatments during each of the 3 years.

Table 1. Effects of Interseeding Legumes into Endophyte-Infected Fescue Pastures on Performance of Steers, Southeast Agricultural Research Center

	1998			1999			2000		
	Legume			Legume			Legume		
Item	Lespedeza	Red Clover	Ladino Clover	Lespedeza	Red Clover	Ladino Clover	Lespedeza	Red Clover	Ladino Clover
Grazing Phase									
No. of days	223	223	223	218	218	218	218	218	218
No. of head	14	15	15	15	15	14	15	14	15
Initial wt., lb	572	574	573	565	565	565	552	549	552
Ending wt., lb	779[a]	803[a]	849[b]	775	784	779	774	792	780
Gain, lb	207[a]	230[a]	276[b]	210	219	214	223	243	229
Daily gain, lb	0.93[a]	1.03[a]	1.24[b]	0.97	1.01	0.98	1.02	1.12	1.05
Finishing Phase									
No. of days	154	154	154	140	140	140	111	111	111
No. of head	14	15	15	15	15	14	15	14	15
Starting wt., lb	779[a]	803[a]	849[b]	775	784	779	774	792	780
Final wt., lb	1296	1340	1341	1322	1320	1344	1216	1221	1204
Gain, lb	517[a,b]	537[a]	492[b]	547	535	565	441	429	424
Daily gain, lb	3.36	3.48	3.19	3.90	3.82	4.03	3.98	3.86	3.82
Daily DM intake, lb	25.0	26.3	25.8	27.1	28.2	27.8	27.7	27.4	28.8
Feed/gain	7.4	7.6	8.1	6.9	7.4	6.9	7.0	7.1	7.6
Hot carcass wt., lb	790	813	817	790	800	808	706	720	696
Dressing %	61.0	60.7	60.9	59.7	60.6	60.1	58.1	58.9	57.8
Backfat, in	.39	.38	.40	.51	.44	.45	.41	.42	.43
Ribeye area, in^2	16.0	15.5	15.3	12.0	12.2	12.3	11.6	11.4	11.7
Yield grade	1.8	2.0	2.1	3.3	3.1	3.1	3.0	3.1	2.9
Marbling score	SM^{10}	SM^{79}	SM^{62}	MT^{19}	SM^{70}	MT^{22}	SM^{01}	SM^{10}	SL^{95}
% Choice	62	80	67	92	73	100	40	42	47
Overall Performance (Grazing + Finishing Phase)									
No. of days	377	377	377	358	358	358	329	329	329
Gain, lb	724	767	768	757	755	779	664	672	652
Daily gain, lb	1.92	2.03	2.04	2.12	2.11	2.18	2.02	2.04	1.98

[a,b]Means within a row within the same year with the same letter are not significantly different (P<0.05).

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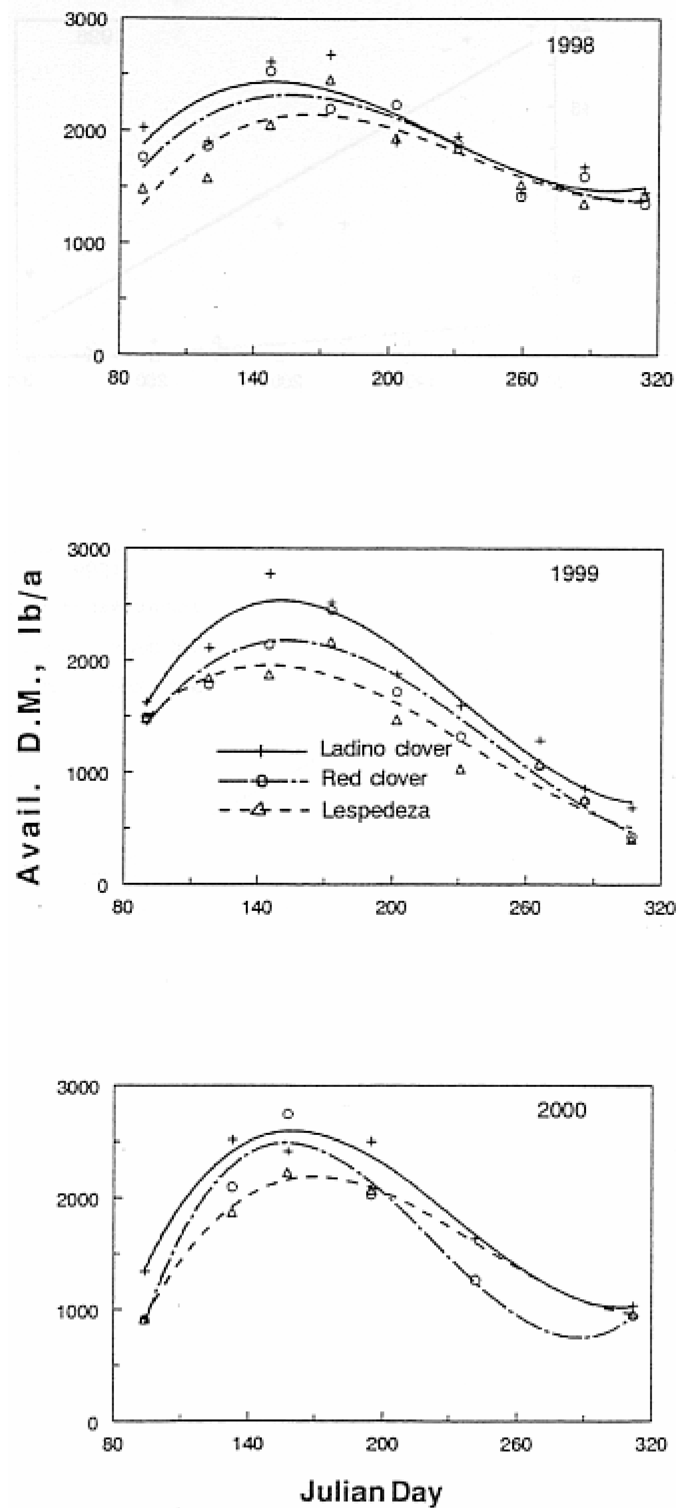

Figure 1. Available Forage in Tall Fescue Pastures Previously Interseeded with Legumes, Southeast Agricultural Research Center. Day 80 is March 21, day 320 is November 16.

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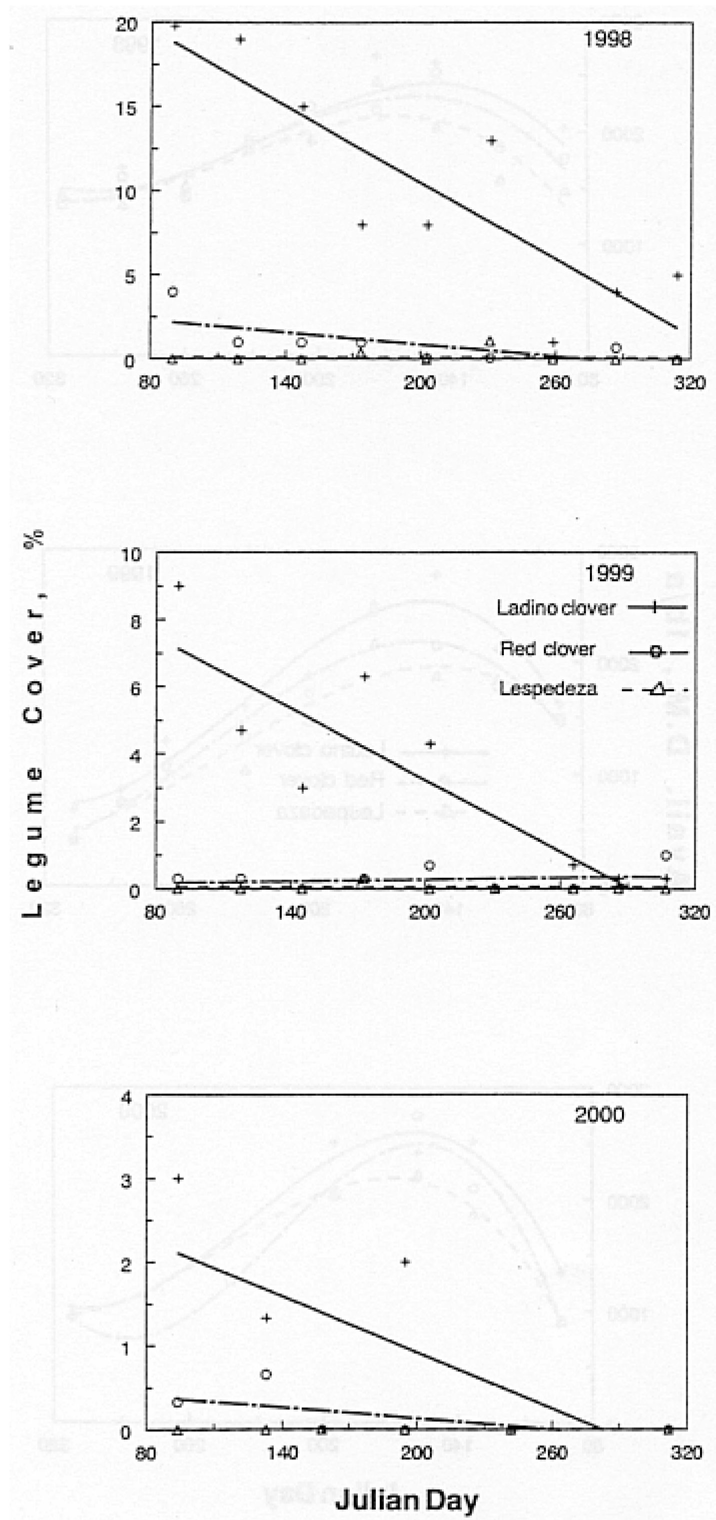

Figure 2. Legume Canopy Cover in Tall Fescue Pastures Previously Interseeded with Legumes, Southeast Agricultural Research Center. Day 80 is March 21, day 320 is November 16.

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Cattlemen's Day 2002

EFFECT OF SOURCE OF CARBOHYDRATE AND DEGRADABLE INTAKE PROTEIN IN SUPPLEMENTS ON LOW-QUALITY FORAGE UTILIZATION BY STEERS

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T. A. Wickersham and D. A. Llewellyn

Summary

Twelve ruminally fistulated steers were used in an experiment to study the impact of the source of carbohydrate (CHO) and degradable intake protein (DIP) in supplements on low-quality forage utilization. Treatments consisted of two different CHO types (fed at 0.16% of initial BW) each offered with an equal amount of DIP (0.087% of initial BW) but with six different proportions of non-protein nitrogen (NPN) and true protein as sources of DIP. The CHO types were starch and dextrose (a simple sugar). The different proportions of the two sources of N contributing to the DIP were 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 % of supplemental N as casein (true protein source) vs urea (NPN source), respectively. Interactions were not evident for the traits presented. Forage OM, total OM, and total digestible OM intake increased in response to an increase in the proportion of supplemental true protein. Although CHO type did not affect intake, digestibility of OM and NDF was greater when the simple sugar rather than starch served as the CHO source.

(Key Words: Forage, Starch, Sugar, Protein, Urea, DIP, Steers)

Introduction

Degradable intake protein (DIP) supplementation improves low-quality forage utilization by cattle. Some supplemental DIP can come from a non-protein nitrogen (NPN) source, such as urea, without harming forage utilization. However, very high concentrations of urea in supplements have been associated with reduced forage utilization, compared with supplements that contain little NPN. A common practice to improve the acceptability of and response to supplements that contain urea is to incorporate a significant quantity of carbohydrate (CHO; typically nonstructural CHO such as starch or sugars) into the supplements. There is some evidence that when sufficient supplemental DIP is provided to maximize forage utilization, the negative effect associated with CHO supplementation is less if the CHO is sugar rather than starch. However, the consistency with which such responses are observed, and potential effects of source of DIP on the response has not been verified. Therefore, this experiment was conducted to study the impact of source of CHO and DIP on low-quality forage utilization in beef steers.

Experimental Procedures

Twelve ruminally fistulated beef steers (BW = 1100 lb) given ad libitum access to tallgrass-prairie hay (5.3%CP, 74.8%NDF) were randomly assigned at the beginning of the experiment to one of 12 treatments. Steers were subjected to two 20-day periods (11 days of adaptation), which included periods for intake and fecal collection, ruminal evacuation, and monitoring ruminal fermentation. Treatments were arranged as a 2 × 6 factorial and consisted of two different CHO types (fed at 0.16% of initial BW), each offered with an equal amount of

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DIP (0.087% of initial BW) but with six different proportions of NPN and true protein. The CHO types were starch and dextrose. The different proportions of the two sources of N contributing to the DIP were 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 % of supplemental N as sodium caseinate (true protein source) vs urea (NPN source), respectively. Treatments were ruminally dosed once daily. Offered and refused hay was weighed to estimate feed intake, and in conjunction with fecal measurements, was used to calculate organic matter (OM) and neutral detergent fiber (NDF) digestibilities.

Results and Discussion

Interactions among CHO and DIP sources were not observed for the reported traits. Forage OM, total OM, and total digestible OM intake increased in response to an increase in the proportion of supplemental true protein (linear, $P<0.05$; Table 1). However, CHO type did not significantly affect intake. Digestibility of OM and NDF was greater when the simple sugar dextrose served as the CHO source compared with starch ($P<0.05$; Table 2). Treatments did not affect ruminal total VFA and pH ($P>0.20$; data not shown). However, ruminal ammonia increased in proportion to the increase in supplemental NPN (linear, $P<0.01$). Ruminal ammonia was also significantly lower for the dextrose than starch treatment ($P<0.01$). In conclusion, while the CHO types evaluated did not interact with source of supplemental DIP with regard to effects on intake and digestion, both factors exerted independent effects on these characteristics. Forage digestibility was affected by the provision of sugar vs starch, whereas the relative proportion of true protein vs NPN in the supplemental nutrients affected forage intake.

Table 1. Intake of Low-Quality Forage by Beef Steers Supplemented with Two Carbohydrate (CHO) and Two Degradable Intake Protein (DIP) Sources

	Intake, g/kg BW.75					
	Forage OM		Total OM		Total DOM[a]	
CHO Source[b]	Starch	Dextrose	Starch	Dextrose	Starch	Dextrose
DIP Source, %[c]						
0:100	47.2	50.9	56.5	59.8	30.2	33.3
20:80	59.5	52.8	68.6	63.0	34.3	38.9
40:60	52.2	50.1	62.2	60.4	31.4	34.5
60:40	54.8	52.9	65.7	63.3	37.5	37.4
80:20	56.7	58.8	68.2	70.1	34.8	42.6
100:0	79.9	62.3	91.8	73.7	44.2	41.0
Average	58.4	54.6	68.8	65.1	35.4	38.0
SEM[d]	6.5		6.5		3.9	

[a]Digestible organic matter.
[b]Carbohydrate sources supplied at 0.16% BW daily (DM basis).
[c]Proportion of DIP supplied from casein vs urea; provided at 0.087% BW daily (DM basis).
[d]Standard error of the mean (n=2).

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Table 2: Total Tract Digestion and Ruminal Ammonia of Low-Quality Forage by Beef Steers Supplemented with Two Carbohydrate (CHO) and Two Degradable Intake Protein (DIP) Sources

	Digestibility, %				Ammonia	
	OM		NDF		mM	
CHO Source[a]	Starch	Dextrose	Starch	Dextrose	Starch	Dextrose
DIP Source, %[b]						
0:100	52.9	55.7	47.7	51.3	18.07	13.10
20:80	50.0	63.0	44.9	60.1	10.34	8.18
40:60	51.4	57.5	44.4	51.3	12.85	9.15
60:40	57.0	58.8	51.8	53.1	7.94	8.11
80:20	50.8	61.0	44.5	56.5	5.49	3.65
100:0	48.3	55.6	42.1	49.0	4.97	5.20
Average	51.7	58.6	45.9	53.6	9.94	7.90
SEM[c]	5.2		5.7		1.52	

[a]Carbohydrate sources supplied at 0.16% BW daily (DM basis).
[b]Proportion of DIP supplied from casein vs urea; provided at 0.087% BW daily (DM basis).
[c]Standard error of the mean (n=2).

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DETERMINING THE INFLUENCE OF DIFFERENT LEVELS OF UREA SUPPLEMENTATION WHEN BEEF COWS GRAZING WINTER PASTURE ARE SUPPLEMENTED AT DIFFERENT FREQUENCIES DURING THE PREPARTUM PERIOD

C. G. Farmer, R. C. Cochran, and T. A. Wickersham

Summary

One hundred sixty spring-calving Hereford × Angus cows grazing low-quality, tallgrass-prairie range during the winter of 2000-2001 were supplemented before calving either daily or three times weekly. The supplement contained 40% CP with 0, 15, 30, or 45% of the supplemental degradable intake protein from urea. Supplement was fed at 4 lbs/head daily to cows receiving supplement daily. Cows receiving supplement three times weekly were fed the same amount of weekly supplement, but split equally among their supplementation events. After calving, all cows received a supplement without urea on a daily basis. In general, prepartum supplements that contained more urea prompted greater body weight loss; however, the effect of increasing urea was most noticeable when supplements were fed only three times weekly. When averaged across supplementation frequencies, increasing the level of supplemental urea tended (P=0.15) to decrease pregnancy rate in beef cows that had received urea supplementation before calving.

(Key Words: Range, Supplementation, Frequency, Urea.)

Introduction

Winter supplementation strategies often use daily feeding of true protein supplements. However, when beef cows are not easily accessible, less frequent supplementation may be more practical. Additionally, because true protein supplements are often costly, incorporation of urea as a degradable protein substitute may be more economical. Previous research at Kansas State University indicated that reducing true protein supplementation frequency from daily to three times weekly resulted in minimal performance differences of beef cows. In other previous research, in the context of a 30% CP supplement, when up to 45% of that supplement's degradable intake protein was supplied as urea, the magnitude of body condition loss over a winter supplementation period was minimal, compared with true protein supplementation. However, it is unknown whether decreasing the feeding frequency of supplements that contain appreciable urea will significantly harm cattle performance. Therefore, our objective was to evaluate the effects of two frequencies of prepartum supplementation with high-protein supplements that delivered four levels of supplemental urea on performance of spring-calving beef cows grazing winter pasture.

Experimental Procedures

One hundred sixty Hereford × Angus cows were weighed and body condition was scored (1 to 9 scale) on November 27, 2000. Initial condition score averaged 5.2, and initial body weight averaged 1157 lbs. Two frequencies of supplementation were assigned randomly to two of four evenly sized pastures. Two pastures contained cows supplemented daily. The other two

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pastures contained cows supplemented Monday, Wednesday, and Friday. Pastures contained low-quality, tallgrass-prairie range (4.1% CP). Pastures were used to represent frequencies of supplementation so that behavior-induced effects on performance would be expressed. Cows were stratified by body condition score and body weight and assigned randomly to one of the four pastures. Finally, within each pasture, cows were assigned randomly to receive one of four different supplements (each of which contained 40% CP) with various urea levels: 1) 0% of degradable intake protein (true protein supplement); 2) 15% of degradable intake protein; 3) 30% of degradable intake protein; and 4) 45% of degradable intake protein. Supplements were comprised of soybean meal and ground milo and offered at 4 lbs/ head daily (as-fed) to cows that received supplement daily. Cows fed three times weekly were also offered 28 lbs of supplement per week, but evenly split among the three days. On their supplementation days, cows were gathered and sorted into their supplement treatment groups. For statistical purposes, treatment group within a pasture was the experimental unit. Supplement refusals were measured through the entirety of the trial. Prairie hay (5.8% CP) was fed (10 lbs/head daily) because of significant snow coverage from December 23 through January 3. Cows were weighed and body condition was scored again on January 9, February 8, and within 48 hours after calving. All cows were fed alfalfa hay (21.6% CP) at 10 lbs/head daily after parturition until there was significant green grass available for grazing. Additional weight and body condition measurements were made immediately before breeding season (May 15) and on August 14. Cows were pregnancy tested on August 14 by rectal palpation. Calves were weighed within 48 hours after birth, on May 15, and on August 14 (ending weight).

Results and Discussion

During December, one to four cows in each of the groups receiving the highest urea level (45% of the degradable intake protein as urea) completely refused the supplement. After December, all cows usually consumed at least a portion of their allotted supplement. On average, from December 6 through February 8, cows fed that supplement three times weekly refused 44% of their supplement. Those fed daily, refused 4%. Cows fed the supplement with 30% of the degradable intake protein as urea three times weekly refused 8% of their supplement. In the period immediately before calving (February 8 to calving), supplement refusal became more dramatic. In that period, cows fed supplement with 45% of the degradable intake protein as urea three times weekly refused 62% of their supplement, versus 23% for those fed daily. From February 8 to calving, cows fed the supplement with 30% of the degradable intake protein as urea three times weekly refused 28% of their supplement. All other treatment groups consumed their entire supplement allotment.

For body weight changes during the winter supplementation period (December 6 – calving), there was a frequency of supplementation × supplemental urea level interaction (Figure 1). In general, as supplemental urea level increased, there was greater loss in body weight. However, the effect of increasing urea level was most dramatic when cows were supplemented only three times weekly. In fact, cows fed the supplement with 45% of the degradable intake protein as urea, three times weekly lost 87 more lbs of body weight than cows fed the same supplement daily. There was no significant frequency of supplementation × supplemental urea level interaction from December 6 through calving for body condition changes; however, the general trend for this trait seemed to follow the

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same pattern as that observed for body weight loss (Figure 1). When averaged across frequency of supplementation, body condition loss increased (linear, P≤.01) with an increase in supplemental urea level during the winter supplementation period (December 6 to calving), whereas no significant difference was observed due to different frequencies of supplementation.

There was no significant frequency of supplementation × supplemental urea level interaction for pregnancy rate (Figure 1), and frequency of supplementation did not affect pregnancy rate. However, when averaged across frequency of supplementation, pregnancy rate tended to decrease with increasing exposure to urea during the prepartum period (linear, P=.15). Cows fed higher levels of urea had pregnancy rates in the mid- to upper-80s compared with low- to mid-90s for those receiving lower levels. Calf birth weights and calf gains during the nursing period were not significantly affected by treatment.

Refusal to consume the supplement that contained 45% of the degradable intake protein as urea is different from our previous experiments with supplements that contained the same percent of degradable intake protein as urea. However, in the present study, all of our supplements contained 40% CP. In previous studies we worked with supplements that contained 30% CP. Clearly, by feeding the same percentage of the degradable intake protein as urea in the context of a higher protein supplement (40% CP) one would be delivering a greater amount of urea as a percent of DM (5% of the DM in the 40% CP supplement compared with 3.6% of the DM in the 30% CP supplement). In conclusion, if one is feeding a 40% CP supplement to prepartum range cows, low-level urea inclusion (≤15% of degradable intake protein from urea) appears to be compatible with less-frequent supplementation. However, because of supplement refusal and subsequent negative performance, caution should be exercised in feeding higher protein supplements with higher levels of urea (>15% of degradable intake protein from urea) at less frequent intervals (i.e. three times weekly), especially if cows enter the winter feeding period in lower body condition.

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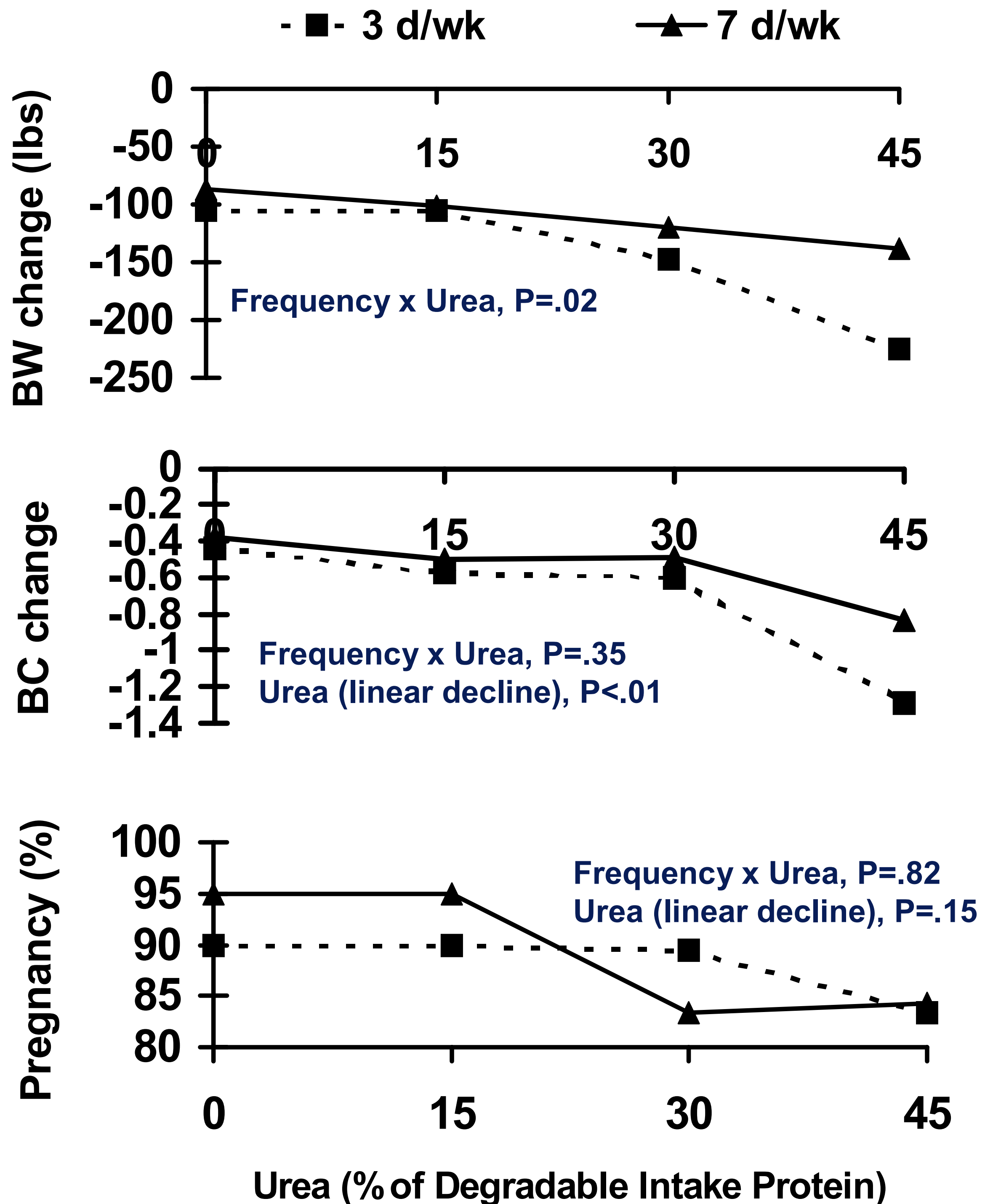

Figure 1. Interaction Between Frequency of Supplementation and Supplemental Urea Level on Beef Cow Body Weight and Body Condition Score Change from December 6 through Calving (Winter Supplementation Period) and Subsequent Pregnancy Rate.

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THE EFFECT OF AUREOMYCIN® IN COMBINATION WITH BOVETEC® IN A MINERAL MIXTURE ON STEERS GRAZING NATIVE GRASS[1]

F. K. Brazle[2]

Summary

Three hundred twelve mixed-breed steers (590 lb) were allotted randomly to eight native grass pastures on April 20. The pastures were grazed until July 13. The steers in four pastures received a basic mineral mix with 800 mg of Bovatec® per lb. The other four pastures received the basic mineral mixture with Bovatec plus 1.6 lb Aureomycin 50 per 50 lb of mineral. The steers receiving the mineral with Aureomycin had greater mineral consumption (P<0.04). Including Aureomycin in the mineral increased gain by 2%; however, the response was not statistically significant.

(Key Words: Bovatec, Ionophore, Aureomycin, Antibiotic, Native Grass.)

Introduction

Feed additives such as Bovatec® or Rumensin® are used in mineral mixtures for cattle grazing native grass during the summer. Also, Aureomycin® has been added to mineral mixtures resulting in excellent improvement in gain. As combination clearances by FDA become available, efficacy of these combination need to be evaluated. Therefore, this research studies the use of Bovatec by itself or in combination with Aureomycin by evaluating the effect on steer gains while grazing native pasture during the summer.

Experimental Procedures

Three hundred twelve mixed-breed steers (590 lb) were allotted randomly to eight pastures on April 20. The pastures were grazed until July 13 (stocking rate = one steer per two acres). The pastures were native tallgrass prairie that had been burned in early April. The steers in four pastures received a basic mineral with 800 mg of Bovatec/lb. The steers in the other four pastures received the same basic mineral with Bovatec, plus 1.6 lb Aureomycin 50 added for each 50 lb of the base mineral offered. The steers were checked weekly for foot rot and eye problems, and any steer that required treatment for either problem was recorded.

Results and Discussion

The combination of Bovatec and Aureomycin in the mineral resulted in an increase in daily mineral intake (.356 vs .213 lb/day, P<0.04, Table 1). The combination of Bovatec and Aureomycin improved gain by 2% over Bovatec alone; however, the response was not statistically significant. The incidence of foot rot was low in the study; therefore, it is difficult to make meaningful comparisons between treatments in this regard.

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Table 1. Effects of Aureomycin in Mineral on Steers Grazing Native Grass for 83 Days

Items	Aureomycin Bovatec	Bovatec	SE
No. steers	143	169	
No pastures	4	4	
Average starting wt, lb	590	589	
ADG, lb	3.209	3.147	0.044
Mineral intake, lb	0.356[a]	0.213[b]	0.023
Incidences of:			
Foot rot, %	0	0.6	0.44
Bovatec, mg/d	285	170	19.3
Aureomycin, mg/d	570	0	

[a,b]Means in the same row with unlike superscripts are different ($P<0.04$).

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SEASONAL FORAGE QUALITY OF RANGELANDS ACROSS KANSAS

K. Harmoney[1], S. Johnson[2], R. Cochran, E. Vanzant T. Jones, J. Wilson, D. Yauk, M. Ploger, G. McClure, M. Holder, B. Allen, W. Bell, and H. Jansonius

Summary

The K-State Research and Extension Forage Task Force surveyed Kansas rangelands during the course of seasonal changes to enable producers and managers to better estimate the feed value of their pasture forage during particular times of the year. Kansas' two distinct rangeland vegetation types, shortgrass and tallgrass prairie, were evaluated. Forage samples were collected monthly from two rangeland sites in each of 10 Kansas counties. Tallgrass vegetation was lowest in acid detergent fiber (ADF) and greatest in crude protein (CP) from May to July, and rapidly increased in ADF and declined in CP the rest of the season. Shortgrass vegetation was also lower in ADF and greater in CP from May to July, but changed less from early summer to the winter than did tallgrass vegetation. Degradable intake protein (DIP) was greatest for tallgrass vegetation in May. Otherwise DIP was similar between tallgrass and shortgrass except in February and March when shortgrass had greater DIP. DIP was greatest in May and June for both vegetation types and gradually declined from June to December. Undegradable intake protein (UIP) values were greater for tallgrass vegetation than for shortgrass vegetation from May through July, but all other months were similar. Seasonal forage quality is different between and within rangeland vegetation types, and identification of dominant vegetation is a key determinant in choosing appropriate animal nutritional management strategies.

(Key Words: Acid Detergent Fiber (ADF), Crude Protein (CP), Degradable Intake Protein (DIP), Forage Quality, Rangelands, Undegradable Intake Protein (UIP).)

Introduction

Forage quality is the predominant plant factor that determines the potential for animal growth and production on grazing lands. Samples from chopped and baled feeds are commonly collected for quality analysis. However, producers rarely sample pastures to determine the quality of available forage during different periods of the year, even though Kansas' land area is approximately 35% rangelands, or about 18 million acres. This information is critical to identify periods when pasture forages are not meeting animal requirements.

Shortgrass prairie and cow/calf systems dominate western rangelands of lower precipitation, while tallgrass prairie and stocker animal production dominate eastern rangelands with greater precipitation. However, many counties in central Kansas have mixed-grass vegetation, and both shortgrass and tallgrass dominated rangelands can be found. Each vegetation type may respond differently to seasonal climatic conditions. Knowing the seasonal changes for vegetation within regions would aid County Extension Agents, consultants, and

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producers by providing dependable information to make more educated decisions on animal management during particular periods of the year.

Experimental Procedures

Samples were collected by County Agents monthly during the growing season, and bi-monthly during the dormant season, from May of 1997 to October of 1999 from native rangelands at two rangeland locations in each of 10 Kansas counties. Prearranged dates of clipping were determined so that samples from all counties would be collected on the same date. Counties included were Hamilton and Wallace from the west, Clark, Ellis, and Edwards from the central, and Chase, Chautauqua, Clay, Coffey, and Riley from the north and east. Vegetation consisted of mostly short grasses (blue grama, buffalograss, little bluestem, western wheatgrass) in the west and north central, and tall grasses (big bluestem, indiangrass, switchgrass, little bluestem) in the east and south central. Pastures with histories of moderate stocking rates for their respective region were used as sample sites. Ten samples from each collection site were hand clipped, dried, and ground, then sent to a single laboratory for analysis.

Samples were analyzed for ADF and CP. The protein fraction was further analyzed for DIP (the portion available to rumen microbes) and UIP (the portion that escapes to the intestinal tract). Samples were statistically analyzed by grouping the vegetation type (short or tallgrass) of a county for each year and month collected. Unless otherwise noted, significance was based on a level of $P<0.05$.

Results and Discussion

Acid Detergent Fiber. ADF values were much lower in May, June, and July for tallgrass rangelands (36.8, 38.7, and 40.9 %, respectively) than for shortgrass rangelands (45.0, 43.7, and 45.0 %, respectively) (Figure 1). ADF values were similar between the two vegetation types during all other months.

Within tallgrass rangelands, May through September all had lower ADF than October through April. From May through September, a significant increase in ADF concentration also occurred every two months, while ADF significantly increased every sampling period from September to December. Within shortgrass rangelands, ADF values were similar May through August, and ADF was significantly lower May through August than October through April.

Within a forage species, digestibility has a negative relationship with ADF; the greater the ADF value, the less digestible the forage. Thus, tallgrasses and shortgrasses had their greatest digestion potential when late spring and early summer ADF values were lowest.

Protein. Tallgrass forage CP reached its greatest levels of 12.3 % and 8.2 % in May and June, statistically greater than any other time period for tallgrass or shortgrass. Similar to tallgrass vegetation, shortgrass CP significantly rose to 7.0 and 6.9 % in May and June, but the rise in CP was less than for tallgrass. April burning of some tallgrass pastures reduced standing dead material and helped to increase average tallgrass CP and decrease ADF in May and June. Shortgrass pastures in western Kansas were not burned. A gradual but significant decline in CP resulted for both vegetation types from July to December (Figure 2).

Degradable intake protein (DIP) is the portion of CP that is utilized by rumen microbes. When energy and protein are well balanced in a diet, DIP is largely incorporated into microbial cells, which become available as a protein source for the animal as the microbes pass out of the rumen and into the intestinal tract. In this study, increases and decreases in CP were paralleled by increases and decreases in DIP (Figure 2). With lower DIP levels in both grass types from July to the following April, energy

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needs may not be met in livestock with high gain potential or in those with high energy requirements for maintenance and lactation because DIP may limit both forage intake and fiber digestion of poor-quality forages.

Undegraded by rumen microbes, UIP passes from the rumen unaltered into the remainder of the gastro-intestinal tract. At present, the National Research Council assumes that approximately 80% of the UIP entering the intestines is digested. However, UIP digestibility can vary greatly from this average. No data is available at present to clarify the extent to which UIP from tallgrass and shortgrass is digested in the intestinal tract. In addition, UIP is of nutritional value to cattle only when their protein demands are not sufficiently met by microbial protein (from the DIP) flowing into the intestines. The factors above make the interpretation of UIP's importance challenging. Tallgrass vegetation had much greater UIP than shortgrass vegetation during May, June, and July (4.4, 3.1 , and 3.1 % vs. 2.3, 2.4, and 2.6 %, respectively). All other months except December were similar between the two vegetation types. Shortgrass consistently ranged from 2.0-2.8 % UIP through the season.

Protein levels in our study were lower than expected, but forage consumed by fistulated grazing cattle has been found to be 2-3% higher in CP than forage clipped on Kansas Flint Hills rangeland. Protein levels were also at their greatest and ADF at its lowest in tallgrass vegetation from May until July in this study (Figures. 1 and 2), the period when stocker animals have historically achieved their greatest average daily gains. Animal gains during the early grazing season were similar to gains in the late season 7 out of 10 years on continuously stocked shortgrass pasture. The narrow margin between the lowest and greatest seasonal protein (Figure 2) and ADF (Figure 1) levels on shortgrass range in the current study could have been a factor in the similar response between early and late season gains of previous grazing trials.

Tallgrass prairie is highest in forage quality during the early spring and summer. Quality rapidly declines from July to October. Shortgrass forage quality fluctuated less between seasons. Because seasonal forage quality is quite different between and within rangeland vegetation types throughout Kansas, identification of dominant rangeland vegetation is a key determinant in choosing appropriate nutritional management strategies.

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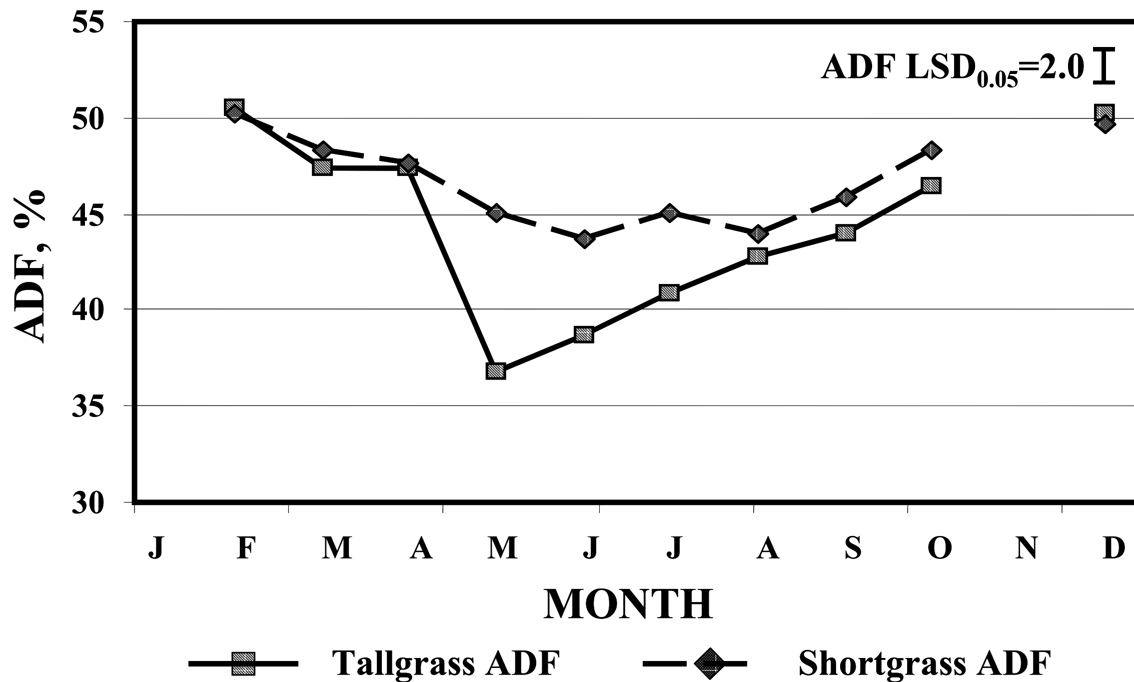

Figure 1. Monthly Acid Detergent Fiber (ADF) Percentage of Kansas Tallgrass and Shortgrass Rangeland Vegetation from Spring of 1997 to Fall of 1999.

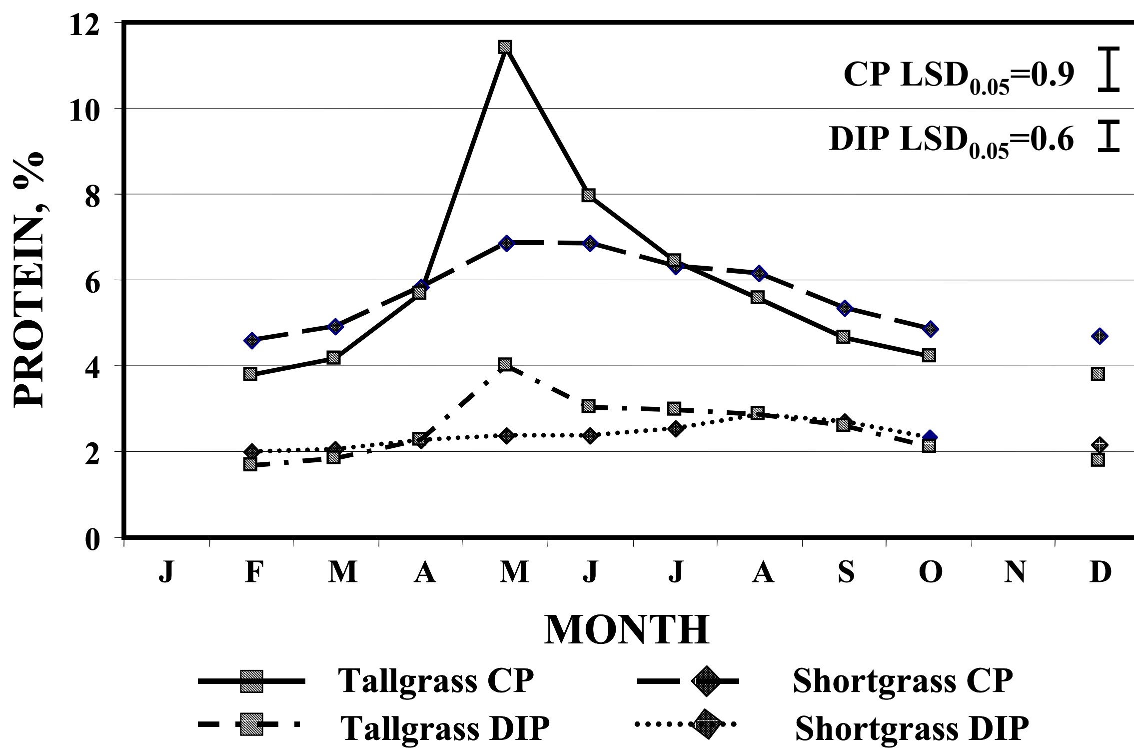

Figure 2. Monthly Crude Protein (CP) and Digestible Intake Protein (DIP) Percentage of Kansas Tallgrass and Shortgrass Rangeland Vegetation from Spring of 1997 to Fall of 1999.

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BIOLOGICAL VARIABILITY AND STATISTICAL EVALUATION OF DATA

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

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

Some papers report correlations C measures of the relationship between traits. The relationship may be positive (both traits tend to get larger or smaller together) or negative (as one gets larger, the other gets smaller). A perfect correlation is either +1 or B1. If there is no relationship at all, the correlation is zero.

You may see an average given as 2.5 " .1. The 2.5 is the average; .1 is the "standard error." That means there is a 68% probability that the "true" mean (based on an unlimited number of animals) will be between 2.4 and 2.6. "Standard deviation" is a measure of variability in a set of data. One standard deviation on each side of the mean is expected to contain 68% of the observations.

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

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

WEATHER DATA, 2000-2001

On the following page are graphs of the 2000 and 2001 Manhattan weather. They were produced by the Kansas State University Weather Data Library. The smooth line that starts in the lower left corner of each graph is the normal accumulated precipitation since January 1. The rough line starting in the lower left corner represents actual accumulated precipitation. A long horizontal section of that line represents time during which no precipitation fell. A vertical section represents precipitation. The other two smooth lines represent average daily high and low temperatures, and the rough lines represent actual highs and lows.

These graphs are included because much of the data in this publication, especially data on animal maintenance requirements and forage yields, can be influenced by weather. Weather graphs have been included in Cattlemen's Day publications since 1985.

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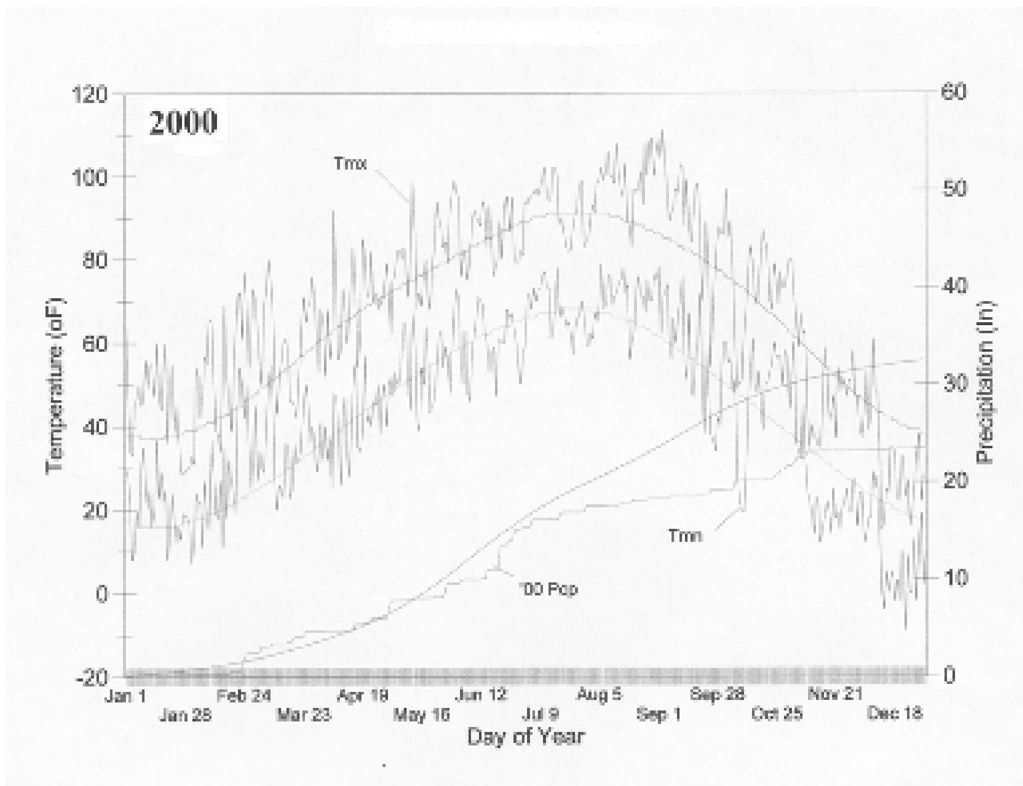

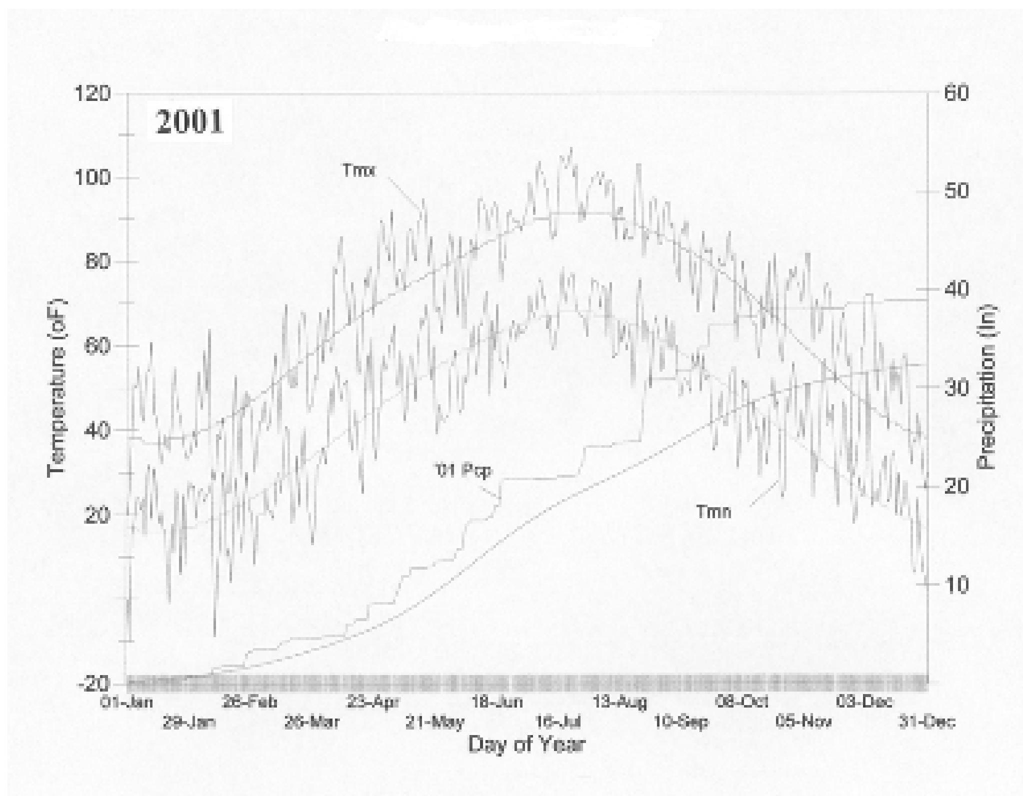

Summaries of Weather in Manhattan, KS, 2000 and 2001

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Corn Marketing Program of Michigan,
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Lee Borck, Larned, Kansas

Brill Corporation, Norcross, Georgia

Cargill Inc., Minneapolis, Minnesota

Dakota Commodities, Scotland, South Dakota

Dow Agrosciences, Indianapolis, Indiana

E.I. duPont de Nemours,
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Elanco Animal Health, Indianapolis, Indiana

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Farnam Companies, Inc., Phoenix, Arizona

Fink Beef Genetics, Manhattan, Kansas

Fort Dodge Animal Health, Fort Dodge, Iowa

Frisbie Construction, Gypsum, Kansas

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ibp, inc., Emporia, Kansas

InterAg, Hamilton, New Zealand

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Kansas Artificial Breeding Service Unit,
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Kansas Beef Council, Topeka, Kansas

Kansas Corn Commission, Garnett, Kansas

Kansas Grain Sorghum Commission,
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Kansas Livestock Assn., Topeka, Kansas

Kansas Soybean Commission, Topeka, Kansas

Livestock and Meat Industry Council (LMIC),
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Merial Limited, Iselin, New Jersey

Minnesota Corn Processors, Inc.,
Marshall, Minnesota

Mohrlang Manufacturing, Brush, Colorado

National Cattlemen's Beef Assn,
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NCBA Cattlemen's Data Service
Greenwood Village, Colorado

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North American Meat Processors Assn.
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SDK Labs, Hutchinson, Kansas

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Schering-Plough Animal Health,
Kenilworth, New Jersey

Select Sires, Plain City, Ohio

Shimadzu Scientific Instruments
Columbia, Maryland

Stork Division, Townsend Engineering
Des Moines, Iowa

Thermo IEC, Needham Heights, Massachusetts

USDA Food Safety Consortium,
Washington, DC

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YSI Incorporated

Yellow Springs, Ohio

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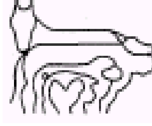

The Livestock & Meat Industry Council, Inc.

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The Livestock and Meat Industry Council, Inc. (LMIC) is a not-for-profit charitable foundation supporting animal agriculture research, teaching and education. This is accomplished through the support of individuals and businesses that make LMIC a part of their charitable giving.

Tax deductible contributions can be made through gifts of cash, appreciated securities, real estate, life insurance, charitable remainder trusts, bequests, as well as many other forms of planned giving. LMIC can also receive gifts of livestock, machinery or equipment. These types of gifts, known as gifts-in-kind, allow the donor to be eligible for a tax benefit based on the appraised value of the gift.

Since its inception in 1970, LMIC has provided student scholarships, research assistance, capital improvements, land, buildings, and equipment to support students, faculty, and the industry of animal agriculture. If you would like to be a part of this mission or would like additional information, please contact the Livestock and Meat Industry Council/Animal Sciences and Industry, Weber Hall, Manhattan, Kansas 66506 or call 785-532-6533.

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