Beef Research Report 1998

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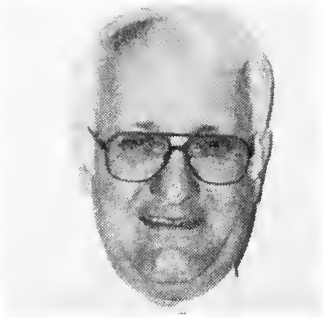

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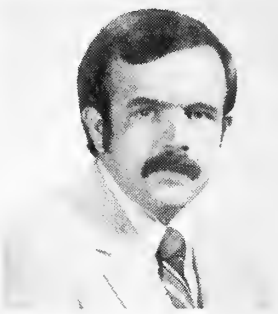

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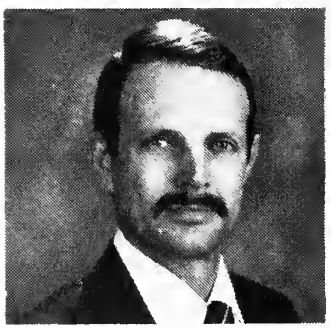

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THANK YOU

THE DEPARTMENT OF ANIMAL SCIENCES GRATEFULLY ACKNOWLEDGES THE ASSISTANCE OF THE FOLLOWING COMPANIES AND PEOPLE IN OUR BEEF PROGRAM

ADM, Decatur, IL
Ajinomoto, Eddyville, IA
Alltech Inc., Nicholasville, KY
American Breeders Service, DeForest, WI
Baldridge Angus Ranch, North Platte, NE
Central Soya, Decatur, IN
Corn Products, Argo, IL
Robert Douglas, LTD, Robinson, IL
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Fats and Proteins Research Foundation, Bloomington, IL
Forsythe Land and Cattle, Marshall, IL
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GTA Feeds, Sioux Falls, SD
Hoechst-Roussel Agri-Vet, Somerville, NJ
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Illinois Beef Association, Springfield, IL
Illinois Corn Marketing Board, Bloomington, IL
Illinois Soybean Program Operating Board, Bloomington, IL
InterAg (DEC International, Inc.), Hamilton, New Zealand
Intervet International, Boxmeer, The Netherlands
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Merial, Inc., Athens, GA
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Shady Brook Angus Farms, Leoma, TN
Sunny Valley Angus, Yorkville, IL
VetLife, Winterset, IA

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BEEF NUTRITION AND MANAGEMENT

REPRODUCTION AND PHYSIOLOGY

THE DEPARTMENT OF ANIMAL SCIENCES
University of Illinois

Greetings from the Department of Animal Sciences at the University of Illinois! We are pleased to describe in this report of a portion of the research that has been accomplished during past the year by our scientists. We trust that our work continues to be valuable to the livestock producers in the state. Don't hesitate to offer suggestions on topics that we might address or on ways that our program can be improved.

There is not a shortage of questions that can be addressed through research. The challenge, for a department such as ours, is to strike an appropriate balance between issues that are of immediate relevance to the producers in the state and those issues that will define the very nature of livestock production 10 and 20 years into the future. We believe that our program provides a good blend of both applied and basic research.

Historically, our focus was on the improvement of productivity and productive efficiency in livestock enterprises. The issues are broader today as the very existence of livestock industries in our increasingly urban environment is challenged. We believe that many of the questions in the public debate can be addressed, and resolved, through the strong programs in biological and management science that exist in this department.

Animal feeding remains the primary market for corn and soybean products. From the perspective of long-term sustainability the argument can be made that crop and animal agriculture should be co-located so that the nutrients in livestock manure can be utilized in the production of row crops. Over the past year a number of faculty members in this department have spent time developing a concept for the relocation and rebuilding of our animal units. As we plan to vacate facilities constructed in the 1920's we are excited by the opportunity to test new concepts in housing and manure management that could become the basis for a robust animal agriculture in the 22nd century.

We continue to appreciate the support of the Illinois beef industry. Best wishes for success in the months ahead.

Dr. Robert A. Easter
Head of Department

PERFORMANCE OF NURSING CALVES FED SUPPLEMENT WITH VARYING PROTEIN LEVELS

D. B. Faulkner and F. A. Ireland

SUMMARY

Nursing steer calves on fescue pasture were used to determine the effects of supplemental feed and protein level of the supplemental feed on calf performance, subsequent feedlot performance and carcass merit. The treatments were 1) control (no creep feed), 2) a corn only creep feed, 3) a corn based creep feed with 25% soybean meal, and 4) a corn based creep feed with 48% soybean meal. During the summer creep feeding period, creep feeding improved ($P < .01$) calf gain by an average of .94 lb/d (Table 3). There was also a linear ($P < .05$) improvement in gain with increasing protein level. The final weight of the calves was increased ($P < .05$) by an average of 52 lb by creep feeding. There also tended ($P < .10$) to be a linear effect of protein level on final weight. These differences are due to the performance while consuming creep feed and the feedlot performance. There was a tendency ($P < .10$) for the creep fed calves to gain faster (.32 lb/d) in the feedlot and for a linear gain response to previous protein level. Intakes also tended ($P < .15$) to be higher for the creep fed calves. This resulted in no differences ($P > .23$) in feed efficiency during the feedlot phase. Total intake of concentrate was increased ($P < .01$) by 540 lbs for the creep fed calves compared to the non creep fed calves. No differences ($P > .21$) were observed for any of the carcass traits. The dams of creep fed steers tended ($P < .10$) to lose less weight (lb/d) than the dams of control steers. Creep feeding improved summer gain, feedlot gain, live weight, carcass weight and numerically improved carcass quality. The increased costs associated with the increased concentrate fed to the creep fed steers would be offset by the increased weight of the steers and the increased carcass merit.

INTRODUCTION

Supplementation of nursing beef calves is commonly referred to as creep feeding and traditionally consists of allowing calves unlimited access to a grain mix. Creep feeding calves has increased weight gains; however, the supplemental feed efficiencies (SFE) have been relatively poor (more than 8 kg of feed per kilogram of gain: Stricker et al., 1979: Faulkner et al., 1994). Creep feeding with corn has been shown to improve carcass merit with little influence on feedlot performance (Faulkner et al., 1994).

A response to protein has been observed for creep fed calves on warm season grasses (Lusby, 1986; Lusby and Wetterman, 1986). There is limited data on the influence of higher protein levels on calf performance on cool season grasses. The amount of supplemental protein may influence feedlot performance and carcass merit. Our objectives were to evaluate performance of calves that were creep fed with varying levels of protein.

MATERIALS AND METHODS

Eighty-four Angus x Hereford cows nursing Angus x Hereford steer calves (two breed reciprocal crossbreeding program) were allotted randomly to four treatments resulting in three replications of four treatments with seven cow-calf pairs per group. The groups were assigned randomly to 3-ha, endophyte-infected tall fescue pastures that were adjacent to each other in a large, flat, uniform area. After restriction from feed and water for 16 h, the weight of the calves and cows was measured at the beginning and end of the trial to evaluate ADG. The treatments were 1) control (no creep feed), 2) a corn only creep feed (**L**), 3) a corn based creep feed with 25% soybean meal (**M**), and 4) a corn based creep feed with 48% soybean meal (**H**) (Table 1). The supplemental diets were formulated to supply 10, 20 and 30% crude protein. The creep feed was weighed and put in a self feeder in each pasture.

Calves were weaned at 206 d of age after 61 d on creep and remained in their respective groups until slaughter (238 d in feedlot). Twenty-eight days prior to weaning the calves were vaccinated with Fermicon 7/Somungen, Vibo-5, and Elite 4 (Bio-Ceutic) and were treated for parasites with Ivomec (Merck, St. Louis, MO). At weaning they received boosters of the same vaccinations. They were implanted with Ralgro at weaning and Revalor on d 128 in the feedlot. They were adapted to a finishing ration (Table 2) over a 28 d period by removing hay from the diet in four steps. Body weight of the calves after a 16-h removal from feed and water was measured at the beginning and end of each period. Gain, intake, and feed efficiency were measured. At the conclusion of the finishing period, all calves were slaughtered and carcasses were evaluated to determine yield grade, hot carcass weight, adjusted fat thickness, marbling score, rib eye area, internal fat (kidney, pelvic, and heart), and quality grade.

Data were analyzed using pasture and feedlot pen as the experimental unit according to the GLM procedure of SAS (1985). The model included the calf performance measurements as dependent variables and replication and treatment, and their interactions as independent variables. There were no significant ($P > .15$) replication by treatment interactions. Treatment means were separated using orthogonal contrasts. They included control verses the three creep treatments and a linear and quadratic comparison of protein levels. Carcass measures were evaluated in the same way as the performance measures except that animal was used as the experimental unit.

RESULTS AND DISCUSSION

During the summer creep feeding period, creep feeding improved ($P < .01$) calf gain by an average of .94 lb/d (Table 3). There was also a linear ($P < .05$) improvement in gain with increasing protein level. These results are similar to those observed in other studies (Stricker et al., 1979; Faulkner et al., 1994). Increased growth rate by calves fed higher protein levels has also been reported on warm season grasses (Lusby, 1986).

The final weight of the calves was increased ($P < .05$) by an average of 52 lb by creep feeding. There also tended ($P < .10$) to be a linear effect of protein level on final weight. These differences are due to the performance while consuming creep feed and the feedlot performance. There was a tendency ($P < .10$) for the creep fed calves to gain faster (.32 lb/d) in the feedlot and for a linear gain response

to previous protein level. Intakes also tended ($P < .15$) to be higher for the creep fed calves. This resulted in no differences ($P > .23$) in feed efficiency during the feedlot phase. Total intake of concentrate was increased ($P < .01$) by 540 lbs for the creep fed calves compared to the non creep fed calves. These results are quite similar to those previously observed by Faulkner et al., 1994.

As expected, the carcass weights followed the same trends as the live weights previously discussed (Table 4). No differences ($P > .21$) were observed for any of the carcass traits. Despite the creep fed calves having heavier carcasses there were no differences in fat thickness. Quality grades were numerically higher for the creep fed calves and the lack of significant differences may be due to the limited number of calves on each treatment (21 head). This possible improvement in quality grade would be consistent with previous observations (Faulkner et al., 1994).

The dams of creep fed steers tended ($P < .10$) to lose less weight (lb/d) than the dams of control steers. Lusby (1986) and Lusby and Wettemann (1986) observed no influence of creep feed on dam weight change. The increase in weight change reported in this study may be the result of increased forage availability to the dams caused by a reduction in forage intake of creep fed calves (Faulkner et al., 1994). The dam response may be a function of forage availability in the studies.

Creep feeding improved summer gain, feedlot gain, live weight, carcass weight and numerically improved carcass quality. The increased costs associated with the increased concentrate fed to the creep fed steers would be offset by the increased weight of the steers and the increased carcass merit.

LITERATURE CITED

Faulkner, D. B., D. F. Hummel, D. D. Buskirk, L. L. Berger, D. F. Parrett, and G. F. Cmarik. 1994. Performance and nutrient metabolism by nursing calves supplemented with limited or unlimited corn or soyhulls. J. Anim. Sci. 72:470.

Lusby, K. S. 1986. Comparison of limit-fed high protein creep feed and free-choice grain creep for spring-born calves on native range. Oklahoma Agric. Exp. Sta. Res. Rep. MP-118:207.

Lusby, K. S., and R. P. Wettemann. 1986. Effects of limit-fed high protein creep feed or early weaning on performance of fall-born calves and their dams. Oklahoma Agric. Exp. Sta. Res. Rep. MP-118:202.

SAS. 1985. SAS User's Guide: Statistics. SAS Inst. Inc., Cary, NC.

Stricker, J. A., A. G. Matches, G. B. Thompson, V. E. Jacobs, F. A. Martz, H. N. Wheaton, H. D. Currence, and G. F. Krause. 1979. Cow-calf production on tall fescue-ladino clover pastures with and without nitrogen fertilization or creep feeding: Spring calves. J. Anim. Sci. 48:13.

Table 1. Composition of creep feed, %

	Creep diet		
	10	20	30
Cracked corn	97	72	47
Soybean meal	--	25	50
Molasses	3	3	3
% CP	9.1	18.8	28.5

Table 2. Ingredient composition of finishing diet fed to steers[c]

Ingredients	% DM basis
Cracked corn	84.0
Chopped hay	10.0
Soybean meal	3.75
Urea	.25
Limestone	1.00
Dicalcium phosphate	.50
Trace mineralized salt[a]	.50
Vitamin premix[b]	+

[a]Composition (%): NaCl, 95 to 99; Mn, >.2; Fe,>.3; Co,>.033; Zn,>.01; I>.007; Co,>.003.

[b]Composition: vitamin A, 680,400; D, 68,040; E, 4,540 USP/kg.

[c]Rumensin was at 22g/1000kg.

Table 3. Performance of steers receiving creep feed with three protein levels

	Creep feed, % CP				Contrasts (P)		
	Control	10	20	30	SE	Control vs creep	Protein level linear	Protein level quadratic
Initial wt, lb	312	315	324	322	5.0	.17	.35	.42
Wean wt, lb	366	403	436	438	6.2	.001	.01	.09
Summer gain, lb/d	.88	1.45	1.84	2.17	.20	.01	.05	.89
Creep intake, lb/d	0	5.2	5.7	5.7	.28	.001	.28	.55
Final wt, lb	1066	1079	1131	1152	22	.036	.07	.33
Feedlot gain, lb/d	3.21	3.37	3.53	3.69	.12	.06	.12	.99
Feedlot intake, lb/d	17.8	18.2	18.7	19.1	.43	.13	.17	.99
Feed/gain	5.53	5.39	5.29	5.21	.16	.23	.43	.96
Gain/feed	.181	.186	.189	.193	.006	.25	.41	.99
Total intake, lb[a]	4235	4646	4784	4896	97	.003	.11	.91

[a]Includes creep feed and all finishing diet fed on a per steer basis.

Table 4. Carcass traits of steers receiving creep feed with three protein levels

	Creep feed, % CP				Contrasts (P)		
	Control	10	20	30	SE	Control vs creep	Protein level linear	Protein level quadratic
Carcass wt, lb	663	669	702	704	.14	.09	.07	.38
REA, sq in	11.7	11.9	12.2	12.0	.23	.18	.66	.33
Backfat, in	.46	.47	.48	.48	.04	.70	.81	.90
KPH, %	2.3	2.4	2.3	2.4	.10	.72	.85	.38
Marbling score[a]	1123	1175	1143	1160	24	.21	.67	.40
% Choice	94	95	95	95	.05	.87	.97	.99
% ≥ Avg Choice	49	67	70	62	.10	.21	.75	.66
% Prime	0	9	0	9	.05	.29	.99	.11

[a]900 = Select, 1000 = Low Choice, 1100 = Average Choice.

Table 5. Dam performance of steers receiving creep feed with three protein levels

	Creep feed, % CP				Contrasts (P)		
	Control	10	20	30	SE	Control vs creep	Protein level linear	Protein level quadratic
Initial wt, lb	960	928	948	969	28	.17	.35	.42
Initial condition score[a]	4.2	4.2	4.3	4.2	.17	.92	.81	.59
Final wt, lb	899	885	907	926	25	.26	.97	.82
Final condition score	3.9	4.0	3.9	4.1	.17	.58	.70	.26
Pregnancy, %	95	85	90	85	7	.31	.95	.57
Gain, lb/d	-1.01	-.72	-.68	-.72	.14	.06	.99	.77

[a]1-9 scale (1 = very thin, 5 = average, 9 = very fat).

COMPARISON OF THREE WEANING AGES ON COW-CALF PERFORMANCE AND STEER CARCASS TRAITS

S. E. Myers, D. B. Faulkner, F. A. Ireland, and D. F. Parrett

SUMMARY

An experiment was conducted to compare three weaning ages on cow-calf performance and steer carcass traits. One hundred sixty-eight (½ Simmental × ¼ Angus × ¼ Hereford) crossbred steers were randomly assigned to three treatments with eight pens per treatment. Treatments were: 1) weaned at an average of 90 d of age (90 ± 13 d) and placed in the feedlot, 2) weaned at an average of 152 d of age (152 ± 13 d) and placed in the feedlot, and 3) weaned at an average of 215 d of age (215 ± 13 d) and placed in the feedlot. The number of days steers were finished decreased by 55 and 38 d (linear, P = .0001) as weaning age increased when harvested at a constant fat endpoint (.81 cm). Weaning at an average of 90 and 152 d of age improved overall ADG by .15 and .07 kg/d, respectively, over weaning at an average of 215 d of age (linear, P = .005). Over the entire finishing period, intake increased (linear, P = .0006) and efficiency was poorer (linear, P = .004) as weaning age increased. Due to differences in finishing days and intake, total concentrate consumed increased (linear, P = .03) as weaning age decreased. No differences (P > .21) were observed for carcass weight, longissimus muscle area, or yield grade. No differences (P > .19) were observed in marbling score, percentage of steers grading greater than or equal to Choice or Average Choice. Cow body condition score improved (linear, P = .0001) as weaning age decreased. Pregnancy rate improved 12 percentage units (linear, P = .15) for cows on the 90 d weaning treatment. In this study, early weaning improved gain and feed efficiency, but increased total concentrate consumed when compared to steers weaned at an average of 215 d.

INTRODUCTION

Economic pressures to improve production efficiency have prompted the beef cattle industry and researchers to evaluate different production systems. Maintaining pasture productivity and calf gain during midsummer is a problem for most cattle producers. Reduced calf gain is due, in part, to reduced milk consumption after the third month of lactation (Neville, 1962; Robison et al., 1978), and also to reduced productivity of pastures (Burns et al., 1983). Early weaning (Peterson et al., 1987; Myers et al., 1998) has shown promise as a means of increasing calf growth. Green and Buric (1953) concluded that 90-d weaning did not adversely affect beef calves, and the main difference between 90- and 180-d weaned groups was in rate of gain, wherein the average gain per 28-d feeding period was much more uniform for the 90-d group. This study was conducted to evaluate the effects of three weaning ages on 1) steer performance and carcass traits, and 2) cow performance, body condition score, and pregnancy rates.

MATERIALS AND METHODS

Steers and Diets. One hundred sixty-eight commercial Angus × Hereford crossbred cows (414 ± 61 kg initial weight; 129 ± 5 cm initial height; body condition score (BCS) 4 ± .65) nursing

Simmental sired steer calves (90 ± 5 kg) were used in a study at the Dixon Springs Agricultural Center, in Simpson, IL. The study was conducted from May 9, 1996 to June 25, 1997. Steers were born from January-March and nursed their dams while grazing endophyte infected tall fescue (*Festuca arundinacea* Schreb.)- red clover (*Trifolium pratense* L.) pastures until May when they were randomly assigned to one of three weaning age treatments where the steer calves were: 1) weaned at an average of 90 d of age and placed in the feedlot (**90** ± 13 d; 89 ± 9 kg), 2) weaned at 152 d of age and placed in the feedlot (**152** ± 13 d; 89 ± 3 kg), or 3) weaned at 215 d of age and placed in the feedlot(**215** ± 13 d; 93 ± 4 kg). We utilized 24 pens with 8 pens per treatment. The cows were maintained on endophyte infected tall fescue pastures for the duration of the experiment. Dams in the study were estrous synchronized and artificially inseminated by multiple sires.

Steers were vaccinated with Cattlemaster 4 + L5, and Ultrabac 7/Somubac® (Smith Kline Beecham, West Chester, PA) on the 90 d weaning. They received boosters of the same vaccinations 3 wk later. On the 152 d weaning, steers were given Cattlemaster 4 + VL5, and Ultrabac 7/Somubac® (Smith Kline Beecham). Prior to calving (January, 1996), cows received an injection of ScourGuard 3 (Smith Kline Beecham, West Chester, PA). Cows were vaccinated with an injection of Cattlemaster 4 + VL5, and Ultrabac 7/Somubac® (Smith Kline Beecham), and were treated for parasites with Ivomec® (Merck, Rahway, NJ) on the 152 d weaning.

At each of the respective weaning ages, all steers were weighed, measured at the hip, and implanted with 36 mg of zeranol (Ralgro®, Mallinckrodt Veterinary Inc., Mundelein, IL). Additionally, dams were weighed and assigned a BCS (1 to 9 scale). All individual steer and cow weights were taken without withdrawal from feed and water. Steers were implanted with 120 mg of trenbolone acetate and 24 mg of estradial (Revalor®-S, Hoechst Roussel Vet, Somerville, NJ) as a treatment 146, 132, and 104 d prior to harvest for the 90, 152, and 215 d weaning age treatments, respectively.

Beginning at the time of weaning, steers were given ad libitum access to diet one (Table 1). Chopped hay was removed from and corn gluten feed was added to the finishing diet in a stepwise fashion, and steers were adapted to their final diet within 44 d. Steers were allowed to consume the high-concentrate diet on an ad libitum basis for the remaining feeding period. Each treatment had eight pens with seven steers per pen during finishing. Steers were finished in an outdoor confinement facility with overhead shading and solid concrete floors. Pens were equipped with self feeders and automatic waterers.

Steer backfat was monitored by ultrasound. Steers were harvested at a constant fat endpoint (.81 ± .21 cm actual). Four dates were used to harvest steers at a commercial packing facility. Three additional dates were used to process nine lighter weight steers at the targeted external fat thickness. Steer hip height was recorded prior to shipping. Harvest weight was determined by dividing hot carcass weight by .61. Average daily gain, DMI, efficiency (gain/feed), and total concentrate consumed were calculated. Feed intakes are expressed as a daily average over the entire feeding period on a pen basis.

Hot carcass weights were obtained from all steers at the time of harvest. After carcasses were chilled for 24 h, the following measurements were obtained by trained University of Illinois personnel: 1) longissimus muscle area (LMA) taken by direct grid reading of the longissimus at the 12th rib, 2) subcutaneous fat over the longissimus muscle at the 12th rib (subjectively adjusted for unusual fat distribution), 3) kidney, pelvic, and heart fat estimated as a percentage of carcass weight, and 4) marbling score (USDA, 1975). Carcass measurements were used to calculate yield and quality grades.

Statistical Analysis. Feedlot performance and carcass characteristics were analyzed as a completely randomized design experiment (Steel and Torrie, 1980) using the GLM procedure of SAS (1985). Pen was the experimental unit for the performance data. Steer was the experimental unit for the carcass data. External fat thickness at harvest was used as a covariate for the analysis of both the performance and carcass characteristics.

Cow was the experimental unit for the cow performance data. All analysis were conducted using treatment as the independent variable. Treatment differences were evaluated using linear and quadratic orthogonal contrasts.

RESULTS AND DISCUSSION

Effect of Weaning Age on Calf Performance. The effects of weaning age on steer performance traits are shown in Tables 2 and 3. There were no differences ($P > .27$) in initial weight or harvest weight due to weaning age. The number of days steers were finished decreased by 55 and 38 d (linear, $P = .0001$) as weaning age increased when harvested at a constant fat endpoint. The age at harvest of the steers increased by 10 and 34 d (linear and quadratic, $P = .0001$) as weaning age increased (419, 429, and 463 d of age for the 90, 152, and 215 weaning age treatments, respectively).

Steers that were weaned at an average of 90 d exhibited .34 kg/d higher ADG (linear and quadratic, $P = .0001$) between 90 and 152 d of age than steers that were still nursing their dams. Steers weaned at an average of 90 and 152 d of age exhibited .85 kg/d higher ADG (linear and quadratic, $P = .0001$) between 152 and 215 d of age than steers weaned at an average of 215 d. Harvey et al. (1975) and Williams et al. (1975) observed differences of .18 and .29 kg between early-weaned and normal-weaned calves, respectively. Neville and McCormick (1981) reported results which indicated that spring-born, early-weaned calves had higher ADG than normal-weaned calves (noncreep-fed) from early (62 d of age) to normal (230 d of age) weaning. Lusby et al. (1981) reported no differences in calf weights between early- and normal-weaned calves (noncreep-fed) born to spring-calving, 2-yr-old cows. However, they concluded the calves needed a complete mixed diet or a better quality forage than was used to make adequate gains without milk.

There were no differences ($P > .17$) in ADG when all steers were in the feedlot. Weaning at an average of 90 and 152 d of age improved overall ADG by .15 and .07 kg/d, respectively, over weaning at an average of 215 d of age (linear, $P = .005$). These results are consistent with Myers et al. (1998) who found early weaning improved overall ADG by .07 kg/d over normal-weaned steers.

There were no differences in initial height (P > .48), or height change from 90 to 152 d of age (P > .30). Earlier weaning resulted in a linear (P = .0001) increase in height change between 152 and 215 d of age. From 215 to 438 d of age there was a linear (P = .02) decrease in height change. No differences (P > .21) in overall height change were observed due to weaning age. These results are consistent with Myers et al. (1998).

Steers weaned at an average of 90 d of age consumed 3.39 kg/d and exhibited gain:feed ratio of .325 units prior to 152 d of age. During 152 to 215 d of age, intake for the steers weaned at an average of 90 and 152 d of age were 6.19 and 5.58 kg/d (linear, P = .04), respectively. Treatment did not affect efficiency (P = .15) during this time period. Harvey et al. (1975) used equal numbers of steer and heifer calves and found that feed efficiency (feed:gain) from 150 to 234 d of age was 5.67 for early-weaned calves. Williams et al. (1975), using only bull calves, reported a feed efficiency of 4.56 (feed:gain) from 106 to 205 d of age for early-weaned calves. Intake and efficiency were similar (P > .32) among treatments after d 215 of age. Over the entire feedlot period, intake increased (linear, P = .0006) and efficiency (gain:feed) was poorer (linear, P = .004) as weaning age increased. From 215 to 438 d of age, steers consumed 1.9, 2.0, and 2.2% of body weight for the 90, 152, and 215 d weaning age treatments, respectively. This may help explain some of the differences observed in efficiency overall. Although these intakes are lower than typical feedlot cattle, they are consistent with Fox et al. (1988) which suggested a 10% decrease in predicted DMI by cattle started on feed as calves compared with cattle started on feed as yearlings. Due to differences in finishing days and intake, total concentrate consumed increased (linear, P = .03) as weaning age decreased.

Carcass Evaluation. The effects of weaning age on carcass quality traits are shown in Table 4. No differences (P > .23) were observed for carcass weight, percentage of carcasses under 250 kg, or LMA. Kidney, pelvic, and heart fat tended (linear, P = .14) to increase as weaning age increased. No differences (P > .21) were observed for yield grade, except for the percentage of yield grade 3 carcasses which were lower (quadratic, P = .02) for the steers weaned at an average of 152 d. Eighty-seven percent of the steers had a yield grade of 2.9 or below, with an average yield grade of 2.4.

No differences (P > .19) were observed in marbling score, percentage of steers grading greater than or equal to Choice or Average Choice. Over 90% of the steers in all three treatments graded Choice or higher. In an experiment by Myers et al. (1998), early weaning improved marbling score (1,100 = Modest^{00}) by 66 units over normally weaned (with and without creep feed) Angus × Hereford crossbred steers. Similar results were also observed using Simmental crossbred and Wagyu crossbred steers. However, in that experiment steers were harvested at .30 cm more external fat thickness than those in this study.

Health of Steers. A quadratic response was observed for the percentage of morbidity-respiratory steers treated (P = .004) and morbidity-digestive steers treated (P = .04, Table 5). The steers weaned at an average of 90 d had not received a vaccination prior to weaning, which could explain the high percentage of morbidity-respiratory treated steers. The high percentage of morbidity-respiratory for the steers weaned at an average of 215 d may be attributed to effects of weather. In the 30 days after weaning for each treatment, steers weaned at an average of 215 d had a

maximum daily variation that was 5.6° C higher and had an average of 1.7° C more daily variation compared to steers weaned at an average of 90 or 152 d of age. A similar response for morbidity-respiratory was observed by Myers et al. (1998) for steers early and normal weaned compared to steers weaned at an average of 152 and 215 d in this study. No differences ($P > .15$) were observed between treatments for the percentage of mortality-respiratory, mortality-digestive, or mortality-unknown. One steer on the 90 d treatment died of polio. Two steers died on the 152 d treatment, one due to respiratory problems and one due to unknown reasons. Three steers died on the 215 d treatment, two due to respiratory problems, and one due to an injury.

Effect of Weaning Age on Cow Performance. The effects of weaning age on cow performance are shown in Table 6. Initial weights and weights 152 d postpartum were similar ($P > .47$) among treatments. Cow weight, at 215 d postpartum, was increased linearly ($P = .01$) as weaning age decreased. Higher ADG (linear and quadratic, $P < .0003$) were observed between 90 and 152 d postpartum for those cows whose calves were weaned at an average of 90 d of age. Early weaning improved ADG between 152 and 215 d postpartum (linear, $P = .0001$) as weaning age decreased. The ADG from 90 to 215 d postpartum increased (linear and quadratic, $P > .003$) as weaning age decreased. These differences were reversed (linear, $P = .006$) from d 215 to 375 postpartum, but some of the difference in ADG still remained. Myers et al. (1998) also reported that cows with early weaned steers improved ADG by .53 kg/d over cows with normal weaned calves (creep and noncreep fed).

There were no differences ($P > .32$) in initial BCS due to weaning age. Weaning at an average of 90 d improved cow BCS at 152 d postpartum (linear and quadratic, $P = .05$). The BCS improved (linear, $P = .0001$) as weaning age decreased. Weaning at an average of 90 d increased BCS change (linear and quadratic, $P < .009$) from 90 to 152 d postpartum. The BCS change decreased (linear, $P = .0001$) as weaning age increased between 152 and 215 d postpartum. The BCS change from 90 to 215 d postpartum increased (linear and quadratic, $P > .09$) as weaning age decreased. Myers et al. (1998) gave further evidence that early weaning improved BCS compared to cows with normal weaned steers (creep and noncreep fed). These differences were reduced (linear and quadratic, $P < .07$) from d 215 to 375 postpartum, but some of the difference in BCS still remained. The BCS changes agreed with changes in ADG.

Peterson et al. (1987) reported that cows with early-weaned calves gained 2.5 kg, while cows with normal-weaned calves lost 18.2 kg between early and normal weaning. Cows with normal-weaned calves lost body weight and condition due to the greater energy requirements for lactation as compared with early-weaned cows. The lactating cows did not consume enough feed to meet their energy requirements for lactation; thus, body stores were utilized. The cows with early-weaned calves consumed enough feed to meet energy requirements for maintenance and weight gain.

Pregnancy rate improved by 18% (linear, $P = .15$) for cows on the 90 d weaning treatment. Pregnancy results were similar for the 152 and 215 d treatments which would be expected since the calves were removed after the breeding season. Laster et al. (1973) reported that weaning prior to the breeding season increased overall conception by 25.9% in 2-yr-old cows, 15.6% in 3-yr-olds, and 7.9% in cows 4 yr old and older.

In a study by Smith and Vincent (1972), calves were early-weaned at 30 d of age. The breeding period on pasture for the dams and dams nursing their calves began at that time and continued for 70 d. Dams of early-weaned calves had a higher pregnancy rate and a shorter interval from parturition to conception than dams that nursed their calves. In a study by Laster et al. (1973), calves were early weaned at 57 d of age and cows began a 42-d breeding period 1 wk after early weaning. Dams of early weaned calves had an overall higher conception rate than dams nursing calves; conception rate was higher for 2 yr olds than for mature dams. However, among the cows bred, the interval from calving to conception was not affected by early weaning but was affected by breed of cow and calving date.

CONCLUSIONS

Early weaned steers increased number of days in the feedlot, reduced harvest age, improved gain, improved feed efficiency, and reduced daily intake, but increased total concentrate consumed compared to weaning at an average of 215 days of age. Cow gain, body condition score and subsequent pregnancy rate were improved by early weaning.

LITERATURE CITED

Burns, J. C., R. W. Harvey, F. G. Giesbrecht, W. A. Cope, and A. C. Linnerud. 1983. Central Appalachian hill land pasture evaluation using cows and calves. III. Treatment comparisons of per animal and hectare responses. Agron. J. 75:878-885.

Fox, D. G., C. J. Sniffen, and J. D. O'Connor. 1988. Adjusting nutrient requirements of beef cattle for animal and environmental variation. J. Anim. Sci. 66:1475-1495.

Green, W. W., and J. Buric. 1953. Comparative performance of beef calves weaned at 90 and 180 days of age. J. Anim. Sci. 12:561-572.

Harvey, R. W., J. C. Burns, T. N. Blumer, and A. C. Linnerud. 1975. Influence of early weaning on calf and pasture productivity. J. Anim. Sci. 41:740-746.

Laster, D. B., H. A. Glimp, and K. E. Gregory. 1973. Effects of early weaning on postpartum reproduction of cows. J. Anim. Sci. 36:734-740.

Lusby, K. S., R. P. Wettemann, and E. J. Turman. 1981. Effects of early weaning calves from first-calf heifers on calf and heifer performance. J. Anim. Sci. 53:1193-1197.

Myers, S. E, D. B. Faulkner, F. A. Ireland, L. L. Berger, and D. F. Parrett. 1998. Production Systems Comparing Early Weaning to Normal Weaning With or Without Creep Feeding for Beef Steers. J. Anim. Sci. 76(In press).

Neville, W. E., Jr. 1962. Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J. Anim. Sci. 21:315-320.

Neville, W. E., Jr., and W. C. McCormick. 1981. Performance of early- and normal-weaned beef calves and their dams. J. Anim. Sci. 52:715-724.

Peterson, G. A., T. B. Turner, K. M. Irvin, M. E. Davis, H. W. Newland, and W. R. Harvey. 1987. Cow and calf performance and economic considerations of early weaning of fall-born beef calves. J. Anim. Sci. 64:15-22.

Robison, O. W., M.K.M. Yusuff, and E. U. Dillard. 1978. Milk production in Hereford cows: I. Means and correlations. J. Anim. Sci. 47:131-141.

SAS. 1985. SAS User's Guide: Statistics (Version 5 Ed.). SAS Inst. Inc., Cary, NC.

Smith, L. E., Jr., and C. K. Vincent. 1972. Effects of early weaning and exogenous hormone treatment on bovine postpartum reproduction. J. Anim. Sci. 35:1228-1232.

Steel, R.G.D., and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach (2nd Ed.). McGraw-Hill Publishing Co., New York.

USDA. 1975. Official United States standards for grades of carcass beef. USDA Food Safety and Quality Serv., Washington, DC.

Williams, D. B., R. L. Vetter, W. Burroughs, and D. G. Topel. 1975. Effects of ration protein level and diethylstilbestrol implants on early-weaned beef bulls. J. Anim. Sci. 41:1525-1531.

Table 1. Composition of finishing diets fed to steers

	Diet sequence, %[a]				
Ingredient	1	2	3	4	5
Cracked corn	48.70	51.49	53.97	55.07	65.90
Soybean meal	18.44	16.03	13.56	10.76	- -
Chopped hay	30.43	20.41	10.20	- -	- -
Corn gluten feed	- -	10.20	20.40	29.83	29.80
Limestone	1.13	1.13	1.13	1.10	1.10
Trace mineralized salt[b]	.56	.56	.56	.55	.55
Potassium chloride	.56	.56	.56	.55	.55
Nutra-max plus (molasses)	- -	- -	- -	1.94	1.94
Thiamine, 16,000 mg/kg	.10	.10	.10	.10	.10
Rumensin-60[c]	.02	.02	.02	.01	.01
Tylan-10[d]	.05	.05	.05	.05	.05
Vitamin A, IU/kg	603	603	603	787	787
Feed Analysis					
Crude Protein, %	16.79	17.64	18.33	18.51	13.69
NE_M, Mcal/kg	.36	.38	.41	.42	.42
NE_G, Mcal/kg	.23	.25	.27	.28	.29

[a]DM basis.

[b]Composition (%): NaCl (82 to 87), Fe (≥2.85), Zn (≥2.30), Mn (≥.22), Cu (≥.20), I (≥.01), Se (≥.0086).

[c]Contains 132 g of monensin/kg.

[d]Contains 22 g of tylosin/kg.

Table 2. Effects of three weaning ages on steer performance[ab]

Item	Weaning age, d			SEM[d]	P = Contrast[c]	
	90	152	215		L	Q
No. of pens	8	8	8			
Initial wt, kg	89	89	93	3	.44	.47
Harvest wt[e], kg	476	460	462	9	.36	.27
Days in feedlot	335	280	242	7	.0001	.20
ADG, kg						
90-152 d of age	1.09	.75	.73	.03	.0001	.0001
152-215 d of age	1.60	1.53	.72	.05	.0001	.0001
215-438 d of age	1.05	1.05	1.15	.04	.17	.19
Overall	1.16	1.08	1.01	.03	.005	.89
Initial ht, cm	86.4	86.2	87.3	.87	.53	.48
Height change, cm						
90-152 d of age	6.0	7.0	7.2	.7	.30	.58
152-215 d of age	14.4	11.2	7.6	.6	.0001	.61
215-438 d of age	18.6	22.5	24.6	1.4	.02	.48
Overall	39.0	40.7	39.4	1.3	.88	.21

[a]Least squares means.
[b]External fat thickness was used as a covariate (mean = .81 cm).
[c]P value of a linear (L) and quadratic (Q) affect of treatment.
[d]Greatest standard error of treatment means (SEM) reported.
[e]Calculated as hot carcass weight/.61.

Table 3. Effects of three weaning ages on steer performance[ab]

Item	Weaning age, d			SEM[d]	P = Contrast[c]	
	90	152	215		L	Q
No. of pens	8	8	8			
DMI, kg/d[e]						
90-152 d of age	3.39	--	--	.10	--	--
152-215 d of age	6.19	5.58	--	.17	.04	--
215-438 d of age	6.80	6.88	7.19	.25	.32	.55
Overall	5.90	6.53	7.19	.19	.0006	.93
Gain/feed[e]						
90-152 d of age	.325	--	--	.01	--	--
152-215 d of age	.260	.281	--	.009	.15	--
215-438 d of age	.155	.154	.160	.007	.66	.57
Overall	.195	.178	.160	.006	.004	.99
Total conc., kg/hd[f]	1,984	1,826	1,758	58	.03	.41

[a]Least squares means.
[b]External fat thickness was used as a covariate (mean = .81 cm).
[c]P value of a linear (L) and quadratic (Q) affect of treatment.
[d]Greatest standard error of treatment means (SEM) reported.
[e]Greatest standard error of treatment means (SEM) reported.
[f]Total concentrate, during finishing phase.

Table 4. Effects of three weaning ages on carcass quality[ab]

	Weaning age, d				P = Contrast[c]	
Item	90	152	215	SEM[d]	L	Q
No. of steers	55	53	50			
Carcass wt, kg	288	287	285	5	.69	.96
≤250 kg, %	5	10	11	4	.29	.69
LMA[e]						
Sq cm	78.0	77.6	79.1	1.18	.50	.49
Sq cm/kg HCW[f]	.27	.27	.28	.01	.23	.45
Est. KPH[g], %	2.7	2.8	2.9	.1	.14	.69
Avg. Yield grade	2.45	2.33	2.39	.06	.50	.21
Yield grade 1, %	15	21	22	5	.37	.63
Yield grade 2, %	66	74	64	7	.88	.27
Yield grade 3, %	19	5	14	4	.39	.02
Marbling score[h]	1,140	1,121	1,115	15	.24	.69
≥Choice, %	98	96	92	3	.19	.76
≥Avg. Choice, %	65	53	56	7	.38	.34
≥Prime, %	11	9	6	4	.37	.84

[a]Least squares means.
[b]External fat thickness was used as an covariate (mean = .80 cm).
[c]P value of a linear (L) and quadratic (Q) affect of treatment.
[d]Greatest standard error of treatment means (SEM) reported.
[e]Longissimus muscle area.
[f]Hot carcass weight.
[g]Kidney, pelvic, heart fat.
[h]1,100 = Modest[00].

Table 5. Health of steers weaned at three ages[a]

	Weaning age, d				P = Contrast[b]	
Item	90	152	215	SEM[c]	L	Q
Morbidity-respiratory, %	25	6	22	.05	.70	.004
Morbidity-digestive, %	7	0	7	.05	.95	.04
Mortality-respiratory, %	0	2	4	.03	.15	.99
Mortality-digestive, %	2	0	0	.02	.23	.49
Mortality-unknown, %	0	2	2	.02	.38	.62

[a]Least squares means.
[b]P value of a linear (L) and quadratic (Q) affect of treatment.
[c]Greatest standard error of treatment means (SEM) reported.

Table 6. Effects of three weaning ages on cow performance[a]

Item	Weaning age, d			SEM[c]	P = Contrast[b]	
	90	152	215		L	Q
No. of cows	53	55	54			
Initial wt, kg	411	418	417	8	.54	.59
d 152[d] wt, kg	414	404	408	8	.58	.47
d 215[d] wt, kg	459	439	432	8	.01	.47
ADG, kg						
d 90-152[d]	.05	-.22	-.15	.04	.0003	.0002
d 152-215[d]	.72	.56	.38	.03	.0001	.98
d 90-215[d]	.39	.17	.12	.03	.0001	.003
d 215-375[de]	-.08	-.02	.04	.03	.006	.82
Initial BCS[f]	4.2	4.3	4.2	.09	.86	.32
d 152[d]	4.4	4.1	4.2	.09	.04	.05
d 215[d]	4.9	4.5	4.2	.08	.0001	.30
BCS change						
d 90-152[d]	.12	-.23	-.08	.08	.09	.009
d 152-215[d]	.53	.39	.07	.08	.0001	.35
d 90-215[d]	.67	.16	.00	.09	.001	.09
d 215-375[de]	-.66	-.22	-.33	.13	.06	.07
Pregnancy, %	79	67	67	6	.15	.45

[a]Least squares means.
[b]P value of a linear (L) and quadratic (Q) affect of treatment.
[c]Greatest standard error of treatment means (SEM) reported.
[d]Postpartum.
[e]Only pregnant cows (subsequent calving day of 375, ± 20 d, n = 111).
[f]Body condition score (1=emaciated, 9=extremely fat).

PERFORMANCE AND CARCASS TRAITS OF EARLY WEANED STEERS RECEIVING EITHER A PASTURE GROWING PERIOD OR A FINISHING RATION AT WEANING

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SUMMARY

A 2-yr study was conducted to evaluate 1) steers fed ad libitum high concentrate after weaning (CONC), or 2) steers grown on pasture for 82 d, followed by high concentrate finishing (PAST) on the performance and carcass traits of 74 early weaned (117 d of age) steers. Potential breed differences were evaluated using steers of three different breed types: 1) ¾ Angus × ¼ Simmental (BRI), 2) ¾ Simmental × ¼ Angus (CON), and 3) ½ Wagyu × ¼ Angus × ¼ Simmental (WAG) crossbred. Steers were randomly assigned within breed to the two treatments. There was no interactions (P > .10), so the data were pooled over years. The CONC steers had .17 kg/d higher ADG (P = .0001), 1.09 kg/d lower intake (P = .0001), and .013 units better gain:feed (.190 vs .177, P = .008) than PAST steers overall. Growing treatment did not affect total concentrate consumed (P = .97). The BRI steers required 31 fewer d than CON steers (P = .008), and 23 fewer d than WAG steers (P = .05) when fed to a constant fat endpoint (1.1 cm). The BRI steers exhibited .16 kg/d higher ADG (P = .0003), tended (P = .07) to have .49 kg/d higher intake, and exhibited .01 units better gain:feed (.189 vs 180) than WAG steers. When compared to CON steers, BRI steers consumed 310 kg less total concentrate (P = .0003). No differences (P > .38) were observed between growing treatments for carcass characteristics or sensory attributes except, CONC steers tended (P = .11) to improve percentage of steers grading Average Choice or higher by 47% over PAST steers. The WAG steers had a 76 unit higher marbling score (1,000 = Small^{00}, 1,100 = Modest^{00})(P = .006) than BRI steers resulting in 19% more (P = .09) steers grading ≥ to Choice, and 82% more (P = .03) grading ≥ to Average Choice. Liver (P = .15) and rumen (P = .01) weights as a percentage of hot carcass weight were reduced for CONC steers. The CONC steers had higher gain, lower intake, better efficiency, reduced liver and rumen weights, and consumed the same amount of total concentrate when compared to PAST steers. The BRI steers had less finishing days and lower daily intake compared to CON steers. The WAG steers had more days finishing, lower gain, lower intake, more undesirable efficiencies, consumed the same amount of total concentrate, and improved quality grades compared to BRI steers.

INTRODUCTION

Economic pressures to improve production efficiency have prompted the beef cattle industry and researchers to evaluate the performance of different biological types of cattle and methods to produce cattle that result in higher quality grade. Feeding grain diets to cattle is generally considered to result in meat that is more tender, flavorful, and juicy than forage-fed cattle.

Early weaning systems have been utilized when available feed is of poor quality, when grazing forages with a short growing season, when cows are milking poorly, when calves are nursing first calf heifers, during periods of drought, when there is a feed shortage, or in late calving herds. Robison et al.

(1978) and Bartle et al. (1984) concluded that, after 2 to 4 mo of lactation, cows were producing insufficient milk to meet the calves energy requirements.

Some researchers have reported that composition of carcasses is similar whether cattle are fed a grain-based diet immediately after weaning or after a period of slower growth (Ridenour et al., 1982). Other investigators have indicated, however, that nutrition impacts carcass composition (Dikeman et al., 1985a).

A great deal of interest currently exists in beef eating quality. Tenderness is generally regarded as the most important sensory characteristic affecting palatability of beef, although juiciness and flavor are also important. Tenderness differences in beef are likely associated with a number of factors such as: amount of intramuscular fat, sarcomere length, collagen content, size and type of muscle fibers, and enzymatic activity involved in postmortem aging (Whipple et al., 1990). Cover et al. (1956) and Palmer et al. (1958) found a low correlation between marbling and tenderness.

Altering feed intake and protein concentration in the diet may alter visceral organ mass. Changes in visceral organ mass may then change the energy and protein available for gain and efficiency of gain. Tissues of the viscera, namely liver and gut, have been estimated to account for 40 to 50% of total body heat production (Webster, 1981) and compose only 6 to 10% of body weight (Burrin et al., 1990). Studies have demonstrated that changes in maintenance energy requirements are closely correlated to size of metabolically active visceral organs (Koong et al., 1982; Ferrell and Koong, 1986). The objectives of the present study were to determine the effects of feeding a high concentrate diet to steers after weaning versus a growing period on pasture and then a high concentrate diet on performance, carcass and meat quality, and evaluation of three breed types in these two production systems.

MATERIALS AND METHODS

Steers and Diets. The 2-yr experiment was conducted at the University of Illinois Beef Research Unit in Urbana. The first year the trial was conducted from June 29, 1995 through June 13, 1996 and the second year from June 19, 1996 through June 27, 1997. A total of 74 spring born (January-April) steers calves were early weaned (117 ± 23 d) and fed a high energy diet prior to trial initiation. Steers were randomly assigned within breed type to one of two treatments where the steers were: 1) fed ad libitum high concentrate after weaning (**CONC**), or 2) grown on pasture for 82 d, followed by high concentrate finishing (**PAST**). Twenty-six ¾ Angus × ¼ Simmental (**BRI**, 140 ± 34 kg), 24 ¾ Simmental × ¼ Angus (**CON**, 158 ± 18 kg), and 24 ½ Wagyu × ¼ Angus × ¼ Simmental (**WAG**, 142 ± 28 kg) crossbred steers were utilized to evaluate potential breed type differences. The steers used in this study were from at least eight different sires of each breed type.

In yr 1, steers were ear-tagged with Cutter Blue insecticide tags (Miles, Shawnee Mission, KS), treated for parasites with Ivomec® (Merck, Rahway, NJ), and vaccinated with One Shot®, Ultrabac 7/Somubac®, Bov Eye® (Smith Kline Beecham, West Chester, PA), Fermicon 7/Somnugen (Bio-Ceutic, St. Joseph, MO), Pyramid MLV 4 (Fort Dodge, Fort Dodge, IA), and Vision® 7 Somnus (Bayer Corporation, Shawnee Mission, KS) at weaning. Steers then received boosters of the same vaccinations 2 wk later. In yr 2, the steers were vaccinated with One Shot®, Bovi Shield 4®, Bov

Eye® (Smith Kline Beecham), and Vision® 7 Somnus (Bayer Corporation) at weaning. Steers then received boosters of the same vaccinations 3 wk later. In yr 2, following the 82 d growing period, steers were given TSV-2, Cattle Master IBR PI_3 BRSV (Smith Kline Beecham), and were treated for parasites with Ivomec® (Merck).

At 127-d of age, steers were assigned to their respective treatment, weighed, measured at the hip, and implanted with Synovex®-C (100 mg of progesterone and 10 mg of estradiol benzoate; Syntex, Palo Alto, CA). The CONC steers were separated into two pens and were allowed an adjustment period of 28 d during which the corn level was gradually increased to 77%. Diet composition is shown in Tables 1 and 2. The PAST steers were rotated three times on endophyte infected tall fescue (*Festuca arundinacea* Schreb.), Smooth bromegrass (*Bromus inermis* Leyss.), and orchardgrass (*Dactylis glomerata* L.) pastures through d 127 to 208. Those steers were also supplemented with .91 kg of cracked corn per head daily. All individual calf weights were taken without withdrawal from feed and water.

At 208 d of age, steers were weighed, measured at the hip, and implanted with Synovex®-S (200 mg of progesterone and 20 mg of estradiol benzate; Syntex, Palo Alto, CA). The PAST steers were separated into two pens and were allowed an adjustment period of 28 d in which the corn level of the finishing ration was gradually increased to 77%. From this point until the end of the trial both treatments were fed the same diet. Steers were finished in an open sided barn on solid-floor pens. Pens were bedded and were equipped with automatic waterers. Steers were implanted with Synovex®-S (200 mg of progesterone and 20 mg of estradiol benzate; Syntex) on d 292 of the trial.

Pinpointer 4000B (UIS Corp., Cookeville, TN) feeding devices or "imitation" pinpointer feeding devices were used to measure individual feed intakes (DeHaan et al., 1990). The "imitation" feeders had the same dimensions as the pinpointer feeders, allowing only one steer to eat at any one time, but did not possess the electronic scales. Steers were rotated between the two types of feeders at 2-wk intervals. Individual feed intakes were recorded using the pinpointer feeders, and pen feed intakes were recorded from the "imitation" feeders during the 2-wk periods. Individual feed intakes from "imitation" feeders were then estimated by calculating the individual's percentage intake of pen intake from pinpointer feeders. This percentage was then multiplied by pen intake from "imitation" feeders (DeHaan et al., 1990).

Steer backfat was monitored by ultrasound. Steers were slaughtered at a constant fat endpoint (1.1 cm ± .33 actual). Final weights and hip heights were taken. Harvest weight was determined by dividing hot carcass weight by .61. No differences in dressing percent were observed due to treatment ($P > .05$). The weights from d 127, 208, and 413 were used to calculate the performance of steers during those time periods. Average daily gain and efficiency (gain/feed) were calculated.

Steers were processed at the University of Illinois Meats Laboratory. Hot carcass weights were obtained from all steers at the time slaughter. After the carcasses were chilled for 24 h, the following measurements were obtained by trained University of Illinois personnel: 1) longissimus muscle area (**LMA**) taken by direct grid reading of the longissimus at the 12th rib, 2) subcutaneous fat over the longissimus muscle at the 12th rib (subjectively adjusted for unusual fat distribution), 3) kidney,

pelvic, and heart fat estimated as a percentage of carcass weight, and 4) marbling score (USDA, 1975). Carcass measurements were used to calculate yield and quality grades.

Meat Quality Measurements. Meat quality assessments were made by removing the 9-10-11 rib cut from the left side of each carcass according to the procedure of Hankins and Howe (1946). All removed sections were collected and frozen (-20°C) and stored until all steers from that respective year had been processed. The remaining portion of the longissimus (12th rib area) was vacuum-packaged, and aged at 4°C until 14 d postmortem, then frozen at -20°C until shear force and sensory evaluation could be completed. The 9-10-11 rib cut portions were thawed at 4°C and deboned. Weights of the bones, and lean and fat tissue were recorded. The fat and lean tissue was then ground in a bowl mixer. Subsamples were taken and frozen (-20°C) for subsequent chemical analysis. Samples were used to determine the percentage of protein, fat, and moisture contents.

Proximate analysis procedures for fat and water contents were conducted on the 9-10-11 rib subsamples using the procedures described by Novakofski et al. (1989). All samples were oven dried (110°C for 24 to 48 h). Fat was extracted using an azaeotropic mixture of warm chloroform and methanol (4:1). Two samples of every 9-10-11 rib subsample were also assayed for protein using a Kjeldahl procedure (AOAC, 1992).

Two steaks, 2.5 cm thick, from the ribeye roll were cut with a band saw for shear force and sensory evaluation. Steaks were individually wrapped in paper and frozen at -20°C until the analyses could be completed. Steaks for shear force determination were thawed for 24 h at 4°C and then cooked on a Farberware open-hearth grill (model 155N, Walter Kidde, Bronx, NY) to an internal temperature of 70°C. Temperature was monitored using copper Constantan thermocouples and a recording thermometer (Campbell Scientific, Logan, UT). Steaks were weighed before and after cooking to determine cooking loss. Steaks were cooled to 25°C and six 1.3-cm diameter cores were removed parallel to the meat fibers. Shearing was accomplished with an Instron model 1122 Universal Testing Machine (Instron, Cantaon, MA) fitted with a Warner-Bratzler shear attachment. The full scale load was set at 10 kg, and the chart drive and crosshead speeds were 200 mm/min. Shear force steaks were cooked, cored, and sheared the same day. Mean shear force was calculated from the six cores.

Steaks for sensory evaluations were prepared and cooked using the same procedures as for shear force. Six panelists consisting of faculty and graduate students at the Meat Science Laboratory were trained according to the procedures for sensory evaluation described by the American Meat Science Association (1978). Panelists evaluated juiciness, tenderness, and off-flavor intensity using a 15-cm structured line scale with anchors and a midpoint (0 cm = extremely dry, tough, and intense off-flavor to 15 cm = extremely moist, tender, and no off-flavor). Water was provided to panelists to cleanse the palate. Each judge scored the meat samples while in the confines of an individual booth that was illuminated with red light. Order of taste panel steaks was at random, and each treatment and breed was represented once each tasting session (five total each yr).

Visceral Measurements. To compare visceral organ mass between treatments, weights of visceral tissues were obtained on the CON steers in yr 2 of the study (n = 14). Internal organs were removed from the abdominal (viscera) and thoracic cavity (pluck). Digestive contents and adhering adipose tissue were removed from the gastrointestinal tract before weighing the stomach complex

(reticulorumen, omasum, and abomasum) and lower tract (duodenum through anus). Weights of the entire digesta-free gastro-intestinal tract (separated into reticulorumen, omasum, abomasum, small and large intestine), liver, spleen, heart, lungs with trachea, and adipose tissue were recorded.

Statistical Analysis. Feedlot performance and carcass characteristics were analyzed using the GLM procedure of SAS (1985). Steer was the experimental unit for performance, carcass data, and meat quality. The model included year, treatment, breed, and their interactions as independent variables. There was no interactions (P > .10), so the data were pooled over years. Breed means were compared (orthogonal contrasts; Steel and Torrie, 1980) by the following contrasts: 1) BRI vs CON, and 2) BRI vs WAG.

The model for visceral organ mass included treatment as an independent variable and external fat thickness as a covariate.

RESULTS AND DISCUSSION

Effect of Growing Treatment on Steer Performance. No differences (P = .45) were observed between growing treatments for initial and slaughter weights (Table 3). The CONC steers were fed 46 more d than PAST steers (P = .0001). Duckett et al. (1993) reported that intramuscular fat deposition seemed to be a function of the number of d that cattle are exposed to a high-concentrate diets. Duckett et al. (1993) found that approximately 112 d on a high-concentrate diet was needed for yearling, British-cross steers to reach Choice quality grade. Steers in this experiment were fed 268 and 222 d for the CONC and PAST treatments, respectively. Lunt and Orme (1987) stated that fat thickness, rather than weight, is the most important factor in determining slaughter readiness. This is because when cattle are grown at an accelerated pace, adipose tissue accretion is greater than that observed in cattle grown at a slower rate (Lunt and Orme, 1987). Therefore, to obtain the same carcass composition, cattle which are fed an energy-dense diet soon after weaning would need to be slaughtered at a lighter weight than cattle which are fed on forage for a period of time prior to finishing (Lunt and Orme, 1987). This may be true for calves weaned at about 205 d of age but it is not consistent with our results on early weaned steers. The CONC steers were 37 d younger (P = .0002) than PAST at slaughter, 394 and 431 d, respectively.

The CONC steers exhibited .85 kg/d higher ADG (P = .0001) than PAST steers prior to 208 d of age. Lancaster et al. (1973) conducted a 194-d feeding trial to compare the feedlot performance of 205-d-old calves placed directly on a high concentrate finishing ration with calves allowed a growing period of 76 d before being placed on the finishing ration. At the end of the 76-d growing period, the steers on the high concentrate finishing ration were 19.5 kg heavier and had gained .28 kg/d more than the steers on the high roughage grower ration. The PAST steers had .12 kg/d higher ADG (P = .008) than CONC steers after d 208. Lancaster et al. (1973) observed similar results and reported that the grower ration steers had a .18 kg advantage in average daily gain, which resulted in typical compensatory growth characteristics being exhibited by the steers previously fed the grower ration. The CONC steers had .17 kg/d higher ADG (P = .0001) overall. Oltjen et al. (1971) reported that steers fed a forage diet initially did not sufficiently out gain steers on a continuous high concentrate diet when both groups were on a high concentrate diet to compensate for the differences in ADG that

occurred initially. Thus, the steers on a continuous high concentrate diet in their study showed a slight advantage in ADG over the entire feeding trial.

No differences (P = .57) were observed for initial height between growing treatments. CONC steers had 2.8 cm more height change (P = .0001) than PAST prior to 208 d. Lancaster et al. (1973) observed similar results, as change in wither height during the first period was 1.57 cm more for the steers on the finishing ration, and suggested that structural growth occurred at a faster rate on the finishing ration than on the grower ration. However, PAST steers had 2.2 cm more height change (P = .01) than CONC steers after 208 d. No differences (P = .44) due to growing treatment was observed in height change overall.

The feedlot performance of CONC steers from 127 to 208 d of age shows that young calves are extremely efficient (Table 4). Steers consumed 4.58 kg/d and exhibited a gain:feed ratio of .287. Intake was not affected (P = .51) by growing treatment between 208 and 413 d of age, but PAST steers had .012 units (gain:feed) better feed conversions (P = .009) compared to CONC steers. From 208 to 413 d of age, steers consumed 1.7, and 1.9% of body weight for the CONC and PAST treatments, respectively. This may help explain some of the differences observed in efficiency overall. Although these intakes are lower than typical feedlot cattle, they are consistent with Fox et al. (1988) which suggested a 10% decrease in predicted DMI by cattle started on feed as calves compared with cattle started on feed as yearlings. Lipsey et al. (1978) and Loveday and Dikeman (1980) report this may have been due to the fact that CONC steers had higher maintenance-energy requirements and greater requirements for depositing tissue because they were heavier and were depositing more fat. However, Lancaster et al. (1973) reported that accelerated steers were more efficient than conventional steers. Overall, CONC steers had 1.09 kg/d lower intake (P = .0001) and .01 units better feed conversion (P = .008) than PAST steers. Lancaster et al. (1973) indicated that steers on the finishing ration were slightly more efficient in terms of converting feed to weight gain. Feeding steers concentrate from 127 d of age did not affect total concentrate consumed (P = .97).

Effect of Breed Type on Steer Performance. The effects of breed type on performance traits are shown in Tables 5 and 6. The CON steers were 18 kg heavier (P = .02) than the BRI steers on d 127 of age, and 66 kg heavier at slaughter (P = .0001). There were no differences (P > .31) in initial and slaughter weights between the BRI and WAG steers.

Differences (P < .05) existed between breed types for the number of days steers were fed the finishing diet (Table 5). BRI steers required 31 fewer days than CON steers (P = .008), and 23 fewer d than WAG steers (P = .05) when fed to a fat constant endpoint. Greene et al. (1989) found that only approximately 65 d were needed for purebred Angus steers to reach Choice grade, whereas Zinn et al. (1970) reported that 210 d were necessary for purebred Hereford steers fed an 80% concentrate diet to reach Choice grade. The BRI steers were 44 d younger than CON (P = .0003), and 47 d younger than WAG steers (P = .0002) when slaughtered at a fat constant endpoint (382, 426, and 429 d for BRI, CON, and WAG steers, respectively).

The ADG from 127 to 208 d of age was not affected (P > .12) by breed type. The ADG between BRI and CON steers was not different (P > .58) from 208 to 413 d of age or overall. However, breed type influenced ADG between BRI and WAG steers. The BRI steers had .19 kg/d higher ADG (P

= .0007) than WAG steers after 208 d of age. Similar results were observed for overall ADG as BRI steers exhibited .16 kg/d higher ADG (P = .0003) than WAG steers. The results are consistent with Myers et al. (1998).

The BRI steers were 4.5 cm shorter (P = .0005) than CON steers on d 127 of age. No differences (P = .44) were observed for height change between BRI and CON steers throughout the experiment. However, breed type did affect height change between BRI and WAG steers differently during the two phases. The WAG steers tended (P = .06) to have 1.1 cm more height change prior to 208 d of age than BRI steers, but BRI steers had 2.5 cm more (P = .02) height change after 208 d of age. No differences (P = .19) in overall height change were observed between BRI and WAG steers.

The BRI steers tended (P = .09) to have lower intake than CON steers from 127 to 208 d of age (Table 6). No differences (P > .26) were observed between BRI and CON steers in intake after 208 d of age or overall intake. Differences in intake were not statistically significant (P = .13) between BRI and WAG steers between 127 and 208 d of age. However, the BRI steers had .63 kg/d higher intake (P = .03) than WAG steers after d 208, and tended (P = .07) to have .49 kg/d higher intake overall.

During the first 82 d of the trial, efficiency tended (P = .09) to be .02 (gain:feed) units higher for the BRI steers than CON steers. No breed differences (P > .22) between BRI and CON steers were observed for efficiency after 208 d of age or overall. The BRI steers had .03 units better feed conversions (P = .03) than the WAG steers from 127 to 208 d of age. The BRI steers tended to exhibit .01 units better gain:feed than WAG steers after 208 d of age (P = .06) and overall (P = .10). Findings of Lunt et al. (1993) also gives further evidence that Angus steers require less feed per unit of gain than Wagyu steers. These findings agree with Myers et al. (1998). When compared to CON steers, BRI steers consumed 310 kg less total concentrate (P = .0003). No difference (P = .60) in total concentrate consumed were observed between the BRI and WAG steers. These results are consistent with Myers et al. (1998).

Carcass Evaluation. In general, carcass traits were similar (P > .05) between growing treatments (Table 7). No differences (P > .38) were observed between growing treatments for carcass weight, external fat thickness, LMA, LMA expressed as square centimeter per kilogram of hot carcass weight, kidney, pelvic, and heart fat, and yield grade. Sixty-eight percent of the steers graded with a yield grade of 2.9 or better, having an average yield grade of 2.8. Lancaster et al. (1973) indicated carcass traits were similar for 205-d-old calves placed directly on a high concentrate finishing ration with calves allowed a growing period of 76 d before being placed on the finishing ration.

No differences (P = .92) were observed between growing treatments for marbling score. Eighty-nine percent of the carcasses in both treatments graded Choice or higher. The CONC steers tended (P = .11) to improve percentage of carcasses grading Average Choice or higher by 47% over those steers grown on pasture for 82 d. No differences (P = .19) were observed in percentage of carcasses grading Prime or higher. Lancaster et al. (1973) reported significantly higher marbling scores for steers weaned to 205 d of age placed directly on a high concentrate finishing ration than those allowed a 76-d growing period. Dahman et al. (1962) found that steers fed a low level of

concentrates for the first 140 d of feeding had a smaller amount of marbling than steers fed a higher level of concentrate.

Carcass quality characteristics by breed type are presented in Table 8. Because of greater live weights, CON steers had a 40 kg heavier carcass weight (P = .0001) at a fat thickness equivalent to that of BRI steers. There were no breed differences (P = .31) in carcass weight between the BRI and WAG steers. The BRI and WAG breed types resulted in 21 and 26 percentage units, respectively, of carcasses below 250 kg; however, steers of CON breed type resulted in no light carcasses. No differences (P > .47) were observed between breeds for external fat thickness, which was expected since steers were harvested at a constant external fat thickness as measured by ultrasound. Compared to BRI steers, CON steers measured with 7.2 sq cm larger (P = .0006) LMA. No differences (P = .27) were observed for LMA between the BRI and WAG steers. When expressed as square centimeters per kilogram of hot carcass weight, CON steers tended (P = .09) to have smaller LMA and WAG steers had larger LMA (P = .01) than BRI steers. There were no differences (P = .72) in percentage of kidney, pelvic, and heart fat between BRI and CON steers; however, BRI had .20 percentage units less (P = .03) than WAG steers.

Breed type did not result in a difference (P > .19) in yield grade, or the percentage of carcasses grading yield grade 1, 2, or 3, which would be expected when steers are slaughtered at equivalent external fat thickness endpoint.

No differences (P > .27) were observed for marbling score between BRI and CON steers, or the percentage of carcasses grading greater than or equal to Choice, Average Choice, or Prime. WAG steers had a 76 unit higher marbling score (P = .006) than BRI steers. This resulted in 19% more (P = .09) carcasses grading greater than or equal to Choice, and 82% more (P = .03) grading greater than or equal to Average Choice. No differences (P = .11) were observed in the percentage of carcasses grading greater than or equal to Prime.

Meat Quality Measurements. Steak weights and cooking parameters by growing treatment and breed type are presented in Tables 9 and 10. No differences (P > .55) were observed between growing treatment for raw weight, cooking loss, or percentage cooking loss. The raw weight of the CON steaks were 22.63 g heavier (P = .007) than BRI steers. This would be expected since CON were 66 kg heavier (P = .0001) at slaughter, had 40 kg heavier carcass weight (P = .0001), and measured with 7.2 sq cm larger (P = .0006) LMA. The CON steers had more cooking loss (P = .05) than BRI steers. There were no differences (P > .22) in raw weight, or cooking loss between BRI and WAG steaks. Breed type did not result in a differences (P > .62) in percentage cooking loss.

The effects of growing treatment and breed type on proximate composition of the 9-10-11 rib are shown in Tables 9 and 10. No differences (P > .16) were observed in the percentage of moisture, protein, or ether extract between growing treatments. There were no differences (P > .45) in the proximate composition of the 9-10-11 rib between BRI and CON breed types. The WAG steers tended (P = .11) to have a lower moisture percentage and higher percentage of ether extract (P = .12) than BRI steers. Lunt et al. (1993) reported that Wagyu crossbred steers had an average of 4.4% more ether extractable fat from the ribeye muscle than Angus steers. The 9-10-11 rib of the BRI steers did have a .58 percentage units higher protein percentage (P = .04) than WAG steers.

Growing treatment did not have an affect on the sensory attributes and shear force of ribeye steaks (Table 9). No differences ($P > .35$) were observed between growing treatments for tenderness, juiciness, off-flavor, and shear force. These results are consistent with Dikeman et al. (1985b) who reported that taste panel evaluations of meat from cattle produced under accelerated nutritional management and that of conventionally produced beef were not different. Additionally, Tatum et al. (1980) concluded that steaks from steers fed 100 d or longer on a high-concentrate diet were similar in palatability, irrespective of quality grade. However, McBee and Wiles (1967) reported that tenderness, juiciness, and flavor increased with increasing degrees of marbling in a direct, linear relationship. McKeith et al. (1985) found that longissimus muscle steaks from Angus steers became acceptable in sensory tenderness between 56 and 112 d of feeding.

In general, no differences ($P > .19$) were observed for sensory evaluation and shear force of ribeye steaks between BRI and CON steers (Table 10). Similar results were observed between BRI and WAG steers. However, WAG steers tended ($P = .07$) to have a greater incidence of off-flavor than BRI steers. Koch et al. (1976) indicated little difference in tenderness, flavor, juiciness, or overall acceptability scores for meat samples from crossbreds sired by Angus, Hereford, Jersey, South Devon, Limousin, Simmental, or Charolais bulls. Fredeen et al. (1972) found no differences among breeds in tenderness (shear force and sensory panel data) of the longissimus muscle. Adams et al. (1977) found no differences in palatability among breed groups, including several British and French crossbred breed-types. Dikeman and Crouse (1975) detected no differences in palatability among Hereford × Angus, Limousin × Angus, or Simmental × Angus crosses fed 200 to 284 d. May et al. (1993) indicated that consumers could detect differences between steaks from Angus and Wagyu steers in a consumer triangle test.

Visceral Measurements. The effect of growing treatment on digestive tract weights expressed as a percentage of hot carcass weight are presented in Table 11. Growing treatment did not result in a difference ($P > .17$) in the weights of the heart, abomasum, omasum, intestines, combined weight (rumen, abomasum, omasum, and small and large intestines), and fat as a percentage of hot carcass weight. The PAST steers tended ($P = .15$) to have a 12% larger liver weight and 14% larger ($P = .01$) rumen weight in respect to CONC steers. Studies have demonstrated that maintenance energy requirements are influenced by factors other than body size, such as age (Graham et al., 1974), breed (Smith and Baldwin, 1974; Jenkins and Ferrell, 1983), temperature (Close and Mount, 1978), and plane of nutrition (Ledger and Sayers, 1977).

Burrin et al. (1989) suggest that changes in visceral-organ growth in response to level of nutrition are associated with concurrent changes in blood flow and O_2 consumption of visceral tissues. Huntington and Prior (1983) and Huntington (1984) have indicated a positive relation between feed intake and portal blood flow in sheep and cattle. Changes in portal blood flow occur during all phases of nutrient assimilation in animals. Canas et al. (1982) evaluated the effects of food intake on organ weights in lactating and nonlactating rats. Their data indicated that during lactation, when feed intake is about twice that of nonlactating animals, weights of the intestine, liver, and heart increase. These organs have higher energy requirements per unit mass than the body average. These observations imply that when food intake increases, hypertrophy occurs in organs that have high maintenance energy expenditures per unit of weight. In the current study, the relative intakes of the steers during the growing phase were not evaluated; however, the above results may be part of that explanation.

Researchers have reported increased portal blood flow after feeding (Huntington, 1982; Bensadoun and Reid, 1962) or as a result of changing the diet from a forage to a high concentrate (Huntington et al., 1981; Huntington, 1983). It is reasonable to expect a relationship between digestion in the gut and the transport mechanism to remove absorbed nutrients.

CONCLUSIONS

Steers placed directly on high concentrate after weaning had higher gain, lower intake, better efficiency, were younger at slaughter, consumed the same amount of total concentrate, and had reduced liver and rumen weights when compared to steers grown on pasture prior to finishing. Steers of British breed type reduced slaughter weights, reduced finishing days, reduced total concentrate consumed, reduced carcass weights, increased percentage of light carcasses, and reduced longissimus muscle area compared to steers of Continental breed type. Steers of Wagyu breed type had more days in the feedlot, lower gain, lower intake, more undesirable efficiencies, consumed the same amount of total concentrate, and improved quality grades compared to steers of British breed type in this study.

LITERATURE CITED

Adams, N. J., G. C. Smith, and Z. L. Carpenter. 1977. Carcass and palatability characteristics of Hereford and crossbred steers. J. Anim. Sci. 46:438-448.

American Meat Science Association. 1978. Guidelines for cookery and sensory evaluation of meat. American Meat Science Association-National Livestock and Meat Board, Chicago, IL.

AOAC. 1992. Official Methods of Analysis (16th Ed.). Association of Official Analytical Chemists, Washington, DC.

Bartle, S. J., J. R. Males, and R. L. Preston. 1984. Effect of energy intake on the postpartum interval in beef cows and the adequacy of the cow's milk production for calf growth. J. Anim. Sci. 58:1068-1074.

Bensadoun, A., and J. T. Reid. 1962. Estimation of rate of portal blood flow in ruminants: Effect of feeding, fasting, and anesthesia. J. Dairy Sci. 45:540-543.

Burrin, D. G., C. L. Ferrell, R. A. Britton, and M. Bauer. 1990. Level of nutrition and visceral organ size and metabolic activity in sheep. Br. J. Nutr. 64:439-448.

Burrin, D. G., C. L. Ferrell, J. H. Eisemann, R. A. Britton, and J. A. Nienaber. 1989. Effect of level of nutrition on splanchnic blood flow and oxygen consumption in sheep. Br. J. Nutr. 62:23-34.

Canas, R., J. J. Romero, and R. L. Baldwin. 1982. Maintenance energy requirements during lactation in rats. J. Nutr. 112:1876-1880.

Close, W. H., and L. E. Mount. 1978. The effects of plane of nutrition and environmental temperature on the energy metabolism of the growing pig. 1. Heat loss and critical temperature. Br. J. Nutr. 40:413-421.

Cover, S., O. D. Butler, and T. C. Cartwright. 1956. The relationship of fatness in yearling steers to juiciness and tenderness of broiled and braised steaks. J. Anim. Sci. 15:464-472.

Dahmen, J. J., T. B. Keith, and T. D. Bell. 1962. Delayed concentrate feeding to steers. Idaho Agric. Exp. Sta. Bull. No. 374.

DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, G. F. Cmarik, and R. J. Favero. 1990. Effects of prenatal testosterone treatment and postnatal steroid implantation on growth performance and carcass traits of heifers and steers. J. Anim. Sci. 68:2198-2207.

Dikeman, M. E., and J. D. Crouse. 1975. Chemical composition of carcasses from Hereford, Limousin and Simmental crossbred cattle as related to growth and meat palatability. J. Anim. Sci. 40:463-467.

Dikeman, M. E., A. D. Dayton, M. C. Hunt, C. L. Kastner, J. B. Axe, and H. J. Ilg. 1985a. Conventional versus accelerated beef production with carcass electrical stimulation. J. Anim. Sci. 61:573-583.

Dikeman, M. E., K. N. Nagele, S. M. Myers, R. R. Schalles, D. H. Kropf, C. L. Kastner, and F. A. Russo. 1985b. Accelerated versus conventional beef production and processing. J. Anim. Sci. 61:137-150.

Duckett, S. K., D. G. Wagner, L. D. Yates, H. G. Dolezal, and S. G. May. 1993. Effects of time on feed on beef nutrient composition. J. Anim. Sci. 71:2079-2088.

Ferrell, C. L., and L. J. Koong. 1986. Influence of plane of nutrition on body composition, organ size and energy utilization of Sprague-Dawley rats. J. Nutr. 116:2525-2535.

Fox, D. G., C. J. Sniffen, and J. D. O'Connor. 1988. Adjusting nutrient requirements of beef cattle for animal and environmental variation. J. Anim. Sci. 66:1475-1495.

Fredeen, H. T., A. H. Martin, G. M. Weiss, S. B. Slen, and L. J. Sumption. 1972. Feedlot and carcass performance of young bulls representing several breeds and breed crosses. Can. J. Anim. Sci. 52:241-257.

Graham, N. McC., T. W. Searle, and D. A. Griffiths. 1974. Basal metabolic rate in lambs and young sheep. Aust. J. Agric. Res. 25:957-971.

Greene, B. B., W. R. Backus, and M. J. Riemann. 1989. Changes in lipid content of ground beef from yearling steers serially slaughtered after varying lengths of grain finishing. J. Anim. Sci. 67:711-715.

Hankins, O. G., and P. E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. USDA Tech. Bull. 926, Washington, DC.

Huntington, G. B. 1982. Portal blood flow and net absorption of ammonia-nitrogen, urea-nitrogen, and glucose in nonlactating Holstein cows. J. Dairy Sci. 65:1155-1162.

Huntington, G. B. 1983. Net nutrient absorption in beef steers fed silage or high concentrate diets containing four levels of limestone. J. Nutr. 113:1157-1164.

Huntington, G. 1984. Relationship of portal blood flow to metabolizable energy intake of cattle. Can. J. Anim. Sci. 64(Suppl.):16-17.

Huntington, G. B., and R. L. Prior. 1983. Digestion and absorption of nutrients by beef heifers fed a high concentrate diet. J. Nutr. 113:2280-2288.

Huntington, G. B., R. L. Prior, and R. A. Britton. 1981. Glucose and lactate absorption and metabolic interrelationships in steers changed from low to high concentrate diets. J. Nutr. 111:1164-1172.

Jenkins, T. G., and C. L. Ferrell. 1983. Nutrient requirements to maintain weight of mature, nonlactating, nonpregnant cows of four diverse breed types. J. Anim. Sci. 56:761-770.

Koch, R. M., M. E. Dikeman, D. M. Allen, M. May, J. D. Crouse, and D. R. Campion. 1976. Characterization of biological types of cattle. III. Carcass composition, quality, and palatability. J. Anim. Sci. 43:48-62.

Koong, L. J., J. A. Nienaber, J. C. Pekas, and J. T. Yen. 1982. Effects of plane of nutrition on organ size and fasting heat production in pigs. J. Nutr. 112:1638-1642.

Lancaster, L. R., R. R. Frahm, and D. R. Gill. 1973. Comparative feedlot performance and carcass traits between steers allowed a postweaning growing period and steers placed on a finishing ration at weaning. J. Anim. Sci. 37:632-636.

Ledger, H. P., and A. R. Sayers. 1977. The utilization of dietary energy by steers during periods of restricted food intake and subsequent realimentation. I. The effect of time on maintenance requirements of steers held at constant live weights. J. Agric. Sci. 88:11-26.

Lipsey, R. J., M. E. Dikeman, and R. R. Schalles. 1978. Carcass composition of different cattle types related to energy efficiency. J. Anim. Sci. 46:96-101.

Loveday, H. D., and M. E. Dikeman. 1980. Diet energy and steer type effects on adipose composition, lipogenesis and carcass composition. J. Anim. Sci. 51:78-88.

Lunt, D. K., and L. E. Orme. 1987. Feedlot performance and carcass evaluation of heifers fed finishing diets as weanling calves or as yearlings. Meat Sci. 20:159-164.

Lunt, D. K., R. R. Riley, and S. B. Smith. 1993. Growth and carcass characteristics of Angus and American Wagyu steers. Meat Sci. 34:327-334.

May, S. G., C. A. Sturdivant, D. K. Lunt, R. K. Miller, and S. B. Smith. 1993. Comparison of sensory characteristics and fatty acid composition between Wagyu crossbred and Angus steers. Meat Sci. 35:289-298.

McBee, J. L., Jr., and J. A. Wiles. 1967. Influence of marbling and carcass grade on the physical and chemical characteristics of beef. J. Anim. Sci. 26:701-704.

McKeith, F. K., J. W. Savell, G. C. Smith, T. R. Dutson, and Z. L. Carpenter. 1985. Tenderness of major muscles from three breed-types of cattle at different times-on-feed. Meat Sci. 13:151-166.

Myers, S. E, D. B. Faulkner, F. A. Ireland, L. L. Berger, and D. F. Parrett. 1998. Production Systems Comparing Early Weaning to Normal Weaning With or Without Creep Feeding for Beef Steers. J. Anim. Sci. 76(In press).

Novakofski, J., S. Park, P. J. Bechtel, and F. K. McKeith. 1989. Composition of cooked pork chops: Effect of removing subcutaneous fat before cooking. J. Food Sci. 54(1):15-17.

Oltjen, R. R., T. S. Rumsey, and P. A. Putnam. 1971. All-forage diets for finishing beef cattle. J. Anim. Sci. 32:327-333.

Palmer, A. Z., J. W. Carpenter, R. L. Alsmeyer, H. L. Chapman, and W. G. Kirk. 1958. Simple correlations between carcass grade, marbling, ether extract of loin eye and beef tenderness. J. Anim. Sci. 17:1153 (Abstr.).

Ridenour, K. W., H. E. Kiesling, G. P. Lofgreen, and D. M. Stiffler. 1982. Feedlot performance and carcass characteristics of beef steers grown and finished under different nutrition and management programs. J. Anim. Sci. 54:1115-1119.

Robison, O. W., M.K.M. Yusuff, and E. U. Dillard. 1978. Milk production in Hereford cows: I. Means and correlations. J. Anim. Sci. 47:131-141.

SAS. 1985. SAS User's Guide: Statistics (Version 5 Ed.). SAS Inst. Inc., Cary, NC.

Smith, N. E., and R. L. Baldwin. 1974. Effects of breed, pregnancy, and lactation on weight of organs and tissues in dairy cattle. J. Dairy Sci. 57:1055-1060.

Steel, R.G.D., and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach (2nd Ed.). McGraw-Hill Publishing Co., New York.

Tatum, J. D., G. C. Smith, B. W. Berry, C. E. Murphey, F. L. Williams, and Z. L. Carpenter. 1980. Carcass characteristics, time on feed and cooked beef palatability attributes. J. Anim. Sci. 50:833-840.

USDA. 1975. Official United States Standards for Grades of Carcass Beef. USDA Food Safety and Quality Serv., Washington, DC.

Webster, A.J.F. 1981. The energetic efficiency of metabolism. Proc. Nutr. Soc. 40:121-128.

Whipple, G., M. Koohmaraie, M. E. Dikeman, and J. D. Crouse. 1990. Predicting beef-longissimus tenderness from various biochemical and histological muscle traits. J. Anim. Sci. 68:4193-4199.

Zinn, D. W., R. M. Durham, and H. B. Hedrick. 1970. Feedlot and carcass grade characteristics of steers and heifers as influenced by days on feed. J. Anim. Sci. 31:302-306.

Table 1. Composition of finishing diets fed to steers

	Diet sequence, %[a]			
Ingredients	1	2	3	4
NH_3 cobs	45.0	33.0	23.0	13.0
Dry corn	45.0	57.0	67.0	77.0
Supplement	10.0	10.0	10.0	10.0
Feed Analysis				
Crude protein, %	9.19	9.69	10.11	10.53
NE_M, Mcal/kg	.44	.47	.50	.52
NE_G, Mcal/kg	.28	.31	.33	.35

[a]DM basis.

Table 2. Ingredient composition of pelleted supplement fed to steers

Ingredient	%[a]
Soybean meal	68.75
Thiamine 8.8%, 88,000 mg/kg	.15
Monensin-80[b]	.15
Copper sulfate acidified	.05
Potassium chloride	1.50
Urea	7.52
Dried molasses	2.58
Blood meal	3.20
Vitamin ADE[c]	.15
Swine trace mineralized salt[d]	3.50
Limestone	10.00
Dicalcium phosphate	2.50

[a]DM basis.

[b]Contains 176 g of monensin/kg.

[c]Composition (per gram): ≥3,300 IU vitamin A, ≥330 IU vitamin D_3, and ≥44 IU vitamin E.

[d]Composition (%): NaCl (82 to 87), Fe (≥2.57), Zn (≥2.86), Mn (≥.57), Cu (≥.23), I (≥.01), Se (≥.009).

Table 3. Performance of early weaned steers receiving a high concentrate diet or grown on pasture prior to finishing[a]

Item	Growing treatments		SEM[b]	P =
	Concentrate	Pasture		
No. of steers	36	36		
Initial wt, kg	144	149	4	.45
Slaughter wt[c], kg	488	491	9	.79
Days on pasture	- -	82	- -	- -
Days in feedlot	268	222	7	.0001
ADG, kg				
127-208 d of age	1.33	.48	.03	.0001
208-413 d of age	1.28	1.40	.03	.008
Overall	1.30	1.13	.02	.0001
Initial ht, cm	100.1	100.7	.73	.57
Height change, cm				
127-208 d of age	8.9	6.1	.3	.0001
208-413 d of age	15.9	18.1	.6	.01
Overall	24.9	24.1	.7	.44

[a]Least squares means.
[b]Greatest standard error of treatment means (SEM) reported.
[c]Calculated as hot carcass weight/.61.

Table 4. Performance of early weaned steers receiving a high concentrate diet or grown on pasture prior to finishing[a]

Item	Growing treatments		SEM[b]	P =
	Concentrate	Pasture		
No. of steers	36	36		
DMI, kg/d[c]				
127-208 d of age	4.58	- -	.14	- -
208-413 d of age	7.75	7.90	.17	.51
Overall	6.81	7.90	.16	.0001
Gain/feed[c]				
127-208 d of age	.287	- -	.004	- -
208-413 d of age	.165	.177	.003	.009
Overall	.190	.177	.003	.008
Total conc., kg/hd[d]	1,816	1,814	48	.97

[a]Least squares means.
[b]Greatest standard error of treatment means (SEM) reported.
[c]During finishing phase.
[d]Total concentrate, finishing and supplement on pasture included.

Table 5. Performance of early weaned steers of three breed types receiving a high concentrate diet or grown on pasture prior to finishing[a]

Item	Breeds[b]			SEM[c]	P = Contrast	
	BRI	CON	WAG		BRI vs CON	BRI vs WAG
No. of steers	24	24	24			
Initial wt, kg	140	158	142	6	.02	.85
Slaughter wt[d], kg	473	539	457	11	.0001	.31
Days in feedlot	227	258	250	8	.008	.05
ADG, kg						
127-208 d of age	.89	.98	.85	.04	.12	.49
208-413 d of age	1.41	1.39	1.22	.04	.78	.0007
Overall	1.26	1.28	1.10	.03	.58	.0003
Initial ht, cm	98.7	103.2	99.2	.92	.0005	.67
Height change, cm						
127-208 d of age	7.0	7.4	8.1	.4	.44	.06
208-413 d of age	17.8	18.0	15.3	.7	.85	.02
Overall	24.8	25.4	23.2	.9	.60	.19

[a]Least squares means.

[b]BRI = ¾ Angus × ¼ Simmental, CON = ¾ Simmental × ¼ Angus, WAG = ½ Wagyu × ¼ Angus × ¼ Simmental.

[c]Greatest standard error of treatment means (SEM) reported.

[d]Calculated as hot carcass weight/.61.

Table 6. Performance of early weaned steers of three breed types receiving a high concentrate diet or grown on pasture prior to finishing[a]

					P =	
					Contrast	
					BRI vs	BRI vs
	Breeds[b]					
Item	BRI	CON	WAG	SEM[c]	CON	WA
No. of steers	24	24	24			
DMI, kg/d[d]						
127-208 d of age	4.21	4.80	4.74	.24	.09	.13
208-413 d of age	7.98	8.16	7.35	.20	.52	.03
Overall	7.42	7.72	6.93	.19	.26	.07
Gain/feed[d]						
127-208 d of age	.302	.283	.277	.008	.09	.03
208-413 d of age	.177	.172	.166	.004	.38	.06
Overall	.189	.182	.180	.004	.22	.10
Total conc., kg/hd[e]	1,697	2,007	1,740	59	.0003	.60

[a]Least squares means.

[b]BRI = ¾ Angus × ¼ Simmental, CON = ¾ Simmental × ¼ Angus, WAG = ½ Wagyu × ¼ Angus × ¼ Simmental.

[c]Greatest standard error of treatment means (SEM) reported.

[d]During finishing phase.

[e]Total concentrate, finishing and supplement on pasture included.

Table 7. Carcass quality of early weaned steers receiving a high concentrate diet or grown on pasture prior to finishing[a]

Item	Growing treatments		SEM[b]	P =
	Concentrate	Pasture		
No. of steers	36	36		
Carcass wt, kg	298	300	5	.79
≤250 kg, %	13	16	5	.67
External fat thickness, cm	1.16	1.17	.05	.82
LMA[c]				
Sq cm	75.7	76.8	1.17	.51
Sq cm/kg HCW[d]	.26	.26	.01	.54
Est. KPH[e], %	2.0	1.9	.1	.38
Avg. Yield grade	2.81	2.77	.07	.72
Yield grade 1, %	0	3	2	.26
Yield grade 2, %	66	66	8	.97
Yield grade 3, %	34	31	8	.74
Marbling score[f]	1,091	1,093	15	.92
≥Choice, %	89	89	5	.95
≥Avg. Choice, %	56	38	8	.11
≥Prime, %	2	10	4	.19

[a]Least squares means.
[b]Greatest standard error of treatment means (SEM) reported.
[c]Longissimus muscle area.
[d]Hot carcass weight.
[e]Kidney, pelvic, heart fat.
[f]1,000 = Small[00].

Table 10. Steak weights, cooking parameters, proximate composition, and sensory attributes of early weaned steers of three breed types receiving a high concentrate diet or grown on pasture prior to finishing[ab]

					P =	
					Contrast	
					BRI vs	BRI vs
	Breeds[c]					
Item	BRI	CON	WAG	SEM[d]	CON	WAG
Raw weight, g	191.15	213.78	201.09	5.72	.007	.22
Cooking loss, g	46.08	52.36	49.39	2.26	.05	.30
Cooking loss, %	24.14	24.44	24.84	.99	.83	.62
Moisture, %[e]	47.89	47.26	46.53	.59	.46	.11
Protein, %[e]	13.75	13.92	13.17	.19	.56	.04
Lipid, %[e]	38.11	38.91	39.76	.74	.45	.12
Tenderness[fg]	9.28	10.01	9.76	.39	.19	.38
Juiciness[fg]	10.35	10.36	10.41	.34	.99	.91
Off-flavor[fg]	14.79	14.83	14.60	.07	.67	.07
Shear force, kg[h]	4.59	4.68	4.41	.18	.72	.48

[a]Least squares means.

[b]External fat thickness was used as a covariate (mean = 1.17 cm).

[c]BRI = ¾ Angus × ¼ Simmental, CON = ¾ Simmental × ¼ Angus, WAG = ½ Wagyu × ¼ Angus × ¼ Simmental.

[d]Greatest standard error of treatment means (SEM) reported.

[e]Proximate composition of the 9-10-11 rib.

[f]Sensory attributes of ribeye steaks.

[g]Evaluated by a trained sensory panel on a 15-cm continuous scale; 15 = tender, juicy, no off-flavors.

[h]Warner-Bratzler shear, peak force.

Table 11. Digestive tract weights of early weaned steers receiving a high concentrate diet or grown on pasture prior to finishing[ab]

	Growing treatments			
Item	Concentrate	Pasture	SEM[c]	P =
No. of steers	7	7		
Liver, %[d]	1.79	2.01	.10	.15
Heart, %[d]	.51	.53	.10	.65
Rumen, %[d]	3.18	3.61	.10	.01
Abomasum, %[d]	.47	.45	.03	.55
Omasum, %[d]	.96	1.03	.08	.58
Intestines, %[de]	2.24	2.25	.15	.96
Combined, %[df]	6.84	7.33	.23	.17
Fat, %[d]	8.24	8.62	.40	.53
Carcass wt, kg	333	310	15	.31

[a]Least squares means.
[b]External fat thickness was used as a covariate (mean = 1.01 cm).
[c]Greatest standard error of treatment means (SEM) reported.
[d]Percentage of hot carcass weight.
[e]Small and large intestines.
[f]Rumen, abomasum, omasum, and small and large intestines.

EFFECTS OF PRENATAL ANDROGENIZATION AND IMPLANTATION ON FEEDLOT PERFORMANCE AND CARCASS COMPOSITION OF SINGLE-CALF HEIFERS

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SUMMARY

Twenty-four lactating Angus x Simmental heifers were used in the single-calf heifer system. Heifer adaptation to a high concentrate diet began 3 to 4 wks prepartum. Two to three days postpartum, 15 control (C) and 9 prenatally androgenized (PA) heifer-calf pairs were weighed and one-half of the C and PA heifers were implanted with Synovex-H. They were then placed in feedlot pens equipped with pinpointer feeding devices. By 1 wk postpartum, all heifers were adapted to an 85% concentrate diet and fed until they possessed approximately 1.1 cm subcutaneous fat cover. Heifers were slaughtered 12 h postweaning. The C and PA heifers had similar ($P = .73$) ADGs of 1.24 and 1.19 kg/d, however, PA heifers tended ($P < .11$) to consume more dry matter. Gain:feed (G:F) was also similar ($P = .35$) for the C and PA heifers; however, the C heifers tended ($P < .08$) to have a improved pair G:F. The implanted (I) and non-implanted (NI) heifers had similar ($P = .89$) ADGs of 1.23 and 1.21 kg/d and had similar ($P = .20$) DMIs of 14.4 and 13.6 kg/d respectively. Heifer G:F and pair G:F were both similar ($P = .53$) for the I and NI heifers. Most carcass measurements were unaffected by treatment. The I heifers tended ($P < .07$) to have higher marbling scores.

INTRODUCTION

Most cow-calf producers seek to maximize the longevity of cows to reduce the costs of replacements. However, the traditional cow-calf production system may not be the most efficient production system for some beef producers. The mature cow utilizes about 75 to 80% of her nutrient intake for maintenance alone, and only 20 to 25% for production (Dikeman, 1984). The single-calf heifer (SCH) system is theoretically more efficient than the traditional cow-calf production system (Crowley, 1973; Taylor et al., 1985). Biological efficiency is higher for younger females because less feed is required for maintenance (Bourdon and Brinks, 1987). Therefore, increased mature cow replacement improves efficiency of the production system (Taylor et al., 1985). In addition, if the calved 2-year-old heifer receives a USDA Choice grade before 30 mo of age, she may be worth 30% more per kg than a cull cow (Brethour and Jaeger, 1989).

In ruminants, males are heavier at birth and whether castrated or intact, exhibit faster growth rates while depositing more protein and less fat than that of females (Klindt et al., 1987). However, prenatal androgenization (PA) has been shown to enhance feedlot performance in heifers (DeHaan et al., 1988; DeHaan et al., 1990) and even in lactating single-calf heifers (Reiling et al., 1995). When cull dairy cows were implanted with Synovex-H® and fed for 70 days, there were no differences in daily gain, feed intake, or efficiency of feed conversion for implanted and non-implanted cows (Jones, 1982). Similar results have been reported when mature beef cows were implanted with testosterone propionate and fed an 85% concentrate diet (Faulkner et al., 1989). The objective of this research was to evaluate the effects of Finaplix-H® in immature, lactating primiparous females for growth, lactation, and carcass characteristics.

MATERIALS AND METHODS

Implants used to deliver testosterone propionate (TP) prenatally were made of a medical grade silastic tubing (i.d. = .635 cm and o.d. = .953 cm). Implants were 15 cm long and contained approximately 2.25 g of TP. The TP implants were estimated to provide an average secretion rate of 37.8 mg of TP per day (Kesler, 1988). Four TP implants were subcutaneously inserted posterior to the scapula and over the dorsal aspect of the rib cage of the pregnant cow at d 77 ± 18 d of gestation and removed approximately 6-wk prior to calving. Prenatally androgenized heifers from TP-implanted cows and control (C) heifers from non-implanted cows were used in the trial.

Eight PA and 17 C Simmental × Angus heifers were bred to Angus sires to calve at approximately 24 mo of age. Heifers were gradually adapted to a 65% concentrate diet prior to calving. This was achieved by feeding a series of diets in which levels of corn were increased at the expense of ammoniated corn cobs. Dam's and their calves were weighed on each of two consecutive days, 4 ± 1 d postpartum. Nine C and 3 PA heifers were implanted with Synovex-H®. Pairs were moved to drylot pens and the heifers were gradually adjusted to an 85% concentrate diet, containing 13.3% CP. The diet, containing 52% high-moisture cracked corn, 25% cracked-dry corn, 13% ammoniated corn cobs, and 10% protein supplement (Table 1), was balanced to meet or exceed NRC (1984) requirements for CP, Ca, P, K, trace minerals, and vitamins. Calves were offered ad libitum access to a corn-based creep containing 70% ground corn, 15% whole oats, 8.3% soybean meal, 5% dry molasses, and 1.7% minerals and vitamins on a DM basis.

Drylot pens were equipped with Pinpointer 4000B (Agricultural Identification Systems, Inc., Cookeville, TN) or "imitation" feeding devices to measure individual feed intakes (DeHaan et al., 1990). Groups of heifer-calf pairs were rotated through the two types of feeding devices at 2-wk intervals. Daily feed intakes for heifers were recorded using the pinpointer feeding devices, and pen feed intakes for the 2-wk periods were recorded from the "imitation" feeding devices. An individual heifer's percentage intake of pen intake from pinpointer feeding devices was multiplied by pen intake from the "imitation" feeding devices to calculate estimated individual feed intakes for heifers while in the drylot pens equipped with "imitation" feeding devices (DeHaan et al., 1990).

Milk yield was measured for the heifers at approximately 6 and 14 wk postpartum with a vacuum machine milker. Calves were separated from their dams at 1430, allowed to nurse from 2030 until 2100. Calves were again separated from their dam until end of the milking procedure. The following morning at 0800, heifers were restrained in a squeeze chute and given 100 USP units of oxytocin intramuscularly. Prior to being milked, heifers udders were washed with warm water to remove any foreign debris. While being milked, udders were massaged by hand to assist in milk letdown. Upon pause in milk flow, the milking machine was removed and udders were stripped of remaining milk, by hand. The milk removed by hand was mixed with the milk from the machine and weighed. Two representative 1-oz samples were collected and preserved with 2-bromo-2-nitropropane-1,3-diol. One milk sample was used to analyze milk for percent fat, percent crude protein, somatic cell count (Dairy Lab Services, Dubuque, IA). The second sample was used to determine solids-not-fat concentrations (Golding, 1959).

Chromic oxide was fed as an external marker to estimate apparent digestibility. Chromic oxide was fed in the diet to supply 7 g/animal/day for a period of 10 d. Following the 10 d adaptation period, fecal grab samples were collected from all heifers at 0600, 1400, and 2200 on d 11 and composited. Fecal and feed samples were dried at 55° C in a dry air oven and ground through a 2-mm screen. The digestible energy of the diet was determined by analyzing the feed and fecal samples by bomb calorimetry and then comparing the concentrations of Cr in the feed and feces. The diet was calculated to supply 3.33 Mcal of DE/kg. Assuming ME to be 82% of DE (NRC, 1984), and using the equations of Garrett (1980), it was determined that the diet supplied 1.81 Mcal/kg of NE_m and NE_l and 1.18 Mcal/kg of NE_g. The net energy system was used to calculate predicted gain of heifers to compare to actual heifer gains using these digestible energy values, individual feed intakes, estimated milk production, and average body weights to determine the efficiency of growth for the heifers.

Heifers remained on feed until they possessed 1.1 cm subcutaneous fat cover as estimated by visual appraisal by two trained university personnel. Final weights for heifers and calves were taken on each of two consecutive days, and calves were weaned from their dams. Heifers were slaughtered at a commercial packing plant. Carcasses were evaluated for longissimus muscle area at 12th rib, fat cover at 12th rib, kidney, pelvic, and heart fat, marbling at 12th rib, and bone and lean maturity 24 h postmortem, by trained university personnel (USDA, 1975). Marbling scores were based on the grading system prior to January 1, 1997.

Statistical analysis. The GLM procedures of SAS (1992) were used to measure significance. For growth performance of heifer and heifer-calf pairs, the model included androgenization, implantation, and the androgenization × implantation interaction as independent variables. For calf growth performance, variation due to calf sex was removed. In the evaluation of heifer lactational performance, days postpartum was used as a covariate. For carcass composition and quality, androgenization, implantation, and the androgenization × implantation interaction were used as independent variables.

RESULTS AND DISCUSSION

Feedlot Performance. Feedlot performance of heifers, calves, and heifer-calf pairs is presented in Table 2. The C and PA heifers had similar ($P = .58$) daily gains of 1.25 and 1.17 kg/d, respectively; however, PA heifers tended ($P = .10$) to consume more dry matter. Efficiency of feed conversion was similar ($P = .22$) for C and PA heifers. In contrast, Reiling et al. (1995) reported that PA heifers gained 22.5% faster ($P < .01$) and were 17.3% more efficient ($P < .01$). Implanted (I) and non-implanted (NI) heifers had similar ($P = .96$) daily gains of 1.22 and 1.21 kg/d and similar ($P = .14$) dry matter intakes. The I and NI heifers were also similar ($P = .26$) in their efficiency of feed conversion. Similarly, Jones (1982) found no difference in daily gain, feed intake, or efficiency of feed conversion between cull dairy cows implanted with Synovex-H® and controls. Similar results have been reported when mature cows were implanted with testosterone propionate (Faulkner et al., 1989).

Regardless of treatment, calves gained an average of .90 kg/d and consumed .58 kg/d of DM of creep feed. When calf performance was considered, C heifers were 16.4% more efficient ($P = .02$) than PA

heifers. Reiling et al. (1995) reported when calf performance was considered, PA heifers were 10.8% more ($P < .01$) efficient than controls. Though similar improvements in efficiency were not observed in this study, PA heifer were 20 kg heavier than C heifers at slaughter. The lack of response may be due to incomplete androgenization or small numbers of animals in this study. A new source of silastic tubing was used and the secretion rate of TP was 24.6 mg per day instead of the 37.8 mg per day as predicted (Kesler, 1988). This difference in diffusion rate may have resulted in less of an androgenization response than previously observed. Implanted and non-implanted heifer-calf pairs had similar ($P = .26$) feed efficiencies of .140 and .150, respectively.

Lactational Performance. Prenatal androgenization and implantation had no effect on heifer lactational performance (Table 3). Prenatally androgenized and C heifers yielded 10.06 and 10.28 kg/d ($P = .91$) of 4% fat-corrected milk (FCM) (NRC, 1989) at 6 wk postpartum. Implanted and non-implanted heifers yielded 11.13 and 9.21 kg/d ($P = .33$) of 4% FCM. Three PA*NI, 2 C*NI, and one C*I heifer reached 1.1 cm subcutaneous fat cover prior to 14 wk postpartum milking. Fourteen weeks postpartum, PA and C heifers yielded 6.92 and 7.14 kg/d ($P = .89$) of FCM. Implanted and NI heifers yielded 7.05 and 7.00 kg/d ($P = .98$) of FCM. Reiling et al. (1995) reported similar milk yields for PA and C heifers at 5 and 15 wk postpartum.

Performance Efficiency. Given individual dry matter intakes, milk production, and average BW for the determination of maintenance requirements, PA heifers gained 137.9% and C heifers gained 143.9% above predicted gains. The I and NI heifers gained 152.6 and 126.9% of the predicted gain. These values are higher than the value reported by Moe et al. (1971) who reported that the partial efficiency of tissue gain in the lactating cow was 27% greater than the partial efficiency of tissue gain in the non-lactating cow. Armstrong and Blaxter (1965) proposed that the improvement in efficiency of gain for lactating females is because during lactation acetate is removed by the mammary gland leaving more efficiently utilized metabolites for efficient production of adipose tissue. Reiling et al. (1995) also observed gains to be 137 and 127% of predicted gains for PA and C heifers.

Carcass Performance. Heifer carcass composition and quality are shown in Table 4. Prenatally androgenized and C heifers had fat thicknesses of 1.06 and 1.27 cm ($P = .28$) and hot carcass weights of 380.0 and 364.7 kg ($P = .35$), respectively. Dressing percentages were 57.68 and 56.64% ($P = .19$) for PA and C heifers, respectively. These dressing percentages are similar to those reported by Reiling et al. (1995) who weaned the calves from the heifers 3 to 4 wk prior to slaughter. Longissimus muscle area was similar ($P = .46$; 90.21 vs 87.54 cm^2) for PA and C heifers, respectively. Yield grades were similar ($P = .53$) for PA and C heifers. Fat thickness was 1.19 and 1.14 cm ($P = .76$) and hot carcass weights were 381.9 and 362.8 kg ($P = .24$) for I and NI heifers, respectively. Implanted and NI heifers had dressing percentages of 57.57 and 56.76% ($P = .31$), respectively. Longissimus muscle area and yield grades were similar ($P = .26$) for I and NI heifers.

Maturity is a concern with single-calf heifers because it has been shown that tenderness decreases with increasing age (Zinn et al., 1970; Smith et al., 1982). According to the new grading system, implemented January 1997, carcasses that have reached B maturity must have modest marbling or higher to receive a choice grade. Bone maturity scores were A^{70} and B^{0} ($P = .23$) and lean maturity scores were A^{90} and A^{70} ($P = .51$) for PA and C heifers, respectively. Marbling scores were similar ($P = .37$; $Small^{70}$ vs. $Small^{70}$) for PA and C heifers, respectively. Implanted and non-implanted heifers

had bone maturity scores of A^{70} and B^{0} (P = .18), respectively. Lean maturity scores for I and NI heifers were A^{70} and A^{90} (P = .21). Marbling scores were $Small^{80}$ and $Small^{60}$ (P = .21) for I and NI heifers. One heifer (C*NI) was classified as hard-boned (C maturity). In addition, 53.3% of PA, 75.0% of C, 70.8% of I, and 57.5% of NI heifers received a USDA low choice grade or higher.

IMPLICATIONS

The single-calf heifer system is an alternative beef management system that holds promise for improved beef production efficiency. Single-calf heifers slaughtered at 30 mo of age showed no response to anabolic agents. Lack of response to androgenization may be due to an inadequate fetal dosage of testosterone propionate and small animal numbers; however, androgenized heifers were heavier than control heifers at the beginning and end of the feeding period. Therefore, the androgenized heifers showed an advantage in gain earlier in development. Though single-calf heifers are lactating and supporting a calf, single-calf heifers can be finished for slaughter with a 120 d feeding period and have the ability to yield a USDA choice carcass by 30 mo of age.

LITERATURE CITED

Armstrong, D. G. and K. L. Blaxter. 1965. Effects of acetic and propionic acids on energy retention and milk secretion in goats. Proc. 3rd Symposium on Energy Metabolism. European Ass. Animal Prod. Publ. 11:59-68. Academic Press, London.

Bourdon, R. M. and J. S. Brinks. 1987. Simulated efficiency of range beef production. III. Culling strategies and nontraditional management systems. J. Anim. Sci. 65:963-969.

Brethour, J. R. and J. R. Jaeger. 1989. The single-calf heifer system. Kansas Agric. Sta. Rep. of Progress 570.

Crowley, J. P. 1973. The facts of once-bred heifer production. In: J. B. Owens (Ed.) The Maiden Female - A Means of Increasing Meat Production. pp 8-17. Proc. Symp., 1972, School of Agric., Univ. of Aberdeen, Scotland.

DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, and G. F. Cmarik. 1988. Effect of prenatal androgenization on growth performance and carcass characteristics of steers and heifers. J. Anim. Sci. 66:1864-1870.

DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, G. F. Cmarik, and R. J. Favero. 1990. Effects of prenatal testosterone treatment and postnatal steroid implantation on growth performance and carcass traits of heifers and steers. J. Anim. Sci. 68:2198-2207.

Dikeman, M. E. 1984. Cattle production systems to meet future consumer demands. J. Anim. Sci. 59:1631-1643.

Faulkner, D. B., F. K. McKeith, L. L. Berger, D. J. Kesler, and D. F. Parrett. 1989. Effect of testosterone propionate on performance and carcass characteristics of heifers and cows. J. Anim. Sci. 67:1907-1915.

Garrett, W. N. 1980. Energy utilization of growing cattle as determined in seventy-two comparative slaughter experiments. In: L. E. Mount (Ed.) Energy Metabolism. EAAP Publ. No. 26. pp 3-8. Butterworths, London.

Golding, N. S. 1959. A solids-not-fat test for milk using density plastic beads as hydrometers. J. Dairy Sci. 42:899 (Abstr.).

Jones, S. D. M. 1982. Performance and carcass characteristics of cull dairy cows given testosterone-estradiol implants. Can. J. Anim. Sci. 62:295-297.

Kesler, D. J. 1988. Novel approaches and applications of steroid hormone delivery via poly(dimethylsiloxane). In: C. G. Gebelein, C. E. Carraher, Jr., and V. R. Foster (Ed.) Applied Bioactive Polymeric Materials. pp 125-137. Plenum Publishing, New York.

Klindt, J., T. G. Jenkins, and J. J. Ford. 1987. Prenatal androgen exposure and growth and secretion of growth hormone and prolactin in ewes postweaning. Proc.Soc. Exp. Biol. Med. 185:201-205.

Moe, P. W., H. F. Tyrrell, and W. P. Flatt. 1971. Energetics of body tissue mobilization. J. Dairy Sci. 54:548-553.

NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, DC.

NRC. 1989. Nutrient Requirements of Dairy Cattle (6th Ed.). National Academy Press, Washington, DC.

Reiling, B. A., L. L. Berger, D. B. Faulkner, F. K. McKeith, and T. G. Nash. 1995. Effect of prenatal androgenization on performance, lactation, carcass, and sensory traits of heifers in a single-calf heifer system. J. Anim. Sci. 73:986-992.

SAS. 1992. SAS User's Guide: Statistics (Version 6.09 Ed.). SAS Inst. Inc., Cary, NC.

Smith, G. C., H. R. Cross, Z. L. Carpenter, C. E. Murphey, J. W. Savell, H. C. Abraham, and G. W. Davis. 1982. Relationship of USDA maturity groups to palatability of cooked beef. J. Food Sci. 47:1100-1118.

Taylor, St. C. S., A. J. Moore, R. B. Thiessen, and C. M. Bailey. 1985. Efficiency of food utilization in traditional and sex-controlled systems of beef production. Anim. Prod. 40:401-440.

USDA. 1975. Official United States standards for grades of carcass beef. USDA Food Safety and Quality Serv., Washington, DC.

Zinn, D. W., C. T. Gaskins, G. L. Gann, and H. B. Hedrick. 1970. Beef muscle tenderness as influenced by days on feed, sex, maturity and anatomical location. J. Anim. Sci. 31:307-309.

Table 1. Composition of supplement fed to single-calf heifers

Ingredient	%[a]
Soybean meal	65.86
Blood meal	3.55
Dry molasses	2.64
Urea	8.08
Monensin-80[b]	.16
Limestone	10.77
Dicalcium phosphate	2.69
Swine TMS[c]	3.77
Vitamin ADEK[d]	.16
Thiamine premix	.16
Potassium chloride	1.62
Copper sulfate acidified	.54
Total	100.00

[a]DM basis.

[b]Contains 176 g of monensin/kg.

[c]Composition (%): NaCl (82 to 87), Fe (≥2.57), Zn (≥2.86), Mn (≥.57), Cu (≥.23),I (≥.01), and Se (≥.009).

[d]Composition (per gram): ≥3,300 IU vitamin A, ≥330 IU vitamin D_3, and ≥44 IU vitamin E.

Table 2. Feedlot performance of prenatally androgenized (PA) and control (C) single-calf heifers which were implanted (I) with Synovex-H® or non-implanted (NI)

	Treatments						P=	
Item	C[a]	PA	SEM	I[a]	NI	SEM	PA	I
Heifer Performance								
No. of animals	16	8		11	13			
Days on test	105	113	5.9	117	100	5.5	.29	.03
On-test wt, kg	549.1	564.4	17.16	560.3	553.2	15.91	.47	.74
Off-test wt, kg	679.8	696.4	20.7	700.9	675.3	19.17	.51	.32
DMI, kg/d	13.55	14.75	.511	14.68	13.62	.473	.07	.10
DMI, % of BW	2.21	2.35	.081	2.33	2.23	.075	.16	.31
Daily gain, kg/d	1.25	1.17	.122	1.22	1.21	.113	.58	.96
Gain:feed	.092	.080	.0081	.084	.088	.0075	.22	.67
Calf Performance								
Birth wt, kg	35.0	37.0	1.49	37.9	34.1	1.39	.31	.06
On-test wt, kg	37.8	39.8	1.78	40.3	37.3	1.66	.39	.20
Off-test wt, kg	135.1	139.1	11.07	143.5	130.7	10.35	.78	.37
Age at weaning, d	109	116	6.2	120	105	5.8	.33	.07
DMI[b], kg/d	.51	.66	.104	.61	.56	.097	.28	.69
Daily gain, kg/d	.93	.88	.064	.89	.92	.060	.58	.76
Pair Performance[c]								
DMI, kg/d	14.12	15.37	.562	15.26	14.22	.521	.08	.14
Daily gain, kg/d	2.20	2.05	.124	2.11	2.14	.115	.33	.84
Gain:feed	.156	.134	.0071	.140	.150	.0066	.02	.26

[a]Performance of one heifer not analyzed because of twin calves.
[b]Creep feed.
[c]Performance of heifer and calf combined.

Table 3. Lactational performance of prenatally androgenized (PA) and control (C) single-calf heifers which were implanted (I) with Synovex-H® or non-implanted (NI)

	Treatments						P=	
Item	C[a]	PA[b]	SEM	I[ab]	NI	SEM	PA	I
First milking, 6 wk postpartum								
No. of animals	16	7		10	13			
24-h yield, kg	12.02	11.07	1.471	11.71	11.37	1.389	.59	.84
24-h 4% FCM[c] yield, kg	10.28	10.06	1.631	11.13	9.21	1.540	.91	.33
Fat, %	2.96	3.14	.344	3.46	2.64	.325	.65	.06
Protein, %	3.44	3.71	.114	3.72	3.44	.108	.06	.05
Solids-not-fat, %	8.75	8.84	.175	8.78	8.81	.166	.66	.89
Second milking, 14 wk postpartum[d]								
No. of animals	13	4		9	8			
24-h yield, kg	10.06	10.00	1.588	9.51	10.56	1.295	.98	.58
24-h 4% FCM[c] yield, kg	7.14	6.92	1.341	7.05	7.00	1.094	.89	.98
Fat, %	2.06	1.86	.368	2.17	1.74	.301	.64	.33
Protein, %	3.73	3.79	.125	3.89	3.63	.102	.71	.10
Solid-not-fat, %	9.02	9.07	.221	9.15	8.94	.180	.87	.44

[a]Lactational performance of one heifer not analyzed because of twin calves.
[b]Lactational peformance of one heifer not analyzed because of poor teat development.
[c]Four percent fat corrected milk
[d]Six heifers reach 1.1 cm subcutaneous fat cover prior to 14 week milking.

Table 4. Carcass composition of prenatally androgenized (PA) or control (C) single-calf heifers which were implanted (I) with Synovex-H® or non-implanted (NI)

	Treatments						P=	
Item	C	PA	SEM	I	NI	SEM	PA	I
No. of animals	17	8		12	13			
Hot carcass wt, kg	364.7	380.0	13.02	381.9	362.8	12.07	.35	.24
Dressing percentage	56.64	57.68	.640	57.57	56.76	.593	.19	.31
Fat thickness, cm	1.27	1.06	.158	1.19	1.14	.147	.28	.76
Longissimus muscle area, cm^2	87.54	90.21	2.958	90.94	86.81	2.742	.46	.26
Longissimus muscle area, cm^2/kg HCW	.226	.238	.0228	.240	.224	.0202	.68	.56
Yield grade	2.96	2.75	.273	2.86	2.85	.253	.53	.96
Heifer age @ slaughter, d	824	831	9.9	837	818	9.1	.56	.14
Bone maturity[a]	198	172	17.0	171	200	15.8	.23	.18
Lean maturity[a]	174	185	13.2	169	190	12.2	.51	.21
Overall maturity[a]	186	179	14.0	170	195	12.9	.66	.16
Marbling score[b]	1074	1035	34.7	1082	1027	32.2	.37	.21
Percentage Choice	75.00	53.33	18.0	70.83	57.50	16.7	.33	.55

[a]Maturity scores: 100 = A^0, 200 = B^0, 300 = C^0.
[b]Marbling scores: 900 = slight^0, 1000 = small^0, 1100 = modest^0.

EFFECTS OF LACTATIONAL STATUS ON THE PERFORMANCE AND CARCASS COMPOSITION OF 30-MONTH-OLD HEIFERS IN THE SINGLE-CALF HEIFER SYSTEM

G. N. Hermesmeyer, L. L. Berger, and T. G. Nash

SUMMARY

Twenty-four Angus x Holstein heifers were utilized in the single-calf heifer system. Calves were weaned from one-half of the dams between d 64 and 89 postpartum. Dam's were gradually adapted to a high concentrate diet over a four wk period at the beginning of the trial. Heifers that had their calves early weaned (EW) gained 44.2% faster ($P < .01$) and consumed 10.8% less ($P < .05$) DM than lactating (L) heifers. The EW heifers were 60.0% more ($P < .01$) efficient than L heifers. However, when calf performance was included with heifer performance, L heifers were 23.7% more ($P < .05$) efficient than EW heifers. The EW heifers had 18.9% heavier ($P < .01$) hot carcasses than L heifers. Backfat thickness was 1.07 and .66 cm ($P < .01$) for the EW and L heifers.

INTRODUCTION

Most cow-calf producers try to maximize longevity of cows to reduce replacement costs. However, the traditional cow-calf production system may not be the most efficient production system for some beef producers. The mature cow utilizes approximately 75 to 80% of her nutrient intake for maintenance, and only 20 to 25% for production (Dikeman, 1984). Research suggests that the single-calf heifer (SCH) system is more efficient than the traditional cow-calf production system (Crowley, 1973; Taylor et al., 1985). Biological efficiency is superior for younger females because less feed is required for maintenance (Bourdon and Brinks, 1987). Therefore, accelerated rates of mature cow replacement improves the efficiency of the management system (Taylor et al., 1985). In addition, if the calved 2-year-old heifer receives a USDA Choice grade before 30-months of age, she may be worth 30% more per kg than a cull cow (Brethour and Jaeger, 1989).

Sell et al. (1988) conducted an economic evaluation of the SCH system in comparison to other beef production systems using average costs of production and average returns for products from 1958 to 1986. They found that the traditional cow-calf production system was only profitable 18 of the 29 years evaluated and had an average yearly return of $.78 per cow. However, the SCH system was profitable 26 years and had an average yearly return of $54.53 per cow.

The objective of this experiment was to evaluate the feedlot performance and carcass composition of 30-month-old single-calf heifers which were still lactating and single-calf heifers whose calves were weaned prior to entering the feedlot.

MATERIALS AND METHODS

Twenty-four Angus × Holstein single-calf heifers (12 lactating; 12 early weaned) were used in the single-calf heifer system. For the early weaned treatment, calves were weaned randomly from their dam between d 64 and 89 postpartum. All calves remaining with their dam were steers. Early weaned heifers and heifer-steer pairs were received from University of Wisconsin, Madison, and

gradually adjusted to an 85% concentrate diet containing 13.3% CP. This was achieved by feeding a series of diets in which levels of corn were increased at the expense of ammoniated corn cobs. The diet, containing 52% high moisture cracked corn, 25% cracked-dry corn, 13% ammoniated corn cobs, and 10% protein supplement (Table 1). The diet was formulated to meet or exceed NRC (1984) requirements for CP, Ca, P, K, trace minerals, and vitamins. Calves were offered ad libitum access to a corn-based creep containing 70% ground corn, 15% whole oats, 8.3% soybean meal, 5% dry molasses, and 1.7% minerals and vitamins on a DM basis.

After the 4-wk adaption period, early weaned (EW) heifers, lactating heifers and their calves were weighed on each of two consecutive days, randomly assigned to groups, and placed in drylot pens. Drylot pens were equipped with Pinpointer 4000B (Agricultural Identification Systems Inc., Cookeville, TN) or "imitation" feeding devices to measure individual feed intakes (DeHaan et al., 1990). Groups of heifer-calf pairs and EW heifers were rotated through the two types of feeding devices at 2-wk intervals. Daily individual feed intakes for heifers were recorded using the pinpointer feeding devices, and pen feed intakes for the 2-wk periods were recorded from the "imitation" feeding devices. An individual heifer's percentage intake of pen intake from pinpointer feeding devices was multiplied by pen intake from the "imitation" feeding devices to calculate estimated individual feed intakes for heifers while in the drylot pens equipped with "imitation" feeding devices (DeHaan et al., 1990).

Heifer-calf pairs and EW heifers remained on feed for 92 d at which point EW heifers and heifers and their calves were weighed on each of two consecutive days and calves were weaned. The lactating heifers and EW heifers were shipped to Wisconsin and processed approximately 12 h later at a commercial packing plant. Carcasses were evaluated for longissimus muscle area at 12th rib, fat cover at 12th rib, kidney, pelvic, and heart fat, and marbling at 12th rib 24 h postmortem by trained university personnel (USDA, 1975). Marbling scores were based on the grading system prior to January 1, 1997.

Statistical Analysis. The GLM procedures of SAS (1992) were used to measure significance. Heifer, calf, heifer-calf pair growth performance, and heifer carcass quality were dependant variables, and lactation status was used as an independent variable.

RESULTS AND DISCUSSION

Feedlot Performance. Heifer, calf, and heifer-calf pair feedlot performance is presented in Table 2. Lactating heifers (L) and heifers whose calves were early weaned (EW) had similar on test weights ($P = .15$; 512.6 vs. 549.3); however, EW heifers were 11.9% heavier ($P = .03$) when slaughtered. The EW heifers gained 44.2% faster ($P < .01$) and consumed 10.8% less ($P = .03$) DM than L heifers. Heifer daily intake as a percentage of body weight was 2.43 and 1.97% ($P < .01$) for L and EW heifers, respectively. Efficiency of feed conversion was 60.0% higher ($P < .01$) for EW heifers than L heifers. However, when calf performance is considered, feed efficiency was .136 and .110 ($P = .02$) for L and EW heifers, respectively. Reiling et al. (1995) found that when calf performance was considered, control heifers efficiency of feed conversion improved from .098 to .158. Calves consumed 1.94 kg of DM/d of creep feed and gained 1.28 kg/d. Heifer performance was decreased due to the high milk production potential for the Holstein × Angus. However, this decrease in heifer

performance was compensated for by an increase in calf performance due to increased milk consumption.

Carcass Performance. Heifer carcass composition and quality is shown in Table 3. Hot carcass weights were 298.7 and 355.1 kg ($P < .01$) for L and EW heifers, respectively. The L heifers were 38.3% leaner ($P < .01$) than EW heifers. Longissimus muscle area per unit of carcass weight was similar ($P = .22$) for L and EW heifers. However, yield grade was lower ($P = .04$) for L heifers when compared to EW heifers. Marbling scores were $Small^{10}$ and $Small^{20}$ ($P = .53$) for L and EW heifers, respectively. Bone maturity was B^{50} and B^{20} ($P = .08$) and lean maturity was B^{40} and B^{0} ($P = .01$) for L and EW heifers, respectively. Reiling et al. (1995) reported younger maturity scores for lactating Angus × Simmental and Angus × Hereford heifers, suggesting that breed may affect maturity scores.

IMPLICATIONS

As an alternative beef management system, the single-calf heifer system has the potential to improve beef production efficiency. Dam's whose calves were weaned early and placed in the feedlot had higher daily gains and consumed less dry matter than lactating females. Utilizing early weaning with the single-calf heifer system allows a producer to receive a calf from a heifer and then place the dam in the feedlot to maximize feedlot performance. Though lactating single-calf heifer's performance is reduced because of supporting a calf, they can be finished for slaughter with a 130 d feeding period and have the potential to yield a USDA choice carcass by 30 mo of age.

LITERATURE CITED

Bourdon, R. M. and J. S. Brinks. 1987. Simulated efficiency of range beef production. III. Culling strategies and nontraditional management systems. J. Anim. Sci. 65:963.

Brethour, J. R. and J. R. Jaeger. 1989. The single-calf heifer system. Kansas Agric. Sta. Rep. of Progress 570.

Crowley, J. P. 1973. The facts of once-bred heifer production. In: J. B. Owens (Ed.) The Maiden Female - A Means of Increasing Meat Production. p 8. Proc. Symp., 1972, School of Agric., Univ. of Aberdeen, Scotland.

DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, G. F. Cmarik, and R. J. Favero. 1990. Effects of prenatal testosterone treatment and postnatal steroid implantation on growth performance and carcass traits of heifers and steers. J. Anim. Sci. 68:2198.

Dikeman, M. E. 1984. Cattle production systems to meet future consumer demands. J. Anim. Sci. 59:1631.

NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, DC.

Reiling, B. A., L. L. Berger, D. B. Faulkner, F. K. McKeith, and T. G. Nash. 1995. Effect of prenatal androgenization on performance, lactation, carcass, and sensory traits of heifers in a single-calf heifer system. J. Anim. Sci. 73:986.

SAS. 1992. SAS User's Guide: Statistics (Version 6.09 Ed.). SAS Inst. Inc., Cary, NC.

Sell, R. S., D. L. Watt, R. D. Little, and T. A. Petry. 1988. Single-calf heifer system profitability compared to other North Dakota beef production systems. Agric. Econ. Report No. 240, North Dakota State University, Fargo.

Taylor, St. C. S., A. J. Moore, R. B. Thiessen, and C. M. Bailey. 1985. Efficiency of food utilization in traditional and sex-controlled systems of beef production. Anim. Prod. 40:401.

USDA. 1975. Official United States standards for grades of carcass beef. USDA Food Safety and Quality Serv., Washington, DC.

Table 1. Ingredients of protein supplement fed to single-calf heifers

Ingredient	%[a]
Soybean meal	65.86
Blood meal	3.55
Dry molasses	2.64
Urea	8.08
Monensin 80[b]	.16
Limestone	10.77
Dicalcium phosphate	2.69
Swine TMS[c]	3.77
Vitamin ADE[d]	.16
Thiamine premix	.16
Potassium chloride	1.62
Copper sulfate acidified	.54

[a]DM basis.

[b]Contains 176 g of monensin/kg.

[c]Composition (%): NaCl (82 to 87), Fe (≥2.57), Zn (≥2.86), Mn (≥.57), Cu (≥.23), I (≥.01), and Se (≥.009).

[d]Composition (per gram): ≥3,300 IU vitamin A, ≥330 IU vitamin D_3, and ≥44 IU vitamin E.

Table 2. Effects of lactation or early weaning on the performance of 30-month-old Angus × Holstein heifers

	Treatment			
Item	Lactating	Early-weaned	SEM	P=
Heifer Performance[a]				
No. of animals	10	12		
On-test wt, kg	512.6	549.3	17.89	.15
Off-test wt, kg	587.5	657.3	21.45	.03
DMI, kg/d	13.26	11.83	.439	.03
DMI, % BW	2.43	1.97	.084	.01
Daily gain, kg/d	.90	1.30	.087	.01
Gain:feed	.069	.110	.0065	.01
Calf Performance[b]				
On-test wt, kg	145.7		5.11	
Off-test wt, kg	252.8		5.95	
DMI[c], kg/d	1.94		.086	
Daily gain, kg/d	1.28		.053	
Pair Performance[d]				
DMI, kg/d	15.00	11.83	.500	.01
Daily gain, kg/d	2.05	1.30	.123	.01
Gain:feed	.136	.110	.0075	.02

[a]Performance of two lactating heifers were not analyzed because of illness unrelated to treatment.
[b]One calf died after beginning of trial.
[c]Creep feed.
[d]Performance of heifer and calf combined.

Table 3. Effects of lactation or early weaning on the carcass composition and quality of 30-month-old Angus × Holstein heifers

	Treatment			
Item	Lactating	Early-weaned	SEM	P=
No. of animals	10	12		
Hot carcass wt, kg	298.7	355.1	11.13	.01
Dressing percentage	53.24	56.25	.539	.01
Fat thickness, cm	.66	1.07	.083	.01
Longissimus muscle area, cm^2	74.62	83.55	2.499	.02
Longissimus muscle area, cm^2/kg HCW	.251	.237	.0074	.22
Yield grade	2.45	2.89	.142	.04
Bone maturity[a]	245	217	11.0	.08
Lean maturity[a]	241	204	10.0	.01
Overall maturity[a]	243	213	9.5	.03
Marbling score[b]	1007	1023	17.3	.53

[a]Maturity scores: 100 = A^0, 200 = B^0, 300 = C^0.
[b]Marbling scores: 900 = slight^0, 1000 = small^0, 1100 = modest^0.

EFFECTS OF ENERGY INTAKE LEVEL DURING THE GROWING PHASE ON FEEDLOT STEER PERFORMANCE AND CARCASS COMPOSITION

G. N. Hermesmeyer, L. L. Berger, and T. G. Nash

SUMMARY

Two experiments were conducted to evaluate effects of energy intake level during the growing phase on steer finishing phase performance and carcass composition. In Exp. 1, Wagyu cross steers were used to compare effects of ad libitum (AL) versus restricted (RS) (75% ad libitum) intakes of a high concentrate diet. In Exp. 2., continental cross steers were used to compare effects of AL versus RS (75% ad libitum) intakes of high concentrate diet versus ad libitum hay on finishing phase performance and carcass composition. Steers were fed until they possessed approximately 1.0 cm subcutaneous fat cover. In Exp. 1, because AL steers were leaner than RS steers, backfat was used as a covariate for finishing phase performance and carcass composition. For Exp. 1 and 2, steer performance for the finishing phase was adjusted to a common dressing percentage. In the growing phase of Exp. 1, AL steers gained 18.6% more ($P < .05$); however, feed efficiencies were similar ($P = .27$) for AL and RS steers. In the finishing phase, ADG was similar ($P = .76$) for AL and RS steers; however, AL steers tended ($P < .12$) to be heavier at time of slaughter. Longissimus muscle area, yield grade, and marbling scores were similar ($P = .23$) for AL and RS steers. All steers received a Choice grade or better. During the growing phase of Exp. 2, AL steers gained faster ($P < .01$) than RS steers, who gained faster ($P < .01$) than hay fed steers. Feed efficiencies were the same for AL and RS, but higher ($P < .01$) than hay steers. Steers fed AL entered the finishing phase 21.9% heavier ($P < .01$) than RS steers, which were 13.9% heavier ($P < .01$) than hay steers. Finishing phase ADG for RS and hay steers were similar ($P = .22$) but hay steers tended ($P < .07$) to be higher than AL steers. Dressing percentage was lower ($P < .01$) for hay steers compared to AL and RS steers. Backfat, longissimus muscle area, and marbling scores were similar ($P = .20$) for all treatments. All hay and RS steers but only 87.5% AL steers graded Choice or better.

INTRODUCTION

The future of the livestock industry depends on the production of wholesome, palatable, and nutritious meat products low in fat, as efficiently as possible (Unruh, 1986). Profit in the livestock industry is directly affected by daily gain, cost of gain, and feed efficiency (Schanbacher, 1984). Feed costs are the primary expense in determining cost of gain. Therefore, for a producer to supply the consumer with an affordable and desirable product, the cost of gain must be reduced. To achieve this, beef producers must use management strategies that will allow them to reduce their production costs.

Restricted feeding is a management practice that may allow beef producers to produce a desirable product at a lower cost. Feeding a high energy diet at restricted levels, allows a producer to target a specific weight gain. After a period of restricted intake, animals have the ability to exhibit compensatory growth. Restricted feeding during the growing phase has the potential to improve gains and feed efficiencies during the growing and finishing phases. Therefore, there will be a

decrease in feed costs in the finishing phase and the exhibition of compensatory growth may improve the efficiency of gain, thus increasing the production efficiency.

MATERIALS AND METHODS

Experiment 1

Thirty-five Wagyu cross steers (152 ± 13 d of age) were used to compare the effects of ad libitum (AL) versus restricted (RS) (75% ad libitum) intakes of a high concentrate, corn and wheat middling based diet (Table 1), on growing and finishing phase performance and carcass composition. Steers were weighed and implanted with Synovex-C®. After a 105 d feeding period, steers were implanted with Synovex-S®, and placed on an ad libitum high concentrate, corn and wheat middling based diet. Twenty-eight day weights were taken to monitor steer performance throughout the trial. Approximately 110 d prior to slaughter, Revalor-S® implants were administered to all steers. Steers were fed until three steers in a pen possessed an average subcutaneous fat cover of 1.0 cm as estimated by real-time linear array ultrasound. The remaining three steers in the pen were then fed until they also possessed an average subcutaneous fat cover of 1.0 cm. Final weights for steers were taken and steers were shipped to be harvested at a commercial packing plant. Hot carcass weights were obtained and carcasses were chilled for 24 h. After being chilled for 24 h, subcutaneous fat thickness at the 12th rib, longissimus muscle area at the 12th rib, kidney, pelvic, and heart fat as a percent of carcass weight, and marbling score at the 12th rib were obtained by trained university personnel (USDA, 1975).

Experiment 2

Fifty-four Angus cross steers (115 ± 21 d of age) were used to compare the effects of AL versus RS (75% ad libitum) intake of a high concentrate, corn and wheat middling based diet, and an ad libitum chopped alfalfa (AH) diet (90% chopped alfalfa hay and 10% concentrate; Table 1) in the growing phase on feedlot performance and carcass composition. Experimental procedures followed those of Experiment 1.

Statistical Analysis. The GLM procedures of SAS (1992) were used to measure significance in both Experiment 1 and 2. For the growth performance and carcass merit, treatment was used as the independent variable. In Experiment 1, variation due to subcutaneous backfat thickness was removed for growth performance in the finishing phase and for carcass composition and quality.

RESULTS

Experiment 1

Feedlot Performance. Growth performance is presented in Table 3. Due to experimental design, RS steers consumed 22.4% less ($P < .01$) DM than AL steers in the growing phase. The AL steers gained 18.6% more ($P < .05$) than RS steers; however, AL and RS steers had similar ($P = .27$) gain:feed of .255 and .277, respectively. Steers who were fed AL during the growing phase tended ($P < .10$) to enter the finishing phase at a heavier weight than RS steers. Performance was similar ($P = .57$) for RS and AL steers while in the finishing phase. In addition, when the feedlot performance of the growing and finishing phases were combined, performance was similar ($P = .31$) for both treatments.

Carcass Composition. When steers were harvested, RS steers possessed more ($P < .01$) subcutaneous fat cover at the 12th rib than AL steers (Table 4). Due to this effect, variation of carcass composition and quality due to subcutaneous fat cover was removed. Carcass composition was similar ($P = .23$) for both treatments. In addition, carcass quality was similar ($P = .81$) for AL and RS steers.

Experiment 2

Feedlot Performance. Steer growth performance is shown in Table 5. Steers fed ad libitum hay started on trial heavier ($P < .05$) than RS, with AL steers being intermediate. This was due to one AL and three AH steers dying after the start of the trial. Restricted steers consumed 27.7% less ($P < .01$) DM than AL steers, because of experimental design, and AH steers DM intakes were intermediate. Daily gains for AL steers were 38.4 and 185.4% higher ($P < .01$) than RS and AH steers, respectively. Feed efficiencies were the same for AL and RS steers, which were higher ($P < .01$) than AH. During the finishing phase, AH tended ($P < .07$) to gain faster than AL steers. Daily intake, feed efficiency, slaughter weights, and days on feed during the finishing phase were similar ($P = .11$) for all treatments. However, when performance for the growing and finishing phases were combined, AL steers had higher ($P < .01$) daily gains than AH, with RS steers being intermediate. In addition, AL and RS steers were more ($P < .01$) efficient in feed conversion than AH steers.

Carcass Composition. Steer carcass composition and quality is presented in Table 6. Carcass dressing percentage was lower ($P < .01$) for AH than AL and RS. In addition, RS had less ($P < .05$) kidney, pelvic, and heart fat percentage than AL and AH. Numerical yield grades were lower ($P < .05$) for RS than AH, with AL being intermediate. Hot carcass weights, subcutaneous backfat thickness, and longissimus muscle area were similar ($P = .15$) for all treatments. All carcass quality traits were similar ($P = .12$) for all treatments. Though nonsignificant, all RS and AH steers received a USDA Choice grade, but only 87.5% of AL received a USDA Choice grade. However, 6.25% of the AL received a USDA Prime grade.

DISCUSSION

Feedlot Performance. The findings in this paper conclude that restriction (75% ad libitum intake) of a 85% concentrate diet resulted in a reduction in daily gains and an improvement in feed efficiency during the growing phase. In addition, ad libitum access to an 85% forage diet, resulted in lower daily gains and feed efficiencies than ad libitum or restricted intakes of a high concentrate diet. In Exp. 2, ad libitum and restricted steers had the same gain:feed ratios during the growing phase; however, the RS steers consumed 27.7% less DM per day. This leads the authors of this paper to believe that either the maintenance requirements of the RS steers has been reduced or the composition of their gain has been altered. Results from both experiments show no effect of limit feeding a high concentrate diet on subsequent feedlot performance. When both growing and finishing phases are combined, restricted intake during the growing phase improved overall feed efficiency when compared to ad libitum intake of a high forage diet during the growing phase. Though it was not significant ($P > .31$), RS steers in Exp. 1 were 10.9% more efficient than AL steers. Leorch (1990) reported that steers limit fed an all concentrate diet had reduced feed intakes, improved feed efficiencies, and tended to have higher daily gains than steers offered ad libitum access of corn silage. In addition Leorch (1990) reported that growing phase diet had no effect on finishing phase daily

gains. It was also reported that when growing and finishing phase performance were combined, overall gains for steers limit fed during the growing phase tended to have greater daily gains. In contrast to these results, Lofgreen et al. (1987) reported that limiting DM intake to 80 or 90% of ad libitum intake until steers reached 318 kg, resulted in a tendency for subsequent feed efficiency to be improved. In addition to this, Hicks et al. (1990) found that limiting DM intake for 56 d tended to improve feed efficiency 7.2% in the following feeding period.

Carcass Composition. In Exp. 1, restricted feeding resulted in no effects on carcass composition or quality. The steers in Exp. 1 all received a Choice grade and a high percentage received a Prime grade; however, steers yield grades only averaged a yield grade 2. This low numerical yield grade for cattle with such high quality grades is most likely due to their Wagyu breed type. In Exp. 2, restricted intakes resulted in a decrease in kidney, pelvic, and heart fat percentage, and increase in dressing percentage, and a decrease in numerical yield grade when compared to ad libitum forage in the growing phase. Loerch (1990) reported that limit feeding an all concentrate diet in the growing phase resulted in heavier hot carcasses when compared to carcasses of steers offered ad libitum access to corn silage in the growing phase. No other differences in carcass composition or quality were reported. Hicks et al. (1990) found that a 20% reduction in DM intake resulted in a decrease in the percentage of carcasses receiving a Choice grade when compared to steers offered ad libitum access to a high concentrate diet. However, when these researchers used hot carcass weight as a covariate, though nonsignificant, there was a 31.2 percentage unit decrease in percent carcass grading Choice. In addition, when variation due to hot carcass weight was removed, Hicks et al. (1990) reported carcasses from restricted fed steers received higher numerical yield grades than steers offered ad libitum access of a high concentrate diet.

IMPLICATIONS

Restricting feed intake during the growing phase to control weight gains may decrease feed costs in the growing phase and have no effect on feedlot performance during the finishing phase. Overall weight gains for both phases combined may be decreased when feed intake is restricted; however, feed efficiencies can be improved. In addition, there may be an improvement in carcass composition and little effect on carcass quality. Therefore, restricted intake to target a specific weight gain during the growing phase is a management strategy beef producers may be able to utilize to improve their production efficiencies. Furthermore, carcass quality may be improved by placing steers in the feedlot at an early age.

LITERATURE CITED

SAS. 1992. SAS User's Guide: Statistics (Version 6.09 Ed.) SAS Inst. Inc., Cary NC.

Schanbacher, B. D. 1984. Manipulation of endogenous and exogenous hormones for red meat production. J. Anim. Sci. 59:1621-1630.

Unruh, J. A. 1986. Effects of endogenous and exogenous growth-promoting compounds on carcass composition, meat quality and meat nutritional value. J. Anim. Sci. 62:1441-1448.

USDA 1975. Official United States standards for grades of carcass beef. USDA Food Safety and Quality Serv., Washington, DC.

Table 1. Composition of ad libitum (AL) and restricted (RS) high concentrate diets and ad libitum hay (AH) diet fed to steers

Item	AL[a]/RS[b]	AH
	----------% DM basis----------	
Chopped alfalfa hay	--	85
Cracked corn	48	--
Wheat middlings	25	--
Corn silage	15	--
Supplement[c]	7	10
Corn distillers solubles	5	5

[a]Fed to all steers in the finishing phase.
[b]Fed at 75% of ad libitum intake.
[c]See Table 2.

Table 2. Composition of supplements in ad libitum (AL) and restricted (RS) high concentrate diets and ad libitum hay (AH) diet fed to steers

Item	AL[a]/RS[b]	AH
	----------% DM basis----------	
Soybean meal	56.64	--
Cracked corn	--	96.24
Limestone	21.49	--
Urea	10.73	--
Potassium chloride	7.16	--
Trace mineral salt + Se[c]	3.58	3.47
Monensin 80[d]	.24	.17
Vitamin ADEK[e]	.16	.12

[a]Diet fed to all steers in the finishing phase.

[b]Diet fed at 75% ad libitum intake.

[c]Composition (%): NaCl (82 to 87), Fe (≥2.57), Zn (≥2.86), Mn (≥.57), Cu (≥.23), I (≥.01), and Se (≥.009).

[d]Contains 176 g of monensin/kg.

[e]Composition (per gram): ≥3,300 IU vitamin A, ≥330 IU vitamin D_3, and ≥44 IU vitamin E.

Table 3. Effects of energy intake levels during the growing phase on steer feedlot performance (Exp. 1)

Item	Ad libitum	Restricted	SEM	P=
Growing Phase				
On-trial wt, kg	116.7	112.2	4.06	.47
Off-trial wt, kg	244.3	219.7	7.49	.08
Daily intake, kg	4.77	3.70	.094	.01
Daily gain, kg	1.21	1.02	.045	.04
Gain:feed	.255	.277	.0121	.27
Finishing Phase[a]				
Off-trial wt, kg[b]	473.8	444.3	7.45	.11
Days on feed	220	224	19.8	.93
Daily intake, kg	8.12	7.72	.519	.69
Daily gain, kg[b]	1.01	1.05	.071	.76
Gain:feed[b]	.122	.138	.0138	.57
Combined phases				
Days on feed	325	329	19.8	.93
Daily intake, kg	7.03	6.39	.327	.35
Daily gain, kg	1.07	1.04	.032	.61
Gain:feed	.165	.183	.0080	.31

[a]Backfat thickness used as covariate.
[b]Adjusted for average dressing percentage of 61.11%.

Table 4. Effects energy intake levels during the growing phase on steer carcass composition and quality (Exp. 1)

Item	Ad libitum	Restricted	SEM	P=
Hot carcass wt, kg[a]	287.2	274.1	9.07	.33
Dressing percentage[a]	61.59	61.29	.433	.65
Backfat thickness, cm	.90	1.26	.084	.01
Longissimus muscle area, cm^{2a}	83.08	78.10	2.795	.23
Kidney, pelvic, and heart fat, %[a]	2.89	2.79	.189	.70
Yield grade[a]	2.41	2.53	.099	.44
Marbling score[ab]	1199	1201	26.1	.95
≥Choice, %[a]	100.00	100.00	--	--
≥Prime, %[a]	19.83	24.19	.120	.81

[a]Backfat thickness used as covariate.
[b]Marbling scores: 1000 = small^0, 1100 = modest^0, 1200 = moderate^0.

Table 5. Effects of energy intake levels during the growing phase on steer feedlot performance (Exp. 2)

Item	Ad libitum	Restricted	Ad libitum hay	SEM
Growing Phase				
On-trial wt, kg[a]	135.9[fg]	125.3[f]	151.2[g]	6.13
Off-trial wt, kg	279.9[e]	229.5[d]	201.5[c]	4.75
Daily intake, kg	5.01[e]	3.62[c]	4.26[d]	.120
Daily gain, kg	1.37[e]	.99[d]	.48[c]	.026
Gain:feed	.274[d]	.274[d]	.113[c]	.0062
Finishing Phase				
Off-trial wt, kg[b]	576.5	553.7	540.1	24.59
Days on feed	233	246	244	7.5
Daily intake, kg	9.03	8.87	9.33	.207
Daily gain, kg[b]	1.27	1.32	1.41	.044
Gain:feed[b]	.141	.149	.151	.0041
Combined phases				
Days on feed	338	352	351	6.8
Daily intake, kg	7.78	7.30	7.81	.163
Daily gain, kg	1.31[d]	1.23[cd]	1.13[c]	.032
Gain:feed	.183[d]	.187[d]	.139[c]	.0035

[a]On-trial weights significantly differ ($P < .05$) because one ad libitum steer and three ad libitum hay steers died after beginning of trial.

[b]Adjusted for average dressing percentage of 61.18%.

[c,d,e]Means differ ($P < .01$).

[f,g]Means differ ($P < .05$).

Table 6. Effects energy intake levels during the growing phase on steer carcass composition and quality (Exp. 2)

Item	Ad libitum	Restricted	Ad libitum hay	SEM
Hot carcass wt, kg	352.3	340.0	333.4	14.11
Dressing percentage	61.69[c]	62.03[c]	59.44[b]	.421
Backfat thickness, cm	.93	.79	.87	.075
Longissimus muscle area, cm^2	91.77	92.87	87.26	3.374
Kidney, pelvic, and heart fat, %	2.97[e]	2.44[d]	2.96[e]	.178
Yield grade	2.41[de]	2.01[d]	2.47[e]	.169
Marbling score[a]	1156	1116	1131	25.5
≥Choice, %	87.50	100.00	100.00	5.893
≥Prime, %	6.25	0.00	0.00	4.313

[a]Marbling scores: 1000 = small[0], 1100 = modest[0], 1200 = moderate[0].
[b,c]Means within row differ ($P < .01$).
[d,e]Means within row differ ($P < .05$).

THE EFFECTS OF CORN MILLING CO-PRODUCTS ON GROWTH PERFORMANCE AND DIET DIGESTIBILITY BY BEEF CATTLE

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SUMMARY

Ninety-six Simmental x Angus crossbred weanling heifer calves (239 ± 2.3 kg) were used in four replications to evaluate three dietary treatments in Trial 1. Treatments were cracked corn-hay based diets supplemented with one of three corn wet milling industry co-products: dry corn gluten feed (DCGF), dried distillers grains (DDG), and a new modified corn fiber (MCF). In Trial 2, four ruminally cannulated mature crossbred beef steers (606 ± 60 kg) were utilized in a 4 × 4 Latin square with 11 d periods to determine digestibility and ruminal metabolism of limit-fed cracked corn-hay diets supplemented with: cornstarch (CON), DCGF, DDG, or MCF. An in situ study was conducted to compare the rate and extent of crude protein (CP) degradation of DCGF, DDG, and MCF. There were no differences in initial weights or dry matter intake (DMI) of heifers fed the three treatments in Trial 1. Average daily gain and feed efficiency (G/F) were improved for heifers fed DCGF ($P < .01$) or DDG ($P < .001$) vs. heifers fed MCF. No differences in digestibilities of any nutrients or in ruminal VFA concentrations were observed in Trial 2 for steers fed DCGF or DDG vs. those fed MCF. Supplementing cornstarch (CON) resulted in decreased ($P < .05$) total dietary fiber (TDF) digestibility, tended ($P < .10$) to improve digestibilities of DM and OM, increased ($P < .05$) total VFA concentrations and concentrations of propionate and valerate, but decreased ($P < .05$) concentrations of butyrate, isobutyrate, and isovalerate when compared to DCGF, DDG, and MCF. Dry corn gluten feed had increased ($P < .05$) and DDG tended to have increased ($P < .10$) percentages of the immediately soluble fraction of CP and both had increased ($P < .05$) rates (K_d) and greater ($P < .05$) extent of ruminal CP degradation than MCF. These data suggest that DCGF and DDG may be utilized in limit-fed high-energy diets without decreasing performance or digestibility. Feeding of MCF resulted in poorer performance of heifers; MCF may have limited feeding value because of poor digestion characteristics.

INTRODUCTION

Recently, increased consumer demand for fructose sweetener and the use of ethanol as a fuel additive have resulted in increased wet and dry milling of corn (Schrage et al., 1991). This has resulted in the production of co-products, such as corn gluten feed and a new ethanol co-product, hereafter referred to as modified corn fiber, which may be used as supplemental feedstuffs.

Wet corn gluten feed is approximately one-third corn steep liquor and two-thirds corn bran. Corn gluten feed has been used in high energy diets for cattle because it contains high levels of readily fermentable fiber and crude protein (Bowman and Patterson, 1988). It is also a feedstuff that will provide additional energy without depressing fiber digestion (Hannah et al., 1990). Dried distillers grains are a co-product of the corn dry milling industry and contain de-alcoholized fermentation residues that remain after cereal grains have been fermented by yeast (Weigel et al., 1997). Dried distillers grains are beneficial in some ruminant diets due to their high content of undegraded intake protein (UIP).

The modified corn fiber (MCF) is a potential product of the corn wet milling industry. It is produced by a secondary fermentation of the corn bran which would enable the corn processor to more fully recover alcohol from the corn. This modified corn fiber may be an effective fiber and protein source to supplement diets. It is high in protein (22%) and moderate in total dietary fiber (36%) and may be an effective supplement if the fiber is highly digestible and the protein quality is acceptable for the ruminant animal. Therefore, the objective of this study was to compare the utilization of the new modified corn fiber in limit-fed high-energy diets to dry corn gluten feed and dried distillers grains.

MATERIALS AND METHODS

Trial 1. Ninety-six Simmental x Angus crossbred weanling heifer calves (239 ± 2.3 kg) at the Orr Research Center, Baylis, Il. were utilized in four replications to evaluate three treatments. This resulted in twelve pens with eight heifers per pen. The three treatments were a cracked corn-hay based diet supplemented with three corn co-products: dry corn gluten feed (DCGF), dried distillers grains (DDG), and modified corn fiber (MCF) (Table 1). The diets were supplemented with trace minerals and Rumensin® and were limit-fed to allow the heifers to attain a predicted daily gain of .8 kg. The diets were fed to supply similar amounts of energy and protein and to ensure that all other nutrients met or exceeded National Research Council (1996) recommendations. Heifers were blocked by weight and randomly assigned to treatment. Full weights were taken on two consecutive days and averaged to obtain initial (d 0) and final weights for each heifer (d 84). Weights were taken every 28 d during the trial. Samples of the three corn co-products were taken bi-weekly, composited, and analyzed for DM, OM, Kjeldahl N (AOAC, 1984), NDF (Jeraci et al., 1988), ADF (Goering and Van Soest, 1970), TDF (Prosky et al., 1984) and gross energy (GE) (Table 2). Heifer liveweight gain and efficiency of gain were evaluated.

Trial 2. Four ruminally cannulated crossbred beef steers (606 ± 60 kg) were utilized in a 4 × 4 Latin square arrangement of treatments with 11 d periods (d 1-7, adaptation; d 8-11, sampling) to evaluate four treatments. The four treatments were a limit-fed cracked corn-hay based diet supplemented with one of four corn co-products: cornstarch (CON), DCGF, DDG, or MCF. The diets (Table 3) were limit-fed at 2% of body weight and were supplemented with Monensin 80®. They were balanced to make the same comparisons as Trial 1 and to meet or exceed all NRC (1996) recommendations. Steers had ad libitum access to trace mineralized salt for the duration of the trial.

A gelatin capsule containing 7.5 g of Cr as Cr_2O_3 was inserted into the rumen daily at 0800 and 2000 to provide a marker to use to estimate fecal output for calculation of total tract digestibility. On d 8 through 11 of each period, fecal grab samples were collected and frozen immediately. Samples were collected every 4 h each day and the sampling times were advanced 1 h each day to yield 23 samples that represent a 24 h period. Fecal samples for each animal in each period were composited and analyzed for Cr concentration according to Williams et al. (1962).

Ruminal fluid samples were collected at 0, 2, 4, 6, 8, 12, 16 and 20 h post-feeding on d 8. Ruminal fluid pH was determined immediately after collection. Subsequently, a 50 mL sample was acidified with 1 mL of 6 N HCl and frozen. Samples were allowed to thaw and a 10 mL subsample was taken from each of the respective samples and composited for VFA analysis (Merchen et al., 1986).

Feed samples were taken prior to and during each collection period and composited. Feed and fecal samples were dried at 55° C and ground through a Wiley Mill equipped with a 2 mm screen. Samples were analyzed for percentage of DM, OM, Kjeldahl N (AOAC, 1984), and TDF (Prosky et al., 1984). Total dietary fiber was analyzed instead of NDF and ADF to more accurately reflect fiber content and to remove interference from inorganic matter and Maillard browning products usually present in corn co-products due to heat treatment or drying during processing. Gross energy was determined for both feed and fecal samples by bomb calorimetry (AOAC, 1984). Digestible energy (Mcal/ kg DM) of the diets was estimated from the GE of the feed and the feces and from the digestibility of the diet DM.

At the conclusion of periods III and IV, in situ disappearance of CP in DCGF, DDG, and MCF were measured using the animal fed the CON diet during the respective period. Original CP percentages were calculated by Kjeldahl N (AOAC, 1984). Approximately 5 g of each sample were placed, in triplicate, into 5 x 10 cm nylon bags and tied closed with string. Duplicate empty bags were placed into the rumen for each time period to account for microbial attachment to the bags. Corrected residues were obtained by subtracting the increase in weight of the blank bags from the sample bags for their respective time of removal. Bags were removed at 0, 3, 6, 9, 12, 18, and 24 h of incubation. Bags for the 0 h incubation were not suspended in the rumen, but were soaked in warm tap water for 20 minutes and then rinsed to determine the immediately soluble fraction. All other bags were suspended in the rumen for their appropriate time of incubation and rinsed with tap water until the rinse water was clear. Bags were subsequently dried at 55° C, subsamples were taken from each bag, and analyzed for Kjeldahl N (AOAC, 1984). Rate of CP disappearance was computed as the slope of the natural logarithm of the % of CP remaining against time. Estimates of the extent of degradation were determined according to Mathers and Miller (1981). The equation utilized is:

$$a + (1- a)(K_d / K_r + K_d)$$

where K_r = rate constant for passage of undegraded CP from the rumen, assumed in this case to be .05/h.

K_d = rate of disappearance of CP from nylon bags (%/h)

a = proportion of CP disappearance at 0 h (assumed soluble and 100 % degradable).

STATISTICAL ANALYSIS

Effects of dietary treatment on heifer performance (Trial 1) were analyzed using the General Linear Models (GLM) procedure of SAS (1992) for a completely randomized design, with pen as the experimental unit. Orthogonal contrasts were used to compare DCGF versus MCF and DDG versus MCF (Trial 1). Data from the digestibility study were analyzed according to the GLM procedure of SAS (1992) for a 4 × 4 Latin square design. Digestion criteria (Trial 2) were analyzed using a model containing digestibility of DM, OM, TDF, CP, GE, and ruminal VFA data as dependent variables and treatment, period, and animal as independent variables. Orthogonal contrasts were used to compare CON versus DCGF, DDG, and MCF; DCGF versus MCF; and DDG versus MCF. Ruminal pH was analyzed using the GLM procedure of SAS (1992) using a model containing treatment, period, animal, hour, and treatment × hour as independent variables and pH as the dependent variable. The same orthogonal contrasts were used as for the digestibility data. There was no treatment × hour interaction (P>.99), so the interaction was removed from the model statement and only the main

effects are reported. Rate and extent of CP degradation were analyzed according to the GLM procedures of SAS (1992), with animal as the experimental unit. Orthogonal contrasts were utilized to compare DCGF versus MCF and DDG versus MCF.

RESULTS AND DISCUSSION

Trial 1. Ingredient composition of diets fed to the growing heifer calves was similar across treatments (Table 1). Composition of the corn co-products is shown in Table 2. Along with the relatively high level of ADF, MCF had higher amounts of acid detergent insoluble nitrogen (ADIN) than DDG or DCGF. TDF content was similar among corn co-products. Heifers consuming the DDG and DCGF treatment had gains that exceeded the projected average daily gain of .8 kg/d (Table 3).

Heifers had similar initial weights and overall DMI across the three treatments. Average daily gain was increased ($P < .001$) by 39% for heifers fed DDG and was increased ($P < .01$) by 29% for heifers fed DCGF compared to those fed MCF. Efficiency of gain (gain:feed) was improved ($P < .001$) by 43% and ($P < .01$) by 34% for the DDG and DCGF treatments, respectively, versus the MCF treatment. No differences were observed for average daily gains and efficiencies of gain between DDG and DCGF. In contrast, Berger and Firkins (1985) observed that steers fed DDG grew more rapidly and were more efficient than those fed DCGF, when DCGF was fed at 34.9% and DDG was fed at 17.4% of the diet. This may be due to the lower energy content of the DCGF diet. Berger and Willms (1992) and Hussein and Berger (1995) observed that limit-fed heifers utilizing 25% WCGF had similar gains as those heifers on a limit-fed corn-corn silage based diets. These data suggest that MCF has a lower energy value or lower protein quality than DDG or DCGF.

Trial 2. The ingredient composition of the diets fed to the cannulated steers are shown in Table 4. Nutrient composition of the treatments is shown in Table 5. Corn co-products were included at 20% of the diets for all treatments. Percentage of DM was similar among diets; however, the MCF diet had a lower OM concentration and the CON diet had lower TDF and CP concentrations than the other treatments.

The effects of corn co-products on apparent total tract digestibility is shown in Table 6. Dry matter intake was similar among treatments as diets were fed at 2% of body weight for each steer. The CON diet tended to have higher ($P < .10$) digestibilities of DM (DMD) and OM (OMD) compared to the other diets, but had decreased ($P<.05$) TDF digestibility (TDFD) compared to the other treatments.

No differences in digestibility were detected utilizing orthogonal contrasts comparing DCGF vs. MCF or DDG vs. MCF. However, the MCF treatment had numerically lower DMD, OMD, and CPD than the DCGF or DDG treatments. The DDG diet had numerically higher TDFD than the DCGF or MCF supplemented diets. Ham et al. (1994) also observed no differences in the digestibilities of OM, starch, NDF, and N when comparing DCGF and wet distillers grains (WDG). In agreement with these data, Hannah et al. (1990) concluded that feeding corn gluten feed had no negative effects on rate of forage digestion or dietary OM, NDF, and ADF digestibilities. Oliveros et al. (1987) stated that the steep liquor portion of corn gluten feed increases microbial activity in the rumen; thus, it may increase the supply of protein and energy to the ruminant animal.

Fecal output (FO) tended ($P < .10$) to decrease when feeding the CON diet was fed vs. other treatments. No statistically significant differences were observed in FO for DCGF and DDG versus MCF, although MCF had numerically higher FO than DCGF or DDG.

The effects of corn co-products on energy intakes and digestibilities are shown in Table 7. Gross energy (GE) content of the feed was similar among treatments as well as GE intake; however, the CON diet had significantly lower ($P < .05$) GE fecal output and tended to have increased ($P < .10$) digestible energy (DE) as a percentage of GE intake when compared to the other treatments. No differences were observed between DCGF and MCF or DDG and MCF; although, MCF had numerically higher GE output in the feces than DCGF or DDG and subsequently had lower numerical value for DE as a percent of GE intake than DCGF or DDG. Digestible energy (Mcal/kg) was calculated for each treatment and no significant differences were observed, although the MCF diet had numerically lower DE (Mcal/kg) than the other treatments. Corn gluten feed not only offers a highly digestible fiber, but the steep liquor also enhances the energy value by moderating ruminal pH and subsequently increasing ruminal fiber digestion (Green and Stock, 1986).

There were no significant differences in ruminal pH (Table 8) when comparing MCF to DCGF or DDG. The CON treatment had a significantly lower ($P< .05$) average pH when compared to the other treatments. The DCGF treatment had numerically lower average pH values when compared to steers fed MCF or DDG; although, MCF and DDG had similar average pH values.

The effects of corn co-products on ruminal VFA concentrations is shown in table 8. No significant differences were observed in VFA concentrations between DCGF or DDG, and MCF. Supplementing cornstarch (CON) resulted in increases ($P < .05$) in total VFA concentrations and concentrations of propionate and valerate, and decreases ($P < .05$) in concentrations of butyrate, isobutyrate, and isovalerate.

Rate and extent of in situ CP degradation of corn co-products are shown in table 9. Initial CP percentages were 19.71, 28.61, and 21.13 % for DCGF, DDG, and MCF, respectively. Dry corn gluten feed had a greater ($P < .05$) fraction and DDG tended to have an increased ($P < .10$) fraction of CP that was immediately soluble (CP disappearance at 0 h, %) when compared to MCF. Immediately soluble fractions as a percentage of original were 62.58, 39.21, and 29.03 % for DCGF, DDG, and MCF, respectively.

Rates of disappearance of the potentially degradable substrate (K_d) were calculated using the slope of the natural logarithm of the percentage of CP remaining against time. Modified corn fiber had a dramatically lower ($P<.05$) rate of CP degradation (-.07 %/h) than DCGF and DDG; there was essentially no disappearance of CP from the polyester bags other than the immediately soluble fraction. Extent of CP degradation (20 h) was calculated according to Mathers and Miller (1981) using an assumed ruminal passage rate of .05 %/ h. Modified corn fiber had lower ($P < .05$) extent of CP degradation (27.58%) than DCGF and DDG (73.19 and 57.60%, respectively). The lower extent of CP degradation for MCF in relation to the immediately soluble fraction (27.58 % versus 29.03%) suggests that the fraction of CP in MCF which is not immediately soluble is completely unavailable.

Firkins et al. (1984) concluded that DCGF had a higher rate of in situ N disappearance then DDG for 2 to 8 h of incubation. They further concluded that N escaping the rumen and reaching the duodenum was higher for DDG than for DCGF, stating that DDG has a higher UIP than DCGF. Firkins et al. (1985) also stated that DDG had higher UIP than corn gluten feed; therefore, increasing the amount of protein directly available to the ruminant.

IMPLICATIONS

Corn gluten feed and dried distillers grains were effective energy and protein sources in these diets. The feeding of modified corn fiber is not an acceptable source of protein and energy for the ruminant animal. Its feeding value is limited due to the unavailability of its protein fraction and lower energy value. Modified corn fiber may have been more efficacious if it were processed in a different manner.

LITERATURE CITED

AOAC. 1984. Official Methods of Analysis. (13th Ed.). Association of Official Analytical Chemists. Washington, DC.

Berger, L.L., and J.L. Firkins. 1985. Corn gluten feed for beef cattle. Proc. Corn Gluten Feed for the Livestock Industry. Iowa State University Extension. pp 1-8.

Berger, L.L., and C.L. Willms. 1992. Energy value of wet corn gluten feed in a restricted feeding program for feedlot cattle. Illinois Beef Research Report. pp 3-5.

Bowman, J.G.P., and J.A. Paterson. 1988. Evaluation of corn gluten feed in high-energy diets for sheep and cattle. J. Anim. Sci. 66:2057-2070.

Firkins, J.L., L.L. Berger, G.C. Fahey Jr., and N.R. Merchen. 1984. Ruminal nitrogen degradability and escape of wet and dry distillers grains and wet and dry corn gluten feeds. J. Anim. Sci. 67:1936-1944.

Firkins, J.L., L.L. Berger, and G.C. Fahey, Jr. 1985. Evaluation of wet and dry distillers grains and wet and dry corn gluten feed for ruminants. J. Anim. Sci. 60:847-860.

Green, D., and R. Stock. 1986. Corn gluten feed in finishing diets. Nebraska Beef Cattle Report. pp 17-19.

Goering, H.K., and P.J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures and some applications). Agric. Handbook No. 379, ARS, USDA, Washington, DC.

Ham, G.A., R.A. Stock, T.J. Klopfenstein, E.M. Larson, D.H. Shain, and R.P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72:3246-3257.

Hannah, S.M., J.A. Paterson, J. E. Williams, and M.S. Kirby. 1990. Effects of corn vs. corn gluten feed on site, extent, and ruminal rate of forage digestion and on rate of efficiency of gain. J. Anim. Sci. 68:2536-2545.

Hussein, H.S., and L.L. Berger. 1995. Effects of feed intake and dietary level of wet corn gluten feed on feedlot performance, digestibility of nutrients, and carcass characteristics of growing-finishing beef heifers. J. Anim. Sci. 73:3246-3252.

Jeraci, J.L., T. Hernandez, J.B. Robertson, and P.J. Van Soest. 1988. New and improved procedure for neutral detergent fiber. J. Anim. Sci. 66 (Suppl. 1): 351(Abstr.).

Mathers, J.C., and E.L. Miller. 1981. Quantitative studies of food protein degradation and the energetic efficiency of microbial protein synthesis in the rumen of sheep given chopped lucerne and rolled barley. Br. J. Nutr. 45:587.

Merchen, N.R., J.L. Firkins, and L.L. Berger. 1986. Effect of intake and forage level on ruminal turnover rates, bacterial protein synthesis and duodenal amino acid flows in sheep. J. Anim. Sci. 62:216-225.

NRC. 1996. Nutrient Requirements of Beef Cattle (7th Ed.). National Academy Press, Washington, DC.

Oliveros, B., F. Goedeken, E. Hawkins, and T. Klopfenstein. 1987. Dry or wet corn bran or corn gluten feed for ruminants. Nebraska Beef Cattle Report, pp 14-16.

Prosky, L., N.G. Asp, I. Furda, J.W. DeVries, T.F. Schweizer, and B.F. Harland. 1984. Determination of total dietary fiber in food and food products: Collaborative study. J. Assoc. Off. Anal. Chem. 67: 1044-1052.

SAS. 1992. SAS User's Guide; Statistics. (Version 6 Ed.) SAS Inst., Inc. Cary, NC.

Schrage, M.P., H.D. Woody, and A.W. Young. 1991. Net energy of ensiled wet corn gluten feed in corn silage diets for finishing steers. J. Anim. Sci. 69:2204-2210.

Weigel, J.C., D. Loy, and L. Kilmer. 1997. Feed co-products of the dry corn milling process. Renewable Fuels Association, Washington D.C., and National Corn Growers Association, St. Louis, Mo.

Williams, C.H., D.J. David, and O. Iismaa. 1962. The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. J. Agric. Sci. (Camb.) 59:381.

Table 1. Composition of diets fed to growing heifer calves (Trial 1)[a]

	Treatments[b]		
Ingredient, kg/DM basis	DCGF	DDG	MCF
	----kg on a DM basis----		
Alfalfa hay	.54	.54	.54
Cracked corn	3.65	4.09	4.09
Dry corn gluten feed	1.25	--	--
Dried distillers grains	--	.82	--
Modified corn fiber	--	--	.82

[a]Heifers also received trace mineralized salt, 114 g/hd/d, composition (%): NaCl, 20-24; Ca, 14.5-16.5; P, >8; Mg, >1.1; S, >.71; K, >2.24; Fe, >.25; Zn, >.25; Mn, >.25; Cu, >.03; Co, >.003; I, >.004; Se, >.0026 and Vitamin A, >529,100; Vitamin D_3, >88,183; Vitamin E, >441 IU/kg; and Rumensin® at ~200 mg/hd/d.

[b]DCGF = limit-fed dry corn gluten feed diet, DDG = limit-fed dried distillers grains diet, MCF = limit-fed modified corn fiber diet.

Table 2. Composition of corn co-products (Trials 1 and 2)

	Treatments[a]		
Item	DCGF	DDG	MCF
DM, %	83.1	87.1	82.2
OM,% DM	93.8	91.9	69.9
CP, % DM	20.1	29.4	23.3
NDF, % DM	37.7	45.2	49.4
ADF, % DM	7.0	12.9	45.4
TDF, % DM	32.3	35.5	35.6
ADIN, % DM	.17	.67	2.53
GE, Mcal/kg	4.55	4.78	4.71

[a]DCGF = dry corn gluten feed, DDG = dried distillers grains, MCF = modified corn fiber.

Table 3. Performance of heifers fed corn co-products (Trial 1)[a]

	Treatments[b]			
Item	DCGF	DDG	MCF	SEM
DMI, kg/d	5.45	5.45	5.45	
Initial wt., kg	237.80	238.03	240.18	1.08
Final wt.(d 84), kg [cd]	313.78	319.56	298.92	2.65
Total wt. gain (d 1-84), kg[cd]	76.09	81.53	58.74	2.57
Avg. daily gain (d 1-84), kg/d[cd]	.905	.970	.699	.031
Gain/feed[cd]	.167	.179	.125	.012

[a]Least squares means.

[b]DCGF = limit-fed dry corn gluten feed diet, DDG = limit-fed dried distillers grains diet, MCF = limit-fed modified corn fiber diet.

[c]CGF vs. MCF ($P < .01$).

[d]DDG vs. MCF ($P < .001$).

Table 4. Ingredient and chemical composition of diets fed to cannulated beef steers (Trial 2)[a]

Ingredient	Treatments[b]			
	CON	DCGF	DDG	MCF
	----kg on a DM basis----			
Alfalfa hay	2.50	2.52	2.50	2.54
Cracked corn	6.46	6.53	6.49	6.58
Cornstarch	2.50	--	--	--
Dry corn gluten feed	--	2.52	--	--
Dried distillers grains	--	--	2.50	--
Modified corn fiber	--	--	--	2.54
Corn steep liquor	.62	.63	.63	.64
Urea, g	124.8	126.1	125.2	127.0
Limestone, g	87.4	88.3	87.6	88.9
Potassium chloride, g	62.4	63.1	62.6	63.5
Monensin 80®, g [c]	1.10	1.11	1.10	1.12
Dry Matter (DM), %	74.40	73.54	74.35	73.39
Organic Matter, % DM	88.78	87.60	87.23	82.88
Total Dietary Fiber, % DM	21.40	27.85	28.49	28.51
Crude Protein, % DM	8.05	11.98	13.83	12.64

[a]Animals had ad libitum access to trace mineralized salt, composition (%): NaCl, 20-24; Ca, 14.5-16.5; P, >8; Mg, >1.1; S, >.71; K, >2.24; Fe, >.25; Zn, >.25; Mn, >.25; Cu, >.03; Co, >.003; I, >.004; Se, >.0026 and Vitamin A, >529,100; Vitamin D_3, >88,183; Vitamin E, >441 IU/kg.

[b]CON = limit-fed cornstarch diet, DCGF = limit-fed dry corn gluten feed diet, DDG = limit-fed dried distillers grains diet, MCF = limit-fed modified corn fiber diet.

[c]Monensin 80® contains 176 g active ingredient/ kg. Was fed to obtain ~200 mg active ingredients/hd./d.

Table 5. Effects of corn co-products on DMI and apparent total tract digestibility (Trial 2)[a]

	Treatments[b]				
Item	CON	DCGF	DDG	MCF	SEM
Dry matter intake, kg/d	12.5	12.6	12.5	12.7	.7
DMD, %[c]	70.8	62.0	62.6	59.6	1.9
OMD, %[c]	70.1	61.0	61.0	54.9	2.2
TDFD, %[d]	24.5	33.7	42.1	38.6	3.9
CPD, %	51.1	43.9	40.8	39.2	4.0
FO, kg/d[d]	3.6	4.8	4.6	5.1	.4

[a]Least squares means.
[b]Co-product supplemented: CON = cornstarch, DCGF = dry corn gluten feed, DDG = dried distillers grains, MCF = modified corn fiber.
[c]CON vs. CGF, DDG, MCF ($P < .10$).
[d]CON vs. CGF, DDG, MCF ($P < .05$).

Table 6. Effects of corn co-products on energy digestibility (Trial 2)[a]

	Treatments[b]				
Item	CON	DCGF	DDG	MCF	SEM
GE feed, Mcal/kg	4.0	4.1	4.1	4.1	
GE intake, Mcal/d	49.8	51.3	51.6	52.1	2.6
GE output, Mcal/d[c]	17.1	21.9	21.7	25.1	2.0
DE, %[d]	65.2	57.0	57.3	51.9	4.8
DE, Mcal/kg	2.6	2.3	2.4	2.1	.2

[a]Least squares means.
[b]Co-product supplemented: CON =cornstarch, DCGF = dry corn gluten feed, DDG = dried distillers grains, MCF = modified corn fiber.
[c]CON vs. CGF, DDG, MCF ($P < .05$).
[d]CON vs. CGF, DDG, MCF ($P < .10$).

Table 7. Effects of corn co-products on ruminal pH and VFA concentrations (Trial 2)

	Treatments[a]				
Item	CON	DCGF	DDG	MCF	SEM
Ruminal pH[b]	5.96	6.19	6.24	6.28	.04
Total VFA, mM[b]	64.41	55.47	56.02	53.34	1.39
Acetate	31.50	32.91	32.63	31.77	.68
Propionate[b]	25.82	13.86	14.17	13.08	1.34
Butyrate[b]	4.59	6.31	6.81	6.36	.38
isoButyrate[b]	.48	.60	.67	.59	.04
Valerate[b]	1.35	.65	.65	.56	.10
isoValerate[b]	.67	1.15	1.10	.99	.06

[a]Co-product supplemented: CON =cornstarch, DCGF =dry corn gluten feed, DDG = dried distillers grains, MCF = modified corn fiber.
[b]CON vs. DCGF, DDG, MCF ($P < .05$).

Table 8. Rate and extent of CP degradation of corn co-products (Trial 2)[a]

	Treatments[b]			
Item	DCGF	DDG	MCF	SEM
Initial CP, % DM	19.71	28.61	21.13	
CP disappearance at 0 h, %[cde]	62.58	39.21	29.03	2.48
K_d, %/h[df]	1.98	2.17	-.07	.17
CP degradation, %/20 h (Extent)[df]	73.19	57.60	27.58	4.74

[a]Least squares means.
[b]DCGF =dry corn gluten feed, DDG = dried distillers grains, MCF = modified corn fiber.
[c]Rate of potentially degradable substrate.
[d]DCGF vs. MCF ($P < .05$).
[e]DDG vs. MCF ($P < .10$).
[f]DDG vs. MCF ($P<.05$).

SITES OF ORGANIC MATTER, FIBER, AND STARCH DIGESTION IN STEERS FED FRESH ALFALFA AND SUPPLEMENTED WITH INCREASED LEVELS OF CRACKED CORN

J. C. Elizalde, N. R. Merchen, and D. B. Faulkner

SUMMARY

The effect of supplementation of different levels of cracked corn (CC) on the sites of OM, total dietary fiber (TDF), and starch digestion in steers fed fresh alfalfa indoors were studied. Six Angus steers (338 ± 19 kg) fitted with cannulas in the rumen, duodenum and ileum, were fed 1) alfalfa (20.4% CP, 41.6% NDF) ad libitum (AALF), 2, 3, and 4) AALF and supplemented (S) with .4, .8, or 1.2% of BW of CC, or 5) alfalfa restricted at the average level of forage intake of S steers (RALF), in a Latin square design with an extra animal. Total OM intake was lower in steers fed RALF ($P < .01$) than in those fed AALF but level of forage intake did not affect ($P > .05$) the sites of OM, TDF, or starch digestion. Forage OM intake was decreased ($P < .01$) linearly (8,496 to 5,840 g/d) but total OM intake was increased ($P = .03$) linearly (8,496 to 9,344 g/d) as CC increased from .4 to 1.2% BW. Ruminal apparent or true OM disappearance (g/d) was not affected ($P > .05$) but OM disappearing in the small intestine (g/d) increased ($P < .01$) linearly with increasing levels of CC. Total tract OM digestibility (71.2 to 76.2%) and the proportion of OM intake that was digested in the small intestine (15.4 to 24.5%) increased ($P < .01$) linearly as CC increased. The TDF intake (g/d) decreased linearly ($P < .01$) as level of CC increased. Total tract TDF digestibility was not different ($P > .05$) among treatments (average 62.9 and 57.8%, respectively). Starch intake and starch digested in the rumen, small and large intestine (g/d) were increased linearly ($P < .01$) with CC level. Ruminal pH and VFA concentrations were decreased and increased ($P < .01$), respectively, with increasing CC. Supplementation increased total OM intake, decreased forage OM intake, and increased the proportion of OM that was digested in the small intestine.

INTRODUCTION

Fresh alfalfa, such as that consumed by grazing ruminants, has a high CP concentration which is inefficiently utilized by the animal. A large portion of the ruminally degraded CP is absorbed as NH_3 N from the rumen, and excreted in the urine as urea (Wallace, 1994). Increasing the transfer of the forage CP into a form than can be used by the animal would be desirable as a means of maximizing utilization of available nutrient resources. One approach to improving use of forage CP might be to increase microbial capture of NH_3 N by providing additional fermentable energy as a modest amount of grain. However, supplementation could negatively affect the digestion of OM and fiber fractions (Hoover, 1986).

Our goal was to study the intake and digestion of OM, fiber, and starch in steers fed fresh alfalfa ad libitum and supplemented with three levels of cracked corn compared to steers fed fresh alfalfa alone at two levels of forage intake (ad libitum or restricted to the average intake of alfalfa consumed by the supplemented steers).

MATERIALS AND METHODS

Forage. Fresh alfalfa (*Medicago sativa* L.) came from a 4.30-ha plot during the second year of growth, located at the South Farms of the University of Illinois at Urbana-Champaign. The second and the third cuts were used for the experiment. Prior to the first cut in May, a subplot of 1.10 ha was selected for stand uniformity and lack of weeds, and approximately 3% of the subplot was cut each day beginning May 25, 1995 for 30 d. This cutting schedule was established to allow cutting of forage that had been maintained with the same rest period and in the same physiological stage during successive cuts on each day of the experiment. When the forage was ready for the second cut, the experiment was started. During the experiment (June 23 to August 25, 1995) alfalfa was collected by hand, and approximately 1 t of fresh material was transported by truck to the building where the animals were housed. During the experiment the forage had, on average, 30 d of growth between cuttings; it was intended that alfalfa would be maintained in the late bud stage. An estimation of standing forage (kg DM/ha) was done every three days by sampling the plots using a steel ring (.167 m^2 inside area) thrown randomly 6 times across the plots assigned for the next three days at a given time of sampling.

Animals and Treatments. Six Angus steers (average BW 338 ± 19 kg) surgically fitted with cannulas in the rumen, proximal duodenum, and terminal ileum were used. Steers were allotted randomly to five treatments in a Latin square design with 5 periods and six animals. The extra animal was included to increase the degrees of freedom of the statistical analysis and treatments were randomly allotted to this animal across periods. Treatments were: 1) fresh alfalfa restricted (RALF) to the average alfalfa intake of the animals supplemented with cracked corn (CC), 2) fresh alfalfa offered ad libitum (AALF) allowing 10% of refusals, and 3, 4, and 5) AALF plus CC supplemented at .4, .8, and 1.2% of BW. Alfalfa consumption in the RALF steers was established according to the average forage intake of the previous day of the supplemented animals.

Feeding regime. Forage was collected from the field and moved to the metabolism unit at 0800. The forage was spread in a thin layer on pallets on the floor of the room and fed throughout the day. Animals were fed 6 times a day starting at 1000 after collecting and sampling the feed refusals from the previous day. Corn grain was fed twice a day, the first feeding was offered two hours in advance (0800) of the first forage offering and the second meal was fed 12 h later (2000). The amount of CC fed to each animal was adjusted according to the weight of the steers recorded at the beginning of each experimental period.

Markers, Sample Collection and Analyses. Duodenal and ileal flows and fecal output were estimated using chromic oxide (Cr_2O_3) dosed at 12 g/d (twice daily, 6 g/ gelatin cap) via the rumen cannula at 1000 and 2200. Steers were adjusted to diet for 9 d in each period. Following adjustment, samples were collected over 4 d. Two composite samples of the fresh forage were taken daily in each period by sampling the forage at each feeding. One of the samples was frozen, and subsequently thawed, freeze-dried, ground (1-mm screen), and saved for analyses. The other sample was used for DM determination by oven-drying at 105 °C. Corn was sampled on a daily basis, making a composite sample for each period.

Duodenal, ileal, and fecal samples were taken every 6 h during the 3 d of sampling but displaced 2 h each day, so that samples were taken at 12 equally spaced intervals over a 24-h period. Fecal samples were obtained by grab samples, collected at the same times as duodenal and ileal samples, and composited within animal and period. Rumen samples for pH and VFA determination were taken every 3 h after the morning feeding on d 4 of sampling in each period. A bacteria rich fraction was additionally isolated from whole rumen contents. Duodenal and ileal samples were thawed, composited within steer and period, stirred continuously, subsampled, freeze-dried, and ground (Wiley mill, 1-mm screen). Fecal samples were oven dried at 57 °C and ground.

Forage, corn grain, duodenal, ileal, and fecal samples were analyzed for DM, OM, ash, starch, and total dietary fiber (TDF, Prosky et al., 1985). Forage and CC were also analyzed for NDF. Chromium concentration was determined by atomic absorption spectrophotometry. Freeze-dried isolated bacteria were analyzed for purines and OM.

Statistical Analysis. Data were analyzed by analysis of variance of a 5 × 5 (treatments × periods) Latin square design using the MIXED procedure of SAS (SAS, 1995). To increase sensitivity of the model to treatments effects, an extra animal was used, which was allotted randomly to the treatments across periods. Model sums of squares were separated into animal, period, and treatment effects. Least squares means are reported and treatment comparisons were made by contrasts. The AALF was compared with RALF to evaluate effects of level of forage intake on digestion of OM components. The contrast was RALF vs supplemented (S) to compare the effect of grain additions in animals fed AALF but whose forage intake was, on average, equal to RALF intake. Linear (L) and quadratic (Q) contrasts were conducted to determine the response to increased levels of CC in steers fed AALF. For data collected at successive times (ruminal pH and VFA), data were analyzed as repeated measures using the MIXED procedure of SAS.

RESULTS AND DISCUSSION

Available standing forage during the experiment (Table 1) was, on average, 3,450 kg DM/ha; however, because of drought conditions, DM availability varied from 4,450 in late June to 2,770 kg DM/ha in mid August. Despite variations in forage growth, forage composition in terms of total dietary fiber (TDF), NDF, and starch concentrations was relatively constant across the experiment as indicated by the low SD for these components.

Forage OM intake (Table 2) did not differ ($P = .79$) between RALF and S steers (6,631 vs 6,721 g/d), but S steers had greater ($P < .01$) total OM intakes than RALF steers due to CC additions. Moreover, forage OM intake decreased ($P < .01$) linearly but total OM intake increased ($P = .03$) linearly as CC increased. There was a linear relationship between CC intake (CCI, g/kg BW) and forage intake (FI, g/kg BW): $FI = 23.7 - .69\ CCI$, $P < .01$, $r^2 = .62$. The average substitution rate (change in unit of forage intake per unit of CC fed) was .69 g/g. The depression in forage intake due to starch supplementation is greater with high-quality than with low-quality forages (Jarrige, et al. 1986; Horn and McCollum, 1987). Bowman and Sanson (1996) concluded that substitution rates increased as DM intake of forage without supplementation, forage CP, and supplemental starch intake increase. Our values for forage substitution in AALF steers due to CC are explained by the high-quality of the alfalfa forage and by the ad libitum feeding regime that we used.

Duodenal flows of OM (g/d) only tended to be lower (P = .10) in RALF compared to AALF steers because of less OM (P < .01) apparently or truly digested in rumen (g/d) in RALF than in AALF steers. The percentage of OM intake that was apparently digested in the rumen was not different (P = .42) in RALF compared to AALF steers. In response to the increase in total OM intake, duodenal OM flows were greater (P < .01) in S than in RALF steers and were increased (P <.01) linearly as the level of CC increased. Supplemented steers had more (P < .01) OM truly digested in the rumen (g/d) than did RALF steers, but there were no differences (P > .10) in the percentage of OM intake that was truly digested in the rumen between RALF and S steers. Increasing level of CC did not affect (P > .05) the amounts of OM truly digested in the rumen (average 3,976 and 5,723 g/d, respectively). Percentage of OM intake that was truly digested in the rumen tended to decrease (P = .12) linearly with increasing level of CC. This is probably a result of lower ruminal OM degradability of CC compared with fresh alfalfa. A decreased ruminal OM digestibility when grain was included in the diet is in agreement with data reported by Van Vuuren et al. (1993) and Berzaghi et al. (1996) in cows fed fresh forages with corn-based supplements.

Supplemented steers had higher (P < .01) small intestinal disappearance of OM than RALF steers (in g/d or as percentage of OM intake). There were linear (P < .01) and quadratic (P = .03) responses in small intestinal disappearance of OM with increasing level of CC. A quadratic response to grain addition for OM disappearing in the small intestine indicates that small intestinal OM disappearance was maximal when grain was included at .8% of BW. Results show that CC supplementation shifted the sites of OM digestion, increasing the proportion that was digested in the small intestine and also increasing the small intestinal digestibility of OM.

Fecal OM output (g/d) was lower (P < .05) in RALF than in S steers and there was a linear decrease (P = .05) in fecal output with increasing level of CC addition. Large intestinal disappearance was not affected (P > .05) by dietary factors. Total tract OM digestibility tended to be lower (P < .09) in steers fed RALF than in those fed AALF, and was greater (P < .01) in S than RALF steers and increased (P < .01) linearly with increasing CC.

Forage and total TDF intakes (Table 3), and duodenal and ileal flows and fecal outputs of TDF did not differ (P > .05) between RALF and S steers. Forage and total TDF intakes were decreased (P < .01) linearly but duodenal TDF flows were not affected (P = .28) by increasing CC. Ileal flows and fecal outputs of TDF were decreased (P < .01) linearly by CC addition. Because duodenal flows of TDF did not decrease linearly by CC, we speculate that some soluble fiber may escape ruminal fermentation and is solubilized in the acidic conditions of the duodenum causing the linear decrease in ileal flows as CC levels increased. Ruminal and total tract TDF digestibilities were not different (P > .05) among treatments (average 54.8 and 62.9% of intake, respectively). There are no data available regarding the effects of corn grain supplementation on fiber digestion in animals consuming fresh alfalfa. Over a wide range of forages of differing quality, depressions in forage digestion with added grain worsen as forage quality declines perhaps because microbes intimately associated with fiber digestion contribute more to digestion of low- than of high quality forage (Galyean and Goetsch, 1993). Our fresh alfalfa had lower fiber content than in the previous studies and could explain the lack of grain effect on fiber digestion.

Supplementation increased ($P < .01$) linearly the total intake, duodenal and ileal flows, and fecal outputs of starch (Table 5). A greater ($P < .01$) amount of starch (g/d) disappeared in the rumen and the small intestine in the S steers compared to RALF steers and this disappearance was increased ($P < .01$) linearly with the level of CC. However, the percentages of starch consumed that was fermented in the rumen or disappeared in the small intestine were not different ($P > .05$) among treatments.

Disappearance (g/d) and percentage of consumed starch that was fermented in the large intestine were also increased linearly ($P < .01$) by CC addition. Starch digested postruminally in steers fed CC supplements accounted, on average, for 47.5% of starch intake which is greater than range of 5 to 20% summarized by Huntington (1997) for highly processed corn (dry rolling or steam flaking). However, our value is in agreement with that reported for ground corn (44.0%) fed to dairy cows by McCarthy et al. (1989). Corn grain offered in the cracked form might have increased the amount of starch escaping from the rumen compared with more processed forms. Total tract digestibility of starch was not different ($P > .05$) among treatments (average 96.2%). Our results showed that grain addition increased the amount of starch disappearing in each site of the digestive tract but did not change the proportions of starch digested in different sites except for the large intestine.

Corn grain supplementation tended to decrease the percentage of OM that was digested in the rumen and increased the percentage that was digested in the small intestine. This effect appears to be due to replacement of fiber (90% of total digestion occurring in the rumen) from alfalfa by starch from CC which had a lower ruminal digestibility (48.6% of total digestion) and thus, shifted the site of digestion of OM to the small intestine. However, this shift in the site of OM digestion did not affect ruminal or total tract fiber digestibilities.

Ruminal pH was higher ($P <. 01$) in steers fed RALF than in those fed AALF resulting from the higher level of intake in the AALF steers (Table 6). Ruminal pH and total VFA concentrations were lower and greater ($P < .01$), respectively, in S compared to RALF steers, and were decreased and increased ($P < .01$) linearly, respectively, as level of CC increased. Reductions in ruminal pH have often been cited as the major cause of depressed fiber digestion, but may not always explain reductions in intake and digestibility (Caton and Dhuyvetter, 1997). In our experiment, reductions in forage intake were not explained by reduced fiber digestion even when ruminal pH was decreased by grain supplementation.

The proportions of acetate and propionate were lower and higher ($P < .01$), respectively, in S than in RALF steers and were decreased and increased ($P < .01$), respectively as, CC increased. Increased propionate and decreased acetate as a result of concentrate inclusion in the diet is well documented for processed forages (Horn and McCollum, 1987) and for fresh forages (Berzaghi et al., 1996, Judkins et al., 1997), irrespective of the total ruminal VFA concentration.

The molar proportion of butyrate was higher ($P < .01$) in S than in RALF steers and was increased linearly ($P < .01$) by CC addition. Proportions of isobutyrate and isovalerate were higher ($P < .01$) in RALF than S steers and were decreased linearly ($P < .03$) with increasing level of CC. Valerate molar proportion was lower ($P < .01$) in RALF than in S steers and was not increased ($P = .19$) with increasing CC. Branched chain VFA are the end products of the ruminal fermentation of the branched chain amino acids. A linear decrease of branched chain VFA with increasing CC

supplementation is probably related to a decrease in intake of branched chain amino acids in the supplemented animals. Steers fed AALF had higher ($P < .01$) total VFA concentration than RALF steers but had the same profile of VFA. However, S steers had different patterns of fermentation than those fed RALF even though they consumed the same amount of forage. Therefore, the effect of adding CC to AALF steers on ruminal VFA proportions was more important than altering the level of alfalfa intake.

IMPLICATIONS

Supplementation of steers fed high-quality fresh alfalfa with moderate levels of cracked corn increased the total feed intake but substitution effects were present when alfalfa was offered ad libitum. It would be necessary to account for decreased forage intake in grazing animals when supplemental corn is fed by increasing the stocking rate or decreasing the grazing area. When fresh alfalfa was fed ad libitum, supplementation decreased fiber intake and shifted organic matter digestion to the small intestine. Total tract fiber digestibility or its sites of digestion were not affected by supplementation.

LITERATURE CITED

Berzaghi, P., J. H. Herbein, and C. E. Polan. 1996. Intake, site, and extent of nutrient digestion of lactating cows grazing pasture. J. Dairy Sci. 79:1581-1589.

Bowman, J. G. P. and D. W. Sanson. 1996. Starch- or fiber-based supplements for grazing ruminants. In: M. B. Judkins and F. T. McCollum III (Eds.) Proc. 3rd Grazing Livestock Nutrition Conference. Proc. West Sec. Amer. Soc. Anim. Sci. 47 (Suppl.1):118-135.

Caton, J. S. and D. V. Dhuyvetter. 1997. Influence of energy supplementation on grazing ruminants: Requirements and responses. J. Anim. Sci. 75:533-542.

Galyean, M. L. and A. L. Goetsch. 1993. Utilization of forage fiber by ruminants. In: H. G. Jung et al. (Ed.) Forage Cell Wall Structure and Digestibility. p 34. ASA-CSSA-SSSA, Madison, WI.

Horn, G. W. and F. T. McCollum. 1987. Energy supplementation of grazing ruminants. In M. B. Judkins et al. (Ed.) Proc. 1st Graz. Livestock Nutr. Conf. p 125. Jackson, WY.

Huntington, G. B. 1997. Starch utilization in ruminants: From basics to the bunk. J. Anim. Sci. 75:852-867.

Jarrige, R., C. Demarquilly, J. P. Dulphy, A. Hoden, J. Robelin, C. Beranger, Y. Geay, M. Journet, C. Malterre, D. Micol, and M. Petit. 1986. The INRA "fill unit" system for predicting the voluntary intake of forage-based diets in ruminants: A review. J. Anim. Sci. 63:1737-1758.

Jeraci, J. L., T. Hernandez, J. B. Robertson, and P. J. Van Soest. 1988. New and improved procedure for neutral-detergent fiber. J. Anim. Sci. 66(Suppl. 1):351 (Abstr.).

Judkins, M. B., D. W. Holcombe, B. W. Hess, L. J. Krysl, M. A. Branine, and J. D. Hess. 1997. Ardacin for steers grazing endophyte-free tall fescue pasture: Effects on live weight gain, forage intake, nitrogen and fiber digestion, ruminal fluid kinetics, ruminal fermentation, and serum hormones and metabolites. J. Anim. Sci. 75:1100-1111.

McCarthy, R. D., Jr., T. H. Klusmeyer, J. L. Vicini, and J. H. Clark. 1989. Effects of source of protein and carbohydrate on ruminal fermentation and passage of nutrients to the small intestine of lactating cows. J. Dairy Sci. 72:2002-2016.

Prosky, L., N. G. Asp, I. Furda, J. W. DeVries, T. F. Schveizer, and B. F. Harland. 1985. Determination of total dietary fiber in food and food products: Collaborative study. J. Assoc. Off. Anal. Chem. 67:1044-1064.

SAS. 1995. SAS/STAT®. User's Guide (Release 6.03). SAS Inst. Inc. Cary, NC.

Van Vuuren, A. M., C. J. Van der Koelen, and J. Vroons-de Bruin. 1993. Ryegrass versus corn starch or beet pulp fiber diet effects on digestion and intestinal amino acids in dairy cows. J. Dairy Sci. 76:2692-2700.

Wallace, R. J. 1994. Amino acid and proteins synthesis, turnover, and breakdown by ruminal microorganisms. In: J. M. Asplund (Ed.) Principles of Protein Nutrition of Ruminants. p 71. CRC Press, Boca Raton, FL.

Table 1. Composition of fresh alfalfa and cracked corn[a]

Item	Alfalfa	Corn
Available DM, kg/ha	3,450 ± 936	--
DM, %	19.6 ± 3.0	84.8 ± .9
	% of DM	
OM	89.0 ± 1.2	98.6 ± .2
Total N	3.26 ± .3	1.51 ± .02
TDF[b]	54.6 ± 1.3	17.3 ± 1.4
NDF	41.6 ± 1.8	10.9 ± 2.0
Soluble fiber[c]	15.3 ± .20	6.4 ± 1.9
ADF	32.5 ± 1.4	3.4 ± .5
Starch	3.8 ± 1.9	70.9 ± 3.0

[a]n = 20 for alfalfa and n = 5 for corn.
[b]Total dietary fiber (Prosky et al., 1985).
[c]TDF - NDF free of starch, CP, and ash.

Table 2. Organic matter intake and digestion by steers fed fresh alfalfa and supplemented with different levels of cracked corn

	Treatments[a]									
			Corn grain, % of BW				Contrast[b], P =			
Item	RALF	AALF	.4	.8	1.2	SEM[c]	RALF vs AALF	RALF vs S	L	Q
Intake, g/d										
Forage	6,631	8,496	7,499	6,825	5,840	383.6	<.01	.79	<.01	.98
Corn	-	-	1,173	2,381	3,504					
Total	6,631	8,496	8,672	9,206	9,344	405.4	<.01	<.01	.03	.94
Duodenal flow, g/d	3,886	4,349	4,748	5,535	5,167	203.4	.10	<.01	<.01	.06
Ruminal disappearance, true										
g/d	4,336	5,809	5,725	5,358	6,001	415.4	<.01	<.01	.89	.28
% of intake	65.1	68.2	65.6	58.8	64.2	2.81	.42	.47	.12	.14
Ileal flow, g/d	2,839	3,101	2,901	3,010	3,068	151.6	.22	.36	.98	.38
Small intestinal disappearance										
g/d	1,130	1,307	1,844	2,529	2,330	162.3	.42	<.01	<.01	.03
% of intake	17.1	15.4	21.5	26.8	24.5	1.97	.52	<.01	<.01	.05
Fecal output, g/d	2,119	2,399	2,272	2,289	2,212	85.6	<.01	.05	.05	.63
Large intestinal disappearance										
g/d	707	662	633	667	842	124.8	.80	.96	.32	.43
% of intake	10.7	7.8	6.9	7.1	9.0	1.45	.17	.08	.57	.32
Total tract digestibility, %	69.0	71.2	73.6	74.9	76.2	1.50	.09	<.01	<.01	.61

[a]RALF = alfalfa intake restricted to the average forage intake of the supplemented steers; AALF = ad libitum alfalfa; .4, .8, and 1.2 = cracked corn (CC) supplementation, as is, at .4, .8, and 1.2% of BW.

[b]Preplanned contrasts with P values for each comparison: RALF vs AALF; RALF vs supplemented (S); L = linear and Q = quadratic effect of levels of CC (including AALF and the three levels of cracked corn supplementation).

[c]Standard error of the mean.

Table 3. Total dietary fiber[a] (TDF) intakes, and digestion by steers fed fresh alfalfa supplemented with different levels of cracked corn

	Treatments[b]						Contrast[c], P =			
			Corn grain, % of BW							
Item	RALF	AALF	.4	.8	1.2	SEM[d]	RALF vs AALF	RALF vs S	L	Q
Intake, g/d										
Forage	4,060	4,920	4,414	4,072	3,338	269.9	<.01	.59	<.01	.55
Grain	--	--	206.0	418.0	615.7	--	--	--	--	--
Total	4,060	4,920	4,620	4,489	3,954	271.5	<.01	.19	<.01	.53
Duodenal flow, g/d	1,830	2,143	1,876	2,038	1,896	125.3	.07	.43	.28	.60
Ileal flow, g/d	1,881	2,104	1,782	1,800	1,602	111.0	.14	.21	<.01	.55
Fecal output, g/d	1,583	1,767	1,639	1,550	1,487	68.1	.01	.66	<.01	.50
Digestibility, % of intake										
Rumen	54.6	55.5	58.9	53.6	51.3	4.1	.85	.99	.21	.37
Total tract	60.6	63.3	63.9	64.7	61.8	3.0	.30	.18	.65	.33

[a]Total dietary fiber according to Prosky et al. (1985).

[b]RALF = Alfalfa intake restricted to the average forage intake of the supplemented steers; AALF = ad libitum alfalfa; .4, .8, and 1.2 = AALF plus cracked corn (CC) supplementation (as is) at .4, .8, or 1.2% of BW, respectively.

[c]Preplanned contrasts with P values for each comparison: RALF vs AALF; RALF vs supplemented (S); L = linear and Q = quadratic effect of levels of CC (including AALF and the three levels of CC supplementation).

[d]Standard error of the mean.

Table 4. Starch intakes and digestion by steers fed fresh alfalfa and supplemented with different levels of cracked corn

	Treatments[a]						Contrast[b], P =			
			Corn grain, % of BW							
Item	RALF	AALF	.4	.8	1.2	SEM[c]	RALF vs AALF	RALF vs S	L	Q
Intake, g/d										
Forage	280	415	368	341	282	89.6	<.01	.10	<.01	.81
Grain	-	-	868	1,712	2,534					
Total	280	415	1,236	2,053	2,816	98.3	<.01	<.01	<.01	.58
Duodenal flow, g/d	127	96	660	1,038	1,473	145.5	.87	<.01	<.01	.67
Ruminal disappearance										
g/d	144	293	553	1,022	1,297	190.1	.42	<.01	<.01	.96
% of intake	54.5	65.4	47.5	49.8	44.0	11.7	.36	.50	.14	.52
Ileal flow, g/d	28	34	214	338	551	45.5	.92	<.01	<.01	.72
Small intestinal disappearance										
g/d	76	66	443	588	920	121.6	.95	<.01	<.01	.86
% of intake	29.4	24.9	33.7	28.9	34.2	9.7	.71	.78	.56	.84
Fecal output, g/d	11	11	34	85	112	10.6	.99	<.01	<.01	.86
Large intestinal disappearance										
g/d	16	23	195	243	440	34.1	.90	<.01	<.01	.77
% of intake	5.9	5.8	15.4	12.8	17.1	2.46	.97	<.01	<.01	.26
Total tract digestibility, %										
	95.9	95.6	97.8	95.9	95.9	1.33	.80	.62	.86	.31

[a]RALF = alfalfa intake restricted to the average forage intake of the supplemented steers; AALF = ad libitum alfalfa; .4, .8, and 1.2 = AALF plus cracked corn (CC) supplementation (as is) at .4, .8, or 1.2% of BW.

[b]Preplanned contrasts with P values for each comparison: RALF vs AALF; RALF vs supplemented (S); L = linear and Q = quadratic effect of levels of CC (including AALF and the three levels of CC supplementation).

[c]Standard error of the mean.

Table 5. Ruminal pH, VFA concentrations, and ruminal fluid dilution rates in steers fed fresh alfalfa restricted level or ad libitum and supplemented with different levels of cracked corn

	Treatments[a]						Contrast[b], P =			
			Corn grain, % of BW							
Item	RALF	AALF	.4	.8	1.2	SEM[c]	RALF vs AALF	RALF vs S	L	Q
pH	6.51	6.39	6.29	6.22	6.09	.1	< .01	<.01	<.01	.65
Total VFA, m*M*	79.4	88.5	90.3	94.0	94.0	3.6	<.01	<.01	<.01	.44
VFA, mol/100 mol										
Acetate	68.8	68.2	67.0	65.7	63.0	.66	.22	<.01	<.01	.05
Propionate	17.3	17.2	17.8	18.7	21.3	.47	.87	<.01	<.01	<.01
Butyrate	8.8	9.6	10.3	10.9	11.0	.44	.09	<.01	<.01	.40
Isobutyrate	1.8	1.7	1.6	1.4	1.4	.09	.23	<.01	<.01	.44
Valerate	1.2	1.2	1.3	1.3	1.3	.05	.26	<.01	.19	.64
Isovalerate	2.3	2.1	2.0	1.9	1.9	.09	.04	<.01	.03	.18

[a]RALF = alfalfa intake restricted to the average forage intake of the supplemented steers; AALF = ad libitum alfalfa; .4, .8, and 1.2 = AALF plus cracked corn (CC) supplementation (as is) at .4, .8, or 1.2% of BW.

[b]Preplanned contrasts with P values for each comparison: RALF vs AALF; RALF vs supplemented (S); L = linear, and Q = quadratic effect of levels of CC (including AALF and the three levels of CC supplementation).

[c]Standard error of the mean.

SITES OF PROTEIN AND AMINO ACID DIGESTION IN STEERS FED FRESH ALFALFA AND SUPPLEMENTED WITH INCREASED LEVELS OF CRACKED CORN

J. C. Elizalde, N. R. Merchen, and D. B. Faulkner

SUMMARY

We studied the effects of different levels of cracked corn (CC) on N intake, ruminal bacterial CP synthesis, and duodenal flows and small intestinal digestion of amino acids (AA) in steers fed fresh alfalfa indoors. Six Angus steers (average BW 338 ± 19 kg) cannulated in the rumen, duodenum, and ileum were fed each of five diets over five periods in a Latin square design with an extra animal. Steers were fed 1) alfalfa (20.4% CP, 41.6% NDF) ad libitum (AALF), 2, 3, and 4) AALF supplemented (S) with three levels of CC (.4, .8, or 1.2% of BW), or 5) alfalfa restricted (RALF) to the average forage intake of S steers. Average N intake and duodenal flow (g/d) of nonammonia N (NAN) were greater ($P < .01$) in S than in RALF steers. Greater duodenal flows of NAN in S compared with RALF were due to higher ($P = .06$) flows of both bacterial and dietary N. Levels of CC decreased ($P < .01$) linearly N intake (g/d) and increased ($P < .01$) linearly duodenal flow of NAN (g/d) due to a linear increase in nonbacterial N ($P = .15$) but not ($P = .68$) in bacterial N flow. Duodenal NAN flows as percentages of N intake increased ($P < .01$) linearly (69.3 to 91.0%) as CC increased. Ruminal NH_3 N concentration (mg/dL), ruminal CP degradability (%), and the proportion (%) of bacterial N in duodenal NAN were decreased ($P < .01$) linearly as CC increased. Efficiency of net microbial CP synthesis was not affected ($P > .05$) by treatment (average 42.6 and 30.9 g N/kg of OM apparently or truly digested in the rumen, respectively). Small intestinal disappearance (g/d) of total N and individual AA (except for threonine and lysine), and small intestinal digestibility (% entering) of N and individual AA (except for methionine, histidine, and proline) increased ($P < .01$) linearly with the level of CC and were greater ($P < .01$) in S than in RALF steers. Supplementing CC to steers fed fresh alfalfa reduced ruminal N losses and CP degradability, and increased the duodenal flow and the small intestinal disappearance and digestibility of total N and total, essential, and nonessential AA.

INTRODUCTION

Fresh alfalfa usually has a high CP content which is highly degradable in the rumen (Dhiman and Satter, 1997). The amount of escape protein provided by alfalfa is often low and ruminal microbes can not utilize all of the amino acids (AA) and ammonia (NH_3 N) released and more protein will be degraded than is synthesized (Broderick, 1995). Addition of a source of energy such as corn grain to alfalfa-based diets may increase the proportion of the ruminally degraded CP to be utilized for microbial growth and consequently, increase the flow of AA to the small intestine. Therefore, energy supplementation may enhance the efficiency of utilization of the forage N by providing more AA to the animal and reducing ruminal N losses.

Our objective was to study the effects of different levels of cracked corn (CC) supplementation in animals fed fresh alfalfa on ruminal N losses, efficiency of microbial CP synthesis, duodenal N flows, and AA composition of the apparently absorbed N in the small intestine. Because CC can provide

escape protein to the animal but could reduce forage N intake when forages are fed ad libitum due to substitution effects, we were interested to compare the supplemented steers with those fed alfalfa ad libitum or fed alfalfa at a restricted intake equal to the average forage intake of the supplemented animals. Consequently, we fed steers at two levels of alfalfa, ad libitum and restricted, and three levels of cracked corn to steers fed ad libitum alfalfa.

MATERIALS AND METHODS

Forage. Fresh forage of alfalfa (*Medicago sativa* L.) used in this report was described by Elizalde et al. (1998). Forage management applied to the plot prior to and during the experiment were also described by Elizalde et al. (1998). Corn grain was used a supplemental feed and was fed in the cracked form.

Animals and Treatments. Six Angus steers (average BW 338 ± 19 kg) fitted with cannulas at the rumen (Model XC, Bar Diamond, Parma, ID), proximal duodenum, and terminal ileum (both with silicon T-type cannulas, i.d. 19 mm) were used. Feeding regime was also described previously (Elizalde et al., 1998). Steers were allotted randomly to five treatments in a Latin square design with 5 periods and six animals. The extra animal was included to improve the sensitivity of the statistical analysis and treatments were randomly allotted to this animal across periods. Treatments were: 1) fresh alfalfa restricted (RALF) to the average alfalfa intake of the animals supplemented with cracked corn (CC), 2) fresh alfalfa offered ad libitum (AALF) allowing approximately 10% refusals, and 3, 4, and 5) AALF plus CC supplemented at .4, .8, and 1.2% of BW. Alfalfa consumption in the RALF steers was established according to the average forage intake of the previous day of the supplemented animals.

Sample Collection and Analyses. Methods for collection of feed, ruminal, digesta, and fecal samples have been described (Elizalde et al., 1998). Rumen samples were collected to determine NH_3 N and a bacteria rich fraction was isolated from whole ruminal contents.

Feed, orts, duodenal, ileal, fecal, and bacterial samples were analyzed for Kjeldahl N. Feed samples were also analyzed for soluble CP in borate-phosphate buffer according to Licitra et al. (1996). Van Straalen et al. (1997) found that the AA profile of the insoluble residue can be regarded as more representative of that of escaped protein than that of the feedstuff. Consequently, we decided to determine AA in the insoluble residue of the feedstuffs according to McGregor et al. (1978) and we also determined AA in duodenal and bacterial samples. Purine content was determined in bacterial and duodenal samples. The proportion of duodenal N of bacterial origin was calculated by dividing the overall average bacterial N:purine ratio of ruminal bacteria by the N:purine ratio of duodenal digesta for each observation. The statistical analysis was the same as the reported in the previous report (Elizalde et al., 1998)

RESULTS AND DISCUSSION

Total N content in alfalfa and CC was 3.26 and 1.51% DM, respectively. Concentrations of AA in the buffer insoluble residue were also relatively constant across periods in alfalfa as indicated by the low SD.

Forage and total N intakes were impacted by the amount of forage consumed which, in turn, was influenced by the level of CC fed (Table 1). As CC consumption increased, CC was substituted for alfalfa at a rate of .69 g/g of supplemental CC (Elizalde et al., 1998). Because CC contains only about 50% as much N as alfalfa, increasing the level of CC resulted in decreases in both forage and total N intakes although OM intake actually increasing with increasing level of CC (Elizalde et al., 1998). Thus, supplementation decreased the N content of the total diet from 3.7% OM in steers fed unsupplemented alfalfa to 2.8% OM when CC was supplemented at 1.2% BW. Forage N intake, as expected, was not different ($P = .83$) between RALF and the average forage N intake of S steers (245.7 vs 242.8 g/d, respectively). Consequently, total N intake in S steers was greater ($P < .01$) than in RALF steers (278.9 vs 245.7 g/d) because of the N present in CC. Forage and total N intakes were decreased ($P < .01$) linearly from AALF as the level of CC increased due to substitution effects of fresh alfalfa by CC supplementation (Elizalde et al., 1998).

Supplemented steers had greater duodenal NAN flows (g/d) than RALF steers as a result of greater ($P = .06$) flows of both bacterial and nonbacterial N. Duodenal NAN flows (g/d) were increased ($P = .03$) linearly as level of CC increased. However, supplementation did not increase ($P = .68$) bacterial N flows and tended ($P = .15$) to increase linearly the flows of nonbacterial N with increasing level of CC.

The NAN/NI were increased ($P < .01$) linearly by level of CC, as a result of a decreasing N intakes and higher duodenal NAN flows as level of CC increased. A greater NAN/NI was also observed in cows fed high quality fresh forages and supplemented with corn-based supplements (Van Vuuren et al., 1993, Berzaghi et al., 1996) although in these experiments the greater NAN/NI was due only to reductions in N intake because duodenal NAN flows were not affected in these experiments.

Ruminal CP degradability (Table 1) expressed as percentage of CP intake was lower ($P = .03$) in S steers compared with RALF steers (80.9 vs 89.1%, respectively) and was also decreased ($P = .04$) from AALF as the level of CC increased. The decreased ruminal CP degradability in S steers was the result of supplementing CC which has a lower degradability of CP (36%; NRC, 1985) compared with fresh alfalfa (average 86.1% in the current experiment). The proportion of bacterial N in duodenal NAN tended ($P = .09$) to be lower in S than in RALF; however, it was not affected by level of CC.

Ruminal NH_3 N concentrations were lower ($P < .01$) in RALF than in AALF steers probably because of the lower N intakes of steers fed RALF. Ruminal NH_3 N did not differ ($P = .43$) between RALF and S steers. Part of the consumed N in S steers came from CC whose CP is less degradable in the rumen than that of alfalfa. Furthermore, greater bacterial N flows (g/d) in S steers compared to RALF may be the result of greater utilization of the degraded CP by ruminal bacteria and resultant decreased ruminal NH_3 N concentrations. Levels of CC decreased ($P < .01$) linearly the ruminal NH_3 N concentration with respect to AALF. The linear decrease in ruminal NH_3 N in our study may be related to the linear decrease of N intake as level of CC increased. There was a relationship between ruminal NH_3 N and N content of the total diet [NH_3 N (mg/dL) = -17.3 + 1.54 N (g/kg OM), $P < .01$, $R^2 = .49$].

Apparent net efficiency of bacterial CP synthesis was not different ($P > .05$) among treatments. True bacterial efficiency tended ($P = .07$) to be higher in RALF than in AALF steers and may explain the

trend for a higher bacterial N:duodenal NAN observed in steers fed RALF. Bacterial efficiencies in RALF and AALF were in agreement with results obtained in other diets based on fresh forages (Berzaghi et al., 1996; O'Mara et al. 1997). Bacterial efficiencies obtained in these studies and in our experiment were higher than those measured with diets based on processed forages and concentrates (O'Mara et al., 1997). Greater bacterial N flows in S steers compared with RALF steers (Table 1) are explained by a greater amount of OM truly fermented in the rumen (Elizalde et al., 1998) because bacterial efficiencies were not different. In our study, increasing levels of CC did not increase the efficiency of bacterial CP synthesis. Chamberlain and Thomas (1979) and Mathers and Miller (1981) reported quadratic responses to levels of concentrate for microbial efficiencies with maximal values obtained when concentrate inclusion was about 30% of the total diet. Chamberlain and Thomas (1979) explained the lower efficiencies observed in all forage diets compared with mixed diets by a lack of readily fermentable carbohydrates. Lack of response to levels of CC could be due to higher efficiencies in steers fed RALF and AALF due to the high content of soluble fiber in the alfalfa (Elizalde et al., 1998) and a high rate of digestion of NDF in fresh alfalfa, which provided a source of readily available energy to the ruminal microbes. Although level of CC did not increase ($P > .05$) net efficiencies of bacterial CP synthesis compared to AALF, because N intake and ruminal CP degradability were decreased as CC increased, supplementing with CC did increase the capture of N from degraded CP.

Disappearance of N (g/d) from the small intestine was greater ($P = .04$) in AALF with respect to RALF steers as a result of higher duodenal NAN flows because the intestinal disappearance as a percentage of N entering was not affected ($P = .37$) by level of forage intake. Small intestinal disappearance of N (g/d, percentage of N intake, or percentage of N entering) was greater ($P < .05$) in S steers than in RALF steers and was increased ($P < .01$) linearly as the level of CC increased. Merchen et al. (1986) also observed a greater postruminal N digestibility in wethers consuming a diet composed of 25% alfalfa hay and 75% CC when fed a diet of 75 and 25%, respectively, of the same ingredients. Adding CC to the diets of steers fed fresh alfalfa shifted the fate of the consumed N by reducing ruminal N losses and increasing N disappearing in the small intestine. As a result of higher small intestinal digestibility in the supplemented animals, the ileal flows of N were not affected ($P > .05$) by treatments. Apparent total tract N digestibility was not different between S and RALF steers but was decreased ($P < .01$) linearly by supplementation. A linear decrease in total tract N digestibility was observed due to decreased N intakes and a linear increase ($P = .11$) in fecal N output as levels of CC increased.

In general, results for duodenal AA flows and disappearance in the small intestine mirror results observed for total N. Flows to the duodenum of all individual AA and total AA (Table 2) were higher ($P < .01$) in AALF and S steers than in RALF steers. Duodenal flows of leucine, histidine, and arginine increased ($P < .10$) linearly, while there was a quadratic response ($P < .10$) for flows of isoleucine, histidine, lysine, and arginine to levels of CC. Flows to the duodenum of individual and total nonessential AA (NEAA) were increased ($P < .05$) linearly by supplementation except for aspartate, glycine, and tyrosine. Total essential AA (EAA), total nonessential AA (NEAA) and total AA flows were increased ($P < .11$, $P < .04$, $P < .06$, respectively) linearly by level of CC.

Small intestinal disappearance (g/d, Table 3) of individual AA were greater ($P < .06$) in S than in RALF, and was also increased ($P < .10$) linearly by levels of CC, except for lysine ($P = .21$). Lysine,

threonine, valine, phenylalanine, histidine, arginine, and all nonessential AA except for cysteine, proline, and glutamate showed a quadratic response to levels of CC ($P < .10$). Adding CC increased the small intestinal disappearance of total AA (g/d) when S steers were compared with those fed RALF (758 vs 528 g/d, respectively). Supplementing CC to AALF increased small intestinal disappearance from 700 to 888 g/d total AA in steers supplemented at 1.2% BW of CC. In S steers, 43% of the consumed CP disappeared, on average, from the small intestine as AA compared with only 34 and 37% in RALF and AALF steers, respectively.

Small intestinal digestibility of all AA (Table 4) were higher ($P < .10$) in S steers than in RALF steers (except for histidine and tyrosine), and was increased ($P < .10$) linearly as the level of CC increased except for methionine and histidine. Essential AA had, on average, comparatively higher digestibilities than nonessential AA (67.1 vs 64.5%, respectively). The average small intestinal disappearance of total AA for RALF and AALF was 4 percentage units lower than the average for S steers (63.2 vs 67.4%). The value for apparent small intestinal digestibilities of total AA in the S steers (67.4%) is similar to the value of 70% suggested by the NRC (1985). Merchen at al. (1986) found that small intestinal digestibility of total N tended to be higher in low fiber diets than in high fiber diets, but they did not find differences for the intestinal digestibility of the AA. It seems that supplementing CC up to 1.2% BW to cattle fed fresh alfalfa diets, enhances the small intestinal digestibility of AA. However, more studies are needed to confirm the results of this experiment as well as to assess the possible mechanisms involved in the increased intestinal digestibility when CC is fed in diets based on fresh forage.

IMPLICATIONS

The nitrogen intake was decreased linearly, but the flow of nitrogen and amino acids was increased linearly in response to levels of cracked corn through a decrease in ruminal protein degradability and an increase in small intestinal digestibility of total nitrogen or amino acids. Comparing with steers fed restricted alfalfa, supplemented steers had, on average, greater the microbial protein synthesis, greater amount of escape protein, and higher small intestinal digestibility. In both cases, ruminal N losses were lower in supplemented steers. It is possible to improve the utilization of nitrogen in fresh alfalfa and to increase the amount of amino acids flowing to and disappearing from the small intestine by supplementing an energy supplement such as cracked corn.

LITERATURE CITED

Berzaghi, P., J. H. Herbein, and C. E. Polan. 1996. Intake, site, and extent of nutrient digestion of lactating cows grazing pasture. J. Dairy Sci. 79:1581-1589.

Broderick, G. A. 1995. Desirable characteristics of forage legumes for improving protein utilization in ruminants. J. Dairy Sci. 73:2760-2773.

Chamberlain, D. G., and P. C. Thomas. 1979. Ruminal nitrogen metabolism and the passage of amino-acids to the duodenum in sheep receiving diets containing hay and concentrates in various proportions. J. Sci. Food Agric. 30:677-686.

Dhiman, T. R., and L. D. Satter. 1997. Yield response of dairy cows fed different proportions of alfalfa silage and corn silage. J. Dairy Sci. 80:2069-2082.

Elizalde, J. C., N. R. Merchen, and D. B. Faulkner. 1998. Supplemental cracked corn for steers fed fresh alfalfa: I. Effects on organic matter, fiber components, and starch. Illinois Beef Res. Rep.

Mathers, J. C., and E. L. Miller. 1981. Quantitative studies of food protein degradation and the energetic efficiency of microbial protein synthesis in the rumen of sheep given chopped lucerne and rolled barley. Br. J. Nutr. 45:587-604.

Merchen, N. R., J. L. Firkins, and L. L. Berger. 1986. Effect of intake and forage level on ruminal turnover rates, bacterial protein synthesis and duodenal amino acid supply. J. Anim. Sci. 62:216-225.

Merchen N.R., and E.C. Titgemeyer. 1992. Manipulation of amino acid supply to the growing ruminant. J. Anim. Sci. 70:3238-3247.

NRC. 1985. Ruminant Nitrogen Usage. National Academy Press, Washington, DC.

O'Mara, F. P., G. K. Stakelum, P. Dillon, J. J. Murphy, and M. Rath. 1997. Rumen fermentation and nutrient flows for cows fed grass and grass supplemented with molassed beet pulp pellets. J. Dairy Sci. 80:2466-2474.

Van Vuuren, A. M., C. J. Van der Koelen, and J. Vroons-de Bruin. 1993. Ryegrass versus corn starch or beet pulp fiber diet effects on digestion and intestinal amino acids in dairy cows. J. Dairy Sci. 76:2692-2700.

Table 1. Nitrogen intake and digestion in steers fed fresh alfalfa and supplemented with cracked corn

	Treatments[a]									
			Corn grain, % of BW				Contrast[b], P =			
Item	RALF	AALF	.4	.8	1.2	SEM[c]	RALF vs AALF	RALF vs S	L	Q
N intake										
g/kg OM intake	36.9	36.9	34.0	30.9	28.0	1.58	.78	<.01	<.01	.86
N intake, g/d										
Alfalfa	245.7	316.0	279.4	247.5	201.7	21.4	<.01	.83	<.01	.68
Corn	--	--	17.9	36.4	53.8					
Total	245.7	316.0	297.3	283.9	255.5	22.0	<.01	.01	<.01	.81
Duodenal NAN[d], g/d										
Total	178.6	212.3	206.0	230.2	234.3	11.3	.01	<.01	.03	.56
Bacterial	148.2	161.1	171.1	171.5	167.0	11.2	.35	.06	.68	.46
Nonbacterial	30.4	51.2	34.9	58.7	67.3	11.3	.15	.06	.15	.25
Total CP degraded in rumen,										
% of CP intake	89.1	83.0	87.9	79.3	75.7	3.23	.18	.03	.04	.18
Ruminal NH_3 N, mg/dL										
	28.9	34.5	30.9	27.9	24.5	3.5	.01	.43	<.01	.97
Duodenal NAN, % of N intake										
(continued on next page)	73.3	69.3	70.6	80.1	91.0	4.27	.44	.10	<.01	.21

Table 1. Nitrogen intake and digestion in steers fed fresh alfalfa and supplemented with cracked corn

	Treatments[a]									
			Corn grain, % of BW				Contrast[b], P =			
Item	RALF	AALF	.4	.8	1.2	SEM[c]	RALF vs AALF	RALF vs S	L	Q
Ileal N, g/d	75.6	86.6	82.0	82.8	79.6	5.2	.11	.28	.33	.88
Small intestinal N disappearance										
g/d	103.5	128.8	127.1	146.2	159.2	9.36	.04	<.01	<.01	.36
% of N intake	42.2	42.1	43.0	50.0	61.7	3.93	.98	.05	<.01	.17
% of N entering	57.6	59.8	60.9	63.5	66.6	1.76	.37	<.01	<.01	.57
Fecal N, g/d	58.7	67.4	68.5	72.6	71.2	3.11	<.01	<.01	.11	.55
Apparent total tract N digestibility, %										
	75.7	78.1	76.4	74.4	72.5	1.39	.09	.26	<.01	.91
Bacterial N synthesis										
g N/kg OMD_{APP}[e]	51.0	41.6	46.3	49.6	42.5	5.57	.18	.40	.77	.22
g N/kg OMD_{TRUE}[f]	34.6	28.6	30.6	32.6	28.3	2.69	.07	.12	.92	.17

[a]RALF = restricted alfalfa intake equal to the average forage intake of the supplemented steers; AALF = ad libitum alfalfa; .4, .8, and 1.2 = cracked corn (CC) supplementation at .4, .8, and 1.2% of BW, respectively.

[b]Preplanned contrasts with P values for each comparison: RALF vs AALF; RALF vs supplemented (S); L = linear and Q = quadratic effect of CC supplementation (including AALF and the three levels of CC).

[c]Standard error of the mean.

[d]Nonammonia N.

[e]Grams of bacterial N entering the small intestine per kg of OM apparently digested in the rumen.

[f]Grams of bacterial N entering the small intestine per kg of OM truly digested in the rumen.

Table 2. Flow (g/d) of amino acids (AA) to the small intestine of steers fed fresh alfalfa and supplemented with cracked corn

	Treatments[a]						Contrast[b], P =			
			Corn grain, % of BW							
Item	RALF	AALF	.4	.8	1.2	SEM[c]	RALF vs AALF	RALF vs S	L	Q
Essential amino acids (EAA)										
Threonine	49.3	59.8	57.5	58.2	63.3	3.85	.02	<.01	.37	.20
Valine	51.1	62.1	58.5	60.0	65.8	4.47	.01	<.01	.34	.12
Methionine	14.5	16.9	17.0	19.7	17.8	1.03	.07	<.01	.21	.29
Isoleucine	45.0	55.3	51.3	53.3	58.5	4.06	.01	<.01	.32	.09
Leucine	69.2	87.8	88.1	96.6	104.9	5.84	<.01	<.01	<.01	.34
Phenylalanine	49.3	62.6	59.3	61.0	65.7	4.86	<.01	<.01	.38	.16
Histidine	17.6	23.5	23.0	22.6	26.5	2.33	<.01	<.01	.10	.06
Lysine	60.6	78.7	70.9	71.5	83.5	5.75	<.01	<.01	.42	.03
Arginine	39.0	48.6	45.3	47.0	54.0	3.43	<.01	<.01	.10	.04
Total EAA	407.9	504.8	485.7	496.9	557.1	32.1	<.01	<.01	.11	.09
Non-essential amino acids (NEAA)										
Aspartate	96.6	122.3	114.0	116.5	129.9	8.02	<.01	<.01	.34	.08
Serine	41.5	50.8	50.5	53.0	58.5	3.52	.01	<.01	.03	.23
Cysteine	12.8	14.5	15.2	18.0	17.7	.59	.06	<.01	<.01	.45
Glutamate	102.5	131.5	133.9	147.5	159.4	8.10	<.01	<.01	<.01	.43
Proline	34.1	47.9	50.0	52.8	55.9	7.04	<.01	<.01	.05	.62
Glycine	62.0	77.7	71.9	69.3	82.8	6.03	<.01	<.01	.45	.02
Alanine	57.0	71.8	70.3	74.8	81.7	4.98	<.01	<.01	.04	.23
Tyrosine	39.1	50.8	46.6	49.8	54.2	4.02	.01	<.01	.33	.16
Total NEAA	446.2	567.2	550.4	581.3	640.2	39.1	<.01	<.01	.04	.16
Total AA, g/d	854	1,072	1,036	1,078	1,197	70.4	<.01	<.01	.06	.12

[a]RALF = restricted alfalfa at a level of the average forage intake of the supplemented steers; AALF = ad libitum alfalfa; .4, .8, and 1.2 = cracked corn (CC) supplementation at .4, .8, and 1.2% of BW, respectively.

[b]Preplanned contrasts with P values for each comparison: RALF vs AALF; RALF vs supplemented (S); L = linear and Q = quadratic effects of CC supplementation (both including AALF and the three levels of cracked corn).

[c]Standard error of the mean.

Table 3. Amino acids (AA) disappearing (g/d) from the small intestine of steers fed fresh alfalfa and supplemented with cracked corn

	Treatments[a]									
			Corn grain, % of BW				Contrast[b], P =			
Item	RALF	AALF	.4	.8	1.2	SEM[c]	RALF vs AALF	RALF vs S	L	Q
Essential amino acids (EAA)										
Threonine	28.4	38.2	35.7	35.9	43.8	3.10	<.01	<.01	.11	.04
Valine	30.8	41.2	37.7	38.9	48.1	3.54	.02	<.01	.09	.04
Methionine	9.02	10.8	11.6	14.0	12.6	1.13	.21	<.01	.09	.26
Isoleucine	28.7	37.4	35.1	36.8	44.7	3.45	.02	<.01	.04	.04
Leucine	44.8	59.8	60.6	68.6	80.7	4.74	.01	<.01	<.01	.13
Phenylalanine	27.6	36.9	35.9	37.9	46.1	3.85	.02	<.01	.02	.10
Histidine	11.7	9.1	16.0	15.8	20.1	2.35	.45	.06	<.01	.59
Lysine	43.0	59.0	51.9	49.9	68.4	4.80	.03	.02	.21	.02
Arginine	29.2	37.3	35.1	36.4	44.7	3.26	.03	<.01	.04	.04
Total EAA	258.6	335.6	326.0	329.3	418.7	25.0	.02	<.01	.02	.03
Non-essential amino acids (NEAA)										
Aspartate	61.0	81.1	78.9	77.8	98.4	7.40	.03	<.01	.07	.07
Serine	23.2	31.2	30.6	33.1	41.3	2.82	.01	<.01	<.01	.04
Cysteine	5.4	5.8	6.6	9.3	9.6	.65	.67	<.01	<.01	.64
Glutamate	64.6	86.1	88.1	98.5	117.6	6.50	.01	<.01	<.01	.12
Proline	19.4	31.5	32.2	36.3	41.7	5.60	.02	<.01	.03	.47
Glycine	41.3	55.3	50.1	46.7	65.3	5.56	.01	<.01	.10	<.01
Alanine	33.5	44.6	44.5	47.3	58.5	4.07	.03	<.01	<.01	.10
Tyrosine	21.2	29.3	25.9	24.8	37.6	2.94	.03	<.01	.04	<.01
Total NEAA	269.6	364.7	356.9	373.7	469.9	31.1	.01	<.01	<.01	.04
Total AA										
g/d	528.1	700.3	682.9	702.9	888.6	54.9	.01	<.01	<.01	.03
g/g of CP intake	.34	.37	.36	.38	.55	.03	.58	.03	<.01	.02

[a]RALF = restricted alfalfa at a level of the average forage intake of the supplemented steers; AALF = ad libitum alfalfa; .4, .8, and 1.2 = cracked corn (CC) supplementation at .4, .8, and 1.2% of BW, respectively.

[b]Preplanned contrasts with P values for each comparison: RALF vs AALF; RALF vs supplemented (S); L = linear and Q = quadratic effects of CC supplementation (both including AALF and the three levels of cracked corn).

[c]Standard error of the mean.

Table 4. Disappearance of amino acids (AA) from the small intestine as a percentage of AA at the duodenum of steers fed fresh alfalfa and supplemented with cracked corn

	Treatments[a]						Contrast[b], P =			
			Corn grain, % of BW							
Item	RALF	AALF	.4	.8	1.2	SEM[c]	RALF vs AALF	RALF vs S	L	Q
Essential amino acids (EAA)										
Threonine	58.0	61.7	61.9	61.3	67.5	2.09	.16	.02	.05	.11
Valine	60.5	65.7	64.0	64.6	71.1	1.71	.05	<.01	.04	.03
Methionine	63.4	64.1	67.3	70.9	68.3	2.74	.86	.09	.17	.26
Isoleucine	64.4	67.2	67.8	68.4	74.3	1.57	.16	<.01	<.01	.07
Leucine	64.3	67.0	68.6	71.0	74.2	1.59	.13	<.01	<.01	.49
Phenylalanine	55.7	58.6	60.3	62.1	67.5	2.24	.25	<.01	<.01	.29
Histidine	65.0	66.5	67.9	68.5	72.8	3.50	.74	.16	.19	.64
Lysine	70.8	74.2	72.2	73.7	79.6	1.91	.18	.05	.05	.05
Arginine	74.9	76.4	76.3	77.0	80.8	1.53	.34	.03	.01	.09
Total EAA	63.3	65.8	66.5	67.1	72.8	1.54	.19	<.01	<.01	.07
Non-essential amino acids (NEAA)										
Aspartate	63.6	66.3	68.3	66.3	73.4	2.10	.34	.03	.05	.21
Serine	55.9	59.6	60.3	61.8	68.2	2.01	.09	<.01	<.01	.06
Cysteine	41.6	40.0	42.9	51.5	52.6	3.24	.73	.06	<.01	.78
Glutamate	63.0	64.8	65.7	66.9	71.2	1.80	.43	.02	.01	.30
Proline	56.4	64.9	65.1	65.8	69.7	2.44	.02	<.01	.15	.42
Glycine	65.1	69.2	68.3	65.8	75.1	2.30	.07	.02	.04	<.01
Alanine	58.3	61.6	62.8	63.0	69.0	1.85	.17	<.01	<.01	.16
Tyrosine	53.9	57.2	54.1	52.6	64.7	2.60	.32	.24	.06	<.01
Total NEAA	60.3	63.7	64.1	63.8	70.5	1.62	.13	<.01	<.01	.05
Total AA	61.7	64.7	65.2	65.4	71.6	1.54	.15	<.01	<.01	.06

[a]RALF = restricted alfalfa at a level of the average forage intake of the supplemented steers; AALF = ad libitum alfalfa; .4, .8, and 1.2 = cracked corn (CC) supplementation at .4, .8, and 1.2% of BW, respectively.

[b]Preplanned contrasts with P values for each comparison: RALF vs AALF; RALF vs supplemented (S); L = linear and Q = quadratic effects of CC supplementation (including AALF and the three levels of cracked corn).

[c]Standard error of the mean.

FORAGE QUALITY OF ALFALFA AND GRASS DURING THE FIRST SPRING GROWTH IN CENTRAL ILLINOIS

J. C. Elizalde, N. R. Merchen, and D. B. Faulkner

SUMMARY

Estimates of the extent of DM and CP degradation were determined for alfalfa, bromegrass, and endophyte-free tall fescue, and endophyte-infected in four stages of maturities across the first spring growth. Forages were collected form April 27 to June 6, 1994, chopped and incubated in two rumen cannulated Simmental x Angus steers. Patterns of DM and CP degradation were fitted using a non linear model, and the extent of degradation (ED) was estimated using a rate of passage of 6.0%. The ED were regressed using days after May 12 for alfalfa, and days after April 27 for grasses, as the independent variable. The ED of DM (EDMD) and CP (ECPD) decreased in alfalfa at a rate of .69%/d and of .40%/d for EDMD and ECPD, respectively, from May 12. The estimated EDMD in early bud (5/20) and early flowering (5/26) were 69.6% and 67.5%, respectively. The EDMD and ECPD decreased in grasses at a rate of .75%/d and .39%/d, respectively from April 27. The estimated EDMD for tillering (4/27) and stem elongation (5/12) were 68.8% and 57.5%, respectively. The EDMD was always higher than ECPD. For the first spring growth, the grazing of grasses at their maximal EDMD (tillering) was 15 d before compared to the grazing of alfalfa at the early flowering stage, recommended for the grazing initiation. If grazing starts at grass tillering, alfalfa will be at early to mid vegetative stage. If grazing starts when alfalfa is at early flower, grasses will lose almost 10% of EDMD, and it will also not be possible to have a high efficiency of utilization of the standing forage during grazing.

INTRODUCTION

Most of the information about forage digestion and utilization by cattle comes from experiments done with low quality forages. Most of grazing areas in Illinois are suitable for pastures including tall fescue, bromegrass, alfalfa, and red clover which have high qualities depending on time of the year and forage management. However, it is well known that animals grazing high quality forages often perform at levels below expectations. Fresh forages have inefficiencies in the conversion of forage N into animal products (Poppi and McLennan, 1995), and they have continuous changes in the nutritive value across the grazing seasons (Reid and Jung, 1982). Patterns of ruminal DM and CP degradation are different among forage species and changes in maturity within forages, which can also affect forage intake and pasture utilization. Mixed pastures of legumes and grasses require a more complex forage management mainly because each forage should be utilized not only when the maximum quality is attained but also accounting for plant survival, maximal forage production and reduced risk of nutritional problems such as bloat. Our goal was to compare the extent of the ruminal DM and CP degradation in different forages (alfalfa, bromegrass, tall fescue endophyte-free, and endophyte-infected) as affected by forage species and period of utilization.

MATERIALS AND METHODS

First growth of perennial tall fescue (*Festuca arundinacea* Schreb. cv Kentucky 31) with or without infection with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982), bromegrass (*Bromus biebersteinii* Roem & Schult.) and alfalfa (*Medicago sativa* L. cv Agripro Dawn), were sampled in the spring of 1994 at the South Farms of the University of Illinois at Urbana-Champaign.

Forages were sampled on eleven dates through different physiological stages during the first growth starting in April 27, 1994. Sample collection began with tillering of the grasses and with the vegetative stage of alfalfa and was finished in the seed ripening stage for grasses and in full flowering for alfalfa. At each date of sampling, plants were morphologically evaluated according to Simon and Park (1983) for the grasses and by the Guide to Determining Alfalfa Maturity Stages (Rohweder, D., Field Card A 3415, University of Wisconsin, Madison) for alfalfa.

Four stages of maturity were chosen for each forage according to the changes in morphology (Table 1). Two rumen-cannulated Simmental x Angus steers fed orchardgrass ad libitum were used to compare effects of both the stage of maturity and different forages on in situ CP and DM degradation. Polyester Dacron bags were used in duplicates for each forage and maturity stage. Bags were placed in the ventral sac of the rumen at 60, 48, 36, 24, 18, 12, 9, 6, and 3 h. The CP content (AOAC, 1990) was determined for each residue and original forage.

Dry matter and CP disappearance were calculated as the percentage of the incubated CP and DM after substraction of the residues. Estimates of the kinetics of DM and CP degradation were obtained using the model of Orskov and McDonald (1979): $D = A + B(1 - e^{-kd*t})$ where D = disappearance at time (t), A = soluble fraction (%, wash value at 0 h), B = insoluble potentially digestible fraction (%), and kd = rate of degradation (%/h). Model estimates were obtained using the nonlinear (NLIN) procedure of SAS (1995). The extent of DM and CP degradation (ED) was calculated according to Orskov and McDonald (1979), $ED = A + [(B \times kd)/(kd + kp)]$, where kp = the fractional rate of passage (6.0%/h). Regression analyses were performed for the extent of DM and CP degradation using days after April 27 for grasses or days after May 12 for alfalfa as independent variable.

RESULTS AND DISCUSSION

Variation in the extent of DM degradation for alfalfa and grasses during the first growth are shown in Figure 1. On April 27, alfalfa was in early vegetative stage reaching the mid vegetative stage by May 12 and the flowering stage by the end of May corresponding with a 45 d period between the initiation of growing and flowering. From April 27, grasses were in tillering stage until May 1, and then initiated the period of stem elongation. Grasses started to grow by April 10 and were ready for grazing at the end of April or beginning of May. Maturity stages were reached earlier in grasses than in alfalfa. Alfalfa had the greater decrease for EDMD between early bud and early flowering. For grasses the greater decrease in the extent of DM degradation occurred when forages were between heading and flowering (Figure 1). Regressions for the EDMD using days from May 12 for alfalfa and from April 27 for grasses as independent variable, were significant for all the forages:

$EDMD_{alfalfa}$ (%) = 85.57 - .70 * day, r^2 = .51, P < .027
$EDMD_{bromegrass}$ (%) = 65.45 - .69 * day, r^2 = .95, P < .0001
$EDMD_{t.\ fescue\ end.\ free}$ (%) = 69.3 - .70 * day, r^2 = .71, P < .005
$EDMD_{t.\ fescue\ end.\ infected}$ (%) = 71.4 - .75* day, r^2 = .95, P < .001

Since there were no differences (P > .05) in the regression coefficients among grasses, a common relationship was fitted :

$ED_{grasses}$ = 68.8 - .75* day, r^2 = .86, P < .001

The EDMD was higher in alfalfa than in grasses but decreased at almost the same rate as grasses. Alfalfa is grazed or cut for haying when plants are close to the flowering initiation. The estimated EDMD degradation in alfalfa was 69.6% and 67.5% for early bud (5/20) and in early flowering (5/26), respectively. For legumes with apical meristems such as alfalfa, the bud is usually removed during grazing, forcing them to regrow from the base. In alfalfa, the rate of forage growth must rely on root reserves in each cycle of basal stem initiation; therefore it is important to let the plant accumulate enough reserves which can be completed at the end of the bud stages or at the beginning of the flowering stage.

From April 27, the estimated EDMD in grasses at tillering (4/27) and stem elongation (5/12) stages were of 68.8% and 57.5%, respectively. High quality forage or pasture is most likely if plants are managed to minimize the proportion of plants with reproductive stages. Grasses need to be cut early before boot (Nelson and Moser, 1994) which occurred at the end of April. Therefore, for the first growth in central Illinois, there is a difference of 15 days between the optimal time for grazing grasses (coincidental with the maximal EDMD (tillering at the end of April) and the optimal time for grazing alfalfa (early flowering stage for grazing initiation). If grazing starts at tillering for grasses, alfalfa will be in young stages and bloat problems may also arise. If the decision is to start grazing when alfalfa is at late bud, grasses will lose almost 10% in the EDMD, affecting DM intake, and performance. If animal selection in grasses in reproductive stages is allowed, a high efficiency of forage harvesting by the animal will not be possible. Grasses will have a high proportion of stems after April 10 which usually decreases the harvest efficiency. Therefore, most of the forage grown will be lost as death material and will probably decrease the amount of forage grown and utilized during the next regrowth.

Patterns of extent of CP degradation for alfalfa and grasses across days are shown in Figure 2. There also was a significant relationship between the extent of CP degradation (ECPD) and days after May 12 for alfalfa, and days after April 27 for grasses:

$ECPD_{alfalfa}$ (%) = 88.8 - .40 * day, r^2 = .78, P < .002
$ECPD_{bromegrass}$ (%) = 77.31 - .32 * day, r^2 = .65, P < .009
$ECPD_{t.\ fescue\ end.\ free}$ (%) = 82.45 - .28 * day, r^2 = .44, P < .04
$ECPD_{t.\ fescue\ end.\ infected}$ (%) = 84.21 - .5 * day, r^2 = .81, P < .001

Neither regression coefficients nor intercepts were different among grasses. Therefore, a common regression for the ECPD across days, was calculated for grasses:

$$ECPD_{grasses}\ (\%) = 81.3 - .39 * day,\ r^2 = .67,\ P < .001$$

For every day from April 27 the extent of CP degradation decreased, on average, .4% in alfalfa, and .39%, on average, in grasses. The ECPD was always higher than the EDMD. The decrease of ECPD is almost a half of the EDMD degradation (.69%/d and .75%/d for alfalfa and grasses, respectively). Moreover, in fresh forages with a high CP content, the amount of CP degraded in the rumen usually exceeds the CP requirements of the microbial population compared to the availability to provide energy for bacteria through fermentation. However, the amount of CP degraded in the rumen is not only related with changes in the extent of CP degradation but also with changes in the CP content of the forage. Delaying the beginning of the grazing in order to decrease the amount of CP degraded in rumen (and also increase the escape of CP) will not be useful because it will have almost a twice the negative effect on DM degradation and, by extent on the amount fermented by rumen bacteria, and also on the DM intake.

From these results, it is important to find a forage management strategy in order to decrease the period of time between the optimal utilization of grasses and of legumes in mixed pastures. Grasses should be planted alone or with legumes that do not require long resting periods prior to the utilization, especially during the first growth (i.e., white clover, birds foot trefoil). However, this combination may lead to a less productive and drought resistant pasture (Nelson and Moser, 1994). However, the more complex is the composition of the pasture, the more difficult is the management for keeping the pasture at the highest quality, and at a high harvesting efficiency by the animals. Currently, it is possible to find varieties of grasses and legumes with different growth patterns that may allow to reduce the difference between periods of optimal utilization for grasses and legumes. Varieties of grasses with high requirements of low temperatures and long day lengths (late flowering varieties) should be recommended when alfalfa is present in the mixtures. Alfalfa varieties which can reach the early flowering stage sooner than others, should be selected in order to have a better quality in mixed pastures.

CONCLUSIONS

There were differences among forage species in CP and DM degradation as affected by maturity. In grasses, for each day after April 27, the extent of DM and CP degradation decreased .75%/d and .39%/d, respectively. For alfalfa the decrease from May 12 was .69%/d and .40%/d for DM and CP, respectively. When grasses were ready for grazing, alfalfa needed 15 days more in order to let the plant have a physiological stage compatible with stand persistence and the avoidance of bloat problems. Provided that mixed grasses and legume are recommended, it is necessary to reduce the period between the optimal time for grazing utilization between grasses and legumes through variety selection and forage management.

LITERATURE CITED

AOAC. 1990. Official Methods of Analysis (15 th Ed.). Association of Official Analytical Chemists, Arlington, VA.

Morgan - Jones, G. and W. Gams. 1982. Notes of hypomycetes. XLI. An endophyte of *Festuca arundinacea* and the anamorph of *Epichloe typhina*, a new taxa in one of the two sections of Acremonium. Mycotaxon 15:311.

Nelson, C. J. and L. E. Moser. 1994. Plant factors affecting forage quality. In: G. C. Fahey, Jr., M. Collins, D. R. Mertens, and L. E. Moser (Ed.). Forage Quality, Evaluation, and Utilization. pp. 115-154. Am. Soc. Agronomy, Crop Sci. Am., Soil Sci. Soc. Am., Madison.

Orskov, E. R. and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rates of passage. J. Agric. Sci. Camb. 92:449-503.

Poppi, D. P. and S. R. McLennan. 1995. Protein and energy utilization by ruminants at pasture. J. Anim. Sci. 73:278-290.

Reid, R. L. and G. A. Jung. 1982. Problems of animal production from pastures. In: J.B. Hacker (Ed.). Nutritional Limits to Animal Production from Pastures. pp. 21-43. Farnham Royal Farm. Commonwealth Agric. Bureau. Slough, UK.

SAS.1995. SAS/STAT®. User's Guide (Release 6.03). SAS Inst. Inc. Cary, NC.

Simon, U. and B. H. Park. 1983. A descriptive scheme for stages of development in perennial forage grasses. In: J.A. Smith, and V.A. Hays (Ed.). Proc. Int. Grassld. Congr. June 15-24, 1981, pp. 416-418. Westview Press, Co.

Table 1. Dates of harvest selected for the in situ study

Forage	Dates and physiological stages			
Alfalfa[a]	5/12 Mid Vegetative (1.2)	5/20 Early bud (3.8)	5/26 Early Flower (5.9)	6/6 Late Flower (6.7)
Bromegrass[b]	4/27 Tillering (25)	5/12 End of stem elongation (39)	5/20 Heading (58)	6/1 Flowering (68)
T. Fescue[b] End. Free	4/27 Tillering (25)	5/12 End of stem elongation (39)	5/20 Heading (58)	6/1 Flowering (68)
T. Fescue[b] End. Inf.	4/27 Tillering (25)	5/12 End of stem elongation (39)	5/23 Heading (58)	6/1 Flowering (68)

[a]Values in parenthesis represent maturity stages, 1: mid - vegetative, late - vegetative, 3: early bud, 4: late bud, 5: early flower, 6: late flower. Rohweder D. (1988), Field Card A3415. Agric. Bull. 30. U. of Wisconsin, Madison.

[b]Values in parenthesis represent stages of development according to Simon and Park (1983):20 to 29 describes tillering, 31 to 39 refers to stem elongation, 50 to 58 to inflorescence emergence, 60 to 68 anthesis, and 75 to 93 to seed ripening, End. Free and End. Inf: endophyte free or infected with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982).

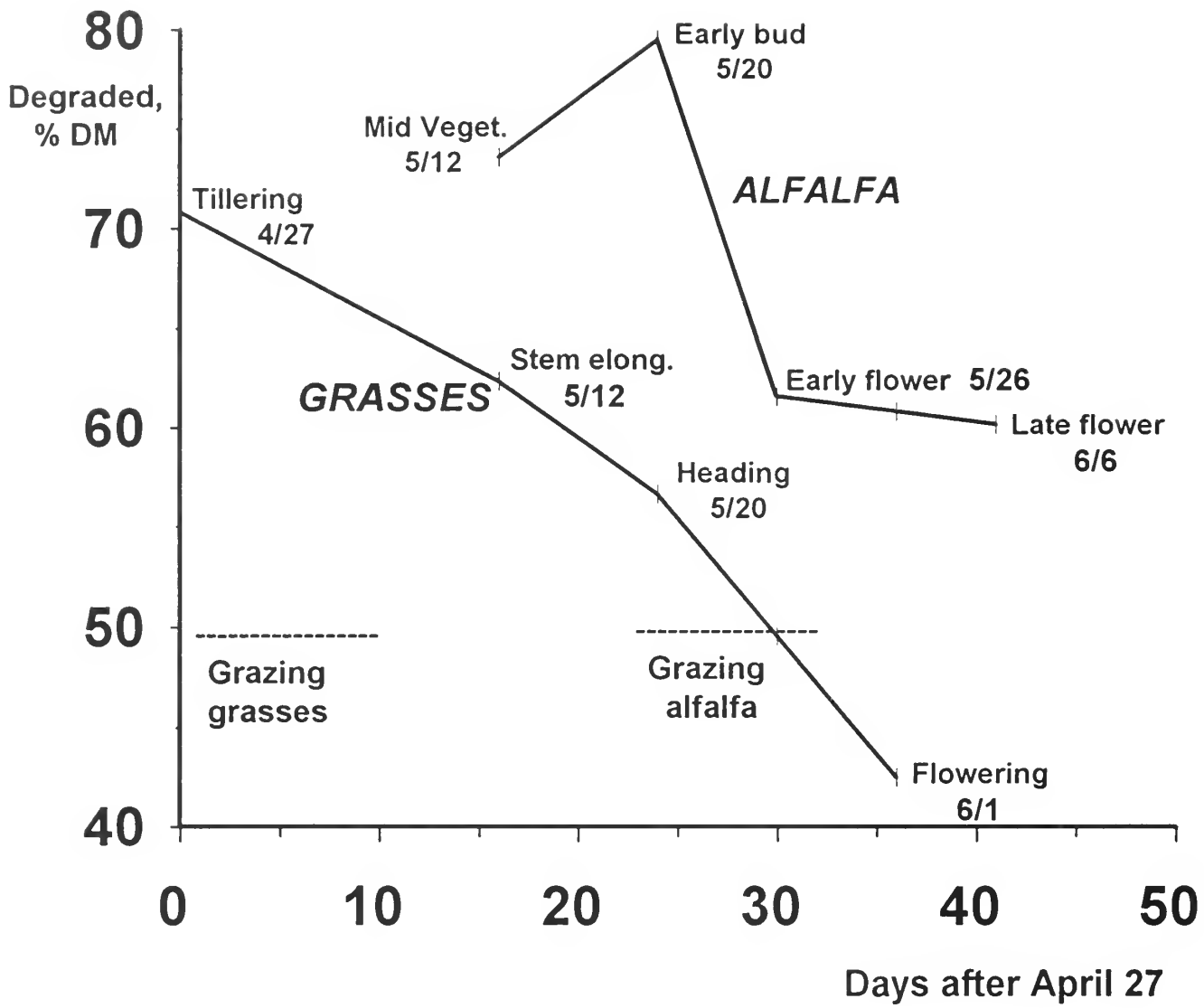

Figure 1. Relationship between maturity stages and days after April 27 for fresh alfalfa and grasses (bromegrass, tall fescue endophyte free and infected). Dashed lines represent the time for grazing grasses or alfalfa.

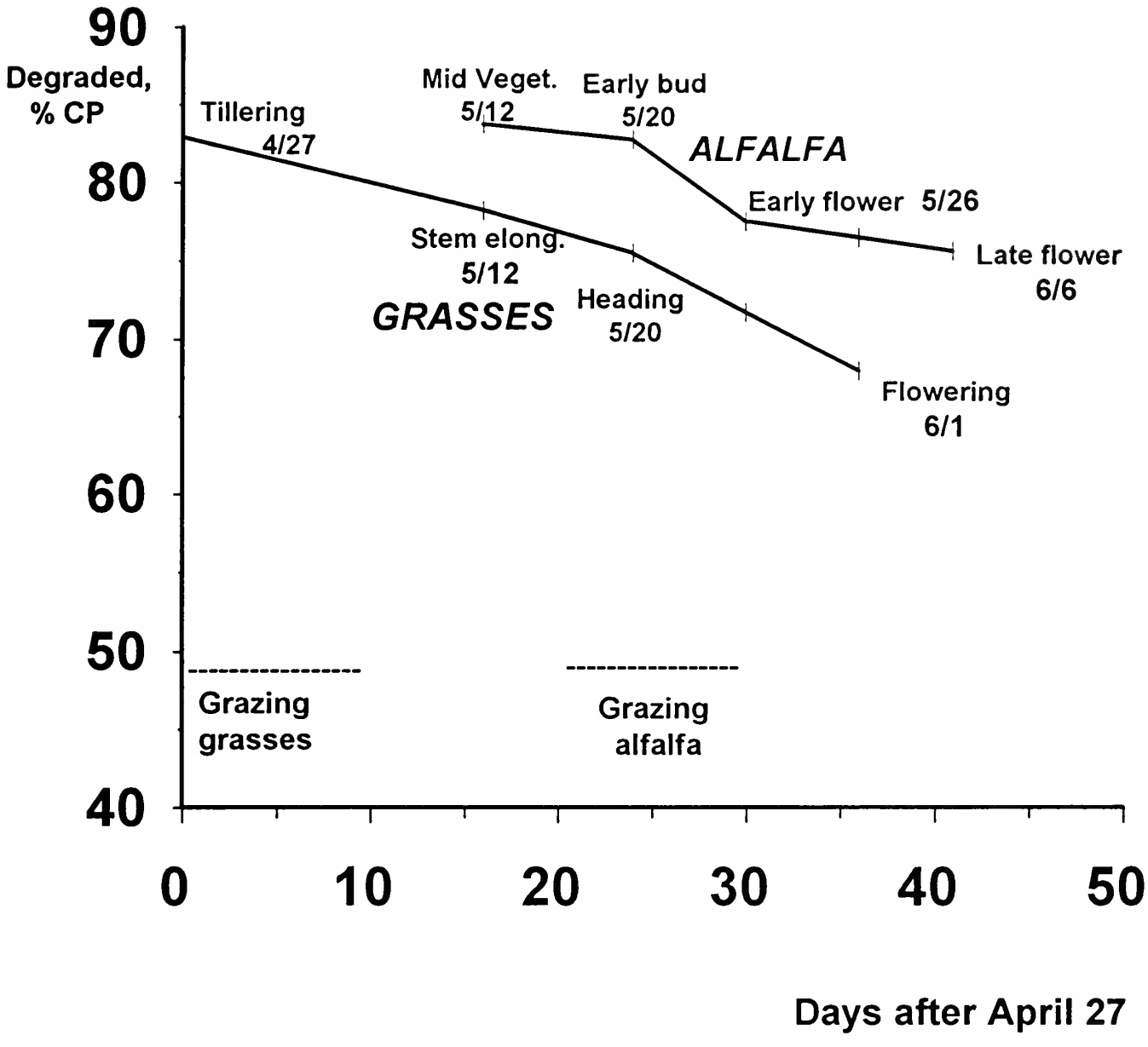

Figure 2. Extent of degradation of CP in fresh alfalfa and grasses (bromegrass, tall fescue endophyte free, and infected) at different maturities. Dashed lines represent the time for grazing grasses or alfalfa.

COMPOSITION OF FRESH FORAGES DURING THE SPRING GROWTH

J. C. Elizalde, N. R. Merchen, and D. B. Faulkner

SUMMARY

The composition of the fiber and CP of alfalfa, bromegrass, and tall fescue endophyte free and infected forages (FOR) was compared during the spring growth from vegetative to reproductive stages. Forages were cut from April 27 to June 6 in 1994, and from April 27 to June 11 in 1995 with 11 and 12 dates of harvest, respectively. Total dietary fiber (TDF) was fractionated in insoluble and soluble fiber (SF). The CP of the forages was fractionated into non protein N (A), soluble CP (B1), insoluble CP that was soluble in neutral detergent (B2), CP insoluble in neutral detergent but soluble in acid detergent (B3), and CP insoluble in acid detergent (C). Effects of year, forages, and number of days after the first cut (used as a covariate) were included in the model. Alfalfa (A) had lower ($P < .001$) TDF and higher ($P < .001$) SF than grasses (GR), A: 49.9, 14.4; GR 60.4, 4.5 for TDF and Sf, respectively). Alfalfa had higher ($P < .01$) CP (20.6% of DM) than GR (15.3%). The fraction A (% of CP) was not different ($P > .05$) among FOR (22.5%) but B1 (% of CP) was higher ($P < .05$) in A (17.1%) than in GR (13.2%). The B2 fraction (% of CP) was higher ($P < .01$) in A compared to GR (51.6% vs 45.9%, respectively). Alfalfa had lower ($P < .01$) B3 (3.0 % of CP) than bromegrass (18.6%) and tall fescue (13.2%). The fraction C was not different ($P > .05$) among FOR (3.8%). The decrease in CP (% of DM) across days was higher ($P < .05$) for bromegrass (-.4%/d) than for the other FOR (-.29%/d). Fraction B2 (% of CP) decreased in A (-.21 %/d) but was unchanged in GR across days. The fraction B3 (% of CP) increased ($P < .05$) in A (.1%/d), decreased in tall fescue infected (-.20%/d), and did not change ($P > .05$) in the other FOR. Alfalfa had less TDF and more SF than grasses. Grasses had more CP linked to the NDF than alfalfa. Maturity had a smaller effect on forage CP composition compared to FOR species.

INTRODUCTION

Forage composition is affected by stage of growth and by forage species. The effect of forage species and maturity on digestion and animal performance results mainly from changes in cell wall components, which affects DM intake and digestibility (Van Soest, 1994). However, quantification of different fiber and CP fractions have not been extensively conducted in fresh forages at stages of maturity used in grazing situations. Our objective was to analyze and compare the composition of fiber and CP fractions of the spring growth of alfalfa, bromegrass, and tall fescue endophyte free and infected forages as affected by maturity.

MATERIALS AND METHODS

Forage species and management were despected in the companion report (Elizalde et al., 1998). Forages were sampled on 11 dates through different physiological stages during the first growth in 1994 and 12 dates in 1995. Sample collection began with tillering of the grasses and with the vegetative stage of alfalfa. Sampling was finished in the seed ripening stage for grasses and in full flowering for alfalfa. Sampling dates were: 4/27, 5/2, 5/5, 5/9, 5/12, 5/16, 5/20, 5/23, 5/26, 6/1, and 6/6 in 1994. In 1995, forages were sampled on the same dates but because of a slower transition

between heading and flowering, forages were also sampled on 6/11. At each date of sampling, plants were morphologically evaluated according to Simon and Park (1983) for the grasses. The Guide to Determining Alfalfa Maturity Stages (Field Card A 3415, University of Wisconsin, Madison) was used to evaluate alfalfa at each date of harvest.

Chemical analyses. Forages samples were analyzed for DM, OM, NDF, ADF, and ADL (Goering and Van Soest, 1970). The NDF was determined using the termamyl procedure described by Jeraci et al. (1988). Total dietary fiber (TDF) was determined in forage samples according to Prosky et al. (1985). The TDF accounts not only for the insoluble fiber but also for the soluble fiber, which is removed by the neutral detergent together with the cell contents. Soluble fiber was determined by the difference between TDF and NDF (free of ash and CP).

The Net Carbohydrate and Protein System (Figure 1) is one of the schemes developed for the feed CP fractionation (Sniffen et al., 1992). Fraction A is nonprotein nitrogen (NPN), B is true protein, and C is unavailable true protein. Fraction B is further divided into three fractions (B1, B2, and B3) that are assumed to have different rates of ruminal degradation. Fractions A and B1 are soluble in phosphate-borate buffer and are rapidly degraded in the rumen. Fraction B2 is insoluble in buffer but soluble in neutral detergent, and fraction B3 is insoluble in buffer and in neutral detergent, but is soluble in acid detergent. Buffer insoluble protein minus the fraction B3 is used to estimate fraction B2. The fraction B2 is fermented in the rumen at lower rates than buffer soluble fractions and some B2 fraction escapes to the lower gut. Fraction B3 is slowly degraded in the rumen because of its association with the cell wall being more affected by the rate of passage than fraction B2. Fraction C is insoluble in acid detergent (acid detergent insoluble protein, ADIN), is highly resistant to microbial and mammalian enzymes, and it is assumed not to be degraded by ruminal bacteria but does not provide absorbable amino acids postruminally. Crude protein was partitioned into five fractions using the procedures described by Krishnamoorthy et al. (1982), and Licitra et al. (1996) in order to obtain the fractions shown in Figure 1. The forage CP content was analyzed for total N (Kjeldahl N, AOAC, 1990), neutral detergent insoluble N (NDIN), and ADIN. Soluble protein was extracted with bicarbonate-phosphate buffer. The NPN was obtained by precipitation of true N with trichloroacetic acid (TCA, final concentration 10%) and nonprotein N (NPN) was determined as the difference between total forage N and the N present in the residue.

Statistical analysis. Data were analyzed using the GLM procedure of SAS (1995). Forage composition data were analyzed as a randomized block design using year as blocking factor, and forage species was used as a main effect. Orthogonal contrasts among forage species compared alfalfa vs grasses, bromegrass vs tall fescue, and tall fescue endophyte free vs endophyte infected. The effect of number of days after the first cutting (April 27) was used as a covariate in the covariance analysis to check if maturity (expressed as number of days from the first cut) had any effect on forage composition. The interaction between the number of days and forage species was also tested to check if the maturity effect on chemical composition was influenced by forage specie. For those variables which were affected by forage species and number of days, intercepts and regression coefficients were reported. For those variables affected by forage species but not by maturity, only least square means were reported.

RESULTS AND DISCUSSION

Alfalfa had lower ($P < .01$) NDF, ADF, and higher ($P < .01$) ADL than grasses (Table 1). However, there were no differences ($P > .05$) for the rate of increase of NDF, ADF and ADL among forages. The rate of increase of NDF and ADF for all the forages was .46%/d and .44%/d for NDF and ADF, respectively.

The TDF values showed in similar trend as NDF (Table 2). The TDF intercept for alfalfa was almost 10% units lower ($P < .001$) compared to grasses. However, there were no differences ($P > .05$) in TDF contents among grasses. The rate of TDF accumulation tended ($P < .15$) to be higher in grasses than in alfalfa. When SF is accounted for, alfalfa had 20% units less insoluble fiber than grasses (35.4 and 55.9% for alfalfa and grasses, respectively). Most of the SF is made of pectins, soluble hemicelluloses and gums present in the middle lamella (Van Soest, 1994). Furthermore, SF accounted for 30% of the TDF in alfalfa, whereas SF was only 7.5% of the TDF in grasses.

Alfalfa had a higher ($P < .01$) CP contents compared with grasses. There was a decrease in the CP content across days in all forages (Table 3). Moreover, CP decreased in alfalfa at the same rate ($P > .05$) as in grasses, but bromegrass had a higher decrease ($P < .01$) than both endophyte free and endophyte infected tall fescue. Buffer soluble CP was not affected ($P > .05$) by days after first cut, but Least square means values tended ($P < .07$) to be higher in alfalfa than in grasses in coincidence with data reported by Sniffen et al. (1992) with higher soluble CP for alfalfa (46%) than for grasses (42.5%). Soluble CP was always a constant fraction of the total CP even when alfalfa ranged from 27% to 15% CP and grasses from 26 to 7% CP. A reduction in soluble CP as maturity advanced, could be anticipated; however, Hoffman et. al. (1993) and Cherney et al. (1997) found small changes in the percentage of soluble protein as maturity advanced.

The fraction A comprises the amount of the soluble nitrogen which is not true protein (non protein nitrogen). Fraction A, as percentage of total CP, was not affected ($P >.05$) by forage and days after first cutting. The difference between soluble protein and fraction A is the soluble true protein (fraction B1). Alfalfa had a higher proportion of fraction B1 expressed as percentage of total CP ($P < .03$) or soluble CP ($P < .01$) compared to grasses. The higher B1 fraction may explain the higher total soluble CP in alfalfa, since the fraction A was not different among forages.

Fraction B2 accounts for the buffer insoluble protein, but soluble in neutral detergent. Fraction B2 was the largest CP fraction in all forages. Values for fraction B2 were higher than those calculated from the data of Sniffen et al. (1992) for alfalfa pastures (average: 41% of CP) and grass pastures (average: 37% of CP) in different seasons. This difference with our data is partially explained by the higher soluble CP reported by Sniffen compared to those obtained in our experiment, giving lower values for B2. Least square means showed a higher ($P < .01$) proportion of B2 in alfalfa than in grasses (Table 3). The fraction B2 decreased with days but this decrease was affected by forages species, since it decreased in alfalfa but not in bromegrass and tall fescue endophyte infected whose regression coefficients were not different from zero.

The fraction B3 represents the protein insoluble in neutral detergent but soluble in acid detergent. This fraction is slowly degraded in the rumen because of its low digestion rate, and B3 is able to

escape ruminal digestion and make an important contribution to the dietary protein escaping rumen degradation (ECP). Fraction B3 (% of CP) was lower ($P < .01$) in alfalfa compared to grasses. Bromegrass had higher ($P < .04$) fraction B3 than tall fescue. For unknown reasons, tall fescue endophyte free had lower values ($P < .01$) than tall fescue endophyte infected. Least square means for B3 showed that grasses had four to six times ($P < .01$) more B3 (% of CP) than alfalfa. Abdalla et al. (1988) reported values for B3 of 15.8% of total CP for grazed mixed pastures of birdsfoot trefoil and bromegrass, and 21.4% for pasture of bromegrass alone. However, those values represent to the N linked to the NDF, which also includes the fraction C. After correction by fraction C, values were 13% for birdsfoot trefoil and bromegrass and 19.3% for bromegrass, which are close to our values. Values of B3 reported by Sniffen et al. (1992) ranged between 10% for alfalfa pastures and 14.5% of the CP for grass pastures during the spring.

The fraction C is the unavailable or bound protein which is insoluble in acid detergent. The fraction C was affected ($P < .01$) by days after first cutting but was not affected ($P > .05$) by forage species or its interaction with day of cutting. For each day after April 27, the fraction C increased .08%/d as percentage of CP for all the forages. Least square means for alfalfa (4.8% of CP) and grasses (3.5% of CP) were slightly higher than the values reported for alfalfa and grass pastures (2.2% of CP) by Sniffen et al. (1992). Values were also in the range found by Cherney et al. (1997) for alfalfa (1.8 to 4.6% of CP) and grasses (1.0 to 6.6% of CP) from samples collected at 3 maturity stages. The contribution of each CP fraction as percentage of total CP is shown in Figure 3. Insoluble fraction made up 60% in alfalfa and 65% in grasses and the differences in B3 fractions between alfalfa and grasses is also evident.

CONCLUSIONS

Composition of the fiber components was different between alfalfa and grasses. Soluble fiber can make important contributions in alfalfa. The composition of the forage protein differed between alfalfa and grasses and this effect was as important as maturity. Alfalfa had more soluble protein but also had four to six times less protein associated with neutral detergent fiber compared to grasses. The implications of this differences on the overall rate of CP degradation are still unclear.

LITERATURE CITED

Abdalla, H. O., D. G. Fox, and R. R. Seany. 1988. Variation in protein and fiber fractions in pasture during the grazing season. J. Anim. Sci. 66:2663-2667.

AOAC. 1990. Official Methods of Analysis (15 th Ed.). Association of Official Analytical Chemists, Arlington, VA.

Cherney, D. J. R., Cherney, J. R., and A. H. Davidson. 1997. Characterization of legume and grass residues following in vitro and in sacco ruminal digestion. Proc. Int. Grassld. Congress. 17:401.

Elizalde, J. C., N. R. Merchen, and D. B. Faulkner. 1998. Effects of species and stages of maturity of fresh forages on in situ dry matter and crude protein degradation. Illinois Beef Res. Rep.

Goering, H. K. and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures and some applications). Agric. Handbook 379. ARS, USDA, Washington, DC.

Hoffman, P. C., S. J. Sievert, R. D. Shaver, D. A. Welch, and D. K. Combs. 1993. In situ dry matter, protein, and fiber degradation of perennial forages. J. Dairy Sci. 76:2632-2643.

Jeraci, J. L., T. Hernandez, J. B. Robertson, and P. J. Van Soest. 1988. New and improved procedure for neutral-detergent fiber. J. Anim. Sci. 66 (Suppl. 1):351 (Abstr.).

Krishnamoorthy, U., T. V. Muscato, C. J. Sniffen, and P. J. Van Soest. 1982. Nitrogen fractions in selected feedstuffs. J. Dairy Sci. 65:217-225.

Licitra, G., T. M. Hernandez, and P. J. Van Soest. 1996. Standardization of procedures for nitrogen fractionation of ruminant feeds. Anim. Feed Sci. Technol. 57:347-358.

Prosky, L., N. G. Asp, I. Furda, J. W. DeVries, T. F. Schveizer, and B. F. Harland. 1984. Determination of total dietary fiber in food and food products: Collaborative study. J. Assoc. Off. Anal. Chem. 67:1044-1064.

SAS. 1995. SAS/STAT®. User's Guide (Release 6.03). SAS Inst. Inc. Cary, NC.

Simon, U. and B. H. Park. 1983. A descriptive scheme for stages of development in perennial forage grasses. In: J.A. Smith, and V.A. Hays (Ed.). Proc. Int. Grassld. Congr. June 15-24, 1981, p. 416-418. Westview Press, Co.

Sniffen, C. J., J. D. O'Connor, P. J. Van Soest, D. G. Fox, and J. B. Russell. 1992. A net carbohydrate and protein system for evaluating diets: II. Carbohydrate and protein availability. J. Anim. Sci. 70:3562-3577.

Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant (2nd ed.) Cornell University Press, Ithaca, NY.

Table 1. Linear regression equations to predict forage fiber composition in different forages as affected by days after first cutting (April 27)

						Contrast[a]		
			T. Fescue Endophyte			A vs	Br vs	TFFr vs
	Alfalfa	Bromegrass	Free	Infected	SEE[b]	Gr	TF	TFInf
NDF, % DM								
Intercept[c]	26.8	51.2	50.4	50.1	.81	.01	.61	.87
Reg. coeff.[c]	.52	.46	.41	.46	.06	.24	.65	.55
LSM[d]	38.4	61.6	59.6	60.3				
ADF, % DM								
Intercept	20.97	26.58	26.85	24.39	.54	.01	.46	.11
Reg. coeff.	.40	.45	.38	.44	.04	.59	.44	.25
LSM	29.9	36.7	35.4	34.4				
ADL, % DM								
Intercept	3.56	1.69	1.61	1.29	.11	.01	.35	.29
Reg. coeff.	.09	.09	.08	.08	.007	.50	.16	.76
LSM[d]	5.5	3.8	3.4	3.0				

[a]Orthogonal contrasts with the associated P values, n=24, A: alfalfa, Gr: grasses, Br: bromegrass, TFFr and TFInf.: tall fescue endophyte free and infected with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982).

[b]SEE: Standard error of the estimate.

[c]Intercept and regression coefficient for the linear regression between each dependent variable and days after first cutting as independent variable; e.g., on April 27 alfalfa was predicted to have 26.8% DM as NDF which would decrease .52% units each day of advancing maturity.

[d]Least square means; e.g., alfalfa had, on average, 38.4% of DM as TDF across dates of harvest.

Table 2. Fiber fractionation of different forages from samples collected at different dates after April 27 1994, and 1995

						Contrast[a]		
			T. Fescue Endophyte			A vs	Br vs	TFFR vs
	Alfalfa	Bromegrass	Free	Infected	SEE[b]	Gr	TF	TFInf
% TDF[c]								
Intercept[d]	39.3	48.1	48.5	47.2	1.4	.01	.89	.49
Reg. coeff.[d]	.50	.60	.58	.57	.05	.15	.70	.85
LSM[e]	49.9	60.9	61.0	59.3				
% NDF[f]								
Intercept	24.2	43.4	44.9	43.6	1.4	.01	.65	.52
Reg. coeff.	.53	.59	.50	.58	.06	.63	.46	.29
LSM	35.4	56.1	55.5	56.0				
% SF[g]								
LSM	14.4	4.8	5.4	3.3	1.3	.01	.53	.98

[a]Orthogonal contrasts with the associated P values, n=24, A: alfalfa, Gr: grasses, Br: bromegrass, TFFr and TFInf.: tall fescue endophyte free and infected with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982).

[b]SEE: Standard error of the estimate.

[c]Total Dietary Fiber (Prosky et al., 1995).

[d]Intercept and regression coefficients for days after first cutting (April 27) as independent variable; e.g., on April 27 alfalfa was predicted to have 39.3% of DM as TDF which would decrease .50% units each day of advancing maturity. When estimates are not shown, there was no effect of days after first cutting, or there was no interaction between days and forage specie.

[e]Least square means; e.g., alfalfa had, on average, 49.9% of DM as TDF across dates of harvest.

[f]Neutral detergent fiber residue (Jeraci et al., 1988) - Nitrogen in the NDF (NDIN) - Ash in the NDF.

[g]Soluble fiber: TDF - NDF[f].

Table 3. Coefficients of linear regression equations to predict the CP content and fractions of soluble CP, as affected by days after the first cutting (April 27)

						Contrast[a]		
			T. Fescue Endophyte			A vs	Br vs	TFFr vs
	Alfalfa	Bromegrass	Free	Infected	SEE[b]	Gr	TF	TFInf
Total CP, %DM								
Intercept[c]	26.9	25.8	21.4	21.2	.49	.01	.01	.89
Reg. coeff.[c]	-.28	-.41	-.30	-.29	.04	.19	.01	.78
LSM[d]	20.6	16.7	14.5	14.6				
SCP, %CP[e]								
LSM	40.5	35.1	35.1	36.3	1.1	.07	.44	.34
A[f], % CP								
LSM	23.4	23.0	22.0	21.8	.80	.24	.34	.24
B1[g], % CP								
LSM	17.1	12.1	13.2	14.5	.96	.01	.10	.92
B2[h], % CP								
Intercept	56.3	43.9	46.7	43.6	1.1	.01	.62	.27
Reg. coeff.	-.21	-.06	0.8	.13	.07	.01	.01	.66
LSM	51.6	42.6	48.5	46.5				
B3[i], % CP								
Intercept	.60	19.1	13.3	18.5	0.7	.01	.04	.005
Reg. coeff.	.11	-.02	-.02	-.22	.05	.01	.10	.005
LSM	3.0	18.6	12.8	13.6				
C[j] % CP								
Intercept	2.02	1.18	1.20	1.78	.30	.23	.59	.37
Reg. coeff.	.12	.10	.11	.08	.02	.13	.95	.30
LSM	4.8	3.3	3.6	3.6	.30	.23	.59	.37

[a]Orthogonal contrasts with the associated P values, n = 24, A: alfalfa, Gr: grasses, Br: bromegrass, TFFr and TFInf.: tall fescue endophyte free and infected with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982).

[b]SEE: Standard error of the estimate.

[c]Intercept and regression coefficients for days after first cutting (April 27) as independent variable; e.g., on April 27 alfalfa was predicted to have 26.9% of DM as CP which would decrease .28% units each day of advancing maturity. When estimates are not shown, there was no effect of days after first cutting, or there was no interaction between days and forage specie.

[d]Least square means; e.g., alfalfa had, on average, 20.6% CP across dates of harvest.

[e]Soluble CP in borate-phosphate buffer (as percentage of total CP).

[f]A = non protein N (N x 6.25) expressed as percentage of total CP (Licitra et al., 1996).

[g]B1 fraction = SCP - A expressed as percentage of total CP (Licitra et al., 1996).

[h]Fraction B2 = 100 - SCP - CP in the NDF (NDIN).

[i]Fraction B3 = NDIN - CP in the ADF (ADIN).

[j]Fraction C = ADIN.

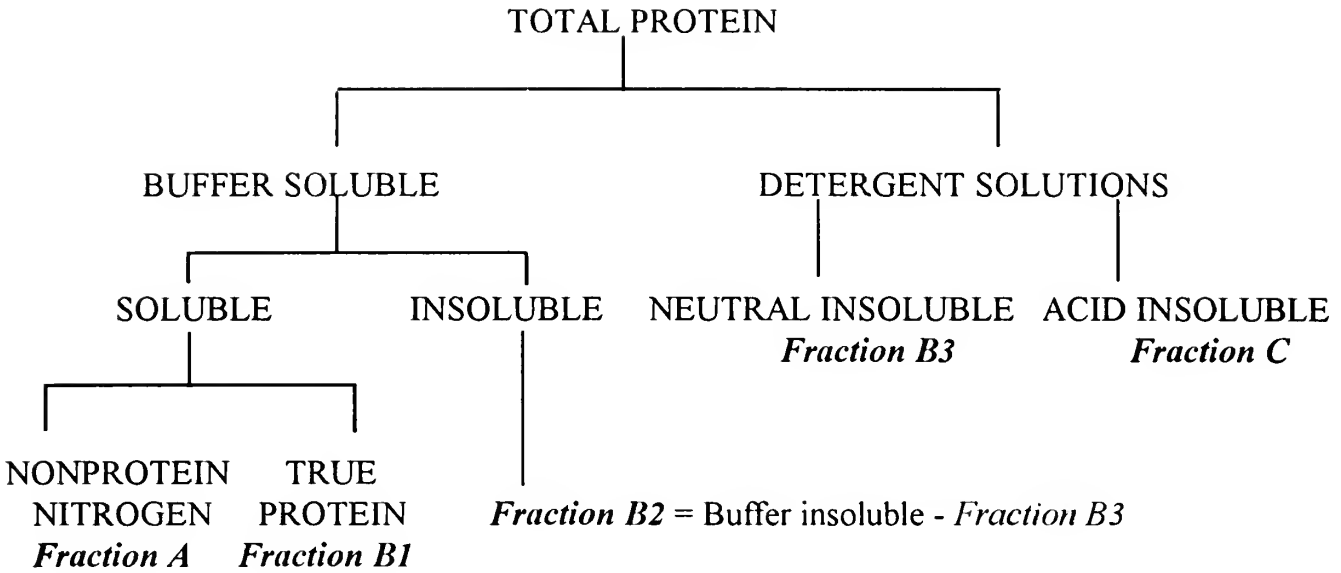

Figure 1. Fractionation of CP in feedstuffs (Krishnamoorthy et al., 1982; Licitra et al., 1996)

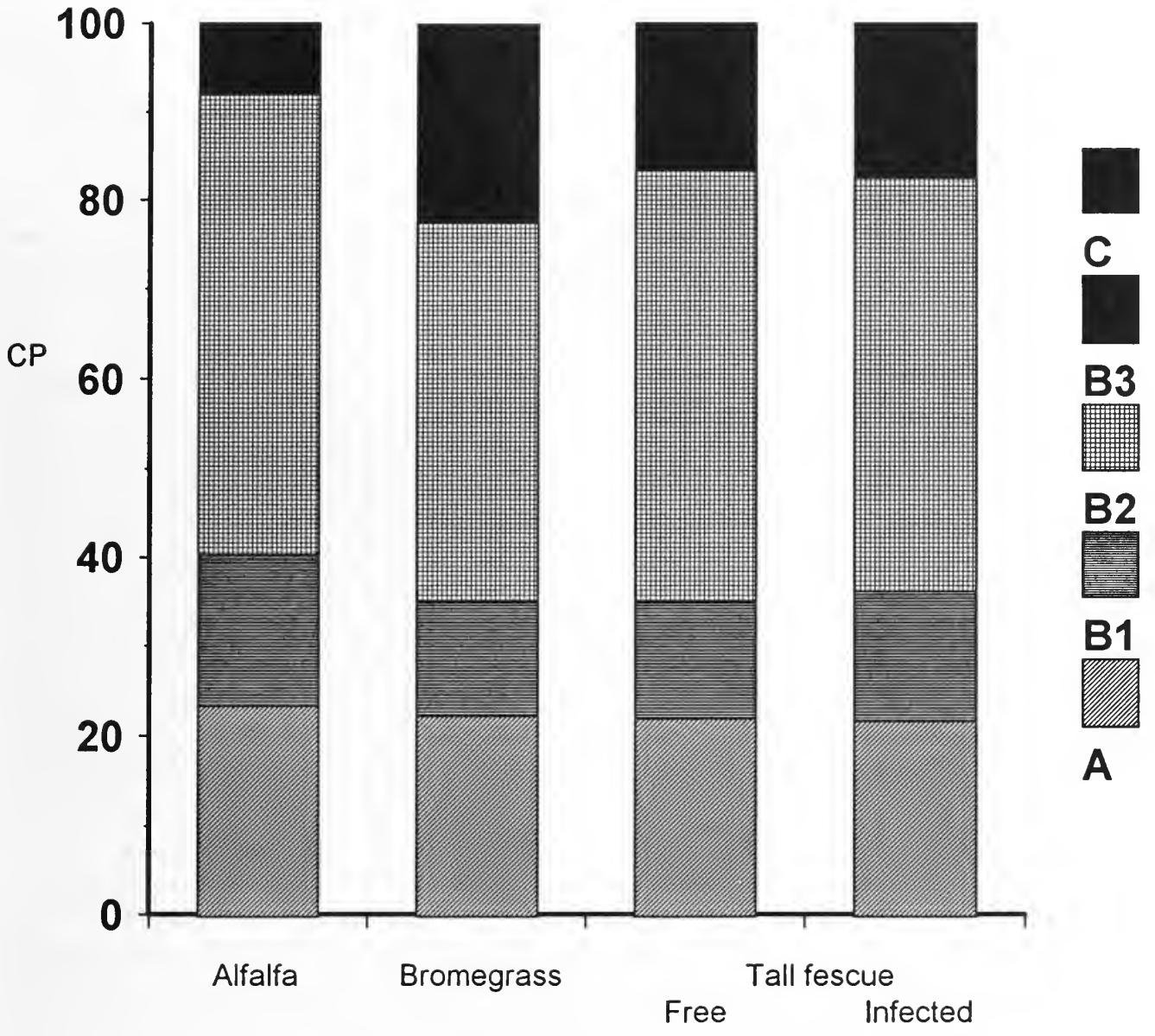

Figure 2. Least square means (average) for crude protein (CP) fractions (expressed as % of CP) in different forages. Tall fescue free or infected with Acremonium caenophyalum (Morgan-Jones and Gams, 1982). Crude protein fractions are depicted in Figure 1.

EFFECTS OF SPECIES AND STAGES OF MATURITY OF FRESH FORAGES ON IN SITU DRY MATTER AND CRUDE PROTEIN DEGRADATION

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SUMMARY

Fresh forages of alfalfa (A) in vegetative, early bud, early flowering, and late flowering stages, and of bromegrass, and endophyte free and infected tall fescue (tillering, stem elongation, heading, and flowering stages) were evaluated for ruminal DM and CP degradation kinetics using nonlinear models. Duplicate Dacron bags were incubated for 0, 3, 6, 9, 12, 16, 24, 36, 48, and 60 h in 2 Simmental x Angus steers fitted with ruminal cannulas. The effects of animal, forage species (FOR), and maturity (MAT) within FOR were evaluated. Alfalfa (A) had higher ($P < .04$) soluble (36.6%) and lower ($P < .02$) potentially digestible DM (43.0%) and tended ($P < .10$) to have higher extent of DM degradation (66.3%) than grasses (27.2, 53.5, and 54.6% for soluble, potentially digestible DM, and extent of DM degradation, respectively). Extent of CP degradation was similar among FOR (77.4%) but A tended ($P < .09$) to have a higher CP degradation rate than grasses (16.1%/h vs 12.5%/h). Extent of degradation of DM and CP decreased ($P < .05$) with MAT in A (71.2% to 57.5%, 81.1% to 72.9% for DM and CP, respectively) and in grasses (67.2% to 39.6%, 80.2% to 65.8% for DM and CP, respectively). Escape CP (g/kg DM) tended ($P < .13$) to be higher in A (40.0 g/kg) than in grasses (34.9 g/kg), and decreased ($P < .05$) with MAT in grasses (40.4 to 28.3 g/kg) but not in A. The escape CP (as percentage of forage CP content) increased with maturity, but when expressed as g/kg DM decreased with maturity due to the decline of the CP content. Stage of maturity within FOR had a greater effect than FOR species on ruminal DM and CP degradation.

INTRODUCTION

The effects of forage maturity on digestion and animal performance have been characterized in processed forages (Shaver et al., 1988; Nelson and Satter, 1990). For alfalfa and other perennial grasses, most of the experiments studying the kinetics of DM and CP degradation were done with hays or artificially dried forage samples. Changes in forage quality result mainly from the variation in cell wall components and lignification which affects DM digestibility (Cherney et al., 1992). However, the kinetics of situ DM and CP degradation may differ if forage samples are incubated in dried or in fresh form (McNabb et al., 1996). Our goal was to evaluate the effects of forage species and maturities on the kinetics of degradation of fresh materials, and also estimate the amount of dietary CP reaching the small intestine in animals fed fresh forages.

MATERIALS AND METHODS

First growth of perennial tall fescue (*Festuca arundinacea* Schreb. Cv Kentucky 31) with or without infection with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982), bromegrass (*Bromus biebersteinii* Roem & Schult., unknown origin) and alfalfa (*Medicago sativa* L.cv Agripro Dawn), were sampled in the spring of 1994 at the South Farms of the University of Illinois at Urbana - Champaign. Forages were sampled on eleven dates through different physiological stages during the first growth, starting in April 27, 1994. Four stages of maturity were chosen for each forage according to the changes in morphology (Table 1). Samples were taken using mechanical shears,

cutting at approximately 5 cm above the soil level taking approximately 5 kg of fresh material without stubble. Harvested samples of each forage were plunged into liquid nitrogen, frozen at -20 °C, then thawed and chopped in a food chopper (Hobart Corp., Troy, OH) to simulate forage disruption due to chewing. Initial DM of the forages was determined by freeze drying and an aliquot was used for determining absolute DM (drying in an oven at 105°C during 24 h; AOAC, 1990). Samples were analyzed for OM, NDF, ADF, and ADL. Crude protein was partitioned into five fractions according to Licitra et al. (1996).

Two rumen cannulated Simmental x Angus steers fed orchardgrass hay ad libitum were used for the in situ incubation of the forages. Polyester bags (Ankom, Fairport, NJ), 6.25 x 12.7 cm with a pore size of 53± 10 µm and three sides heat sealed, were used. Duplicate bags for each fresh forage and maturity stage were placed in the ventral sac of the rumen of each steer at 60, 48, 36, 24, 18, 12, 9, 6, and 3 h prior to soaking in water at 39°C for 15 min (Nocek, 1985). At the end of the incubation period, bags were placed in buckets with 39°C tap water, agitated gently by hand, changing the water of the bucket 4 times. Each bag was rinsed with tap water (until the wash water was clear), then opened and washed outside and inside the bag with gentle agitation for 1 min, squeezed, and dried for 48 h in a 57°C forced air-oven. After drying, bags were weighed and Kjeldahl N analyses were performed on the bag plus residues, and on the blanks.

Dry matter and CP disappearance at each incubation time were calculated as the inverse of the residues at each time of incubation. Estimates of the kinetics of DM and CP degradation, were obtained using the model of Orskov and McDonald (1979): $D = A + B(1 - e^{-kd*t})$ where D= disappearance at time (t), A = soluble fraction (%, wash value at 0 h), B = insoluble potentially digestible fraction (%), and kd = rate of degradation (%/h). Model estimates were obtained using the nonlinear (NLIN) procedure of SAS (1995). The extent of DM and CP degradation calculated according to Orskov and McDonald (1979), ED = A + [(B x kd)/(kd + kp)], where kp = the fractional rate of passage (6.0%/h, Broderick et al., 1992).

For the in situ data, results were analyzed by analysis of variance accounting for the effects of steer, and forage type, and maturity within forage. The effects of forage species were compared using orthogonal contrasts and maturity within forage were compared using LSD.

RESULTS AND DISCUSSION

The chemical composition of the forages at each maturity stage is shown in Table 2. The DM content increased and CP content decreased with maturity in both alfalfa and grasses but the maturity effect was more important in grasses. Bromegrass had the highest CP values at initial stages than tall fescue, and then decreased sharply. The neutral detergent insoluble nitrogen (NDIN) was lower in alfalfa (average: 2.1%) compared to grasses (average: 3.0%) but the acid detergent insoluble nitrogen (ADIN) were similar between alfalfa (.37%) and grasses (.38%) across maturities. The NDF and ADF values were lower in alfalfa, and as a result of maturity values increased in both alfalfa and grasses.

The in situ degradation estimates for DM and CP for the different forages are shown in Table 3. For DM, alfalfa had the highest ($P < .04$) soluble fraction (A) and lowest ($P < .02$) potentially digestible fraction (B). This difference may result from an increased CP and low NDF in alfalfa compared to

grasses. Bromegrass had lower soluble fraction tall fescue, but all the grasses had similar B fractions. The total digestible fraction (A + B) was not different among forages as indicative that compensation may occur between both fractions. The fractional rate of DM degradation was twofold in alfalfa (13.7%/h) compared to grasses (average: 6.7%/h). These results are in agreement with those found by Hoffman et al. (1993) showing higher rates of degradation in legumes (15.7%/h) compared with grasses (6.3%/h). There were no differences for the rate of degradation as well as for the extent of DM degradation among grasses.

No differences were found ($P > .05$) for the estimates A, B, and T for CP degradation between grasses and alfalfa (Table 3). However, bromegrass had lower values of A ($P < .003$) and tended to have lower values for B ($P < .07$) compared to tall fescue. Rate of CP degradation tended to be higher in alfalfa ($P < .09$) than in grasses. Alfalfa had a lower proportion of total nitrogen associated to the NDF (10.6% and 16.5% for alfalfa and grasses, respectively) or ADF (1.9 and 2.8% for alfalfa and grasses, respectively), and lower cell wall contents (Table 2) which may allow a higher N degradation compared to grasses. However, the extent of rumen CP degradation (as percentage of forage CP) was not different ($P > .05$) among forages. As a result of its high CP content, the amount of CP escaping rumen degradation (g/kg forage DM) tended to be higher ($P < .13$) for alfalfa with respect to grasses.

The kinetics of ruminal DM degradation of all forages, was affected ($P < .05$) by maturity (Figures 1 and 2, Table 4), although the effects were lower in alfalfa than in grasses. While in alfalfa, the fractional rate kd decreased from 17.6%/h to 11.4%/h. The decrease was more important in tall fescue (free: 8.6%/h to 2.7%/h; infected: 9.3%/h to 2.8%/h) than in bromegrass (11.5%/h to 5.6%/h). Hoffman et al. (1993) reported a decrease for both alfalfa and grasses across maturities, although the decline was also much lower for alfalfa. Lower and higher values of the rate of degradation across maturities were associated with greater increases in NDF, ADF, and ADL contents compared to alfalfa. For the extent of DM degradation maturity had a greater effect than forage species (Tables 3 and 4). This is in agreement with the data reported by Cherney et al. (1992) and by Hoffman et al. (1993) for grasses and legumes harvested at three maturity stages. For alfalfa, the greater decrease in the rate and extent of DM degradation was between early bud (14.3%/h, 77.3% for rate and extent of degradation, respectively) and early flowering (11.8%/h, 59.1%, respectively). For grasses there was a constant decrease in extent of DM degradation; although, an important decline occurred between heading and flowering.

Extent of CP degradation was higher for CP than for DM and also less affected by maturity (Table 5, Figures 1 and 2). The decrease in CP degradability was usually associated with the change toward a higher proportion of nitrogen bound to the NDF as maturity increases (Sanderson and Wedin, 1989; Hoffman et al., 1993). In our experiment, there was not a clear tendency of the NDIN increase (as % of TN) associated with maturity for the four forages. As discussed, part of the increased NDIN associated with maturity in the other experiment could be the effect of the way of processing of the sample. The increase in cell wall resistance to microbial attack and breakdown may also decrease CP degradation (Sanderson and Wedin, 1989).

Values for the ruminal escape CP (ECP, 100 - ED, Table 5) in alfalfa ranged from 27.1% in late flower to 18.9% in mid vegetative. In grasses, ECP ranged between 17.6% and 39.4%. However, since ECP is a percentage of the total CP, forages may have different ECP (g/kg DM) if they have

different CP contents (g/kg DM). The amount of ECP (g/kg forage DM) was also affected by forage maturity with a greater decrease in grasses. The decrease of ECP in grasses with maturity may be related with a decline in the extent of degradation but also with the decrease of the forage CP content (Table 5). From Figure 3, it can be seen that as forage CP decreased due to maturity, the ECP (as percentage of the total forage CP) increased; however, the ECP in forage (g/kg DM) decreased. This decline may have consequences for the protein nutrition of the animal. While high ECP is desirable, this may not have any effect in increasing the amount of dietary CP reaching the small intestine if forage ECR is low.

CONCLUSIONS

There were differences in CP and DM degradation as affected by species and maturity. However, maturity has the largest effect than forages species. Higher soluble DM fractions and rates of degradation led to higher DM disappearance in alfalfa than in grasses. The CP degradation was less affected than DM degradation by maturity or forage species. For alfalfa and grasses, as maturity advanced, CP content decreased, and the escape CP (% forage CP) increased. However, when ECP is expressed as g/kg DM, the amount of ECP decreased with maturity and being higher in alfalfa or in grasses at the early maturities.

LITERATURE CITED

AOAC. 1990. Official Methods of Analysis (15 th Ed.). Association of Official Analytical Chemists, Arlington, VA.

Broderick, G. A., S. M. Abrams, and C. A. Rotz. 1992. Ruminal in vitro degradability of protein in alfalfa harvested as standing forage or baled hay. J. Dairy Sci. 75:2440-2446.

Cherney, D. J., J. H. Cherney, and R. F. Lucey. 1993. In vitro digestion kinetics and quality of perennial grasses as influenced by forage maturity. J. Dairy Sci. 76:790-797.

Hoffman, P. C., S. J. Sievert, R. D. Shaver, D. A. Welch, and D.K. Combs. 1993. In situ dry matter, protein, and fiber degradation of perennial forages. J. Dairy Sci. 76:2632-2643.

Licitra, G., T. M. Hernandez, and P. J. Van Soest. 1996. Standardization of procedures for nitrogen fractionation of ruminant feeds. Anim. Feed Sci. Technol. 57:347-358.

McNabb, W. C., G. C. Waghorn, J. S. Peters, and T. N. Barry. 1996. The effect of condensed tannins in *Lotus pedunculatus* on the solubilization and degradation of ribulose-1,5-biphosphate carboxylase (*EC* 4.1.1.39; Rubisco) protein in the rumen and the sites of Rubisco digestion. Br. J. Nutr. 76:535-549.

Morgan - Jones, G. and W. Gams. 1982. Notes of hypomycetes. XLI. An endophyte of *Festuca arundinacea* and the anamorph of *Epichloe typhina*, a new taxa in one of the two sections of Acremonium. Mycotaxon 15:311.

Nelson, W. F. and L. D. Satter. 1990. Effect of stage of maturity and method of preservation of alfalfa on production by lactating dairy cows. J. Dairy Sci. 73:1800-1811.

Nocek, J. E. 1985. Evaluation of specific variables affecting in situ estimates of ruminal dry matter and protein digestion. J. Anim. Sci. 60:1347-1358.

Orskov, E. R. and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rates of passage. J. Agric. Sci. Camb. 92:449-503.

Sanderson, M. A. and W. F. Wedin. 1989. Nitrogen in detergent fibre fractions of temperate legumes and grasses. Grass and Forage Sci. 44:159-168.

SAS. 1995. SAS/STAT®. User's Guide (Release 6.03). SAS Inst. Inc. Cary, NC.

Shaver, R. D., L. D. Satter, and N. A. Jorgensen. 1988. Impact of fiber content on digestion and digesta passage in lactating dairy cows. J. Dairy Sci. 71:1556-1565.

Simon, U. and B. H. Park. 1983. A descriptive scheme for stages of development in perennial forage grasses. In: J.A. Smith, and V.A. Hays (Ed.). Proc. Int. Grassld. Congr. June15-24, 1981, pp. 416-418. Westview Press, Co.

Table 1. Dates of harvest selected for the in situ study

Forage	Dates and physiological stages			
Alfalfa[a]	5/12 Mid vegetative (1.2)	5/20 Early bud (3.8)	5/26 Early Flower (5.9)	6/6 Late Flower (6.7)
Bromegrass[b]	4/27 Tillering (25)	5/12 End of stem elongation (39)	5/20 Heading (58)	6/1 Flowering (68)
T. Fescue[b] End. Free	4/27 Tillering (25)	5/12 End of stem elongation (39)	5/20 Heading (58)	6/1 Flowering (68)
T. Fescue[b] End. Inf.	4/27 Tillering (25)	5/12 End of stem elongation (39)	5/23 Heading (58)	6/1 Flowering (68)

[a]Values in parenthesis represent maturity stages, 1: mid - vegetative, late - vegetative, 3: early bud, 4: late bud, 5: early flower, 6: late flower. Rohweder D. (1988), Field Card A3415. Agric. Bull. 30. U. of Wisconsin, Madison.

[b]Values in parenthesis represent stages of development according to Simon and Park (1983):20 to 29 describes tillering, 31 to 39 refers to stem elongation, 50 to 58 to inflorescence emergence, 60 to 68 anthesis, and 75 to 93 to seed ripening, End. Free and End. Inf: endophyte free or infected with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982).

Table 2. Forage composition (% DM) of the fresh forages used in the in situ incubation affected by the stage of harvest

	DM	OM	CP	NDIN[a]	ADIN	NDF	ADF	ADL
Alfalfa[b]								
Late vegetative	16.9	88.4	22.4	3.17	.38	34.8	26.3	4.5
Early bud	18.4	88.3	21.2	1.11	.27	36.1	30.9	5.4
Early flower	18.0	89.1	18.9	2.31	.42	41.1	35.9	6.6
Late flower	23.3	87.8	15.8	1.74	.41	46.0	34.6	6.7
Bromegrass[c]								
Tillering	14.9	87.0	25.8	6.16	.29	53.8	29.8	2.3
Stem elongation	16.4	88.1	14.8	3.17	.38	61.9	36.0	2.5
Heading	21.8	88.6	12.0	1.11	.27	63.9	41.5	3.8
Flowering	25.0	89.8	10.2	2.27	.40	66.5	46.6	5.2
T. Fescue E. Free[c]								
Tillering	20.6	88.1	19.8	3.47	.23	52.2	28.1	1.5
Stem elongation	18.5	89.0	21.4	3.06	.51	54.2	30.8	1.9
Heading	19.7	90.0	14.1	3.44	.27	60.9	37.1	3.7
Flowering	24.9	90.6	8.2	1.57	.37	66.9	44.3	4.4
T. Fescue E. Inf.[c]								
Tillering	20.7	89.0	23.3	4.56	.45	49.2	26.2	1.6
Stem elongation	17.2	89.0	20.7	3.36	.56	53.5	29.8	1.9
Heading	19.9	90.9	12.7	2.20	.38	62.3	38.4	3.2
Flowering	22.6	91.7	7.4	1.32	.47	66.4	44.1	4.0

[a]NDIN: neutral detergent insoluble N (expressed as N*6.25).

[b]Maturity stages according to Rohweder D. (1988), Field Card A 3415. Agric. Bull 30. U. of Wisconsin, Madison.

[c]Stages of development according to Simon and Park (1981), End. Free and End. Inf: endophyte free or infected with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982).

Table 3. Means for DM and CP degradation of forages species

	Forage species[a]					Contrast[b]		
			Tall Fescue			Al vs	Br vs	TF Fr vs
Estimates[d]	Alfalfa	Bromegrass	Free	Infected	SEM[c]	Gr	TF	TFInf
Dry matter								
A	36.6	20.9	31.7	29.0	3.6	.04	.05	.60
B	43.0	56.7	50.9	52.8	3.5	.02	.27	.71
T	79.6	77.6	82.6	81.7	3.9	.38	.72	.95
kd (%/h)	13.8	7.7	6.0	6.4	1.0	.01	.39	.86
ED	66.3	52.3	56.0	55.6	5.7	.10	.63	.96
Crude Protein								
A	40.7	35.3	49.8	42.7	2.4	.52	.01	.06
B	50.6	53.8	38.5	45.8	4.9	.43	.07	.31
T	91.3	89.1	88.3	88.5	3.3	.38	.65	.79
kd (%/h)	16.1	11.8	12.9	12.8	2.0	.09	.62	.95
ED	77.2	70.9	77.0	73.6	3.2	.38	.28	.46
ECP[e], g/kgDM	40.0	39.4	31.0	34.5	2.7	.13	.06	.37

[a]Tall Fescue Free and Infected: free or infected with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982), respectively.

[b]Orthogonal contrasts, n=8, Al = alfalfa, Gr = grasses: bromegrass (Br) and tall fescue endophyte free (TF Free) and infected (TF Inf) with the associated P values.

[c]Standard error of the mean.

[d]A = soluble fraction (%), B = insoluble potentially digestible fraction (%), T = A + B, kd: rate of degradation, ED = extent of ruminal DM or CP degradation (%), ED = A + [(B x kd)/(kd + kp)] at a ruminal rate of passage (kp) = 6.0%/h.

[e]ECP: escape CP.

Table 4. Means for the in situ DM degradation kinetics of perennial forages by stages of maturity[a]

		Fraction[b]				
Species	Maturity	A	B	T	kd	ED[c]
Alfalfa	Mid vegetative	35.5[d]	48.0	83.5[d]	17.6[d]	71.2[d]
Alfalfa	Early bud	49.9[e]	39.1	89.1[d]	14.3[d]	77.3[e]
Alfalfa	Early flowering	32.0[d]	41.2	73.2[e]	11.8[e]	59.1[f]
Alfalfa	Late flowering	29.1[g]	43.6	72.7[e]	11.4[e]	57.5[f]
Bromegrass	Tillering	24.3	64.0[d]	88.3[d]	11.5[d]	66.1[d]
Bromegrass	Stem elong.	18.6	64.3[d]	83.0[de]	6.6[e]	52.1[e]
Bromegrass	Heading	20.8	55.4[d]	76.2[e]	7.2[e]	50.9[e]
Bromegrass	Flowering	19.8	43.2[e]	63.0[f]	5.6[e]	40.2[f]
T. Fescue Free	Tillering	33.8[e]	53.8[d]	87.6[d]	8.6[d]	65.5[d]
T. Fescue Free	Stem elong.	28.4[e]	58.2[d]	86.6[d]	7.4[e]	60.3[e]
T. Fescue Free	Heading	41.1[e]	40.6[e]	81.7[d]	5.4[ef]	60.0[e]
T. Fescue Free	Flowering	23.3[ef]	51.0[f]	74.4[e]	2.7[f]	38.1[f]
T. Fescue Inf.	Tillering	39.9[d]	46.1	89.5[d]	9.3[d]	70.1[d]
T. Fescue Inf.	Stem elong.	28.1[e]	58.3	86.4[d]	8.5[d]	62.2[e]
T. Fescue Inf.	Heading	24.4[e]	54.1	78.5[e]	4.9[e]	49.7[f]
T. Fescue Inf.	Flowering	23.3[e]	52.6	81.0[de]	2.8[e]	40.4[g]
SEM[h]		1.43	2.11	1.70	0.8	.77

[a]Alfalfa stages according to Rohweder, Field Card A 3415. Agric. Bull 30. U. of Wisconsin, Madison. Grass stages according to Simon and Park (1981) for grasses, End. Free and End. Inf: tall fescue endophyte free or infected with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982). Maturities were compared using LSD, n=2, means of the same column (within a forage) with different superscripts differ ($P < .05$).

[b]A: soluble fraction (%), B: insoluble potentially digestible fraction (%), T: A + B, kd: rate of degradation (%/h).

[c]ED = extent of ruminal DM or CP degradation (%), $ED = A + [(B \times kd)/(kd + kp)]$ at a ruminal rate of passage (kp) = 6.0%/h.

[d,e,f,g]Means within same row differ ($P < .05$).

[h]SEM: Standard error of the mean.

Table 5. Means for in situ CP degradation kinetics of perennial forages by stages of maturity[a]

		Fraction[b]					ECP, g/
Species	Maturity	A	B	T	kd	ED[c]	kg DM
Alfalfa	Mid vegetative	40.2	53.6^{d}	93.8	19.6^{d}	81.1^{d}	37.7
Alfalfa	Early bud	41.3	53.1^{d}	94.4	16.1^{de}	79.8^{d}	38.0
Alfalfa	Early flowering	40.1	48.5^{de}	88.5	16.7^{de}	74.9^{e}	44.1
Alfalfa	Late flowering	41.3	47.1^{e}	88.4	12.2^{e}	72.9^{e}	40.6
Bromegrass	Tillering	32.3^{e}	63.8^{d}	96.1^{d}	16.8^{d}	79.2^{d}	46.7^{e}
Bromegrass	Stem elong.	27.1^{ef}	64.3^{d}	91.4^{d}	10.3^{de}	67.6^{e}	44.4^{ef}
Bromegrass	Heading	36.2^{e}	51.2^{e}	87.4^{e}	11.4^{de}	69.7^{e}	34.0^{f}
Bromegrass	Flowering	45.6^{d}	35.7^{f}	81.3^{e}	8.9^{e}	67.0^{e}	32.4^{f}
T. Fescue Free	Tillering	43.8^{f}	49.2^{d}	90.0^{d}	16.9^{d}	79.8^{de}	36.2^{f}
T. Fescue Free	Stem elong.	46.8^{e}	46.0^{d}	92.9^{d}	13.3^{d}	82.4^{d}	32.1^{e}
T. Fescue Free	Heading	55.8^{d}	32.2^{e}	88.0^{d}	10.7^{e}	76.1^{e}	31.6^{f}
T. Fescue Free	Flowering	52.5^{de}	26.7^{e}	75.2^{e}	11.0^{f}	69.9^{f}	24.0^{g}
T. Fescue Inf.	Tillering	45.2	49.0^{d}	91.7^{d}	17.1^{d}	81.7^{d}	38.4^{ef}
T. Fescue Inf.	Stem elong.	41.5	51.9^{d}	93.4^{d}	15.1^{d}	78.7^{d}	39.6^{e}
T. Fescue Inf.	Heading	41.1	48.9^{d}	90.0^{d}	11.8^{de}	73.4^{e}	31.3^{f}
T. Fescue Inf.	Flowering	42.9	33.3^{e}	76.2^{e}	7.2^{e}	60.6^{f}	28.6^{f}
SEM[h]		1.55	1.93	1.60	1.6	1.22	2.04

[a]Maturity stages according to Rohweder, Field Card A 3415. Agric. Bull 30. U. of Wisconsin, Madison for alfalfa. Stages of development according to Simon and Park (1981) for grasses, End. Free and End. Inf: tall fescue endophyte free or infected with *Acremonium caenophyalum* (Morgan-Jones and Gams, 1982). Maturities were compared using LSD, n=2, means of the same column (within a forage) with different superscripts differ ($P < .05$).

[b]A: soluble fraction (%), B: insoluble potentially digestible fraction (%), T: A + B, kd: rate of degradation.

[c]ED = extent of ruminal DM or CP degradation (%), $ED = A + [(B \times kd)/(kd + kp)]$ at a rate of passage (kp) = 6.0%/h.

[d,e,f,g]Means within same row differ ($P < .05$).

[h]SEM: Standard error of the mean.

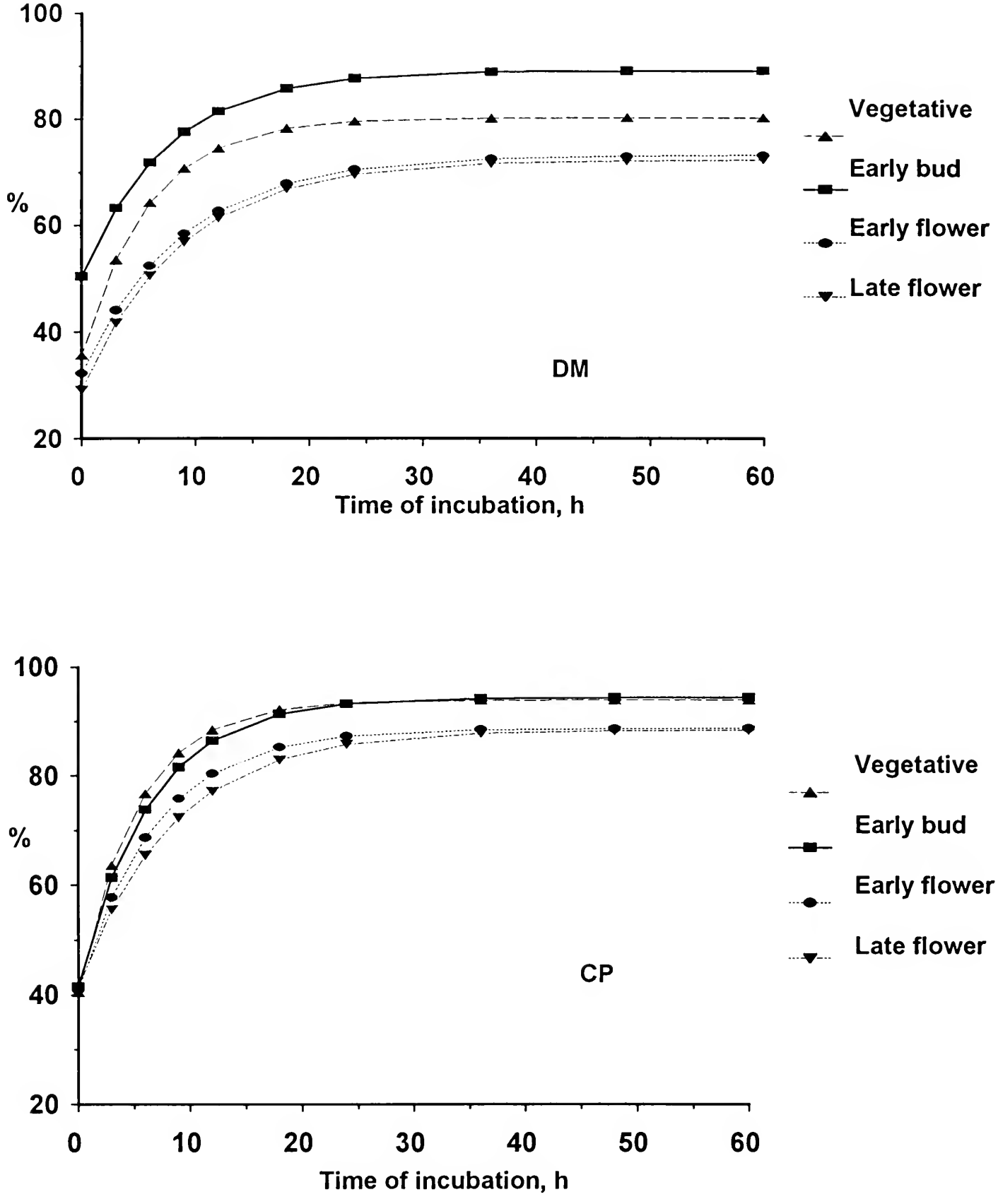

Figure 1. Patterns of in situ DM and CP degradation of fresh alfalfa at different maturities

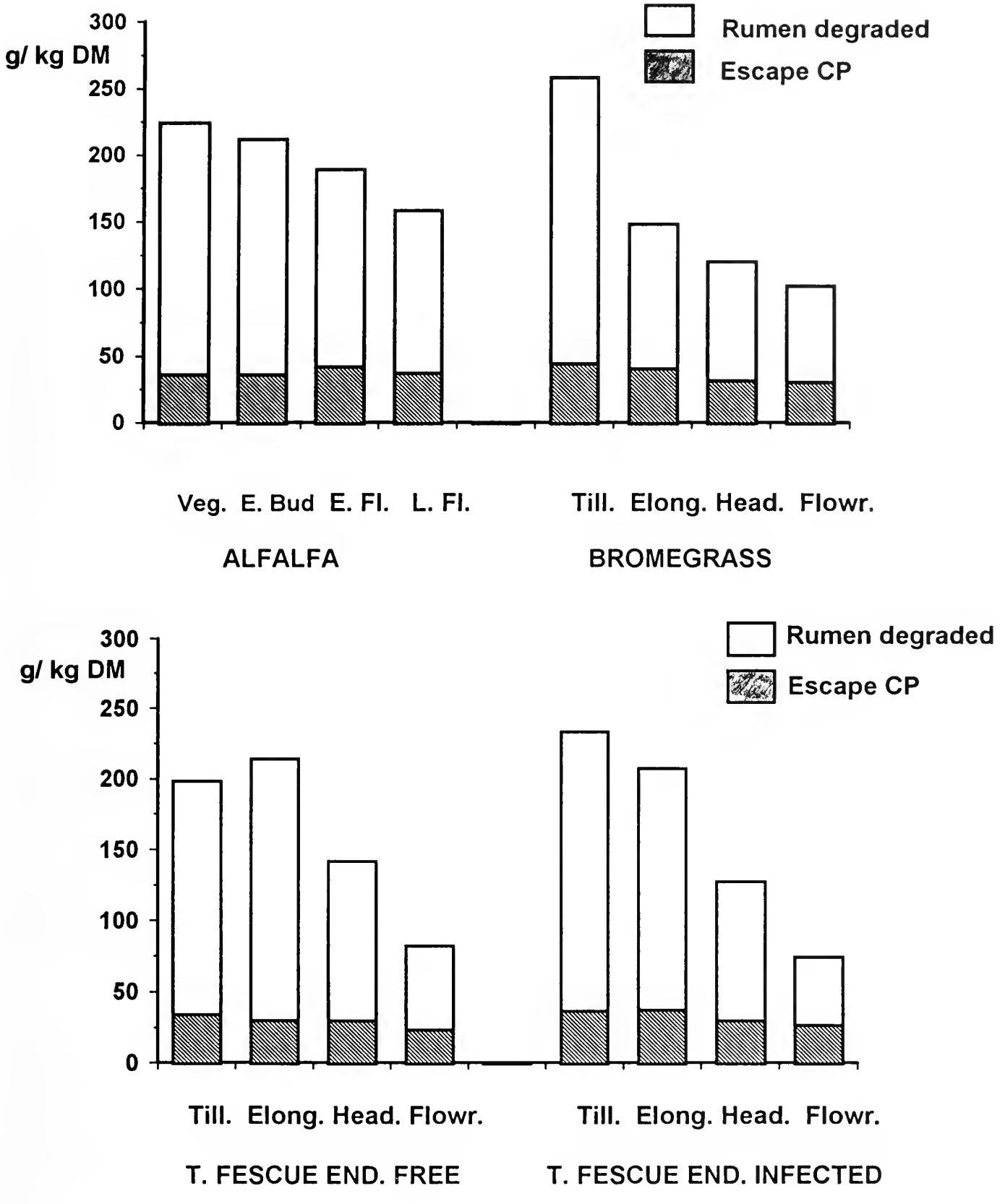

Figure 3. Total crude protein content (g/kg of DM), rumen degraded CP (g/kg of DM) and escape CP (ECP, g/kg of DM) in different forages and maturities incubated in situ

A SUMMARY OF THE ILLINOIS IRM-SPA BEEF COW BUSINESS RECORD

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SUMMARY

A summary of the 47 herds participating in the University of Illinois' SPA Beef Cow Business Record Program was compiled. This summary includes data on the production, reproduction and cost averages for beef enterprises in Illinois. These 47 herds are geographically distributed throughout the state and include both commercial and seedstock producers. The average financial cost to maintain a cow for a year in 1997 was $385.99, of which $238.32 was feed cost. Contributing to this feed cost was a financial Total Cost per Ton of Hay Produced of $45.21 and pasture Cost per Day per Animal Unit of $0.30. Illinois SPA Cooperators had an average Weaning Percentage of 81.9% and 86.9% of their Calves Born During the First 63 Days of the calving season. Pounds Weaned per Exposed Female equaled 415. Total Capital Investment/Cow was $1,591 (cost basis) and $2,768 (market basis).

INTRODUCTION

The Standardized Performance Analysis (SPA) Program uses a standardized methodology to measure the biological and financial performance of cow calf, pasture and hay production enterprises. The focus of the SPA Program is to help the beef industry separate the various enterprises within a farming operation, for enterprise specific analysis.

In 1994, the University of Illinois Cooperative Extension Service adopted the Iowa State University SPA Software Package for analysis of Illinois cow-calf enterprises. The ISU Software was selected because of the similarities of farming enterprises and beef management practices. In addition, this cooperative effort allows for the development of a multi-state data base.

In both 1994 and 1995, the Illinois SPA Summary included 20 cow herds. In 1996 and 1997 the summary grew to 27 herds and 47 herds respectively. The SPA Summaries have been used extensively in Extension's educational programs for beef producers.

MATERIALS AND METHODS

The Illinois IRM-SPA Program consists of a workbook that assists producers in tracking cow herd inventories, cattle purchases and sales, operating and depreciation expenses, pasture and hay productivity and expenses, labor costs, capital and land utilization, and feed usage. This information is analyzed with a spreadsheet software package and summarized into a set of output pages that provide the beef producer with information about the economic and production efficiencies of the operation.

Each producer's data is analyzed for both financial and economic cost of production. The financial enterprise analysis is taken directly from the income statement. Expenses include cash operating

expenses, interest for operating capital, term debt, and non-cash expenses. The financial analysis does not account for the economic opportunity cost of land, raised feed, or equity capital invested in the enterprise. Actual land mortgage, livestock, machinery, and operating capital interest expense are included in the financing expense. The economic analysis accounts for the opportunity cost of resources (land, operator and family labor) used in production of the commodity in addition to expenses in the financial analysis.

A summary of the data that is generated for each producer is then used to generate a yearly state summary. The 1997 data is compiled here. In addition to providing financial and economic analysis columns in the summary for all 47 participating herds, two columns are provided that summarize the financial and economic data for the participating herds which are classified as commercial herds with more than 50 cows. Twenty herds fit in this category.

RESULTS AND DISCUSSION

Ten "Critical Success Factors" have been identified as key areas for producers and extension personnel to focus on when analyzing past SPA summaries. In the 1997 Summary (Table 1), Return to Capital, Labor and Management was a negative $58 on the financial side, and a negative $1,733 on the economic side. When only commercial herds with more than 50 cows were summarized, Return to Capital, Labor and Management was $1,753 on the financial side and negative $1,478 on the economic side.

Total Feed Cost per Cow were $238.32 (financial) and $268.20 (economic). This figure includes all purchased and raised feeds, including pasture. Total feed cost is the largest component of Total Cost per Cow in Herd which was $385.99 (financial) and $517.33 (economic). Most of the difference in Total Cost is due to Family and Operator Labor which is $67.90 per cow. The remainder is accounted for by the increase in capital charges from $10.61 (financial) to $44.17 (economic).

Total Cost per Ton of Forage Produced was $45.21 (financial) and $66.85 (economic). These figures remained similar when commercial herds with more than 50 cows were separated out. The Pasture Summary revealed that the Cost per Day for 1000 lbs of Body Weight was $0.30 (financial) and $0.45 (economic). Total Feed Fed per Cow was 4,641 lbs., 61% of which was raised hay.

Illinois SPA Cooperators had an average weaning percentage of 81.9% based on the number of cows exposed in the previous year. Calving distribution data showed that 86.9% of the calves were born during the first 63 days of the calving season. This percentage increased to 93.5% for commercial herds with more than 50 cows. Pounds Weaned per Exposed Female was 415.

Total Capital Investment per Cow equaled $1,591 (cost basis) and $2,768 (Market Basis).

A further division of the 1997 SPA data by herd size is displayed in Table 2. This data would tend to indicate that among the commercial herds in Illinois that participate in the SPA program, economies of scale do exist. Total Cost per Cow (financial) was reduced from $437.27 for the smallest herds to $293.75 for the largest. Forage production systems also tended to be very inefficient for the 1-49 cow group as Cost per Ton of Forage Produced (financial) was $58.59 and

Pasture Cost per Day per Animal Unit (financial) was $0.37. Pounds Weaned per Exposed Female appeared to have little effect on Return to Capital, Labor & Management, but this figure is somewhat complicated by the number of herds practicing early weaning strategies.

An analysis of the 11 herds that have been on the program for 4 years shows a decline in Total cost per Cow from $488.31 in 1994 to $404.93 in 1997 (Table 3). This decline is accounted for by the decline in feed cost from $333.48 to $247.96 which is partially accounted for by the decline in pasture cost from $.040 to $.029 per animal unit day. Production traits such as Calf Crop Percentage and Calves Born During the 1st 63 Days of the Calving Season also showed dramatic improvement.

IMPLICATIONS

The Illinois SPA Program provides beef producers with a tool to identify their cost of production. Summaries such as the 1997 Illinois SPA Summary are providing benchmarks for producers to utilize in the analysis of their production systems. This data also provides direction for university research and extension programming efforts.

Table 1. 1997 Illinois SPA Summary

	Average for all commercial and seedstock herds (47)		Average for commercial herds with more than 50 cows (20)	
Returns for Cow-Calf Enterprise	Financial	Economic	Financial	Economic
1. Return to Capital, Labor & Mgmt.	**($58)**	**($1,733)**	**$1,753**	**($1,478)**
2. Return to Labor & Mgmt.	**($707)**	**($5,112)**	**$813**	**($6,002)**
3. Net Profit	**XXXXX**	**($9,218)**	**XXXXX**	**($10,423)**
4. Return per $100 of Feed Fed	$160	$149	$158	$141
5. Annual % Return on Capital Investment	-1.6%	-2.7%	0.3%	-2.3%
6. Return per Hour of Operator Labor	$0.96	($3.88)	$6.08	($4.68)
Costs for Cow-Calf Enterprises				
7. January 1 Number of Cows in Herd	85	85	125	125
8. a. Pasture Cost per Cow	$89.22	$97.21	$80.92	$94.20
b. Crop Residues per Cow	$2.69	$2.69	$1.31	$1.31
c. Harvested Forages per Cow	$65.76	$87.64	$57.97	$76.36
d. Non-Purchased Raised Feed Fed per Cow	$41.24	$41.24	$49.88	$49.88
e. Purchased Feed per Cow	$39.42	$39.42	$29.76	$29.76
f. Total Feed Cost per Cow	**$238.32**	**$268.20**	**$219.85**	**$251.52**
9. Operating Cost per Cow	$87.11	$87.11	$59.12	$59.12
10. Depreciation Cost per Cow	$40.15	$40.15	$34.66	$34.66
11. Capital Charge per Cow	$10.61	$44.17	$9.75	$35.74
12. Hired Labor Cost per Cow	$9.80	$9.80	$9.66	$9.66
13. Family & Operator Labor Charge per Cow	XXXXX	$67.90	XXXXX	$42.34
14. Total Cost per Cow in Herd, January 1	**$385.99**	**$517.33**	**$333.04**	**$433.04**
15. a. Return to Management per Cow	**($41.14)**	**($84.92)**	**($11.07)**	**($54.32)**
b. Margin per Cwt Beef Produced, Inventory Included	($11.51)	($22.88)	($2.30)	($10.38)
Costs/Cwt for Cow-Calf Enterprises				
16. Feed Cost per Cwt of Beef Produced	$46.70	$53.90	$43.49	$50.05
17. a. Operating Cost per Cwt of Beef Produced	$14.79	$14.79	$9.31	$9.31
b. Vet Med Cost per Cwt of Beef Produced	$4.92	$4.92	$4.55	$4.55
18. Depreciation Cost per Cwt of Beef Produced	$8.29	$8.29	$6.95	$6.95
19. Capital Cost per Cwt of Beef Produced	$1.79	$9.41	$1.77	$7.30
20. Family & Operator Labor Cost per Cwt of Beef Produced	XXXXX	$14.05	XXXXX	$8.10
21. Total Cost per Cwt of Beef Produced	**$76.49**	**$105.37**	**$66.06**	**$86.25**
Production & Sales for Cow-Calf Enterprises				
22. Total Number of Feeder Calves Sold		74		113
23. Average Age at Weaning		192		191
24. Average Weight of Feeder Calves Sold		533		483
25. Pounds of Calf Weight Sold per Cow		446		441
26. Price per Cwt of Feeder Calves Sold		$80.66		$80.58
27. Total Number of Breeding Stock Sold		15		20
28. Average Weight of Breeding Stock Sold		1,290		1,273
29. Pounds of Breeding Stock Sold per Cow		248		209
30. Price per Cwt of Breeding Stock Sold		$43.85		$36.30
31. Total Pounds of Beef Produced per Cow		549		515
32. Total Pounds of Beef Sold per Cow		678		639
33. Total Value of Production Sold per Cow		$472.08		$429.32

Table 1(cont.). 1997 Illinois SPA Summary

	Average for all commercial and seedstock herds (47)		Average for commercial herds with more than 50 cows (20)	
Forage Production Costs	Financial	Economic	Financial	Economic
1. Number of Acres in Forage Production	58.3	58.3	78.4	78.4
2. Land Charge per Acre	$47.82	$70.44	$37.78	$67.07
3. Operating Cost per Acre	$103.76	$103.76	$121.11	$121.11
4. Depreciation Cost per Acre	$30.18	$30.18	$28.09	$28.09
5. Non-Real Estate Loan, Principal & Interest per Acre	$5.07	XXXXX	$1.96	XXXXX
6. Family & Operator Labor per Acre	XXXXX	$62.99	XXXXX	$49.56
7. Total Cost per Acre of Land in Forage Production	**$186.84**	**$267.38**	**$188.94**	**$265.83**
8. Yield per Acre of Forage Production, Tons	4.2	4.2	4.3	4.3
9. Land Charge per Ton	$11.45	$18.87	$8.85	$17.95
10. Operating Cost per Ton	$25.45	$25.45	$29.19	$29.19
11. Depreciation Cost per Ton	$7.10	$7.10	$6.39	$6.39
12. Non-Real Estate Loan, Principal & Interest per Ton	$1.21	XXXXX	$0.63	XXXXX
13. Family & Operator Labor per Ton	XXXXX	$15.43	XXXXX	$11.14
14. Total Cost per Ton of Forage Produced	**$45.21**	**$66.85**	**$45.05**	**$64.68**
Pasture Summary				
15. Number of Acres Pastured	156.4	156.4	243.6	243.6
16. Land Charge per Acre	$26.40	$35.66	$20.83	$30.01
17. Operating Cost per Acre	$21.10	$33.67	$21.17	$27.21
18. Depreciation Cost per Acre	$3.51	$3.51	$2.10	$2.10
19. Non-Real Estate Loan, Principal & Interest per Acre	$1.37	XXXXX	$0.53	XXXXX
20. Family & Operator Labor per Acre	XXXXX	$12.57	XXXXX	$6.04
21. Total Cost per Acre of Land in Pasture Production	**$52.38**	**$85.42**	**$44.63**	**$65.36**
22. Acres per Cow-Calf Pair	1.8	1.8	2.0	2.0
23. Animal Unit Months from Pasture	872.7	872.7	1,317.8	1,317.8
24. Pasture Cost per Cow-Calf Pair	$89.22	$134.54	$80.92	$114.81
25. AUM per Acre	6.7	6.7	6.1	6.1
26. Cost per AUM	$8.85	$13.54	$7.69	$11.20
27. Cost per Day for 1000 lbs of Body Weight	**$0.30**	**$0.45**	**$0.26**	**$0.37**
Aftermath Grazing Summary				
28. Acres per Producing Cow	1.6	1.6	1.3	1.3
29. Cost per Acre	$1.18	$1.18	$1.12	$1.12
30. Cost per Cow	$1.51	$1.51	$1.46	$1.46
31. AUM per Acre	1.7	1.7	2.0	2.0
32. Cost per AUM	$0.71	$0.71	$0.75	$0.75
33. Cost per Day for 1000 lbs of Body Weight	$0.02	$0.02	$0.02	$0.02
Feed Utilization Summary	**Dry Matter (lbs)**	**Feed Market Value ($)**	**Dry Matter (lbs)**	**Feed Market Value ($)**
34. Raised Hay Fed per Cow	2,845	$73.19	2,348	$62.08
35. Other Home-Raised Feed Fed per Cow	1,274	$41.24	1,514	$49.88
36. Purchased Hay Fed per Cow	236	$6.50	98	$1.36
37. Purchased Supplements Fed per Cow	135	$26.92	108	$21.42
38. Purchased Silages & Concentrates Fed per Cow	151	$5.99	225	$6.00
39. Total Feed Fed per Cow	**4,641**	**$153.83**	**4,293**	**$140.73**
40. Feed Fed per Cwt. Marketed	710	XXXXX	706	XXXXX

Table 1(cont.). 1997 Illinois SPA Summary

	Average for all commercial and seedstock herds (47)		Average for commercial herds with more than 50 cows (20)	
Reproduction & Production Measures				
1. Pregnancy Percentage		93.9%		93.9%
2. Pregnancy Loss Percentage		2.7%		1.7%
3. Calving Percentage		91.2%		92.2%
4. Calf Death Loss		9.3%		7.3%
5. Calf Crop or Weaning Percentage		**81.9%**		**84.9%**
6. Female Replacement Rate		16.3%		12.7%
7. Calf Death Loss Based on No. of Calves Born		6.1%		5.1%
Calving Distribution:				
8. Beginning Calving Date:				
9. Calves Born During 1st 21 Days		52.9%		58.3%
10. Calves Born During 1st 42 Days		75.8%		85.2%
11. Calves Born During 1st 63 Days		**86.9%**		**93.5%**
12. Calves Born After 1st 63 Days		13.1%		6.5%
Production Performance Measures:				
13. Average Age at Weaning (Days)		192		191
Actual Weaning Weights				
14. Steers/Bulls		523		484
15. Heifers		500		464
16. Average Weaning Weight		512		475
17. Pounds Weaned per Exposed Female		**415**		**392**
	Cost Basis	**Market Basis**	**Cost Basis**	**Market Basis**
Summary of Investment per Breeding Cow				
18. Breeding Livestock	$647	$666	$590	$604
19. Machinery, Equipment & Structures	$94	$286	$63	$163
20. Current Assets	$85	$85	$70	$70
21. Total Capital Investment/Cow	$825	$1,037	$724	$837
Summary of Investment per Forage Production Acre				
22. Structures & Equipment	$95	$325	$99	$276
23. Real Estate	$338	$677	$243	$504
24. Current Assets	$85	$85	$91	$91
25. Total Capital Investment/Forage Production Acre	$519	$1,086	$433	$871
26. Total Capital Investment in Forage Production/Cow	$268	$583	$180	$369
Summary of Investment per Pasture Acre				
27. Structures & Equipment	$11	$30	$6	$18
28. Real Estate	$274	$610	$183	$550
29. Current Assets	$27	$39	$26	$32
30. Total Capital Investment/Pasture Production Acre	$312	$680	$214	$600
31. Total Capital Investment in Pasture Production/Cow	$498	$1,148	$396	$1,089
32. Total Capital Investment/Cow	**$1,591**	**$2,768**	**$1,300**	**$2,296**

Table 2. Critical Success Factors by Herd Size

	All Illinois Producers	Illinois Commercial Producers		
		1-49 Cows	50-99 Cows	100+ Cows
Total Cost per Cow (Financial)	$385.99	$437.27	$381.08	$293.75
Feed Cost per Cow (Financial)	$238.32	$277.42	$251.94	$193.59
Total Feed Fed per Cow	4641	4366	4725	3940
Cost per Ton of Forage Produced (Financial)	$45.21	$58.59	$45.83	$44.51
Calf Crop Percentage	81.90%	NA	86.30%	83.90%
Pasture Cost per Day per Animal Unit (Financial)	$0.30	$0.37	$0.27	$0.25
Pounds Weaned per Exposed Female	415	387	388	395
Calves Born During 1st 63 Days	86.90%	87.70%	85.20%	97.00%
Total Capital Invested per Cow (Market Basis)	$2,768	$3,616	$2,111	$2,447
Return to Capital, Labor & Mgmt.	($58)	($3,222)	($1,873)	$4,720

Table 3. 1994-1997 SPA Cooperator Improvement, Averages for the 11 herds with 4 years of SPA data

	Averages			
	1994	1995	1996	1997
Total Cost per Cow (Financial)	$488.31	$439.47	$442.01	$404.93
Feed Cost per Cow (Financial)	$333.48	$277.58	$287.29	$247.96
Total Feed Fed per Cow	5789	5797	6181	5234
Cost per Ton of Forage Produced (Financial)	$53.34	$47.74	$46.17	$53.28
Calf Crop Percentage	89.60%	77.19%	83.28%	81.05%
Pasture Cost per Day per Animal Unit (Financial)	$0.40	$0.39	$0.34	$0.29
Pounds Weaned per Exposed Female	436	421	415	425
Calves Born During 1st 63 Days	80.44%	84.39%	88.35%	87.56%

EFFECT OF PROSTAGLANDIN $F_{2\alpha}$- AND GONADOTROPIN RELEASING HORMONE-INDUCED LUTEINIZING HORMONE RELEASES ON OVULATION AND CORPUS LUTEUM FUNCTION OF BEEF COWS

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SUMMARY

Luteinizing hormone (LH) concentrations were measured in suckled beef cows treated during the postpartum period with prostaglandin $F_{2\alpha}$ (5 mg Alfaprostol; $PGF_{2\alpha}$) and then gonadotropin releasing hormone (100 µg Cystorelin 30 h after $PGF_{2\alpha}$; GnRH). The objective was to determine if $PGF_{2\alpha}$ would cause a release of LH in the absence of progesterone and affect the GnRH-induced LH release and ovulation (Experiment 1). LH concentrations increased ($P < .05$) after $PGF_{2\alpha}$ treatment in both anestrous and cyclic cows but to a greater extent ($P < .05$) in anestrous cows. The GnRH-induced LH release and ovulation response in previously anestrous cows were greater ($P < .05$) when $PGF_{2\alpha}$ was administered 30 h earlier. In Experiment 2, 49 beef cows received $PGF_{2\alpha}$ (5 mg Alfaprostol) and GnRH (100 µg Cystorelin) 30 h later to determine if the profile of the preovulatory LH surge was associated with the occurrence of subnormal luteal phases in postpartum beef cows suckling calves. Cows that had normal luteal phases had a greater ($P < .05$) mean area under the GnRH-induced LH response curve and a greater ($P < .05$) mean GnRH-induced LH peak amplitude than cows that had subnormal luteal phases. In summary, results suggest that $PGF_{2\alpha}$ may exert a fertility effect by causing a LH release independent of progesterone withdrawal; administration of $PGF_{2\alpha}$ 30 h before GnRH elevated the GnRH-induced LH release and ovulation response. In addition, cows with subnormal luteal phases had GnRH-induced LH surges of less area and peak amplitude than cows with normal luteal phases.

INTRODUCTION

In addition to its well established role of causing luteolysis, prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) has been shown to enhance fertility in cattle (Macmillan and Day, 1982). In a study involving 5,000 dairy cows, Macmillan and Day (1982) reported a higher calving rate (69% vs 60%) in $PGF_{2\alpha}$-treated cows than in untreated cows. $PGF_{2\alpha}$ may exert a fertility effect by stimulating a release of luteinizing hormone (LH; Louis et al., 1974) upon demise of the corpus luteum and reduced progesterone concentrations (Hafs et al., 1975). Jöchle et al. (1987) reported that equine LH and follicle stimulating hormone (FSH) concentrations were elevated in pituitary and jugular venous blood after the administration of the synthetic $PGF_{2\alpha}$ luprostiol. The objective of Experiment 1 was to determine if $PGF_{2\alpha}$ 1) would cause a release of LH in the absence of progesterone in anestrous cows, 2) would affect the gonadotropin releasing hormone (GnRH)-induced LH release, and 3) would affect the GnRH-induced ovulation response of previously anestrous cows.

GnRH, another compound that exerts a fertility effect, has been demonstrated to hasten the first postpartum ovulation in beef cows. Although it has been shown that GnRH induced a high proportion of anestrous cows to ovulate (approximately 65%), the majority (approximately 85%) had subnormal luteal phases (Kesler et al., 1978; Lishman et al., 1979; Kesler et al., 1980; Garverick et al., 1980; Zaied et al., 1980; Troxel and Kesler, 1984a; Benmrad and Stevenson, 1986; Troxel et al.,

1993). Subnormal luteal phases have also been identified in humans (Zelinski-Wooten et al., 1991), other primates (Wilks et al., 1976), and sheep (Coleman and Dailey, 1983). Suggested causes of subnormal luteal phases in cattle include a premature release of $PGF_{2\alpha}$ (Troxel and Kesler, 1984a; Troxel and Kesler, 1984b; Copeland et al., 1987; Copeland et al., 1989; Garverick et al., 1992; Smith et al., 1996) and folliculogenesis of less duration than during an estrous cycle (Lishman et al., 1979; Garcia-Winder et al., 1987). Another cause that has been identified in humans and sheep is a preovulatory LH surge of less duration than a spontaneous LH surge (Zelinski-Wooten et al., 1991; Vincent et al., 1984; Vincent and Kesler, 1985). The objective of Experiment 2 was to determine if the profile of the preovulatory LH surge was associated with the occurrence of subnormal luteal phases in cattle.

MATERIALS AND METHODS

In Experiment 1, 40 postpartum beef cows, suckling calves, from the Dixon Spring Agricultural Center (Simpson, IL) were randomly assigned to a 2 x 2 factorial experiment with estrous cycles (with [cyclic] and without [anestrus]) and treatment (buffer and $PGF_{2\alpha}$) as the main effects. Cows were administered a 5 mL intramuscular injection of $PGF_{2\alpha}$ (5 mg Alfaprostol or 5 mL of buffer) in the upper rear leg musculature. All cows were intramuscularly administered GnRH (100 µg Cystorelin in 2 mL potassium phosphate buffer) in the shoulder 30 h later. All injections were done with 5 cc syringes and 18 g needles 3.61 cm long. Cows were bled via jugular venipuncture into heparinized evacuated tubes with 20 g needles 3.61 cm long 7 days before and immediately before $PGF_{2\alpha}$ (or buffer) treatment and 2, 4, 6, 8, and 10 h after $PGF_{2\alpha}$ (or buffer) treatment and immediately before and 1, 2, 3, and 4 h after GnRH treatment. Although spontaneous LH surges are of greater duration than 4 h, a 4 h sampling period was concluded to be adequate for analysis of area under the curve (Swanson and Hafs, 1971; Helmer and Britt, 1987). Additional blood samples were collected 6 days after GnRH treatment and cows were examined per rectum for corpora lutea. Final numbers of cows per group were established after determining progesterone concentrations in blood samples collected 7 days before and immediately before $PGF_{2\alpha}$ (or buffer) treatment (7 anestrous and 7 cyclic cows were treated with buffer and 11 anestrous and 15 cyclic cows were treated with $PGF_{2\alpha}$).

In Experiment 2, 49 postpartum beef cows, suckling calves, from the Dixon Spring Agricultural Center (Simpson, IL) were intramuscularly administered a luteolytic dose of $PGF_{2\alpha}$ (5 mg Alfaprostol; 5 mL in the upper rear leg musculature) followed by an intramuscular injection of GnRH (100 µg Cystorelin in 2 mL potassium phosphate buffer in the shoulder) 30 h later. All injections were done with 5 cc syringes and 18 g needles 3.61 cm long. Blood samples were collected via jugular venipuncture into heparinized evacuated tubes and 20 g needles 3.61 cm long 7 days before $PGF_{2\alpha}$ treatment, immediately before $PGF_{2\alpha}$ treatment, immediately before GnRH treatment, and hourly for four h after GnRH treatment. Additional blood samples were collected on days 6, 10, and 14 after GnRH treatment and cows were examined per rectum on day 6 for corpora lutea. Final numbers of cows per group were established after determining progesterone concentrations in blood samples collected 7 days and immediately before $PGF_{2\alpha}$ treatment (31 were anestrus and 18 were cyclic). Forty-three of the cows ovulated and were analyzed with regard to the luteal phase (26 were anestrus and 17 were cyclic).

Blood samples were placed in an ice water bath after collection and plasma was collected after centrifugation at 1,600 x g. All blood samples were centrifuged within 6 h after collection and plasma was stored in duplicate at -20°C until assayed (Wiseman et al., 1983).

Plasma samples were assayed for progesterone and LH concentrations by validated radioimmunoassay procedures (Troxel et al., 1980). All samples were assayed in duplicate and samples from one cow were analyzed within one assay. Intra-assay and inter-assay coefficients of variation were 1.7% and 5.6%, respectively, for progesterone. Intra-assay and inter-assay coefficients of variation were 2.3% and 4.4%, respectively, for LH. Progesterone concentrations on days -7 and 0 (before $PGF_{2\alpha}$ treatment) were used to classify cows with (cyclic) or without (anestrus) estrous cycles. Cows with progesterone concentrations ≥ 1.0 ng/mL in either one of the two blood samples were considered cyclic; cows with < 1.0 ng/mL in both of the blood samples were considered anestrus. Cows with progesterone concentrations ≥ .5 ng/mL with corpora lutea 6 days after GnRH treatment were considered to have ovulated to GnRH treatment (Kesler et al., 1981). Cows that ovulated and had ≥ 1.5 ng/mL of progesterone on days 10 and 14 were considered to have normal luteal phases; cows that ovulated with < 1.5 ng/mL on days 10 and 14 were considered to have subnormal luteal phases (Kesler et al., 1981).

Categorical data were analyzed by chi-square analysis (Cochran and Cox, 1957). LH concentrations after $PGF_{2\alpha}$ treatment were analyzed by 2 x 6 factorial split-plot analysis of variance (Gill and Hafs, 1971) with treatment (buffer or $PGF_{2\alpha}$) and time (0, 2, 4, 6, 8, and 10 h) as the main effects. GnRH-induced LH concentrations 30 h after $PGF_{2\alpha}$ (or buffer) treatment were analyzed by 2 X 5 factorial split-plot analysis of variance (Gill and Hafs, 1971) with treatment (buffer or $PGF_{2\alpha}$) and time (0, 1, 2, 3, and 4 h) as the main effects. LH concentrations after GnRH treatment were analyzed by 2 x 2 x 5 factorial split-plot analyses of variance (Gill and Hafs, 1971) with estrous cycles (cyclic or anestrus), GnRH-induced ovulation response (ovulated or failed to ovulate) or GnRH-induced luteal phase (normal or subnormal), and time (0, 1, 2, 3, and 4 h) as the main effects. Area under the response curve (determined mathematically) and GnRH-induced peak amplitude were analyzed by analysis of variance (Hicks, 1964).

RESULTS

After buffer treatment, LH concentration remained relatively constant and similar for anestrous and cyclic cows (Figure 1). LH concentrations increased ($P < .05$) after $PGF_{2\alpha}$ treatment in both cyclic and anestrous cows (Figure 1) but the increase was greater ($P < .05$) in anestrous cows (Experiment 1).

More ($P < .05$) $PGF_{2\alpha}$-treated anestrous cows ovulated after GnRH treatment than buffer- treated anestrous cows (Table 1). The mean GnRH-induced LH area under the curve and peak LH amplitude were greater ($P < .05$) in $PGF_{2\alpha}$-treated anestrous cows than in buffer-treated cows (Table 1).

Eighty-four and 94% of the previously anestrous (26/31) and cyclic (17/18) cows, respectively, ovulated after GnRH treatment in Experiment 2 ($P > .20$). The mean GnRH-induced LH area under the curve and mean peak LH amplitude were similar ($P > .20$) for the cows that ovulated and cows that failed to ovulate (21.4 ± 2.2 and 19.6 ± 3.7 units under the LH response curve and 107.7 ± 11.0

and 103.6 ± 14.5 ng/mL of LH at the peak for cows that ovulated and cows that did not ovulate, respectively).

More ($P < .05$) previously anestrous cows (85%) than cyclic cows (23%) had subnormal luteal phases in Experiment 2. The mean GnRH-induced LH area under the curve and mean peak LH amplitude were greater ($P < .05$) in cows (both cyclic cows and previously anestrous cows) with normal luteal phases than cows with subnormal luteal phases (Table 2).

DISCUSSION

Previous research has demonstrated that LH concentrations increase after $PGF_{2\alpha}$ treatment due to withdrawal of progesterone during luteolysis (Hafs et al., 1975). Data herein demonstrate that LH concentrations increase after $PGF_{2\alpha}$ treatment in anestrous cows in the absence of progesterone. Furthermore, LH release from the anterior pituitary in response to GnRH treatment was greater after $PGF_{2\alpha}$ priming and the ovulation response was also higher ($P < .05$) in cows administered $PGF_{2\alpha}$ 30 h before GnRH treatment. The LH release and the priming of the anterior pituitary by $PGF_{2\alpha}$, as also reported by Jöchle et al. (1987), may be an explanation for the observed fertility effect of $PGF_{2\alpha}$ treatment by Macmillan and Day (1982). Others have also observed fertility effects due to $PGF_{2\alpha}$ treatment. Roche (1976) reported a 7% calving rate in cows previously with inactive ovaries administered a prostaglandin analogue. Troxel et al. (1983) reported a ovulation response of 89% in previously anestrous cows after the second of two injections of $PGF_{2\alpha}$ administered 11 days apart. Although no control cows were included in these two studies, in another study only 33% of the untreated cows, as compared to 71% of the $PGF_{2\alpha}$- (Lutalyse) treated cows ($P = .08$), exhibited estrus within 7 days of a single injection of $PGF_{2\alpha}$ (or buffer) with similar ($P > .25$) pregnancy rates (67%) from AI at that estrus (estrus within 7 days of treatment; unpublished data). Collectively, these data suggest that $PGF_{2\alpha}$ hastened fertile estrus in some previously anestrous cows.

The ovulation response after GnRH treatment herein was similar to previous reports (Lishman et al., 1979; Kesler et al., 1980; Garverick et al., 1980; Troxel and Kesler, 1984a; Troxel et al., 1993). Although GnRH effectively induced ovulation in previously anestrous cows, the subsequent luteal phases were subnormal in most cases as previously reported (Lishman et al., 1979; Kesler et al., 1980; Garverick et al., 1980; Troxel and Kesler, 1984a; Troxel et al., 1993). The incidence of subnormal luteal phases for the cyclic cows was higher than previously observed (Troxel et al., 1983); however, the interval between $PGF_{2\alpha}$ and GnRH was less than for previous protocols. Although the duration of the follicular phase, which was reduced in this study, has not been related to formation and function of corpora lutea, this was the only obvious difference between this study and earlier studies.

Subnormal luteal phases appear to be due, in part, to the release of $PGF_{2\alpha}$ during the early postpartum period (Troxel et al., 1984c). Subnormal luteal phases occur after the corpus luteum becomes responsive to the luteolytic effects of $PGF_{2\alpha}$ (Lauderdale et al., 1974) and $PGF_{2\alpha}$ is elevated in postpartum cows before the first ovulation (Troxel et al., 1984a; Troxel et al., 1984c; Copeland et al., 1987; Smith et al., 1996). Troxel et al. (1984b) demonstrated that norgestomet treatment before the first postpartum ovulation suppressed the concentrations of the major stable $PGF_{2\alpha}$ metabolite (PGFM). Norgestomet treatment before the first ovulation has also been demonstrated to synchronize folliculogenesis (Garcia-Winder et al., 1987; Vasconcelos et al., 1994) and elevate the

peak amplitude of the GnRH-induced LH surge (Troxel et al., 1980; Troxel et al., 1984b). doValle et al. (1997) administered GnRH 30 h after norgestomet implant removal and reported a 9% incidence of subnormal luteal phases in previously anestrous cows compared to 85% without norgestomet pre-treatment (Lishman et al., 1979; Kesler et al., 1980; Garverick et al., 1980; Troxel and Kesler, 1984a; Troxel et al., 1993). Therefore, results from studies using norgestomet-treated cows are confounded as norgestomet appears to 1) reduce PGFM concentrations, 2) synchronize folliculogenesis, and 3) enhance the subsequent preovulatory LH surge. In ewes, administration of GnRH in a sustained release carrier (Kesler and Vincent, 1980; Troxel et al., 1983) induced preovulatory LH surges with similar amplitude and duration to spontaneous LH surges at estrus (Vincent et al., 1984; Vincent and Kesler, 1985). Ewes induced to ovulate with this system had normal luteal phases (Vincent et., 1984; Vincent and Kesler, 1985).

Unconfounded data herein support the theory that although GnRH-induced LH surges atypical of spontaneous preovulatory LH surges (Swanson and Hafs, 1971; Helmer and Britt, 1987) induce ovulation in anestrous cattle, the subsequent luteal phases are not normal. Previous research in primates and sheep agree with these results (Vincent et al., 1984; Vincent and Kesler, 1985; Zelinski-Wooten et al., 1991).

LITERATURE CITED

Benmrad, M. and Stevenson, J.S., 1986. Gonadotropin-releasing hormone and prostaglandin $F_{2\alpha}$ for postpartum dairy cows: estrus, ovulation, and fertility traits. J. Dairy Sci. 69:800.

Cochran, W.G. and Cox, G.M., 1957. Experimental Designs. John Wiley and Sons, Inc., New York, NY.

Coleman, D.A. and Dailey, R.A., 1983. Effect of repeated removal of large ovarian follicles and treatment with progestin on ovarian function in the ewe. Biol. Reprod. 29:586.

Copelin, J.P., Smith, M.F., Garverick, H.A., and Youngquist, R.S., 1987. Effect of the uterus on subnormal luteal function in anestrous beef cows. J. Anim. Sci. 64:1506.

Copelin, J.P., Smith, M.F., Keisler, D.H., and Garverick, H.A., 1989. Effect of active immunization of pre-partum and post-partum cows against prostaglandin $F_{2\alpha}$ on lifespan and progesterone secretion of short-lived corpora lutea. J. Reprod. Fertil. 87:199.

doValle, E.R., Cruz, L.C., and Kesler, D.J., 1997. Gonadotropin-releasing hormone enhances the calving rate of beef females administered norgestomet and alfaprostol for estrus synchronization. J. Anim. Sci. 75:897.

Garcia-Winder, M., Lewis, P.E., Townsend, E.C., and Inskeep, E.K., 1987. Effects of norgestomet on follicular development in postpartum beef cows. J. Anim. Sci. 64:1099.

Garverick, H.A., Elmore, R.G., Vaillancourt, D.H., and Sharp, A.J., 1980. Ovarian response to gonadotropin-releasing hormone in postpartum dairy cows. Am. J. Vet. Res. 41:1582.

Garverick, H.A., Zollers, W.G., and Smith, M.F., 1992. Mechanisms associated with corpus luteum lifespan in animals having normal or subnormal luteal function. Anim. Reprod. Sci. 28:111.

Gill, J.L. and Hafs, H.D., 1971. Analysis of repeated measurements of animals. J. Anim. Sci. 33:331.

Hafs, H.D., Louis, T.M., Stellflug, J.N., Convey, E.M., and Britt, J.H., 1975. Blood LH after $PGF_{2\alpha}$ in diestrous and ovariectomized cattle. Prostaglandins 10:1001.

Helmer, S.D. and Britt, J.H., 1987. Hormone secretion and characteristics of estrous cycles after treatment of heifers with human chorionic gonadotropin or prostaglandin $F_{2\alpha}$ during corpus luteum formation. J. Anim. Sci 64:782.

Hicks, C.R., 1964. Fundamental Concepts in the Design of Experiments. Holt, Rinehart, and Winston, New York, NY.

Jöchle, W., Irvine, C.H.G., Alexander, S.L., and Newby, T.J., 1987. Release of LH, FSH and GnRH into pituitary venous blood in mares treated with a PGF analogue, luprostiol, during the transition period. J. Reprod. Fertil. 35:261.

Kesler, D.J., Garverick, H.A., Youngquist, R.S., Elmore, R.G., and Bierschwal, C.J., 1978. Ovarian and endocrine responses and reproductive performance following GnRH administration in early postpartum dairy cows. Theriogenology 9:363.

Kesler, D.J., Troxel, T.R., and Hixon, D.L., 1980. Effect of days postpartum and exogenous GnRH on reproductive hormone and ovarian changes in postpartum suckled beef cows. Theriogenology 13:287.

Kesler, D.J. and Vincent, D.L., 1980. Effect of carrier and administration on luteinizing hormone release by gonadotropin releasing hormone. J. Dairy Sci. 63:2121.

Kesler, D.J., Weston, P.G., Pimentel, C.A., Troxel, T.R., Vincent, D.L., and Hixon, J.E., 1981. Diminution of the in vitro response to luteinizing hormone by corpora lutea induced by gonadotropin releasing hormone treatment of postpartum suckled beef cows. J. Anim. Sci. 53:749.

Lauderdale, J.W., Sequin, B.E., Stellflug, J.N., Chenault, J.R., Thatcher, W.W., Vincent, C.K., and Loyancano, A.F., 1974. Fertility of cattle following $PGF_{2\alpha}$ injection. J. Anim. Sci. 38:964.

Lishman, A.W., Allison, S.M.J., Fogwell, R.L., Butcher. R.L., and Inskeep, E.K., 1979. Follicular development and function of induced corpora lutea in underfed postpartum anestrous beef cows. J. Anim. Sci. 48:867.

Louis, T.M., Stellflug, J.N., Tucker, H.A., and Hafs, H.D., 1974. Plasma prolactin, growth hormone, luteinizing hormone and glucocorticoid after prostaglandin $F_{2\alpha}$ in heifers. Proc. Soc. Expt. Biol. Med. 147:128.

Macmillan, K.L. and A.M. Day, 1982. Prostaglandin $F_{2\alpha}$ - A fertility drug in dairy cattle? Theriogenology 18:245.

Roche, J.R., 1976. Fertility in cows after treatment with a prostaglandin analogue with or without progesterone. J. Reprod. Fertil. 46:341.

Smith, G.D., Sawyer, H.R., Mirando, M.A., Griswold, M.D., Sadhu, A., and Reeves, J.J., 1996. Steady-state luteinizing hormone receptor messenger ribonucleic acid levels and endothelial cell composition in bovine normal- and short-lived corpora lutea. Biol. Reprod. 55:902.

Swanson, L.V. and Hafs, H.D., 1971. LH and prolactin in blood serum from estrus to ovulation in Holstein heifers. J. Anim. Sci. 1038.

Troxel, T.R., Cmarik, G.F., Ott, R.S., Lock, T.F., and Kesler, D.J. 1983. The effect of method of GnRH administration and short-term calf removal on ovarian function and reproductive performance in postpartum suckled beef cows administered $PGF_{2\alpha}$ for estrous synchronization. Theriogenology 20:417.

Troxel, T.R. and Kesler, D.J., 1984a. Ability of indomethacin to alter prostaglandin metabolite concentrations and to enhance the function of corpora lutea in postpartum suckled beef cows. J. Anim. Sci. 59:177.

Troxel, T.R. and Kesler, D.J., 1984b. The effect of progestin and GnRH treatments on ovarian function and reproductive hormone secretions of anestrous postpartum suckled beef cows. Theriogenology 21:699.

Troxel, T.R., Kesler, D.J., Noble, R.C., and Carlin, S.E., 1980. Ovulation and reproductive hormones following steroid pretreatment, calf removal and GnRH in postpartum suckled beef cows. J. Anim. Sci. 51:652.

Troxel, T.R., Opsomer, M.J., and Kesler, D.J., 1984c. The effect of days postpartum, indomethacin and oxytocin on prostaglandin metabolite concentrations in postpartum suckled beef cows. Theriogenology 22:187.

Troxel, T.R., Cruz, L.C., Ott, R.S., and Kesler, D.J., 1993. Norgestomet and gonadotropin-releasing hormone enhance corpus luteum function and fertility of postpartum suckled beef cows. J. Anim. Sci. 71:2579.

Vasconcelos, J.L., Pursley, J.R., and Wiltbank, M.C., 1994. Effects of syncromate B combined with GnRH on follicular dynamics and time of ovulation. J. Anim. Sci. 72(Suppl. 1):174 (Abstr.).

Vincent, D.L., Kinser, A.R., and Kesler, D.J., 1984. The effect of method of administration on ovarian response of seasonally anestrous ewes administered gonadotrophin releasing hormone. Anim. Reprod. Sci. 6:267.

Vincent, D.L. and Kesler, D.J., 1985. Prolonged release of gonadotropin releasing hormone enhanced subsequent pituitary and ovarian responses of postpartum anestrous ewes. In: N.A. Peppas and R.J. Haluska (Eds.). Proc. Int. Symp. Cont. Rel. Bioact. Mat., Controlled Release Soc., Inc., Lincolnshire, IL. 12:247.

Wilks, J.W., Hodgen, G.D., and Ross, G.T., 1976. Luteal-phase defects in the rhesus monkeys: the significance of serum FSH:LH ratio. J. Clin. Endocrinol. Metab. 43:1261.

Wiseman, B.S., Vincent, D.L., Thomford, P.J., Scheffrahn, N.S., Sargent, G.F., and Kesler, D.J., 1983. Changes in porcine, ovine, bovine, and equine blood progesterone concentrations between collection and centrifugation. Anim. Reprod. Sci. 5:157.

Zaied, A.A., Garverick, H.A., Bierschwal, C.J., Elmore, R.G., Youngquist, R.S., and Sharp, A.J., 1980. Effect of ovarian activity and endogenous reproductive hormones on GnRH-induced ovarian cycles in postpartum dairy cows. J. Anim. Sci. 50:508.

Zelinski-Wooten, M.B., Lanzendorf, S.E., Wolf, D.P., Chandrasekher, Y.A., and Stouffer, R.L., 1991. Titrating luteinizing hormone surge requirements for ovulatory changes in primate follicles. I. Oocyte maturation and corpus luteum function. J. Clin. Endocrinol. Metab. 73:577.

Table 1. GnRH-induced ovulation response and LH release in previously anestrous cows administered $PGF_{2\alpha}$ 30 h before GnRH (Experiment 1)

Item	Treatment	
	Buffer	$PGF_{2\alpha}$
Ovulated	4/ 7[a] (57%)	11/11[b] (100%)
LH Area Under the Response Curve	14.7[a] ± 2.0	21.3[b] ± 1.9
GnRH-Induced Peak LH Amplitude (ng/mL)	69.5[a] ± 12.4	97.4[b] ± 9.7

[a,b]Values within rows with different superscripts differ ($P < .05$).

Table 2. GnRH-induced LH releases in cows with subnormal and normal luteal phases (Experiment 2)

Item	Luteal Phases	
	Subnormal	Normal
Anestrus	22/26[a] (85%)	4/26 (15%)
Estrous Cycles	4/17[b] (23%)	13/17 (77%)
LH Area Under the Response Curve	19.0 ± 3.3[c]	28.8 ± 3.8[d]
GnRH-Induced Peak LH Amplitude (ng/mL)	98.0 ± 13.7[c]	142.5 ± 16.9[d]

[a,b]Values within the same column with different superscripts differ ($P < .05$).
[c,d]Values within the same row with different superscripts differ ($P < .05$).

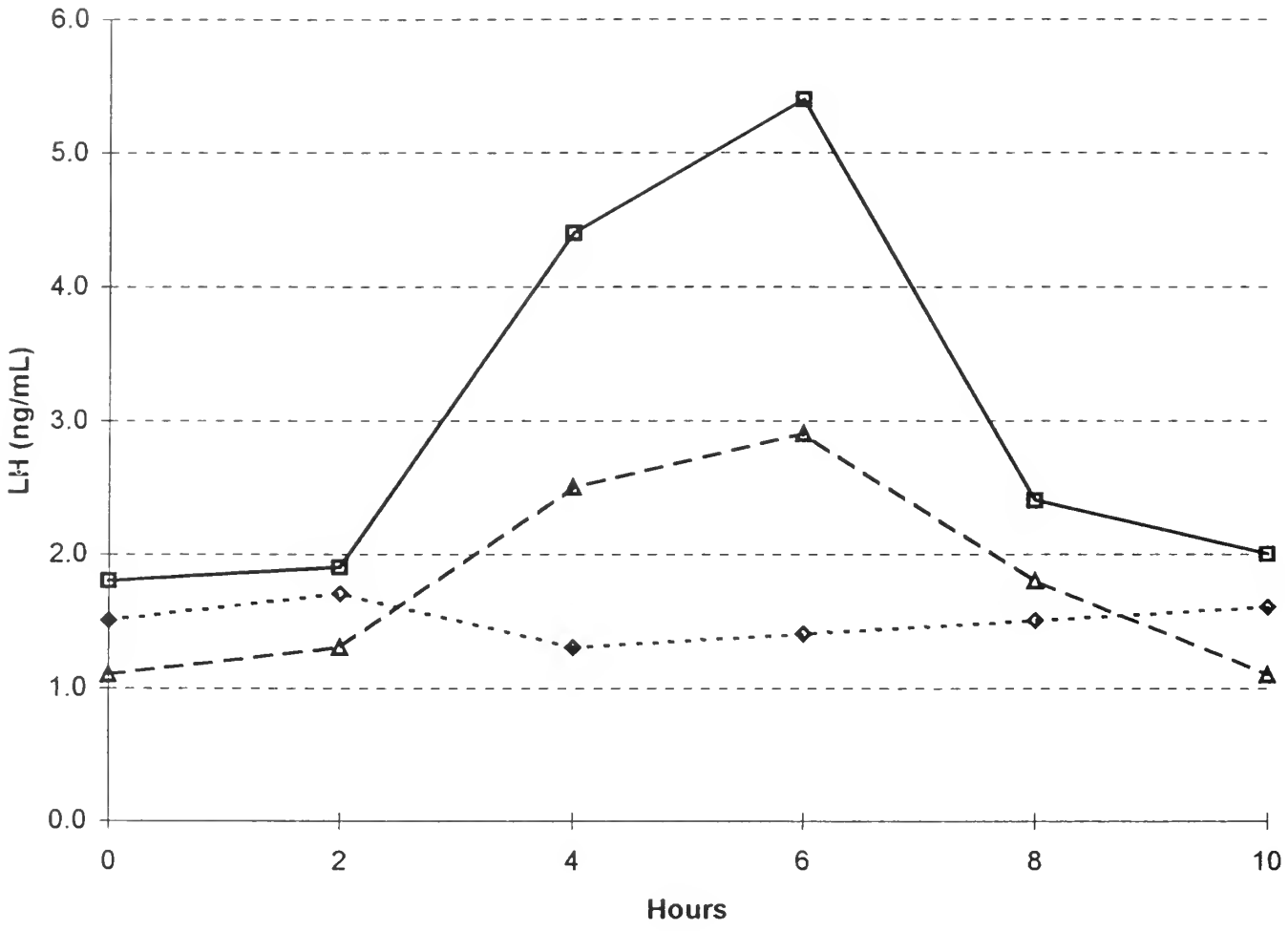

Figure 1. LH concentration in cows treated with buffer (diamonds), and anestrous cows (squares) and cyclic cows (diamonds) treated with $PGF_{2\alpha}$.

EFFECT OF GONADOTROPIN RELEASING HORMONE ON PREGNANCY RATES OF BEEF HEIFERS AND COWS ESTRUS-SYNCHRONIZED WITH MELENGESTROL ACETATE AND PROSTAGLANDIN $F_{2\alpha}$

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SUMMARY

Crossbred beef females (171 heifers and 462 cows) from the Dixon Springs Agricultural Center were fed MGA daily for 14 d and administered $PGF_{2\alpha}$ 15 (cows) or 17 (heifers) d after the last d of MGA. To determine if GnRH treatment would enhance pregnancy rates of estrus-synchronized females, females were randomly assigned to treatments in a 2 x 2 factorial design with GnRH (none or 100 µg) 7 d before the injection of $PGF_{2\alpha}$ and GnRH (none or 100 µg) about 54 h after the injection of $PGF_{2\alpha}$ as the main effects. Females were bled before the injection of $PGF_{2\alpha}$ and 3 d later, and the samples were assayed for progesterone. Fertile bulls outfitted with chin ball markers were included with the females during the 54 h after the injection of $PGF_{2\alpha}$. About 72 h after the injection of $PGF_{2\alpha}$, females not marked by bulls were artificially inseminated. After the injection of $PGF_{2\alpha}$ (78 h to 10 d), fertile bulls outfitted with chin ball markers were included with the females. GnRH treatment 7 d before the injection of $PGF_{2\alpha}$ reduced ($P < .01$) the incidence of estrus in cows before the 72-h AI. GnRH treatment 54 h after the injection of $PGF_{2\alpha}$ reduced ($P < .01$) the incidence of estrus in cows after the 72-h AI. The incidence of corpora lutea regression by 72 h after the injection of $PGF_{2\alpha}$ was less ($P < .05$) in cows treated with GnRH 7 d before the injection of $PGF_{2\alpha}$ than in untreated cows. GnRH treatments had no effect ($P > .20$) on pregnancy rate from the 72-h AI and the 4 d of synchronized breeding for the heifers. Pregnancy rates from the 72-h AI were improved ($P < .01$) by administering GnRH 54 h after the injection of $PGF_{2\alpha}$ in the cows and may have value in estrus synchronization programs for cows but not for heifers.

INTRODUCTION

Only a small percentage of beef cattle are currently bred by AI because of the absence of an estrus synchronization procedure that allows for AI at a predetermined time with consistently high pregnancy rates. The concurrent use of melengestrol acetate (MGA) and prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) has been successfully used to synchronize estrus in heifers and cows (Brown et al., 1988; Jaeger et al., 1992; Patterson et al., 1995). However, pregnancy rates of females bred at a predetermined time have been variable (King et al., 1994; Larson et al., 1996; Kesler et al., 1996b).

The objective of this study was to determine if gonadotropin-releasing hormone (GnRH) treatment would enhance pregnancy rates of beef heifers and cows that have been estrus-synchronized with MGA and $PGF_{2\alpha}$ (Kesler et al., 1996b). We hypothesized that GnRH treatment 7 d before the injection of $PGF_{2\alpha}$ would enhance pregnancy rates of estrus-synchronized females because Pursley et al. (1995) demonstrated that an injection of GnRH 7 d before the injection of $PGF_{2\alpha}$ enhanced the likelihood of having growing dominant follicles at the time of $PGF_{2\alpha}$ administration. We also hypothesized that the administration of GnRH 54 h after the injection of $PGF_{2\alpha}$ would enhance pregnancy rates from a timed AI because Troxel et al. (1993) and Pursley et al. (1995) demonstrated that administration of GnRH hastened and synchronized ovulation.

MATERIALS AND METHODS

Crossbred beef females (171 heifers and 462 cows suckling calves) from the Dixon Springs Agricultural Center (Simpson, IL) were included in these experiments. The cows were 4 to 14 y old and 35 to 123 d postpartum, and the heifers were 12 to 16 mo old at the time of the 72-h AI. The experiments were conducted during the months of March and April 1996. All females were fed .5 mg MGA in 1.36 kg of ground corn daily for 14 d and .23 kg of soybean meal for the 14 d after the MGA feeding period. The females also received ad libitum fescue hay and a complete vitamin and mineral mixture before and during treatments and inseminations to meet NRC requirements (NRC, 1996). $PGF_{2\alpha}$ (25 mg; 5 mL Lutalyse® Sterile Solution) was administered to all females i.m. in the upper rear musculature 17 d (heifers) and 15 d (cows) after the last day of MGA feeding. The interval between the last day of MGA feeding and $PGF_{2\alpha}$ differed for heifers and cows because results of a previous study suggested that the optimum interval differed for heifers and cows (Kesler et al., 1996b). Females were randomly assigned, before any treatments were initiated, to treatments in a 2 x 2 factorial design (one for heifers and one for cows) with GnRH treatment (none or 100 μg) 7 d before the injection of $PGF_{2\alpha}$ and GnRH treatment (none or 100 μg) about 54 h after the injection of $PGF_{2\alpha}$ as the main effects. GnRH was dissolved in a potassium phosphate buffer at a concentration of 50 µg per mL and 2 mL was administered i.m. in the upper rear leg musculature with 18-g needles (3.81 cm long). Fertile bulls outfitted with chin ball markers were included with the females during the 54 h immediately after the injection of $PGF_{2\alpha}$. Females were observed twice daily and females with paint marks were recorded. Approximately 72 h after the injection of $PGF_{2\alpha}$, females, that had not been inseminated, were artificially inseminated using commercially available semen. AI service sire was assigned to the females before random assignment of females to treatment groups. After the injection of $PGF_{2\alpha}$ (78 h to 10 d), fertile bulls outfitted with chin ball markers were included with the females. Females were observed twice daily for paint marks. Females with paint marks were recorded. See Figure 1 for the schedule of treatments.

All females were bled via jugular venipuncture using 18-g needles (3.81 cm long) immediately before and 72 h after the injection of $PGF_{2\alpha}$. After collection, blood was stored in ice water until centrifugation at 2,000 x g within 6 h after collection (Wiseman et al., 1983). Sera were harvested after centrifugation and stored at - 4°C until assayed for progesterone. Progesterone concentrations were determined using a validated progesterone ELISA (Kesler et al., 1990).

Females with progesterone concentrations ≥ 1.5 ng/mL immediately before the injection of $PGF_{2\alpha}$ were considered to have corpora lutea. Corpora lutea were considered to have regressed after the injection of $PGF_{2\alpha}$ if progesterone concentrations were < 1.0 ng/mL 3 d later (at the 72-h AI) (Kesler et al., 1996b). Nineteen females (nine heifers and 10 cows) had one or both of the blood samples missing and were excluded from the analyses of the parameters that were based on progesterone.

Bulls included with the females were of a different genetic make up (Simmental and Wagyu) than the bulls used for AI (Angus and Gelbvieh). Calving rate from the 72-h AI was based on phenotype of the offspring.

Occurrence of estrus before the 72-h AI was analyzed as a 2 x 2 factorial design with GnRH treatment 7 d before the injection of $PGF_{2\alpha}$ (with or without) and corpora lutea at the time of $PGF_{2\alpha}$

administration (with or without) as the main effects using the categorical data (CATMOD) procedure of SAS (1988). GnRH 54 h after the injection of $PGF_{2\alpha}$ was not included in the model as treatment was done after the time period. Occurrence of estrus after the 72-h AI and calving rates were analyzed as a 2 x 2 x 2 factorial design with GnRH treatment 7 d before the injection of $PGF_{2\alpha}$ (with or without), GnRH 54 h after the injection of $PGF_{2\alpha}$ (with or without), and corpora lutea at the time of $PGF_{2\alpha}$ administration (with or without) as the main effects using the CATMOD procedure (SAS, 1988). The presence of corpora lutea at the time of $PGF_{2\alpha}$ administration and progesterone concentrations were analyzed by analysis of variance (CATMOD procedure) with GnRH treatment 7 d before the injection of $PGF_{2\alpha}$ (with or without) as the main effect (SAS, 1988). Corpus luteum regression by AI and females with progesterone concentrations < 1.0 ng/mL at AI were analyzed as a 2 x 2 factorial design with GnRH treatment 7 d before the injection of $PGF_{2\alpha}$ (with or without) and GnRH 54 h after $PGF_{2\alpha}$ administration (with or without) as the main effects using the CATMOD procedure (SAS, 1988).

RESULTS

Treating heifers with GnRH 7 d before or 54 h after the injection of $PGF_{2\alpha}$ did not ($P > .20$) alter the number of heifers observed in estrus (Table 1) or the number heifers with corpora lutea before the injection of $PGF_{2\alpha}$ or at the 72-h AI (Table 2). However, progesterone concentrations were greater ($P < .05$) in heifers administered GnRH 7 d before the time of the $PGF_{2\alpha}$ injection than in untreated heifers. The pregnancy rate from the 72-h AI and the 4-d inseminations averaged 33% and 48%, but were not affected ($P > .20$) by the GnRH treatments Table 3).

Treating cows with GnRH 7 d before the injection of $PGF_{2\alpha}$ reduced ($P < .01$) the incidence of estrus during the 2 d before the 72 h-AI, but did not alter ($P > .20$) the number of cows in estrus after the 72 h-AI (Table 4). Administering GnRH 54 h after the injection of $PGF_{2\alpha}$ had no effect ($P > .20$) on the incidence of estrus before the 72-h AI, but decreased ($P < .01$) the incidence of estrus after the 72-h AI (Table 4). The effect was more pronounced in cows with estrous cycles (corpora lutea x GnRH 54 h after the injection of $PGF_{2\alpha}$ interaction; $P < .01$). Twenty-two percent and 4% of the cows without corpora lutea not treated and treated with GnRH, respectively, were in estrus during the 7 d after the 72-h AI. Fifty-two percent and 15% of the cows with corpora lutea not treated and treated with GnRH, respectively, were in estrus during the 7 d after the 72-h AI.

Administration of GnRH 7 d before the injection of $PGF_{2\alpha}$ had no effect ($P > .20$) on the frequency of cows with corpora lutea before $PGF_{2\alpha}$ administration (Table 5). The incidence of corpora lutea regression by 72 h after the injection of $PGF_{2\alpha}$ was less ($P < .05$) in cows treated with GnRH 7 d before the injection of $PGF_{2\alpha}$ than in untreated cows (Table 5). Because of the decreased incidence of $PGF_{2\alpha}$-induced corpora lutea regression in cows administered GnRH 7 d before the injection of $PGF_{2\alpha}$, the number of cows with less than 1.0 ng/mL progesterone at the time of the 72-h AI was lower ($P < .01$) if they were administered GnRH 7 d before the injection of $PGF_{2\alpha}$ than if they were untreated. Although, GnRH treatment 7 d before the injection of $PGF_{2\alpha}$ had no effect ($P > .20$) on pregnancy rates in the cows, GnRH treatment 54 h after the injection of $PGF_{2\alpha}$ improved ($P < .01$) the pregnancy rate in cows (Table 6). The pregnancy rate during the 3 d after the 72-h AI was greater ($P < .01$) for the cows not administered GnRH 54 h after the injection of $PGF_{2\alpha}$ than for the cows administered GnRH 54 h after the injection of $PGF_{2\alpha}$. Therefore, the 4-d pregnancy rate was

similar ($P > .20$) for the cows regardless of GnRH administration 54 h after the injection of $PGF_{2\alpha}$ (Table 6).

DISCUSSION

There are two major strategies for synchronizing estrus in cattle. First, use of $PGF_{2\alpha}$ to hasten estrus by lysing corpora lutea. Second, the combination of progestins and luteolytic or antiluteotropic compounds such as Syncro-Mate B. However, other progestin and luteolytic/antiluteotropic procedures, as listed below, have been developed.

- The administration of a norgestomet implant or a progesterone intravaginal implant and the use of $PGF_{2\alpha}$ 6 to 7 d later and removal of the implant 7 to 8 d after insertion (Macmillan and Peterson, 1993; doValle et al., 1997).
- The administration of GnRH followed by $PGF_{2\alpha}$ about 7 d later (Forbes et al., 1997).
- The administration of MGA for 14 d followed by $PGF_{2\alpha}$ 15 to 17 d after the last MGA feeding as done in this experiment and by others (Kesler et al., 1996b).

A model procedure for estrus synchronization in cattle would include the following attributes.

- It would require minimal animal handling.
- All females would be bred at one predetermined time.
- It would require minimal cost.
- It would be completed in a short period of time that so that heifers would be older, and cows would be farther postpartum in order to allow them to overcome anestrus before implementation.

The advantage of the MGA/$PGF_{2\alpha}$ procedure, as used in this experiment, is that it may fulfill the first three of these requirements; although it is time consuming as it requires 32 to 34 d to complete. Pregnancy rates, both from a 72-h AI and from synchronized breedings, after MGA/$PGF_{2\alpha}$ synchronization in heifers appear to be relatively consistent and the long treatment period may be tolerated. These and the results of others (Brown et al., 1988; Jaeger et al., 1992; Kesler et al., 1996b) suggest that the MGA/$PGF_{2\alpha}$ procedure along with 72-h AI and subsequent breeding for 3 days is an efficacious method of synchronizing the establishment of pregnancy in heifers. Use of GnRH with the MGA/$PGF_{2\alpha}$ procedure provided no additional value in heifers.

Pregnancy rates after synchronization with the MGA/$PGF_{2\alpha}$ have been variable (King et al., 1994; Larson et al., 1996; Kesler et al., 1996b) and the long treatment period is a barrier for use in cows. Therefore, other estrus synchronization procedures that include progestins may be of greater value in beef cows suckling calves.

GnRH has previously been used concurrently with $PGF_{2\alpha}$ to synchronize follicular waves (Pursley et al., 1995). GnRH treatment has caused ovulation in previously anestrous females (Troxel et al., 1993) and in estrus-cycling females (Pursley et al., 1995). A new cohort of follicles then develop so

that approximately 7 to 10 d later a growing dominant follicle is available for ovulation. These dominant follicles have a higher fertility rate than follicles that have persisted (Mihm et al., 1994; Ahmad et al., 1995; Cooperative Regional Research Project, NE-161, 1996). The present data confirm earlier studies that GnRH treatment about 7 d before the injection of $PGF_{2\alpha}$ reduced the incidence of estrus in cows before $PGF_{2\alpha}$ administration (Thatcher et al., 1989; Twagiramungu et al., 1992). The reduced incidence of estrus during this interval may be due to GnRH-induced atresia or ovulation of dominant follicles and(or) delayed luteolysis. Because GnRH eliminates dominant follicles, estrus may be delayed until ovulatory follicles are available. Also, because estradiol is necessary for normal luteolysis, elimination of dominant follicles and estradiol with GnRH treatment may delay luteolysis. Administration of GnRH 7 d before the injection of $PGF_{2\alpha}$ decreased $PGF_{2\alpha}$-induced luteolysis. This may be due to the development of accessory corpora lutea. Previous research has demonstrated that more recently developed corpora lutea have a poorer luteolysis response to $PGF_{2\alpha}$ administration than more mature corpora lutea (Watts and Fuquay, 1985; Kesler et al., 1996b).

GnRH has been previously used after estrus synchronization with norgestomet (Troxel et al., 1993; Hoffman et al., 1995; Kesler and Favero, 1997) and $PGF_{2\alpha}$ (Pursley et al., 1997) for the synchronization of ovulation. Because the administration of the GnRH after luteolysis hastens and synchronizes ovulation (Pursley et al., 1995), its ability to improve pregnancy rates from timed inseminations in cows as reported herein was anticipated. Although additional labor is required to administer the GnRH, less total labor may be required because fewer cows need to be inseminated the three days after the 72-h AI. The ineffectiveness of GnRH in heifers has been previously reported when GnRH was administered after $PGF_{2\alpha}$ (Pursley et al., 1997) but not after norgestomet (doValle et al., 1997).

IMPLICATIONS

Because the administration of GnRH 7 d before $PGF_{2\alpha}$ decreased the efficacy of $PGF_{2\alpha}$- induced luteolysis, other methods of synchronizing follicular waves may be more appropriate. Administration of GnRH 54 h after $PGF_{2\alpha}$-induced luteolysis improved the pregnancy rate from a 72-h AI by hastening ovulation in cows that would have exhibited estrus the three days after the 72-h AI.

LITERATURE CITED

Ahmad, N., F. N. Schrick, R. L. Butcher, and E. K. Inskeep. 1995. Effect of persistent follicles on early embryonic losses in beef cows. Biol. Reprod. 52:1129-1135.

Brown, L. N., K. G. Odde, M. E. King, D. E. LeFever, and C. J. Neubauer. 1988. Comparison of MGA-$PGF_{2\alpha}$ to Syncro-Mate B for estrous synchronization in beef heifers. Theriogenology 30:1-12.

Cooperative Regional Research Project, NE-161. 1996. Relationship of fertility to patterns of ovarian follicular development and associated hormonal profiles in dairy cows and heifers. J. Anim. Sci. 74:1943-1952.

doValle, E. R., L. C. Cruz, and D. J. Kesler. 1997. Gonadotropin releasing hormone enhances the calving rate of beef females administered norgestomet and alfaprostol for estrus synchronization. J. Anim. Sci. 75:897-903.

Forbes, W. L., L. R. Corah, and J. S. Stevenson. 1997. Synchronized follicular growth and luteal regression before insemination of suckled beef cows. J. Anim. Sci. 75(Suppl. 1):90 (Abstr.).

Hoffman, D. P., J. S. Stevenson, R. M. McKee, D. A. Nichols, and C. L. Krehbiel. 1995. Pregnancy rates in virgin heifers and suckled beef cows after synchronized ovulation using $PGF_{2\alpha}$, norgestomet, and GnRH. J. Anim. Sci. 73(Suppl. 1):89 (Abstr.).

Jaeger, J. R., J. C. Whittier, L. R. Corah, J. C. Meiske, K. C. Olson, and D. J. Patterson. 1992. Reproductive response of yearling beef heifers to a melengestrol acetate-prostaglandin $F_{2\alpha}$ estrus synchronization system. J. Anim. Sci. 70:2622-2627.

Kesler, D. J., D. B. Faulkner, R. Machado, F. A. Ireland, and K. E. Tjardes. 1996a. Effect of prostaglandin $F_{2\alpha}$ administered before estrus synchronization with norgestomet and estradiol valerate on calving rates of beef cows. J. Anim. Sci. 74:2076-2080.

Kesler, D. J., D. B. Faulkner, T. S. Dyson, and T. G. Nash. 1997. Synchronization of estrus in beef females with the melengestrol acetate/prostaglandin $F_{2\alpha}$ procedure: estrus and efficacy of 72-hour timed AI. J. Appl. Anim. Res. 11:73-81.

Kesler, D. J., D. B. Faulkner, R. B. Shirley, T. S. Dyson, F. A. Ireland, and R. S. Ott. 1996b. Effect of interval from melengestrol acetate to prostaglandin $F_{2\alpha}$ on timed and synchronized pregnancy rates of beef heifers and cows. J. Anim. Sci. 74:2885-2890.

Kesler, D. J. and R. J. Favero. 1997. Needle-less implant delivery of gonadotropin releasing hormone enhances the calving rate of beef cows synchronized with norgestomet and estradiol valerate. Drug Dev. Ind. Pharm. 23:607-610.

Kesler, D. J., H. Khazali, and R. J. Favero. 1990. Quantification of steroids via a polymer linked second antibody enzyme immunoassay system: methods of linking anti-rabbit IgG to poly(styrene). In: C.G. Gebelein and R.L. Dunn (Eds.) Progress in Biomedical Polymers. Plenum Publishing, New York, pp. 157-170.

King, M. E., M. J. Daniel, L. D. Teague, D. N. Schutz, and K. G. Odde. 1994. Comparison of timed insemination with insemination at estrus following synchronization of estrus with a MGA-prostaglandin system in beef heifers. Theriogenology 42:79-88.

Larson, R. L., L. R. Corah, and C. W. Peters. 1996. Synchronization of estrus in yearling heifers with the melengestrol acetate/prostaglandin $F_{2\alpha}$ system: efficiency of timed insemination 72 hours after prostaglandin treatment. Theriogenology 45:851-863.

Macmillian, K.L. and A.J. Peterson. 1993. A new intravaginal progesterone releasing device for cattle (CIDR-B) for oestrous synchronization, increasing pregnancy rates and the treatment of post-partum anoestrous. Anim. Reprod. Sci. 33:1-25.

Mihm, M., A. Baguisi, M. P. Boland, J. F. Roche. 1994. Association between the duration of dominance of the ovulatory follicle and pregnancy rate in beef heifers. J. Reprod. Fertil. 102:123-130.

NRC. 1996. Nutrient Requirements of Beef Cattle. National Academy Press, Washington, DC.

Patterson, D. J., J. B. Hall, N. W. Bradley, K. K. Schillo, B. L. Woods, and J. M. Kearnan. 1995. Improved synchrony, conception rate, and fecundity in postpartum suckled beef cows fed melengestrol acetate prior to prostaglandin $F_{2\alpha}$. J. Anim. Sci. 73:954-959.

Pursley, J. R., M. O. Mee, and M. C. Wiltbank. 1995. Synchronization of ovulation in dairy cows using $PGF_{2\alpha}$ and GnRH. Theriogenology 44:915-923.

Pursley, J. R., M. C. Wiltbank, J. S. Stevenson, J. S. Ottobre, H. A. Garverick, and L. L. Anderson. 1997. Pregnancy rates per artificial insemination for cows and heifers at a synchronized ovulation or synchronized estrus. J. Dairy Sci. 80:295-300.

SAS. 1988. SAS/STAT User's Guide (Release 6.03). SAS Inst. Inc., Cary, NC.

Thatcher, W. W., K. L. Macmillian, P. J. Hansen, and M. Drost. 1989. Concepts for regulation of corpus luteum function by the conceptus and ovarian follicles to improve fertility. Theriogenology 31:149-164.

Troxel, T. R., L. C. Cruz, R. S. Ott, and D. J. Kesler. 1993. Norgestomet and gonadotropin-releasing hormone enhance corpus luteum function and fertility of postpartum suckled beef cows. J. Anim. Sci. 71:2579-2585.

Twagiramingu, H., L. A. Guilbault, J. Prouix, P. Villeneuve, and J. J. Dufour. 1992. Influence of an agonist of gonadotropin-releasing hormone (Buserelin) on estrus synchronization and fertility in beef cows. J. Anim. Sci. 70:1904-1910.

Watts, T. L. and J. W. Fuquay. 1985. Response and fertility of dairy heifers following injection with prostaglandin $F_{2\alpha}$ during early, middle or later diestrus. Theriogenology 23:655-661.

Wiseman, B.S., D.L. Vincent, P.J. Thomford, N.S. Scheffrahn, G.F. Sargent, and D.J. Kesler. 1983. Changes in porcine, ovine, bovine, and equine blood progesterone concentrations between collection and centrifugation. Anim. Reprod. Sci. 5:157-165.

Table 1. Effect of GnRH treatment 7 d before and 54 h after $PGF_{2\alpha}$ on estrus before and after the 72-h AI in beef heifers administered MGA and $PGF_{2\alpha}$

		GnRH 7 d before $PGF_{2\alpha}$		Treatment Effect
		-	+	P ≤
Before AI:				
	-2	0	0	
	-1	5	6	
	-1 & -2	5/ 91 (6%)	6/ 80 (8%)	
After AI:				
	1	3	2	
	2	8	8	
	3	5	8	
	4	7	8	
	5	7	2	
	6	0	3	
	7	5	2	
	1-7	35/ 91 (39%)	33/ 80 (41%)	

		GnRH 54 h after $PGF_{2\alpha}$		Treatment Effect
		-	+	P ≤
Before AI:				
	-2	0	0	
	-1	4	7	
	-1 & -2	4/ 88 (5%)	7/83 (8%)	
After AI:				
	1	3	1	
	2	10	6	
	3	6	7	
	4	10	5	
	5	5	4	
	6	2	2	
	7	1	6	
	1-7	37/ 88 (42%)	31/ 83 (37%)	

Table 2. Effect of GnRH treatment 7 d before $PGF_{2\alpha}$ on number of heifers with CL (corpora lutea) before $PGF_{2\alpha}$ treatment, number of heifers with regression of CL by the 72-h AI, number of heifers with < 1.0 ng/mL of progesterone at the 72-h AI, and progesterone concentrations in heifers with CL

	GnRH 7 d before $PGF_{2\alpha}$		Treatment Effect
	-	+	P ≤[a]
CL before $PGF_{2\alpha}$[b]	69/ 85 (81%)	69/ 77 (90%)	
P_4[c] in females with CL[b]	6.0 ± .3	6.9 ± .3	.05
CL regression by AI[b]	62/ 69 (90%)	58/ 69 (84%)	
P_4 < 1.0 ng/mL at AI[b]	73/ 85 (86%)	65/ 77 (84%)	

[a]None of the interactions were significant (P > .20).

[b]One or both of the blood samples were lost for nine heifers and were excluded for these analyses.

[c]ng/mL.

Table 3. Effect of GnRH treatment 7 d before and 54 h after $PGF_{2\alpha}$ on 72-h and 4-d synchronized calving rates of heifers administered MGA and $PGF_{2\alpha}$

	GnRH 7 d before $PGF_{2\alpha}$		Treatment Effect
	-	+	P ≤
72-h AI	34/ 91 (37%)	22/ 80 (28%)	
4-d Inseminations[a]	46/ 91 (51%)	36/ 80 (45%)	
	GnRH 54 h after $PGF_{2\alpha}$		Treatment Effect
	-	+	P ≤
72-h AI	27/ 88 (31%)	29/ 83 (35%)	
4-d Inseminations[a]	45/ 88 (51%)	37/ 83 (45%)	

[a]Pregnancies from the 72-h AI and the succeeding inseminations on days 1, 2, and 3.

Table 4. Effect of GnRH treatment 7 d before and 54 h after $PGF_{2\alpha}$ on estrus before and after the 72-h AI in beef cows administered MGA and $PGF_{2\alpha}$

	GnRH 7 d before $PGF_{2\alpha}$		Treatment Effect
	-	+	P ≤[a]
Before AI:			
-2	0	2	
-1	15	4	
-1 & -2	15/229 (7%)	6/233 (3%)	.01
After AI:			
1	19	12	
2	14	14	
3	9	9	
4	10	7	
5	3	7	
6	2	2	
7	1	5	
1-7	58/229 (25%)	56/233 (24%)	

	GnRH 54 h after $PGF_{2\alpha}$		Treatment Effect
	-	+	P ≤
Before AI:			
-2	0	0	
-1	10	11	
-1 & -2	10/235 (4%)	11/227 (5%)	
After AI:			
1	30	1	
2	27	2	
3	15	2	
4	10	7	
5	8	2	
6	1	3	
7	1	5	
1-7	92/235 (39%)	22/227 (10%)	.01[b]

[a]Any significant (P ≤ .10) corpora lutea effects and interactions are noted with superscripts in this column.

[b]GnRH 54 h after $PGF_{2\alpha}$, corpora lutea, and the GnRH 54 h after $PGF_{2\alpha}$ x corpora lutea interaction were significant (P < .01). Twenty-two % and 4% of the cows without corpora lutea not treated and treated with GnRH, respectively, were in estrus during the 7 d after the 72-h AI. Fifty-two % and 15% of the cows with corpora lutea not treated and treated with GnRH, respectively, were in estrus during the 7 d after the 72-h AI.

Table 5. Effect of GnRH treatment 7 d before $PGF_{2\alpha}$ on number of cows with CL (corpora lutea) before $PGF_{2\alpha}$ treatment, number of cows with regression of CL by the 72-h AI, number of cows with < 1.0 ng/mL of progesterone at the 72-h AI, and progesterone concentrations in cows with CL

	GnRH 7 d before $PGF_{2\alpha}$		Treatment Effect
	-	+	P ≤[a]
CL before $PGF_{2\alpha}$[b]	124/225 (55%)	135/227 (60%)	
P_4[c] in females with CL[b]	6.8 ± .2	6.9 ± .3	
CL regression by AI[b]	107/124 (86%)	101/135 (75%)	.05
P_4 < 1.0 ng/mL at AI[b]	203/225 (89%)	180/227 (79%)	.01

[a]None of the interactions were significant (P > .20).

[b]One of both of the blood samples were lost for ten cows and were excluded for these analyses.

[c]ng/mL.

Table 6. Effect of GnRH treatment 7 d before and 54 h after $PGF_{2\alpha}$ on 72-h and 4-d synchronized calving rates of heifers and cows administered MGA and $PGF_{2\alpha}$

	GnRH 7 d before $PGF_{2\alpha}$		
	-	+	P ≤
72-h AI	42/229 (18%)	45/233 (19%)	
4-d Inseminations[a]	70/229 (31%)	67/233 (29%)	
	GnRH 54 h after $PGF_{2\alpha}$		
	-	+	P ≤
72-h AI	29/235 (12%)	58/227 (26%)	.01[b]
4-d Inseminations[a]	77/235 (33%)	60/227 (26%)	

[a]Pregnancies from the 72-h AI and the succeeding inseminations on days 1, 2, and 3.

[b]GnRH 54 h after $PGF_{2\alpha}$ ($P < .01$), corpora lutea ($P < .05$), and the GnRH 54 h after $PGF_{2\alpha}$ x corpora lutea interaction ($P < .05$) were significant. Calving rates from the 72-h AI for cows without corpora lutea not administered and administered GnRH 54 h after $PGF_{2\alpha}$ were 13% and 17%, respectively. Calving rates from the 72-h AI for cows with corpora lutea not administered and administered GnRH 54 h after $PGF_{2\alpha}$ were 13% and 33%, respectively.

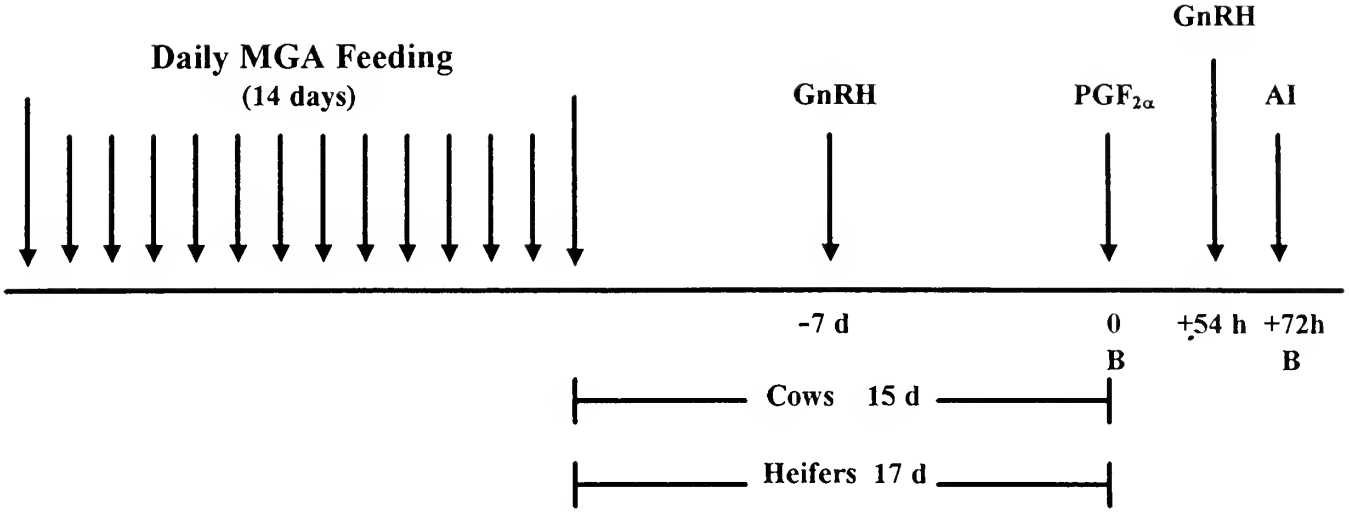

Figure 1. Times of treatments and inseminations in heifers and cows. MGA was fed daily for 14 d. Fifteen (cows) and 17 (heifers) d after the last d of MGA feeding females were administered $PGF_{2\alpha}$. GnRH was administered 7 d before and 54 h after $PGF_{2\alpha}$ treatment. Females were artificially inseminated 72 h after $PGF_{2\alpha}$ treatment.

EFFECT OF METHOD OF SYNCHRONIZATION, TWO INJECTIONS OF $PGF_{2\alpha}$ VS GnRH AND $PGF_{2\alpha}$, ON CORPORA LUTEA DEVELOPMENT AND REGRESSION AND SYNCHRONIZED PREGNANCY RATES: A PRELIMINARY REPORT

D. J. Kesler, D. B. Faulkner, F. A. Ireland, and R. S. Ott

SUMMARY

Three hundred and nineteen crossbred beef cows suckling calves were randomly assigned to treatments in a 2 x 2 factorial design with method of synchronization and gonadotropin-releasing hormone (GnRH) treatment (54 hours after prostaglandin $F_{2\alpha}$ [$PGF_{2\alpha}$]) as the main effects. The two methods of estrus synchronization included 1) two injection of $PGF_{2\alpha}$ 11 days apart and 2) an injection of $PGF_{2\alpha}$ seven days after administration of GnRH. Females were bled 10 days and immediately before injections of GnRH and $PGF_{2\alpha}$ and samples were assayed for progesterone. Cows were exposed to bulls 0 to 54 hours and 78 hours to 63 days after the only (GnRH and $PGF_{2\alpha}$ group) or second injection of $PGF_{2\alpha}$ and all were artificially inseminated at 72 hours. Pregnancy rates were determined by transrectal examination of the reproductive tract and confirmed at calving. Data suggest that GnRH induced the development of corpora lutea in previously anestrous cows. Since fewer estrus-cycling cows had corpora lutea before $PGF_{2\alpha}$ treatment, either accessory corpora lutea from GnRH treatment regressed during regression of existing corpora lutea or GnRH did not induce ovulation and estrus synchronization may have been due to follicular synchronization. $PGF_{2\alpha}$-induced corpus luteum regression and synchronized pregnancy rates were not different among treatment groups. Furthermore, the administration of GnRH 54 hours after $PGF_{2\alpha}$ yielded no additional benefit for either procedure.

INTRODUCTION

Various procedures have been developed to synchronize estrus in beef cattle. One of the more recently promoted, although not FDA approved, procedures is the use of GnRH and $PGF_{2\alpha}$ (Geary et al., 1998). The procedure involves the administration of GnRH seven day before $PGF_{2\alpha}$ treatment. GnRH is administered to control follicular growth and development. Antral follicles will undergo atresia after GnRH treatment and will be incapable of expressing a fertile estrus, even if corpus luteum regression occurs, during the ensuing seven days. $PGF_{2\alpha}$ is administered to cause luteolysis in cows with corpora lutea. The procedure has been referenced as the "Select Synch" and the "Ovsynch" procedure. "Ovsynch" has been primarily used in dairy cattle and utilizes a second injection of GnRH about two days after $PGF_{2\alpha}$. The purpose of this study was to determine the efficacy of this procedure as compared to a commercially available and FDA approved procedure (two injection of $PGF_{2\alpha}$ administered eleven days apart).

METHODS AND MATERIALS

Three hundred and nineteen crossbred beef cows suckling calves were randomly assigned to treatment in a 2 x 2 factorial design with method of synchronization and gonadotropin-releasing hormone (GnRH) treatment (54 hours after prostaglandin $F_{2\alpha}$ [$PGF_{2\alpha}$]) as the main effects. The two methods of estrus synchronization included 1) two injection of $PGF_{2\alpha}$ 11 days apart and 2) an injection of

$PGF_{2\alpha}$ seven days after administration of GnRH. Females were bled 10 days and immediately before injections of GnRH and $PGF_{2\alpha}$ and samples were assayed for progesterone. Cows were exposed to bulls 0 to 54 hours and 78 hours to 63 days after the only (GnRH and $PGF_{2\alpha}$ group) or second injection of $PGF_{2\alpha}$ and all were artificially inseminated at 72 hours. Pregnancy rates were determined by transrectal examination of the reproductive tract and confirmed at calving.

RESULTS

Data suggest that GnRH induced the development of corpora lutea in previously anestrous cows. Since fewer estrus-cycling cows had corpora lutea before $PGF_{2\alpha}$ treatment, either accessory corpora lutea from GnRH treatment regressed during regression of existing corpora lutea or GnRH did not induce ovulation and estrus synchronization may have been due to follicular synchronization. $PGF_{2\alpha}$-induced corpus luteum regression and synchronized pregnancy rates were not different among treatment groups. Furthermore, the administration of GnRH 54 hours after $PGF_{2\alpha}$ yielded no additional benefit for either procedure.

CONCLUSIONS

- $PGF_{2\alpha}$ appeared to hasten fertile estrus in previously anestrous cows as reported by Cruz et al. (1997).
- Both methods of estrus synchronization, two injections of $PGF_{2\alpha}$ and GnRH and $PGF_{2\alpha}$ resulted in moderate pregnancy rates, but neither method was superior.
- Two injections of $PGF_{2\alpha}$ administered 11 days apart would be recommend because it is approved by FDA.

LITERATURE CITED

Cruz, L.C., E.R. doValle, and D.J. Kesler. 1997. Effect of prostaglandin $F_{2\alpha}$- and gonadotropin releasing hormone-induced luteinizing hormone release on ovulation and corpus luteum function of beef cows. Anim. Reprod. Sci. 49:135-142.

Geary, T.W., J.C. Whittier, E.R. Downing, D.G. LeFever, R.W. Silcox, M.D. Holland, T.M. Nett, and G.D. Niswender. 1998. Pregnancy rates of postpartum beef cows that were synchronized using Syncro-Mate B or the Ovsynch protocol. J. Anim. Sci. 76:1523-1527.

Table 1. Number of cows with corpora lutea before and corpora lutea regression after a single injection of $PGF_{2\alpha}$ administered seven days after GnRH or the second injection of two injections of $PGF_{2\alpha}$ and pregnancy rates to the synchronized inseminations

Item	$PGF_{2\alpha}/PGF_{2\alpha}$	$GnRH/PGF_{2\alpha}$	P
Corpora Lutea Before $PGF_{2\alpha}$:			
anestrous cows	11/65 (17%)	26/73 (36%)	< .05
estrus-cycling	66/93 (71%)	50/88 (57%)	< .05
Corpora Lutea Regression:			
anestrous cows	9/11 (82%)	23/26 (89%)	>.20
estrus-cycling	53/66 (80%)	42/50 (84%)	>.20
Synchronized Pregnancy Rate:			
anestrous cows	28/65 (43%)	26/73 (36%)	> .20
estrus-cycling	43/93 (46%)	44/88 (50%)	> .20

EFFICACY OF SUSTAINED RELEASE NEEDLE-LESS CEFTIOFUR SODIUM IMPLANTS IN TREATING CALVES WITH BOVINE RESPIRATORY DISEASE

D. J. Kesler and D. T. Bechtol

SUMMARY

Three experiments were conducted to determine preliminary efficacy of sustained release needle-less implants in effecting a cure in calves with bovine respiratory disease. One hundred and twenty beef calves with a rectal temperature ≥ 40°C and shallow or labored respiration and coughing were used in these experiments. Four groups (1-ceftiofur sodium injections [days 1, 2, and 3], 2-ceftiofur sodium needle-less implants [days 1, 2, and 3], 3-ceftiofur sodium needle-less implants [days 1 and 3], and 4-ceftiofur sodium needle-less implants [day 1] were included. All treatments contained 250 mg of ceftiofur sodium and were administered intramuscularly in the neck after diagnosis of bovine respiratory disease. Experiment 1 included 20 calves (group 1-10 calves and group 3-10 calves; 213 to 255 kg) and calves were monitored for clinical efficacy. Experiment 2 included five calves per group (all four groups; 164 to 192 kg) and calves were bled frequently after treatment for desfuroylceftiofur (the primary ceftiofur metabolite) concentrations. Experiment 3 included 20 calves per group (all four groups; 160 to 205 kg) and calves were monitored for clinical efficacy. Blood desfuroylceftiofur concentrations remained above the minimum inhibitory concentration for Pasteurella haemolytica, Pasteurella multocida, and Haemophilus somnus for 24 hours after injection and 72 hours after implantation ($P < .05$). Mortalities and the number of calves with a positive response and relapse response were similar ($P > .25$) among the four groups. In summary, the administration of one-250 mg ceftiofur sodium needle-less sustained release implant was as efficacious in treating bovine respiratory disease as three daily 250 mg injections of ceftiofur sodium.

INTRODUCTION

Bovine respiratory disease (BRD) is the most economically important infectious disease of calves in North American feedlots (Jensen et al., 1976; Thomson, 1980; Church and Radostits, 1981; Wohlgemuth and Herrick, 1986; Baker et al., 1986). BRD not only threatens the medical health of cattle but also the financial health of the producers who raise them. Morbidity rates as high as 69% and mortality rates as high as 15% have been reported (Kelly and Janzen, 1986). The high incidence of this disease necessitates that feedlot veterinarians and cattlemen must continually rely on the use of antimicrobial agents to deal with BRD. Conventional drug therapy 1) evokes stress on the animal provoking the precarious condition of the animal, 2) requires time and effort, and 3) may require daily applications over a period of three or more days. Because of the time and effort requirements, cattle with minimal symptoms may not be treated promptly intensifying the risk on performance and mortality. Since there is no method to completely protect cattle against BRD, feedlot veterinarians and cattlemen need a convenient delivery system for an antimicrobial that will reduce or eliminate the stress and the time and effort in delivering the antimicrobial to infected animals. These experiments utilized ceftiofur sodium in a delivery system that facilitates therapy and sustains the delivery of the antimicrobial over days. The objective was to determine preliminary efficacy of needle-less ceftiofur sodium implants at a reduced treatment interval and a reduced total dosage in treating calves with BRD.

METHODS AND MATERIALS

Mixed breed beef steer calves that had been shipped through one or more yards were purchased for these experiments. Upon arrival in Canyon, TX, calves were administered ear tags, a pour-on insecticide (Tiguvon®), an anthelmintic (Synanthic®), an anabolic implant (Synovex®S), and vaccines against bovine respiratory syncytial (modified live), parainfluenza$_3$ (modified live), infectious bovine rhinotracheitis virus (modified live), and bovine virus diarrhea (killed) viruses (Horizon® 1+Vac 3) and clostridium chauvoei, septicum, novyi, sordellii, perfringens types C and D, and haemophilus somnus (Vision® 7 Somnus with Spur®), placed in outdoor pens, and observed for signs of BRD. If a calf was suspected of having BRD, 1) it was given an illness score (Table 1, 2) rectal temperature was collected, and 3) body weight was collected. Based on this data, the diagnosis of BRD was confirmed or rejected (Table 1). One hundred and twenty calves were diagnosed with BRD and treated as follows.

Treatment Groups. Experiment 1 included groups 1 and 3 and Experiments 2 and 3 included all four treatment groups.

1. Ceftiofur injections (three doses-days 1, 2, and 3)
2. Ceftiofur implants (three doses-days 1, 2, and 3)
3. Ceftiofur implants (two doses-days 1 and 3)
4. Ceftiofur implants (one dose-day 1)

Experiments 1, 2, and 3 included 10, 5, and 20 calves per group, respectively. Calves assigned to the injection group (group 1) were administered 250 mg of ceftiofur sodium (Naxce® l) at each injection. Calves assigned to the needle-less implant groups (2, 3, and 4) were administered 250 mg of ceftiofur sodium in biodegradable implants. The total quantity of ceftiofur sodium for groups 1, 2, 3, and 4 were 750 mg, 750 mg, 500 mg, and 250 mg, respectively, and differed among groups because of frequency of administration. All treatments were administered intramuscularly in the neck. The day of initial treatment was designated as day 1.

Delivery System and Needle-less Implants. The remote delivery system used operates on the basis of compressed air (DeNicola et al., 1996a). The needle-less implants were delivered at 26,152 cm/second (858 feet/second) producing 3.07 X 10^5 g-cm (22.15 foot-pounds) of kinetic energy (Kesler and Favero, 1989; Jacobson et al., 1995; Willis et al., 1994; DeNicola et al., 1996a). This was accomplished with a fixed regulator attached to the delivery device set at approximately 1100 pounds per square inch (psi). A tank containing compressed air was attached to the regulator. The needle-less implants are capable of being delivered remotely (Kesler and Favero, 1989; Willis et al., 1994; DeNicola et al., 1996a; DeNicola et al., 1996b; DeNicola et al., 1997a; DeNicola et al., 1997b; Jacobsen et al., 1995; Kesler and Favero, 1997; Kesler, 1997; Kesler et al., 1998) and were manufactured from two major components. The outer shell was manufactured from food grade biodegradable and biocompatable food additives (Kesler et al., 1998) and was 0.635 cm in diameter and 2.0 cm long. The second component was the ceftiofur sodium (along with some tableting lubricant and controlled release excipients) and was 0.40 cm in diameter and 1.4 cm long (Kesler, 1993).

It has been demonstrated that upon contact with the skin, the needle-less implant first causes the skin to stretch (Kesler et al., 1998). After stretching, the implant penetrates the skin by producing a slit in the skin. After penetration has occurred, the skin then contracts back to its original form leaving behind a small slit through the skin. The entry slit is shorter than the diameter of the projectile (Swartz et al., 1997). Minimal bleeding occurs after penetration and is followed by scab formation (Kesler and Favero, 1989). The implant does not carry a portion of the animal's hide into the wound. It only leaves a small raised welt on the skin at the point of implant entry (Kesler and Favero, 1989). Upon entry into living tissue the outer shell dissolves within six hours (Kesler, 1997). Kesler et al. (1998) and Swartz et al. (1997) have demonstrated that cortisol concentrations were not significantly increased by administration of the needle-less implants. Further, necropsy of treated animals have revealed that other than damage caused by implant penetration early after administration, the tissue at the administration site was normal (DeNicola et al., 1996a; Swartz et al., 1997).

Experiment 1

These 20 calves with a positive diagnosis of BRD were 213 to 255 kg (238.3 ± 2.6 kg). Since the recommended dose of ceftiofur sodium is 1.1 to 2.2 mg per kg these calves received 1.05 mg per kg ceftiofur sodium (4.6% less than recommended). Calves were administered ceftiofur sodium immediately after positive diagnosis and were processed through the chute for all treatments. Rectal temperature and body weight of the calves were collected on days 1, 2, 3, 4, 5, 6, and 14. Calves were observed daily (for 21 days) for the collection of data described in Table 1. The data were collected by an investigator unaware of which treatments were administered to the calves.

Experiment 2

These 20 calves with a positive diagnosis of BRD were fitted with a jugular catheter and bled. They were then treated and bled 1, 3, 5, 7, 9, 12, 16, and 24 hours after the first treatment. Calves were also bled on the same schedule after the second (groups 1, 2, and 3) and third (groups 1 and 2) treatments. All calves were bled 36, 48, 60, and 72 hours after the first treatment. Blood plasma was harvested from the blood samples within six hours after collection by centrifugation at 2,000 x g. Plasma was stored at - 20°C until assayed for desfuroylceftiofur metabolites.

Desfuroylceftiofur concentrations (the major plasma ceftiofur metabolite; Jaglan et al., 1992) were determined from the blood plasma by the procedure described by Jaglan et al., (1989 and 1990). The procedure determines desfuroylceftiofur metabolites in plasma. The method involves first reducing the metabolites bound to macromolecules (Jaglan et al., 1990). Because desfuroylceftiofur is easily oxidized, it was derivatized with iodoacetamide to stabilize the sulfhydryl group of the molecule. After cleanup using solid-phase extraction techniques, the derivatives were determined via HPLC.

On day one the calves were 164 to 192 kg (177.9 ± 1.8 kg) and received on the average 1.4 mg of ceftiofur sodium per kg of body weight at each treatment which is within the recommended per treatment dose (1.1 to 2.2 mg per kg).

Experiment 3

After diagnosis of BRD 80 calves were randomly assigned to one of the four treatment groups. Calves were 160 to 205 kg (182.7 ± 1.2) and received on the average 1.4 mg of ceftiofur sodium per kg of body weight at each treatment. Calves were administered ceftiofur sodium immediately after

positive diagnosis and were processed through the chute for all treatments. Rectal temperature and body weight of the calves were collected on days 1, 4, 6, 14, and 21. Calves were observed daily (for 21 days) for the collection of data described in Table 1. The data were collected by an investigator unaware of which treatments were administered to the calves.

Experiments 1 and 3

Calves were classified with a positive response or a negative response on the sixth day (Table 1). All negative response calves were then removed from their pen and administered florfenicol (Nuflor®; 3.6 g) on days 6 and 9. If a calf with a positive response appeared abnormal after day 6 and met the same criteria as defined for a positive diagnosis (Table 1), it was diagnosed as a relapse response. Calves with a relapse response were removed from their pens and administered florfenicol (Nuflor®; 3.6 g) at that time and three days later. All mortalities within 30 days after the initial treatment were recorded and calves that died were necropsied for the cause of death.

Analysis. The positive response, relapse response, and mortalities (Experiment 1 and 3) were analyzed by chi-square analysis (Cochran and Cox, 1957). Rectal temperature, illness score, anorexia score, respiratory rate, and nasal discharge score (Experiment 1) were analyzed by split-plot analysis of variance (Gill and Hafs, 1971) as 2 x 2 x 6 factorial designs with response (positive or negative/relapse response), treatment (groups 1 and 3), and time (days 1, 2, 3, 4, 5, and 6) as the main effects. Rectal temperature, illness score, anorexia score, respiratory rate, and nasal discharge score (Experiment 3) were analyzed by split-plot analysis of variance (Gill and Hafs, 1971) as 2 x 4 x 3 factorial designs with response (positive or negative/relapse response), treatment (groups 1, 2, 3, and 4), and time (days 1, 4, and 6) as the main effects. Areas under the blood desfuroylceftiofur response curve were determined mathematically and were analyzed by analysis of variance (Cochran and Cox, 1957). The blood desfuroylceftiofur concentrations were also used to determine the time that blood desfuroylceftiofur concentrations remained above the minimum inhibitory concentration (Robb, 1994).

RESULTS

Although 24 hour post-treatment blood desfuroylceftiofur profiles in calves treated with ceftiofur sodium via injections or needle-less implants were not identical (Fig. 1), area under the curve was not affected ($P > .10$) by method of administration or frequency of administration. The mean peak amplitude of desfuroylceftiofur was greater ($P < .05$) and the mean interval from treatment to peak was less ($P < .05$) in calves administered ceftiofur sodium via injection than implantation. Blood desfuroylceftiofur concentrations remained above the minimum inhibitory concentrations for Pasteurella haemolytica, Pasteurella multocida, and Haemophilus somnus for 24 hours after injection and 72 hours after implantation ($P < .05$).

In Experiment 1 the positive response rate, relapse rate, and mortality rate for groups 1 and 3 were similar ($P > .25$; Table 2). No clinical data were collected from calves in Experiment 2. In Experiment 3, the positive response rate, relapse rate, and mortality rate were similar ($P > .25$; Table 3) for all four groups. In Experiments 1 and 3 combined, 94% of the calves were classified with a positive response. Although, 55 of the calves (59% of the positive response calves) in Experiments 1 and 3 met the same criteria as defined for a positive diagnosis greater than six days after the initial

treatment, this is within the range previously reported for commercial ceftiofur (Smith et al., 1993; Smith et al., 1994a; Smith et al, 1994b) and expected for calves used in this study and administered Naxcel® for BRD (Bechtol, unpublished data).

Five of the calves (6%) in Experiment 3 died 15 to 28 days (21.6 ± 2.6 days) after initiation of the experiment as a result of complications associated with BRD. All calves that died were considered to have responded to treatment by day six; however, they were classified as a relapse response after day six. The mortality rate was within the range previously reported (Smith et al., 1993; Smith et al., 1994a; Smith et al, 1994b) and for cattle used in this study and administered Naxcel® for BRD (Bechtol, unpublished data).

As reported in Tables 2 and 3, mean rectal temperature decreased ($P < .01$) after treatment in both Experiments 1 and 3. In Experiment 1, no other effects or interactions were significant ($P > .25$) and mean rectal temperature decreased similarly. In Experiment 3, the response ($P < .01$) and treatment ($P < .05$) effects and the treatment by response interaction ($P < .05$) were significant. Mean rectal temperature for positive and negative/relapse response calves in groups 1 and 4 were similar; however, they were greater for negative/relapse response calves in groups 2 and 3 than for positive response calves (Experiment 3). Mean rectal temperature for the calves administered more than one ceftiofur sodium treatment decreased more rapidly than for calves administered only one ceftiofur sodium treatment (Experiment 3). After the third injection, mean rectal temperature increased to day 6 which was not apparent in the calves that received ceftiofur implants.

Mean body weight remained constant ($P > .25$) over the first six days in Experiments 1 and 3 regardless of response ($P > .25$) or treatment ($P > .25$) and then increased for the positive response calves. In Experiment 3, all positive response calves gained an average of 23.9 kg (1.2 kg/day) during the 20 days after initial treatment. The changes in mean illness scores, anorexia scores, respiratory rates, and nasal discharge scores were similar to the changes in mean rectal temperature.

DISCUSSION

BRD, also referred to as pneumonia and shipping fever (Fulton, 1987), has a multifactorial etiology involving a complex interaction between stressors and viruses that act separately or together to suppress the defense mechanisms in the lung and predisposes the animal to bacterial pneumonia (Roth, 1987; Confer et al., 1988). Potential causes of immunosuppression, such as environmental, physical, or psychological stress, lead to greater susceptibility to BRD. BRD in cattle is most frequently associated with Pasteurella haemolytica (Confer, 1988); however, Pasteurella multocida and Haemophilus somnus are also isolated in BRD cases (Frank, 1983). Pasteurella haemolytica and Pasteurella multocida are usually sensitive to sulfonamides, penicillin G, ampicillin, amoxicillin, tetracyclines, spectinomycin, tilmicosin, and ceftiofur sodium (Lofgreen, 1988; Hjerpe, 1993; Morock et al., 1993; Baker, 1993; Hansen et al., 1993).

Ceftiofur sodium is approved by the FDA for treatment of BRD (The Upjohn Co., 1988; The Upjohn Co., 1991; Veterinary Medicine Publishing Group, 1997). Similar to our study, other studies have reported a high positive response rate to ceftiofur sodium injections (Smith et al., 1993; Smith et al., 1994a; Smith et al., 1994b). FDA approval of ceftiofur sodium is for daily application three

consecutive days. Additional therapy may be given on days 4 and 5 for animals which do not show a satisfactory response after the initial three treatments (Veterinary Medicine Publishing Group, 1997). Our high relapse response rate, although disappointing, was within the response rate in the literature (Smith et al., 1993; Smith et al., 1994a; Smith et al., 1994b) and typical for cattle purchased from this vendor (Bechtol, unpublished data).

All calves (regardless of method of administration) exceeded the minimum inhibitory concentration for Pasteurella haemolytica, Pasteurella multocida, and Haemophilus somnus by one hour after treatment. The time that blood desfuroylceftiofur concentrations remained above the minimum inhibitory concentration was only 24 hours for the calves administered ceftiofur sodium by injection compared to 72 hours for the calves administered ceftiofur sodium by implantation. This may be why one needle-less implant was as effective in treating BRD as three daily injections although the total dose was lower with the administration of one implant. Reduced stress associated with the delivery of one implant may also facilitate response to treatment as Christie et al. (1977) have demonstrated that glucocorticoids compromise antimicrobial recovery to BRD. One chute handling is less stressful than three daily chute handlings.

All treatment groups had a high relapse response. This may suggest that the duration of time that blood ceftiofur sodium concentrations needed to be elevated above the minimum inhibitory concentration for Pasteurella haemolytica, Pasteurella multocida, and Haemophilus somnus is greater than 72 hours in this situation. Relapse response might have been decreased if ceftiofur sodium injections had been administered for five days or if a second needle-less implant of ceftiofur sodium had been administered on day 4 (72 hours after the first treatment). In addition, it may be prudent to consider other antimicrobials for use in this system.

The needle-less delivery system is convenient for use and evokes minimal or no stress in treated animals (Kesler et al., 1998). Kesler and Favero (1997) reported one of three responses in treated cattle: no response, a kick, or a curious look by the treated animal. Some advantages of needle-less implant delivery as compared to syringe and needle delivery as described by Kesler et al. (1998) follow.

1. Labor and time savings reducing the cost associated with drug therapy.
2. Reduced stress to animals removing the detrimental effects of stress on performance and recovery to drug therapy.
3. Reduction in tissue damage (bruising) or animal injury and/or death in the absence of chute processing.
4. Elimination of needles removes the possibility of broken needles in animals and the need for their disposal.
5. Reduced risk of mis-dosing since there is no diluting and mixing involved.
6. The system ensures no animal-to-animal contact with needles and blood products, therefore the potential spread of disease is significantly reduced.

In summary, it is concluded that the administration of one 250 mg ceftiofur sodium needle-less sustained release implant was as efficacious in treating BRD as three daily injections of 750 mg of ceftiofur sodium. Remote delivery of one needle-less implant would be a convenient, non-stressful

method of providing therapy to calves with bovine respiratory disease. As done in this study, administration of the needle-less implants in the neck would have no effect on high quality cuts of meat (Dexter et al., 1994; George et al., 1995a; George et al., 1995b; George et al., 1996).

LITERATURE CITED

Baker, John C. 1993: Treating BRSV infection. Vet. Med. 88:900-902.

Baker, John C., James F. Evermann, Merwin L. Frey, Sam Hutchins III, Howard Lehmkuhl, Butch Mercer, Richard E. Mock, Leon Potgieter, Auddie Sharp, and Alfonso Torres. 1986: A closer look at bovine respiratory syncytial virus. Vet. Med. 81:947-956.

Christie, B.M., R.E. Pierson, P.M. Braddy, D.E. Flack, D.P. Horton, R. Jensen, E.A. Lee, E.E. Remmenga, and K.G. Rutt. 1977: Efficacy of corticosteroids as supportive therapy for bronchial pneumonia in yearling feedlot cattle. Bovine Pract. 12:115-117.

Church, T.L. and O.M. Radostitis. 1981: A retrospective survey of diseases of feedlot cattle in Alberta. Can. Vet. J. 22:27-30.

Cochran, W.G. and G.M. Cox. 1957: Experimental Designs. John Wiley & Sons, Inc., New York.

Confer, A.W., R.J. Panciera, and D.A. Mosier. 1988: Bovine pneumonic pasteurellosis: immunity to pasteurella haemolytica. J. Am. Vet. Med. Assoc. 193:1308-1316.

DeNicola, A.J., D.J. Kesler, and R.K. Swihart. 1996a: Ballistics of a biobullet delivery system. Wildl. Soc. Bull. 24:301-305.

DeNicola, A.J., R.K. Swihart, and D.J. Kesler. 1996b: The effect of remotely delivered gonadotropin formulations on reproductive function of white-tailed deer. Drug Dev. Ind. Pharm. 22:847-850.

DeNicola, A.J., D.J. Kesler, and R.K. Swihart. 1997a: Dose determination and efficacy of remotely delivered norgestomet implants on contraception of white-tailed deer. Zoo Biol. 16:31-37.

DeNicola, A.J., D.J. Kesler, and R.K. Swihart. 1997b: Remotely delivered prostaglandin $F_{2\alpha}$ implants terminate pregnancy in white-tailed deer. Wildl. Soc. Bull. 25:527-531.

Dexter, D.R., G.L. Cowman, J.B. Morgan, R.P. Clayton, J.D. Tatum, J.N. Sofos, G.R. Schmidt, R.D. Glock, and G.C. Smith. 1994: Incidence of injection-site blemishes in beef top sirloin butts. J. Anim. Sci. 72:824-827.

Frank, G.H. and P.C. Smith. 1983: Prevalence of pasteurella haemolytica in transported calves. Am. J. Vet. Res. 44:981-985.

Fulton, R.W. 1987: Viruses associated with bovine respiratory diseases and infections. Proc. Bovine Respiratory Disease Seminar-Western Veterinary Conf., Vet. Learning Systems, Co., Inc., Lawrenceville, NJ.

George, M.H., R.A. Ames, R.G. Glock, M.T. Smith, J.D. Tatum, K.E. Belk, and G.C. Smith. 1996: Incidence, severity, amount of tissue affected and effect on histology, chemistry and tenderness of injection-site lesions in beef cuts from calves administered a control compound or one of seven chemical compounds. National Cattlemen's Beef Association, Englewood, CO.

George, M.H., P.E. Heinrich, D.R. Dexter, J.B. Morgan, K.G. Odde, R.D. Glock, J.D. Tatum, G.L. Cowman, and G.C. Smith. 1995a: Injection-site lesions in carcasses of cattle receiving injections at branding and at weaning. J. Anim. Sci. 73:3235-3240.

George, M.H., J.B. Morgan, R.D. Glock, J.D. Tatum, G.R. Schmidt, J.N. Sofos, G.L. Cowman, and G.C. Smith. 1995b: Injection-site lesions: incidence, tissue histology, collagen concentration, and muscle tenderness in beef rounds. J. Anim. Sci. 73:3510-3518.

Gill, J.L. and H.D. Hafs. 1971: Analysis of repeated measurements of animals. J. Anim. Sci. 33:331-336.

Hansen, D.E., C.B. Campbell, J.M. Boyle, N. Stefanides, D. Whitsett, and G. Williams. 1993: Comparison of ceftiofur with various antibiotic-sulfadimethoxine combinations for the treatment of undifferentiated bovine respiratory disease. Agri-Practice 14:13-17.

Hjerpe, C.A. 1993: The bovine respiratory disease complex. In: Howard, Jimmy L. (ed.). Current Veterinary Therapy. W.B. Saunders Co., Philadelphia, 3rd ed.

Jacobsen, N.K., D.A. Jessup, and D.J. Kesler. 1995: Contraception of captive black-tailed deer by remotely delivered norgestomet ballistic implants. Wildl. Soc. Bulletin 23:718-722.

Jaglan, P.S., B.L. Cox, T.S. Arnold, M.F. Kubicek, D.J. Stuart, and T.J. Gilbertson. 1990: Liquid chromatographic determination of desfuroylceftiofur metabolite of ceftiofur as residue in cattle plasma. J. Assoc. Off. Anal. Chem. 73:26-30.

Jaglan, P.S., M.F. Fubicek, T.S. Arnold, B.L. Cox, R.H. Robins, D.B. Johnson, and T.L. Gilbertson. 1989: Metabolism of ceftiofur. Nature of urinary and plasma metabolites in rats and cattle. J. Agri. Food Chem. 37:1112-1118.

Jaglan, P.S., F.S. Yein, R.E. Hornish, B.L. Cox, T.S. Arnold, R.D. Roof, and T.J. Gilbertson. 1992: Depletion of intramuscular injected ceftiofur from the milk of dairy cattle. J. Dairy Sci. 75:1870-1876.

Jensen, Rue, R.E. Pierson, P.M. Braddy, D.A. Saari, L.H. Lauerman, J.J. England, H. Keyvanfar, J.R. Collier, D.P. Horton, A.E. McChesney, Abraham Benitez, and R.M. Christie. 1976:

Diseases of yearling feedlot cattle in Colorado, and shipping fever pneumonia in yearling feedlot cattle. J. Am. Vet. Med. Assoc. 169:500-506.

Kelly, A.P. and E.D. Janzen. 1986: A review of morbidity and mortality rates and disease occurrence in North American feedlot cattle. Can. Vet. J. 27:496-500.

Kesler, D.J. 1993: Solid dosage formation and delivery of lyophilized products. In: Tablet Manufacturing, Ed., L. Antosiak, Medical Manufacturing TechSource, Inc., Ann Arbor, MI, pp. 200-223.

Kesler, D.J. 1997: Remotely-delivered contraception in deer with needle-less norgestomet implants. In: Kreeger, Terry J. (ed.). Contraception in Wildlife Management. U.S. Government Printing Office, Washington, D.C., p. 171-184.

Kesler, D.J. and R.J. Favero. 1989: Estrous synchronization and fertility enhancement in cattle with ballistically administered pharmaceutical agents. In: Pearlman, Rodney and J. Allen Miller (eds.). Proceed. Intern. Symp. Controlled Release Bioactive Materials 16:251-252.

Kesler, D.J. and R.J. Favero. 1997: Needle-less implant delivery of gonadotropin releasing hormone enhances the calving rate of beef cows synchronized with norgestomet and estradiol valerate. Drug Dev. Ind. Pharm. 23:607-610.

Kesler, D.J., D.T. Bechtol, and A.J. DeNicola. 1998: Administration of pharmaceuticals and vaccines via remote delivery in biodegradable, needle-less implants. Large Anim. Pract. 19:22-27.

Lofgreen, G.P. 1988: Nutrition and management of stressed beef calves. In: Howard, J.L. (ed.). The Veterinary Clinics of North America, Food Animal Practice. W.B. Saunders, Co., Philadelphia.

Morck, D., J.K. Merrill, B.E. Thorlakson, M.E. Olson, L.V. Tonkinson, and W. Costerton. 1993: Prophylactic efficacy of tilmicosin for bovine respiratory tract disease. J. Am. Vet. Med. Assoc. 202:273-277.

Robb, E. 1994: Plasma disposition of ceftiofur and metabolites after intravenous and intramuscular administration of ceftiofur sodium to calves of various ages. Research Summaries-Am. Assoc. Bovine Pract., p. 5.

Roth, J.A. 1987: Susceptibility to bovine respiratory disease. Proc. Bovine Respiratory Disease Seminar-Western Veterinary Conf., Vet. Learning Systems, Co., Inc., Lawrenceville, NJ.

Smith, R.A., D.R. Gill, and M.T. VanKoevering. 1993: Effects of tilmicosin or ceftiofur on health and performance of stressed stocker cattle. Oklahoma State University Animal Science Research Report P-933:308-311.

Smith, R.A., D.R. Gill, and M.T. VanKoevering. 1994a: A comparison of tilmicosin and ceftiofur for the treatment of bovine respiratory disease. Bovine Pract. 28:35-37.

Smith, R.A., D.R. Gill, and M.T. VanKoevering. 1994b: Effects of tilmicosin and ceftiofur on health and performance of stocker calves. J. Anim. Sci. 72(Suppl. 1):105 (Abstr.).

Swartz, J.A., R.J. Warren, D.A. Osborn, D.W. Henderson, and D.J. Kesler. 1997: Captive and field tests of a method for immobilization and euthanasia of urban deer. Wildl. Soc. Bull. 25:532-541.

The Upjohn Co. 1988: Naxcel sterile powder for injection (ceftiofur sodium) for treatment of bovine respiratory disease. Freedom of Information Summary (NADA 140-338). The Upjohn Co., Kalamazoo, MI.

The Upjohn Co. 1991: The first-choice solution for shipping fever. The Upjohn Co., Kalamazoo, MI.

Thomson, R.G. 1980: A perspective on respiratory disease in feedlot cattle. Can. Vet. J. 21:181-182.

Veterinary Medicine Publishing Group. 1997: Veterinary Pharmaceuticals and Biologicals. Veterinary Medicine Publishing Co., Lenexa, KS.

Willis, P., G.L. Heusner, R.J. Warren, D. Kesler, and R.A. Fayrer-Hosken. 1994: Equine immunocontraception using porcine zona pellucida: a new method for remote delivery and characterization of the immune response. J. Equine Vet. Sci. 14:364370.

Wohlgemuth, K. and J.B. Herrick. 1986: Bovine respiratory disease complex. Animal Health & Nutrition 41:26-28.

Table 1. Definitions used to classify bovine respiratory disease (BRD) and monitor recovery after treatment

Positive Diagnosis of BRD:

1. Rectal Temperature ≥ 40°C
2. Respiratory Index = 1
   0 = normal
   1 = shallow or labored with moderate to excessive coughing
3. Depression Index ≥ 1
   0 = normal-bright, alert and responsive
   1 = mild-head down but responsive to stimulation
   2 = moderate-head down, still evident after stimulation
   3 = severe-reluctant to rise, head down, dull eyes

Illness Recovery Indicators Monitored:

1. Rectal Temperature
2. Illness Score-the sum of the respiratory and depression indexes
3. Anorexia
   0 = Normal-full feed.
   1 = Mild anorexia (eating but not filled).
   2 = Severe anorexia (not eating).
4. Respiratory Rate
   0 = < 45 breaths/minute
   1 = ≥ 45 breaths/minute but ≤ 75 breaths/minute
   2 = ≥ 75 breaths/minute
5. Nasal Discharge
   0 = none
   1 = excessive, serous
   2 = copious, mucopurulent

Negative Response to Treatment and Relapses with BRD:

1. Negative Response-calves with the following criteria 6 days post-treatment.
   a. Rectal temperature ≥ 40°C
   b. Illness score ≥ illness score on day 1 and administered alternative medication.
2. Relapses-positive response calves with the following criteria > 6 days post-treatment.
   a. Rectal temperature ≥ 40°C
   b. Illness score ≥ illness score on day 1 and administered alternative medication.

Table 2. Response of calves with bovine respiratory disease (BRD) administered ceftiofur sodium via conventional injection or needle-less implants

		Treatment Group[a]	
		1	3
Positive Response[b]	(n)	9/10	9/10
	(%)	90%	90%
Relapses[b]	(n)	5/ 9	4/ 9
	(%)	56%	44%
Mortalities[b]	(n)	0/10	0/10
	(%)	0%	0%
Temperature (°C):	day 1	41.1 ± .2	41.0 ± .2
	day 6	39.8 ± .1	39.6 ± .1
	day 14	40.1 ± .1	39.9 ± .1
Illness Score:	day 1	3.3 ± .2	3.2 ± .1
	day 6	1.6 ± .3	1.3 ± .3
	day 14	1.2 ± .4	.9 ± .4
Body Weight (kg):	day 1	238.4 ± 3.0	238.1 ± 4.4
	day 6	240.8 ± 3.7	235.6 ± 4.9
	day 14	246.2 ± 2.0	245.7 ± 5.5

[a]Treatments were as follows.

1-ceftiofur sodium injections (three doses-days 1, 2, and 3).

3-ceftiofur sodium needle-less implants (two doses-days 1 and 3).

[b]See text for definitions.

Table 3. Response of calves with bovine respiratory disease (BRD) to ceftiofur sodium treatment administered via conventional injection or needle-less implants

		Treatment Group[a]			
		1	2	3	4
Positive Response[b]	(n)	20/20	20/20	18/20	18/20
	(%)	100%	100%	90%	90%
Relapses[b]	(n)	12/20	12/20	13/18	9/18
	(%)	60%	60%	72%	50%
Mortalities[c]	(n)	1/20	2/20	2/20	0/20
	(%)	5%	10%	10%	0%
Temperature (°C):	day 1	40.8± .1	40.9± .1	40.9± .1	40.8± .1
	day 6	39.7± .2	39.8± .1	39.8± .1	40.0± .1
Illness Score:	day 1	3.1± .1	3.1± .1	3.3± .1	3.1± .1
	day 6	1.4± .2	1.2± .2	1.6± .2	1.6± .2
Body Weight (kg):	day 1	183.7±2.0	182.2±2.5	181.3±3.3	183.5±2.3
	day 6	186.2±2.9	186.3±3.1	180.8±3.1	184.8±2.5

[a]Treatments were as follows.

1-ceftiofur sodium injections (three doses-days 1, 2, and 3).

2-ceftiofur sodium needle-less implants (three doses-days 1, 2, and 3).

3-ceftiofur sodium needle-less implants (two doses-days 1 and 3).

4-ceftiofur sodium needle-less implants (one dose-day 1).

[b]See text for definitions.

[c]Mortalities occurred 15 to 28 days (21.6 ± 2.6 days) after the initial treatment.

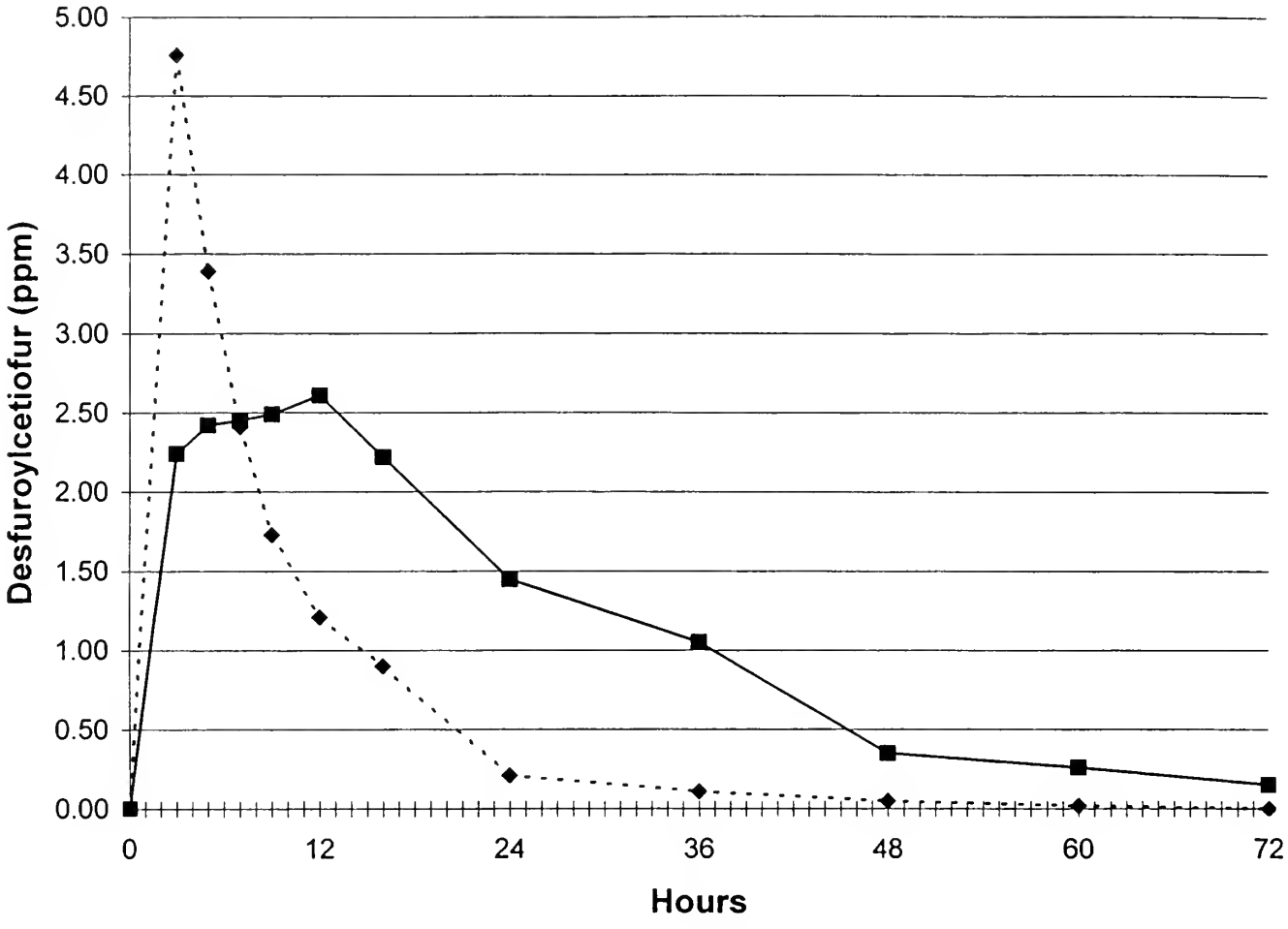

Figure 1. Mean desfuroylceftiofur concentrations in calves treated with ceftiofur sodium via injections (diamonds) or needle-less implants (squares; Experiment 2).

GONADORELIN-INDUCED TESTOSTERONE RELEASE: A BIOLOGICAL ASSAY FOR QUALITY ASSURANCE OF GONADORELIN

D. J. Kesler, R. N Summers, C. A. Peterson, and T. L. Steckler

SUMMARY

Two experiments were conducted with bulls administered norgestomet and gonadorelin to determine if the gonadorelin-induced release of testosterone could be developed into a biological assay for quality assurance of gonadorelin. Implants containing norgestomet (0 to 36 mg) reduced the episodic release ($r=-.81$; $P < .05$) and mean concentrations of testosterone ($r=-.82$; $P < .05$). Gonadorelin-induced testosterone release increased ($r=.99$; $P < .05$) with increasing dosage of gonadorelin up to 5 µg in norgestomet implanted bulls (36 mg). Maximal testosterone was released (> six fold increase) with 5 to 40 µg of gonadorelin. In summary, the gonadorelin-induced testosterone release in bulls administered a synthetic progestin is a sensitive (.008 µg per kg body weight for 5 µg of gonadorelin) biological assay with a rapid turnaround time for the confirmation of gonadorelin potency. Based on a per kg body weight basis, the norgestomet treated bull is the most sensitive biological assay model.

INTRODUCTION

The first therapeutic use for gonadorelin in veterinary medicine, treatment of ovarian follicular cysts in dairy cattle, was reported in 1975; three years before the Nobel prize was awarded to the two scientists that chemically identified it (Guillemin, 1978; Schally, 1978). Gonadorelin is the hypothalamic releasing factor responsible for the release of gonadotropins (luteinizing hormone [LH] and follicle stimulating hormone [FSH]) from the anterior pituitary. The gonadorelin-induced LH release causes luteinization of ovarian follicular cysts and recovery in about 18 to 24 days (Kesler et al., 1981; Kesler and Garverick, 1982; Kesler, 1997). Gonadorelin has been marketed for more than two decades and is subjected to numerous quality control tests, including biological analysis, before and after manufacturing. Although numerous biological assays have been identified, all are time consuming and expensive. Although it has been well known that the gonadorelin-induced LH surge stimulates a significant release of testosterone (Zolman and Convey, 1973: Mongkonpunya et al., 1975; Golter et al., 1973), it has not been used as a bioassay because the pretreatment episodic variability of testosterone concentrations diminishes efficacy. The objective of these experiments was to determine if the gonadorelin-induced release of testosterone could be developed into a biological assay for quality assurance of gonadorelin after synthesis and/or manufacturing.

MATERIALS AND METHODS

Six beef bulls one to two years of age, weighing 644.0 ± 9.3 kg, were included in two experiments. In the first experiment, on day 0 all bulls were bled hourly for four hours. After the last blood collection, bulls were implanted with norgestomet implants containing 6, 12, 18, 24, 30, or 36 mg. The implants were matrix-type silicone implants and were .36 cm in diameter and were 1.2 cm long for each 6 mg of norgestomet. Two days after implantation the bulls were bled hourly for four hours and implants were then removed. Bulls were treated in four cycles and each cycle was initiated every seven days. Hourly bleeding on day 0 was only done on the first cycle. Bulls were assigned to

treatment groups so that they were used only once for each dose. In the second experiment the bulls were implanted with implants containing 36 g norgestomet (each .36 cm x 3.6 cm). Two days after implantation the bulls were administered 0, 1, 5, 10, 20, or 40 μg of gonadorelin (Cystorelin; Merial, Inc., Athens, GA). Blood was collected two hours after gonadorelin treatment. As in the first experiment, bulls were treated in four cycles and each cycle was initiated every seven days. Bulls were assigned to treatment groups so that they were used only once for each dose.

Blood was collected via jugular venipuncture into syringes using 18 g needles 3.81 cm long. After collection, the blood was immediately placed in an ice water bath and was held there until centrifugation which was done within six hours after collection. Serum was harvested by centrifugation at 2,000 x g for 15 minutes at 4°C. Serum samples were individually stored in 1 mL vials at -20°C until assayed. Testosterone concentrations were determined by a validated ELISA (Kesler et al., 1990). Data were analyzed by analysis of variance and linear regression (Steel and Torrie, 1960).

RESULTS

Before implantation in Experiment 1, testosterone concentrations averaged 5.09 ng/mL and were similar to concentrations previously reported for bulls of similar age (Smith et al., 1973; Mongkonpunya et al., 1975; Sitarz et al., 1977; Golter et al., 1973). Because testosterone is released episodically, pretreatment concentrations were variable (standard deviation = 3.21). Mean testosterone concentrations in bulls implanted with norgestomet implants decreased with increasing dose of norgestomet ($r=-.82$; $P < .05$) (Figure 1). Variability in testosterone concentrations decreased with increasing dose of norgestomet ($r=-.81$; $P < .05$) and as mean testosterone concentrations decreased ($r=-.97$; $P < .01$). Figure 2 illustrates the episodic release of testosterone in bulls implanted with implants containing 6 or 36 mg of norgestomet. Although the magnitude of the testosterone concentrations was reduced, testosterone was still released episodically.

In Experiment 2, testosterone concentrations in bulls administered implants containing 36 mg norgestomet were similar to concentrations in Experiment 1. Increasing the dose of gonadorelin to 5 μg increased testosterone release ($r=.99$; $P < .05$; Figure 3). One μg of gonadorelin increased ($P < .05$) testosterone concentrations two hours later (as compared to 0 μg). Five μg of gonadorelin induced a greater ($P < .05$) testosterone release than 0 or 1 μg of gonadorelin, but the 5 μg induced release was similar ($P > .10$) to the 10-40 μg releases. Based on these data, 5 (.008 μg/kg body weight) to 40 μg of gonadorelin-induced maximal testosterone releases. Five to 40 μg of gonadorelin increased testosterone by more than six fold over basal concentrations in norgestomet treated bulls.

DISCUSSION

Gonadorelin has been used with high consistency in effecting a cure for ovarian follicular cysts. All published studies that utilized 100 μg of the gonadorelin Cystorelin are included in Table 1, and illustrate that efficacy of gonadorelin for the treatment of ovarian follicular cysts has not waned. The efficacy of gonadorelin since 1979 has been equal to or greater than the mean efficacy ± one standard deviation for studies conducted before 1980. This degree of assurance must be maintained.

Numerous bioassays for gonadorelin exist as follows, but only the rabbit ovulation bioassay has been validated for quality assurance of gonadorelin.

- Rabbit Ovulation-This bioassay involves the administration of gonadorelin to female rabbits. Twenty-four hours after administration via the marginal ear vein, the rabbits are euthanized and ovaries examined for evidence of ovulation. The rabbit is an excellent biological model for the evaluation of gonadotropins, and their releasing hormones (gonadorelin), because rabbits are induced ovulators (ovulation only occurs after copulation or gonadotropin stimulation). Studies in estrus have demonstrated that the ED_{100} (100% effective dose in inducing ovulation) is 0.5 μg (Reel et al., 1976), 1.0 μg (Amoss et al., 1972; Reel et al., 1976), and 2.5 μg (Humphrey et al., 1973) as summarized in Table 2. The rabbit is a seasonal breeder and is suited for biological evaluation only when the rabbits are in estrus. Ovarian follicles capable of ovulating may not be present at certain times of the year, and LH or its releasing hormone (gonadorelin) will not induce ovulation. The variability observed by Humphrey et al. (1973) may be due to seasonality and/or may be due to variability of the bioassay.

- LH Release-This involves the sampling of LH after gonadorelin treatment. Many species may be used for this bioassay; however, the species that the intended veterinary product is to be used in is most appropriate. Since this is the mechanism of action for gonadorelin in effecting a cure in cows with ovarian cysts it may appear to be a logical biological evaluation (Kesler, 1997). However, although LH is released in a dose dependent manner in the cow, it is not highly sensitive (overlap exists between doses) (Cantley et al., 1975; Seguin et al., 1976). Furthermore, the quantity of LH released is not correlated to the efficacy of gonadorelin (Kesler et al., 1979).

- Progesterone Release-This involves the sampling of progesterone after gonadorelin in heifers or cows with corpora lutea. Many species may also be used for this bioassay; however, again the species that the intended veterinary product is to be used in is most appropriate. Although the gonadorelin-induced LH release stimulates a release of progesterone in the cow, the progesterone response is minimal (Seguin et al., 1977). The minimal response does not allow for sensitive biological evaluation for quality assurance purposes.

- Bovine Ovulation-This bioassay involves the administration of gonadorelin to heifers or cows 5 to 8 days after estrus and ovulation is monitored via transrectal ultrasonography two days later. Ovulation response, however, is less than 100% and is reduced if administered on other days of the estrous cycle (Pursley et al., 1995; Kesler, 1997; Vasconcelos et al., 1997).

- Hamster Ovulation-This bioassay involves the administration of phenobarbital to golden hamsters exhibiting estrous cycles (Humphrey et al., 1973). The ovulation block induced by phenobarbital may be overcome by gonadorelin treatment. Although this bioassay is extremely sensitivity, phenobarbital (a controlled substance) must be administered on the day of proestrus followed by gonadorelin treatment 2 to 3 hours later. Ovulation is determined the next day upon euthanasia of the hamsters.

Results herein demonstrate that the gonadorelin-induced testosterone release may be used as a sensitive bioassay for gonadorelin. Pretreatment episodic variability of testosterone concentrations may be suppressed with norgestomet implants as demonstrated with melengestrol acetate, another synthetic progestin (Haynes et al., 1977). This is an important aspect because the variability reduces the efficacy of the assay. Based on a per kg body weight basis, the gonadorelin-induced testosterone release was the most sensitive biological assay. The most sensitive laboratory animal bioassay was the hamster ovulation bioassay (.110 μg per kg body weight). Other advantages of this biological assay include: bulls are not affected by season, no barbituates are used, and bulls may be retained for production purposes after evaluation. Although the hamster ovulation bioassay is more sensitive on a per animal basis, it is a more time consuming assay (two days vs less than five hours).

Furthermore, this is the first report demonstrating the high sensitivity of the bovine testis in releasing testosterone in response to gonadorelin (Zolman and Convey, 1973: Mongkonpunya et al., 1975; Kesler and Garverick, 1977; Golter et al., 1973). Without norgestomet treatment, most studies have used 40 μg or more of gonadorelin. Therefore, acute exogenous progestin therapy appears to reduce episodic release of testosterone, but does not abolish testosterone synthesis.

CONCLUSION

Gonadorelin-induced testosterone release is a sensitive and economical assay with rapid turnaround time for the determination of gonadorelin potency. This bioassay may be developed to insure that non-biologically active material is not marketed, consumers are receiving the dosage of gonadorelin that was established as efficacious for treating dairy cattle with ovarian follicular cysts, and gonadorelin will continue to remain consistent in effecting a cure in dairy cows with ovarian follicular cysts as it has for the past two decades.

LITERATURE CITED

Abbott Laboratories, Inc., Cystorelin, Abbott Laboratories, Inc., North Chicago, IL, 10 pp (1976).

Amoss, M., R. Blackwell, and R. Guillemin, Stimulation of ovulation in the rabbit triggered by synthetic LRF, J. Clin. Endocrinol., 34, 434-436 (1972).

Bierschwal, C.J., H.A. Garverick, C.E. Martin, R.S. Youngquist, T.C. Cantley, and M.D. Brown, Clinical response of dairy cows with ovarian cysts to GnRH, J. Anim. Sci. 41, 1660-1665 (1975).

Cantley, T.C., H.A. Garverick, C.J. Bierschwal, C.E. Martin, and R.S. Youngquist, Hormonal responses of dairy cows with ovarian cysts to GnRH, J. Anim. Sci., 41, 1666-1673 (1975).

Dinsmore, R.P, M.E. White, and P.B. English, An evaluation of simultaneous GnRH and cloprostenol treatment of dairy cattle with cystic ovaries, Can. Vet. J., 31, 280- 284 (1990).

Dinsmore, R.P, M.E. White, C.L. Guard, D.J. Jasko, J.A. Perdrizet, P.M. Powers, and M.C. Smith, A randomized double blind clinical trial of two GnRH analogs for the treatment of cystic ovaries in diary cows, Cornell Vet., 77, 235-243 (1987).

Elmore, R.G., C.J. Bierschwal, R.S. Youngquist, T.C. Cantley, D.J. Kesler, and H.A. Garverick, Clinical response of dairy cows with ovarian cysts after treatment with 10,000 IU HCG or 100 mcg GnRH, Vet. Med./Sm. Anim. Clin., 70, 1346-1349 (1975).

Garverick, H.A., D.J. Kesler, T.C. Cantley, R.G. Elmore, R.S. Younquist, C.J. Bierschwal, Hormone response of dairy cows with ovarian cysts after treatment with HCG or gonadotropin-releasing hormone, Theriogenology, 6, 413-425 (1976).

Golter, T.D., J.J. Reeves, C.C. O'Mary, A. Arimura, and A.V. Schally, Serum LH levels in bulls treated with synthetic luteinizing hormone-releasing hormone/follicle stimulating hormone-releasing hormone (LH-RH/FSH-RH), J. Anim. Sci., 37, 123-127 (1973).

Guillemin, R., Peptides in the brain: the new endocrinology of the neuron, Science, 202, 390-402 (1978).

Haynes, N.B., T.E. Kiser, H.D. Hafs, and J.D. Marks, Prostaglandin $F_{2\alpha}$ overcomes blockade of episodic LH secretion with testosterone, melengestrol acetate or aspirin in bulls, Biol. Reprod., 17, 723-728 (1977).

Humphrey, R.R., W.C. Dermody, H.O. Brink, F.G. Bousley, N.H. Schottin, R. Sakowski, J.W. Vaitkus, H.T. Veloso, and J.R. Reel, Induction of luteinizing hormone (LH) release and ovulation in rats, hamsters, and rabbits by synthetic luteinizing hormone-releasing factor (LRF), Endocrinol. 92, 1515-1526 (1973).

Kesler, D.J., Therapeutic uses of gonadotropin-releasing hormone. Comp. Cont. Educ. Pract. Vet., 19(Suppl. 1), 1-9 (1997).

Kesler, D.J., R.G. Elmore, E.M. Brown, and H.A. Garverick, Gonadotropin releasing hormone treatment of dairy cows with ovarian cysts. I. Gross ovarian morphology and endocrinology, Theriogenology, 16, 207-217 (1981).

Kesler, D.J. and H.A. Garverick, Luteinizing hormone and testosterone concentrations in plasma of bull calves treated with gonadotropin releasing hormone, J. Dairy Sci., 60, 632-634 (1977).

Kesler, D.J. and H.A. Garverick, Ovarian cysts in dairy cattle: a review, J. Anim. Sci., 55, 1147-1159 (1982).

Kesler, D.J., H.A. Garverick, A.B. Caudle, C.J. Bierschwal, R.G. Elmore, and R.S. Youngquist, Clinical and endocrine responses of dairy cows with ovarian cysts to GnRH and $PGF_{2\alpha}$, J. Anim. Sci., 46, 719-725 (1978).

Kesler, D.J., H.A. Garverick, R.G. Elmore, R.S. Youngquist, and C.J. Bierschwal, Reproductive hormones associated with the ovarian cyst response to GnRH, Theriogenology, 12, 109-114 (1979).

Kesler, D.J., H. Khazali, and R.J. Favero, Quantification of steroids via a polymer linked second antibody enzyme immunoassay system: methods of linking anti-rabbit IgG to polystyrene, In: Progress in Biomedical Polymers, Ed., C.G. Gebelein and R.L. Dunn, Plenum Publishing Co., New York, NY, p. 157-170 (1990).

Mongkonpunya, K., H.D. Hafs, E.M. Convey, H.A. Tucker, and W.D. Oxender, Serum luteinizing hormone, testosterone and androstenedione in pubertal and prepubertal bulls after gonadotropin releasing hormone, J. Anim. Sci., 40, 682-686 (1975).

Pursley, J.R., M.O. Mee, and M.C. Wiltbank, Synchronization of ovulation in dairy cows using $PGF_{2\alpha}$ and GnRH, Theriogenology, 44, 915-923 (1995).

Reel, J.R., Luteinizing hormone-releasing hormone versus human chorionic gonadotropin: differential effect on the development of ovulatory refractoriness and antibodies, Fertil. Steril., 27, 59-64 (1976).

Schally, A.V., Aspects of hypothalamic regulation of the pituitary gland, Science, 202, 18-28 (1978).

Seguin, B.E., E.M. Convey, and W.D. Oxender, Effect of gonadotropin-releasing hormone and human chorionic gonadotropin on cows with ovarian follicular cysts, Am. J. Vet. Res., 37, 153-157 (1976).

Seguin, B.E., W.D. Oxender, and J.H. Britt, Effect of human chorionic gonadotropin and gonadotropin-releasing hormone on corpus luteum function and estrous cycle duration in dairy heifers, Am. J. Vet. Res., 38, 1153-1156 (1977).

Sitarz, N.E., R.E. Erb, T.G. Martin, and P.V. Malven, Effect of repeated sampling on concentrations of testosterone, LH and prolactin in blood of yearling Angus bulls, Theriogenology, 7, 151-158 (1977).

Smith, O.W., K. Mongkonpunya, H.D. Hafs, E.M. Convey, and W.D. Oxender, Blood serum testosterone after sexual preparation or ejaculation, or after injections of LH or prolactin in bulls, J. Anim. Sci., 37, 979-984 (1973).

Steel, R.G.D. and J.H. Torrie., Principles and Procedures and Statistics, McGraw-Hill Book Co., New York, NY (1960).

Vasconcelos, J.L.M., R.W. Silcox, J.R. Pursley, and M.C. Wiltbank, Effect of day of estrous cycle on synchronization of ovulation using GnRH, J. Anim. Sci. 75(Suppl. 1), 89 (1997).

Vasquez, L.A., H.L. Whitmore, B.O. Brodie, D.J. Kesler, and M.D. Brown, Comparison of GnRH treatment and manual rupture of ovarian cysts in dairy cattle, Proc. 10th Int. Cong. Anim. Reprod. AI, p. 476 (1984).

Whitmore, H.L., J.P. Hurtgen, E.C. Mather, and B.E. Seguin, Clinical response of dairy cattle ovarian cysts to single or repeated treatments of gonadotropin-releasing hormone, J. Am. Vet. Med. Assoc., 174, 1113-1119 (1979).

Zolman, J. and E.M. Convey, GnRH: effect on serum FSH and androgens in bulls, J. Anim. Sci., 37, 334 (Abstr.) (1973).

Table 1. Response of dairy cows treated with 100 μg of gonadorelin

Research Report	Cows with Positive Response/Cows Treated	% Positive Response
Bierschwal et al. (1975)	23/ 28	82%
Elmore et al. (1975)	34/ 43	79%
Garverick et al. (1976)	8/ 10	80%
Abbott Laboratories, Inc. (1976)	38/ 58	66%
Abbott Laboratories, Inc. (1976)	14/ 20	70%
Abbott Laboratories, Inc. (1976)	26/ 41	63%
Kesler et al. (1978)	6/ 8	75%
Kesler et al. (1979)	14/ 18	78%
Whitmore et al. (1979)	170/225	76%
Vasquez et al. (1984)	11/ 11	100%
Dinsmore et al. (1987)	108/127	85%
Dinsmore et al. (1990)	23/ 32	72%
Combined	475/621	77%

Table 2. Gonadorelin-induced ovulation in rabbits

Dosage (µg)	Amoss et al. 1972	Humphrey et al. 1973	Reel et al. 1976
0	0%	0%	0%
0.1	0%	----[a]	33%
0.5	----[a]	----[a]	100%[b]
1.0	100%[c]	60%	100%
2.5	----[a]	100%[d]	----[a]
5.0	----[a]	100%	----[a]
10.0	100%	100%	----[a]

[a]Dose was not included in the study.
[b].176 µg/kg body weight.
[c].352 µg/kg body weight.
[d].880 µg/kg body weight.

Table 3. Gonadorelin-induced ovulation in hamsters administered phenobarbital (Humphrey et al., 1973)

Dosage (µg)	Ovulation Response (%)
0	0/20 (0%)
0.001	0/10 (0%)
0.005	6/10 (60%)
0.01[a]	6/ 6 (100%)
0.05	5/ 5 (100%)

[a].110 µg/kg body weight.

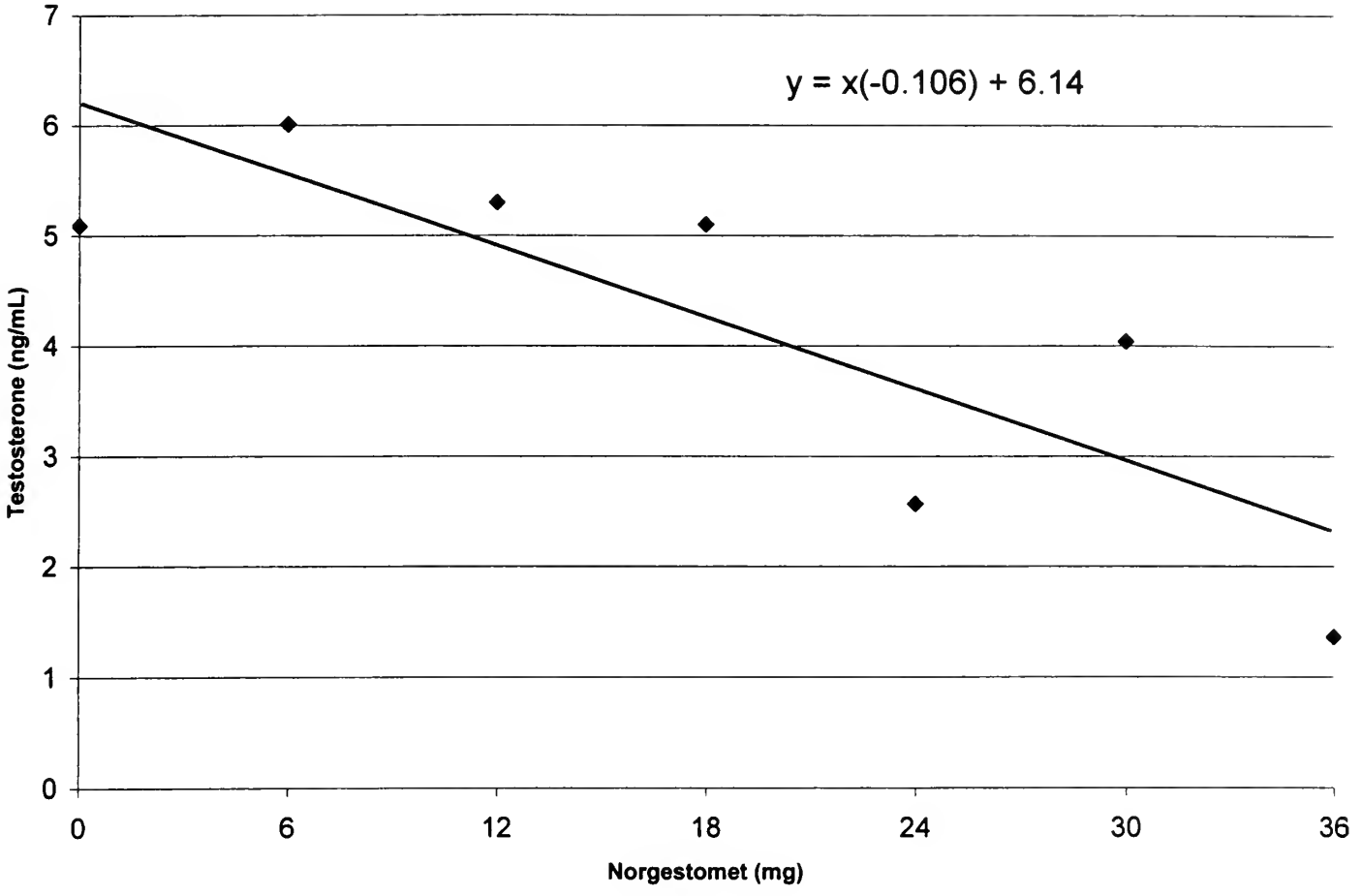

Figure 1. Mean testosterone concentrations (ng/mL) in bull administered implants containing 0-36 mg of norgestomet. Mean testosterone concentrations were correlated (r=-.82) to dose of norgestomet administered.

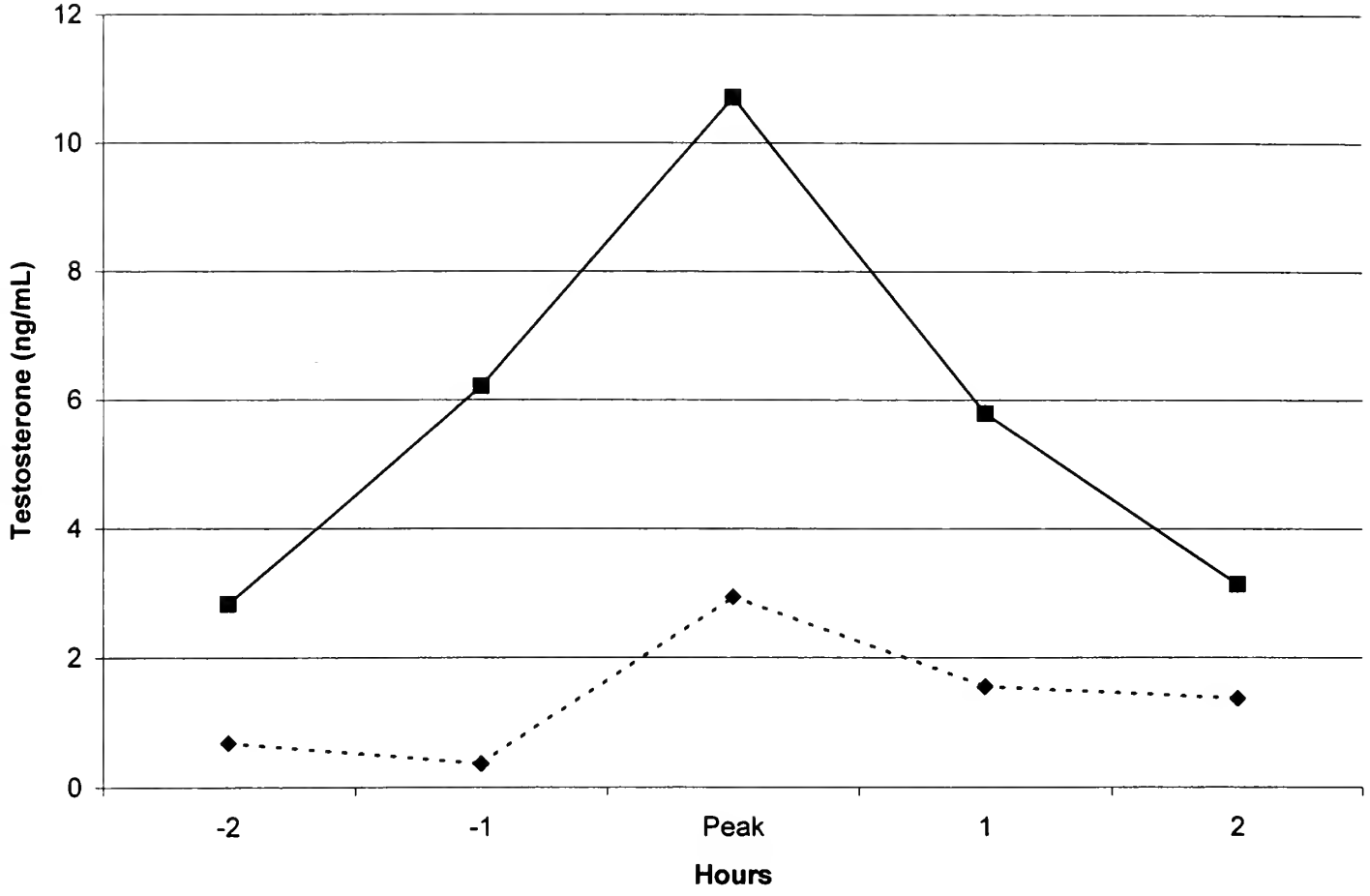

Figure 2. Mean testosterone concentrations (ng/mL) in bulls administered implants containing 6 mg (solid line) or 36 mg (broken line) of norgestomet. Testosterone concentrations are arranged around the peak (highest concentration during the four hour sampling period).

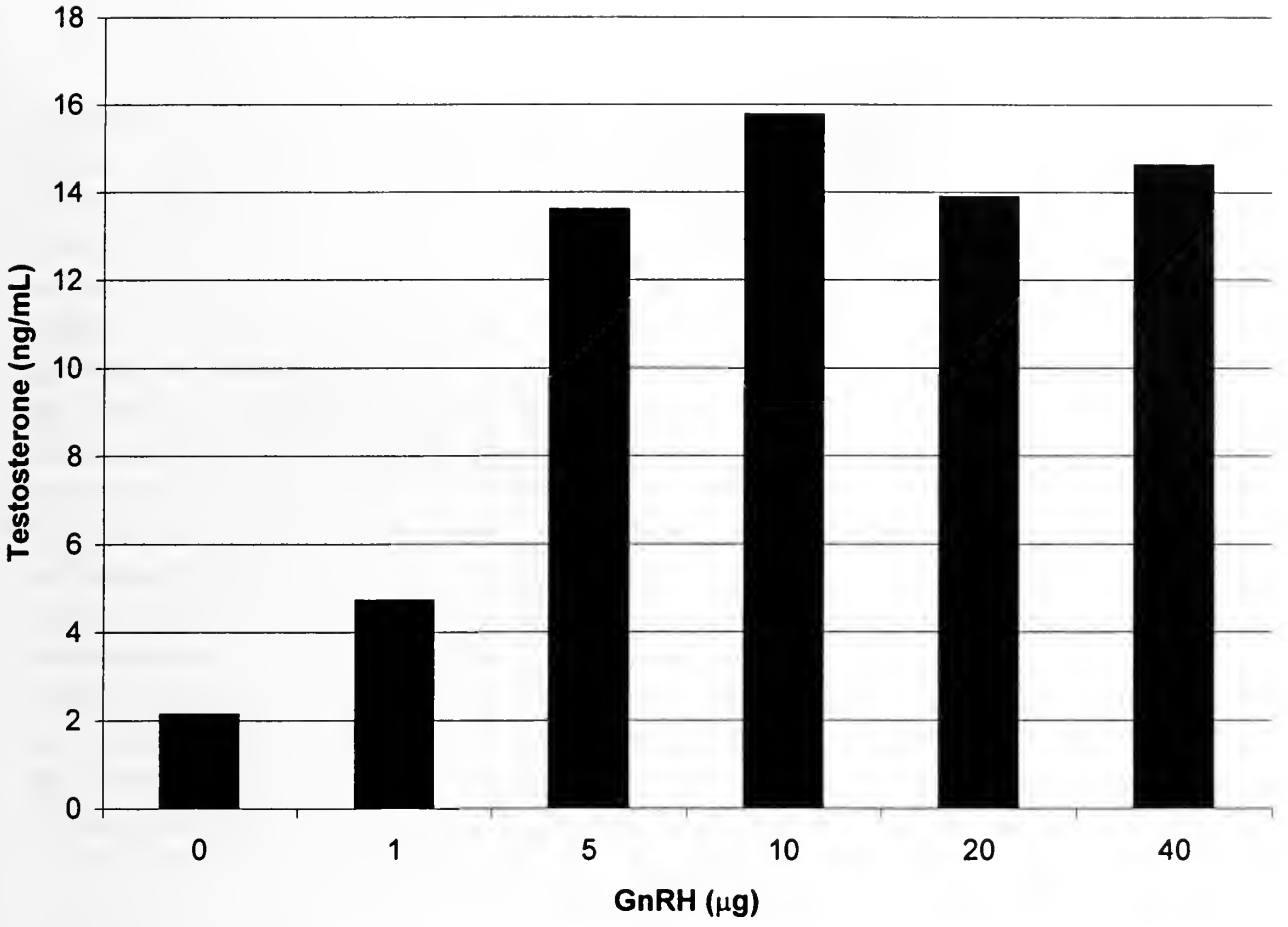

Figure 3. Mean testosterone concentrations (ng/mL) in norgestomet (36 mg) treated bulls two hours after the administration of 0 to 40 µg gonadorelin.

ADMINISTRATION OF PHARMACEUTICALS AND VACCINES VIA REMOTE DELIVERY IN BIODEGRADABLE, NEEDLE-LESS IMPLANTS

D. J. Kesler, D. T. Bechtol, and A. J. DeNicola

SUMMARY

Five experiments were conducted to characterize animal and tissue responses to needle-less implant administration. In Experiment 1, 3 heifers were administered needle-less implants 12, 24, and 36 hours before euthanasia. Slits in the skin smaller than the diameter of the implants, subcutaneous hemorrhaging, and penetration tracts in the muscle were observed at necropsy. However, no portion of the skin, foreign material, or intact portions of the needle-less implants were detected in the musculature at any time after administration. In Experiment 2, 514 beef cows, beef heifers, and dairy heifers administered needle-less implants in the front leg musculature had scab formation or swelling .84 ± .06 cm in diameter two days after treatment but swelling was gone 30 days after treatment. In Experiment 3, only one of five heifers treated with needle-less implants 32 days earlier had a discernable tissue blemish-a .2 x 1.0 cm scar containing connective and adipose tissues. In Experiment 4, 6 white-tailed deer were remotely delivered needle-less implants from concealed positions. Twenty minutes later they and eight control deer were killed instantly using a high-powered rifle shot to the head. Cardiac blood cortisol concentrations (4.0 ± .5 and 5.0 ± .9 ng/mL for control and treated deer, respectively) were similar ($P > .25$). In Experiment 5, four cannulated heifers were administered needle-less implants or injections of saline in a replicated Latin-square design. After treatment, blood cortisol concentrations increased similarly ($P > .25$) to mean maximum concentrations of 9.1 and 10.2 ng/mL (needle-less implant and injected heifers, respectively) 10 to 20 minutes after treatment. In summary, needle-less implants effectively penetrated tissues with minimal stress caused upon the treated animals and dissolved quickly within the tissues.

INTRODUCTION

Administration of pharmaceuticals and vaccines using traditional methods is laborious and requires animal restraint to be accomplished. There is risk of injury, stress compromises recovery rates, and normal physiological processes can be altered. Researchers have demonstrated that stress associated with transport or venipuncture affects the preovulatory luteinizing hormone (LH) surge (Nanda et al., 1989) and suppresses fertility (Hixon et al., 1981; Kesler and Favero, 1996) in cattle. Also, glucocorticoids, which are released upon processing and injecting animals, compromise the recovery of cattle with bovine respiratory disease to antimicrobial therapy (Christie et al., 1977).

A new delivery system utilizing needle-less implants has been developed that allows remote delivery of substances via implantation. The purpose of this paper is to describe the delivery system, characterize tissue penetration and response, and quantify the stress levels of animals administered needle-less implants. Other needle-less implant delivery systems, including the BallistiVet system, have been developed but differ from the system described in this article. Results presented in this article are only relevant for this delivery system and not others. Furthermore, results of other delivery systems are not necessary relevant to the system described herein.

MATERIALS AND METHODS

Delivery System. A remote delivery system used operates on the basis of compressed air (DeNicola et al., 1996a). The delivery system included an adjustable regulator and tank containing compressed air. For all experiments conducted herein, needle-less implants were administered at a distance of 3-6 m from the animals.

Needle-less Implants. The needle-less implants were delivered remotely (Kesler and Favero, 1989; Willis et al., 1994; Jacobsen et al., 1995; DeNicola et al., 1996a; DeNicola et al., 1996b; Kesler, 1996; DeNicola et al., 1997a; DeNicola et al., 1997b; Kesler and Favero, 1997) and were manufactured from two major components. First, they were composed of the outer shell which was manufactured from food grade biodegradable and biocompatable food additives (U.S. Government, 1993). The outer biodegradable shell was 0.635 cm in diameter and 2.0 cm long. The second component consists of the active material (along with some tableting lubricant and controlled release excipients) in the form of a compressed tablet (Kesler, 1993) and was approximately 0.40 cm in diameter and 1.4 cm long. No active material was included in needle-less implants used in these experiments.

Experiment 1

Three beef calves were administered three needle-less implants each into the lower rear leg musculature with a pressure setting of 1,100 to 1,300 psi. Implants were administered at 12 hour intervals for two days in a row. Twelve hours after the last implantation, the calves were euthanized via the captive-bolt method. After euthanasia, the skin was manually pulled from the carcass in a posterior to anterior manner. Administration sites were observed and reactions, noted by discoloration and/or texture of the tissue, that remained on the carcasses were recorded. The tissues underneath the implant penetration sites were dissected in order to identify the final position of the implant. Upon identification of the final position of the implant, gross observations were made of the surrounding tissue.

Experiment 2

Five hundred and fourteen beef cows, beef heifers, and dairy heifers from six locations (location 1 [Western Illinois]-40 beef cows, location 2 [Texas]-39 beef heifers, location 3 [Florida]-43 dairy heifers, location 4 [Wisconsin]-61 dairy heifers, location 5 [Southern Illinois]-291 beef heifers, and location 6 [Eastern Illinois]-40 dairy heifers) were included in this experiment. Females were all administered needle-less implants in the front leg musculature with a pressure setting of 1,100 to 1,300 psi while restrained in a chute and observed for needle-less implant penetration. Administration sites were examined 2 and 30 days after treatment for tissue response to implant administration.

Experiment 3

Needle-less implants were administered to five beef heifers in the right front leg musculature. Thirty-two days after administration, heifers were slaughtered at the University of Illinois Meat Science abattoir. After the carcasses were chilled, the right foreshank musculature of each heifer was dissected and examined for administration site blemishes or other tissue damage.

Experiment 4

Administration of needle-less implants was evaluated on a confined deer herd in southern Connecticut. Deer were habituated to the presence of humans, and all deer were identified with individually numbered ear tags. The facility was 1.76 km^2 of predominantly wooded habitat. Each of six deer, which previously had been selected for removal, were treated with needle-less implants in one of the animal's hindquarters at a pressure setting ranging from 520 to 650 psi (DeNicola et al., 1996a). Approximately 20 minutes later, each deer was killed instantly using a high-powered rifle shot to the head. Within 5 minutes of being shot blood was collected from each of the animals via cardiac puncture. In all cases the rifle shots and the needle-less implants were delivered from concealed positions. Behavioral reactions by the deer before and after being treated with a needle-less implant were noted and recorded. Another group of eight deer, also previously identified for removal, was each killed instantly using a high-powered rifle shot to the head without being administered a needle-less implant. Within 5 minutes, a blood sample was collected from each of the animals via cardiac puncture. Sera was harvested from the blood samples after centrifugation at 1,660 x g for 15 minutes. Sera samples were stored at -20°C until they were assayed for cortisol concentrations. In all cases the rifle shots were fired from concealed positions.

Experiment 5

Four heifers were included in a replicated 2 x 2 Latin-square design. Heifers were intramuscularly administered either an injection of 5 mL of sterile saline via a 5-cc syringe and a 18-g needle that was 3.81 cm long or needle-less implants using a pressure setting of 1,100 to 1,300 psi. Blood samples were collected from catheters fitted 12 to 18 hours before treatments were administered (Aldrich et al., 1996). Collections were made 10 minutes before treatment, and 10, 20, 40, 60, and 80 minutes after treatments. For blood collection the heifers were held in a chute. Serum was harvested from the blood samples after centrifugation at 1,660 x g for 15 minutes and sera were stored at -20°C until assaying it for cortisol concentrations.

Cortisol Assay. Cortisol was extracted by vigorously mixing on a mechanical shaker 100 µL of sera with one mL of diethyl ether in 12 X 75 mm glass culture tubes for 30 seconds. The diethyl ether was decanted into 12 X 75 mm glass culture tubes after freezing the mixture at -20°C. After evaporation of the ether (by heating the tubes in a 60°C water bath), the cortisol was reconstituted into 1 mL of a potassium phosphate buffer by vigorously mixing on a mechanical shaker the contents of the tubes for 30 seconds (.1 µL serum/1 µL buffer). Cortisol concentrations were determined using commercially available cortisol enzyme linked immunoabsorbent assay (ELISA) kits. Seven standards (0, 2, 4, 10, 20, 40, and 100 ng/mL) were included in the assay. Standards (50 µL) or samples (50 µL) and cortisol-peroxidase conjugate (50 µL) were added to the micotiter plates (which were coated with anti-cortisol monoclonal antibody) for one hour at room temperature. Assay components were then discarded and washed from the plates and 150 µL of substrate was added for 30 minutes. Absorbance was then determined at 630 nm and samples were quantified using logit/log transformation. Cortisol concentrations were reported as ng/mL by correcting (correction factor = 200) for volume assayed. Assay of cortisol concentrations was completed within six hours of beginning the extraction.

The assay had 3.4%, 2.1%, and 2.0% crossreactivity with corticosterone, cortisone, and deoxycorticosterone, respectively, and less than 1.0% crossreactivity with 17-hydroxyprogesterone,

androstenedione, progesterone, testosterone, aldosterone, dehydroepiandrosterone, estrone, estradiol, and pregnenolone. Serum samples (n = 4; one mL each) containing 2.27 ng/mL of cortisol spiked with 20 ng of cortisol were determined to have 21.14 ng/mL demonstrating that the extraction procedure was approximately 94.6% efficient. In addition, two heifers that were stressed by normal handling, as defined by methodology of Tulloh (1961), were bled and cortisol concentrations determined along with the experimental samples. Mean serum cortisol concentrations in these heifers were determined to be 36.8 ng/mL. All samples were assayed in one assay and the intraassay coefficient of variation was 4.6%.

Blood cortisol concentrations in Experiment 3 were analyzed by analysis of variance (Hicks, 1964) and in Experiment 4 by split plot analysis of variance (Gill and Hafs, 1971).

RESULTS AND DISCUSSION

The delivery system propels the needle-less implants on the basis of compressed air. The needle-less implant has an internal cavity, open on one end of the shell, capable of holding approximately 275 mg of active compound and controlled release excipients. The other end of the outer shell is pointed and serves as the end that has initial contact with the animal's tissues during penetration. It has been demonstrated that upon contact with the skin, the needle-less implant first causes the skin to stretch (Gould, 1984). The implant penetrates the skin by producing a slit which contracts back to its original form leaving behind a slit shorter than the diameter of the implant (Experiment 1). All 528 needle-less implants penetrated beyond the skin in Experiments 1, 2, and 3. Minimal bleeding, as only a few or several drops of blood were apparent after treatment in Experiment 2, occurred after penetration and that was followed by scab formation (Experiment 2).

Upon entry into living tissue the outer shell dissolved in approximately six hours (Kesler, 1996). A raised welt developed on the skin at the point of implant entry after administration (Experiments 1 and 2). A focal area of hemorrhage was present subcutaneous to the penetration slit (Experiment 1). The muscle had a slit in association with this hemorrhage and the penetration tracts had small darkened areas due to damage of myofibrils. The needle-less implants penetrated the muscle 3 to 8 cm. Although the penetration tracts had small darkened areas, no portion of the skin, foreign material, or intact portions of the needle-less implants were found within the musculature (Experiment 1). In deer, necropsies conducted within one hour of implant administration similarly revealed little tissue damage and minimal intramuscular hemorrhaging and the implant shell was almost completely dissolved (DeNicola et al., 1996a; Swartz et al., 1997). Only a soft gelatinous appearing substance remained in the musculature. Cattle in Experiment 2 had scab formation or swelling .84 ± .06 cm in diameter 2 days after treatment that was gone 30 days after treatment. In Experiment 3, only one of five heifers administered needle-less implants 32 days earlier had a detectable blemish to the muscle-a .2 x 1.0 cm scar containing connective and adipose tissues. One year post-treatment, musculature appeared normal and no lesions, scarring, or implant shell materials were noted in deer (DeNicola et al., 1996a).

The needle-less implant has been propelled from differing compressed air delivery systems. Compressed air used to propel the implant can be generated via a piston (within the delivery system) or obtained from an external tank. Regardless of the source of compressed air, a specific pressure

setting is required depending on the species being treated (DeNicola et al., 1996a). A pressure setting of 520 to 650 psi was used in Experiment 4 because DeNicola et al. (1996a) determined that it was a more appropriate pressure setting for deer. The 1,100 to 1,300 psi pressure setting was necessary for delivery of needle-less implants into mature cattle (Experiments 1, 2, 3, and 5) which have a much thicker skin than deer (Kesler, 1996).

In Experiment 4, serum cortisol concentrations for the deer administered the needle-less implant (5.0 ± .9 ng/mL) were similar ($P > .25$) to cortisol concentrations (4.0 ± .5 ng/mL) in control deer (Table 1). After being treated with a needle-less implant, deer typically flinched or jumped, then walked away seemingly curious about what had occurred. One deer favored the treated leg after treatment but only for a few steps. Similar results were reported by Swartz et al. (1997). Although more adverse reactions were noted when Jacobsen et al. (1995) administered contraceptive needle-less implants to black-tailed deer, the needle-less implants were delivered with a higher pressure setting of 1,100 to 1,300 psi in that study.

One or more of three behavioral reactions were displayed by the cattle upon treatment. The cattle kicked, turned their head to observe the site, or displayed no reaction. In cattle (Experiment 5), the elevation in blood cortisol concentrations subsequent to needle-less implant administration was similar ($P > .25$) to the elevation in blood cortisol concentrations subsequent to an injection (Figure 1). Cortisol concentrations were lower than concentrations (52 ± 32 ng/mL) reported for calves weaned and transported (Faulkner et al., 1992; Table 1). They were similar to cortisol concentrations subsequent to injection (Alam and Dobson, 1986), rectal palpation of the reproductive tract (Alam and Dobson, 1986), and venipuncture (Alam and Dobson, 1986) by other researchers. Other than species, a difference between Experiments 4 and 5 is that although the heifers in Experiment 5 were cannulated, they were handled and restrained for administration of the injection and the needle-less implant. In Experiment 4, the deer were administered the needle-less implant from concealed positions. Therefore, the small elevation in blood cortisol concentrations observed in the heifers may have been due to handling and restraint.

There are several attributes, as described in Table 2, that may be considered regarding the acceptability of a delivery system. The remote needle-less delivery system described herein satisfies several (numbers 1, 2, 3, 4, 5, 6, 8, and 9) of these criteria. More discussion on attribute seven and 10 follow.

This study was not designed to thoroughly investigate the effect of the needle-less implant on tissue damage and lesions (attribute seven; Table 2). Although less of a concern in wild animals, alterations of the musculature due to treatments are important in food animals. Several publications have reported tissue damage after intramuscular injection of various compounds (Dexter et al., 1994; Stokka et al., 1994; George et al., 1995a; George et al., 1995b; George et al., 1996; Rogers et al., 1996). Although clostridial vaccines and long-acting oxytetracycline antibiotics appear to cause a higher incidence of injection site lesions, Rasmussen and Svendsen (1976) and George et al. (1996) demonstrated that saline or excipients alone caused damage to porcine tissue suggesting that the injection site lesions observed may be due to more than just the pharmaceuticals or vaccines being administered. The tissue damage due to intramuscular injection was more extensive than observed in the five heifers included in Experiment 3 (Dexter et al., 1994; Stokka et al., 1994; George et al.,

1995a; George et al., 1995b; George et al., 1996; Rogers et al., 1996). The neck and front leg musculature may be the most appropriate administration sites as these muscles are lower quality cuts of meat. Although the needle-less implants were administered intramuscularly in these experiments, a novel needle-less implant design has been developed and tested that permits remote delivery with subcutaneous implantation (Swartz et al., 1997).

Minimizing repeat therapy (attribute 10; Table 2) depends on the controlled release of product from the needle-less implant. Researchers have discovered several desirable delivery profiles via formulating novel modifications of the needle-less implant (Table 3). Some products, tranquilizers for example, must be immediately available upon entry within the tissues. A needle-less implant design has been developed and tested that effects recumbency in 64 ± 6 seconds; a similar interval to recumbency when remote syringe darts were used (46 ± 12 seconds) (Swartz et al., 1997). An efficacious needle-less implant design has been developed and tested for a compound (prostaglandin $F_{2\alpha}$; $PGF_{2\alpha}$) that has a half-life of less than one minute (Kesler and Favero, 1989; DeNicola et al., 1997b; Table 3). In another situation, a sustained release needle-less implant was developed and demonstrated to prevent reproduction in wild deer for one year (Jacobsen et al., 1995; DeNicola, et al., 1997a; Kesler, 1996). A sustained release needle-less implant was developed in which one 250-mg cephalosporin implant was demonstrated to be as effective in treating bovine respiratory disease as three daily 250 mg injections (Kesler and Bechtol, 1998).

There are many situations where it may be appropriate to administer pharmaceuticals and vaccines via a needle-less implant. The most obvious is in wild animals that are difficult or impossible to restrain. Other situations involve cases where the stress induced by restraint may either impede normal physiology or compromise recovery to therapy being administered during the restraint. Remote delivery may also be valuable in improving safety, reducing processing time, reducing stress and the potential for animal injury, et cetera (Table 2). Alternative portals of entry for other methods of delivery include 1) oral or transmucosal, 2) nasal/pulmonary, 3) transdermal without puncture of the skin, and 4) vaginal. However, all of these portals of entry require animal handling for treatment and although they may be less invasive than injection, stress can result because of handling.

IMPLICATIONS

A method of administering pharmaceuticals and vaccines to domestic and wild animals has been developed. Administration of compounds to animals using this system evokes minimal stress and tissue damage. Treatments should be administered in neck and front leg musculature of domestic meat animals in order to insure that they don't have administration-site blemishes in economically important cuts of meat; however, needle-less implant administration-site blemishes were minimal in this study. This delivery system has other advantages over injection delivery and may be used for drugs requiring immediate release and drugs requiring sustained release.

LITERATURE CITED

Alam, M.G.S. and H. Dobson. 1986. Effect of various veterinary procedures on plasma concentrations of cortisol, luteinising hormone and prostaglandin $F_{2\alpha}$ metabolite in the cow. Vet. Record 118:7-10.

Aldrich, S. L., L. L. Berger, D. J. Kesler, T. G. Nash, and R. H. McCusker, Jr. 1996. Effects of prenatal androgenization and postnatal steroid treatment on growth hormone, insulin-like growth factor I and II, insulin, thyroxine, and triiodothyronine concentrations in beef heifers. J. Anim. Sci. 75:420-428.

Christie, B. M., R. E. Pierson, P. M. Braddy, D. E. Flack, D. P. Horton, R. Jensen, E. A. Lee, E. E. Remmenga, and K. G. Rutt. 1977. Efficacy of corticosteroids and supportive therapy for bronchial pneumonia in yearling feedlot cattle. Bovine Pract. 12:115-117.

DeNicola, A. J., D. J. Kesler, and R. K. Swihart. 1996a. Ballistics of a biobullet delivery system. Wildl. Soc. Bull. 24:301-305.

DeNicola, A. J., R. K. Swihart, and D. J. Kesler. 1996b. The effect of remotely delivered gonadotropin formulations on reproductive function of white-tailed deer. Drug Del. Ind. Pharm. 22:847-850.

DeNicola, A. J., D. J. Kesler, and R. K. Swihart. 1997a. Dose determination and efficacy of remotely delivered norgestomet implants on contraception of white-tailed deer. Zoo Biol. 16:31-37.

DeNicola, A. J., D. J. Kesler, and R. K. Swihart. 1997b. Remotely delivered prostaglandin $F_{2\alpha}$ implants terminate pregnancy in white-tailed deer. Wildl. Soc. Bull. 25:527-531.

Dexter, D. R., G. L. Cowman, J. B. Morgan, R. P. Clayton, J. D. Tatum, J. N. Sofos, G. R. Schmidt, R. D. Glock, and G. C. Smith. 1994. Incidence of injection-site blemishes in beef top sirloin butts. J. Anim. Sci. 72:824-827.

Faulkner, D. B., T. Eurell, W. J. Tranquilli, R. S. Ott, M. W. Ohl, G. F. Cmarik, and G. Zinn. 1992. Performance and health of weanling bulls after butorphanol and xylazine administration at castration. J. Anim. Sci. 70:2970-2974.

George, M. H., R. A. Ames, R. G. Glock, M. T. Smith, J. D. Tatum, K. E. Belk, and G. C. Smith. 1996. Incidence, severity, amount of tissue affected and effect on histology, chemistry and tenderness of injection-site lesions in bef cuts from calves administered a control compound or one of seven chemical compounds. Nat. Cattlemen's Beef Assoc., Englewood, CO.

George, M. H., P. E. Heinrich, D. R. Dexter, J. B. Morgan, K. G. Odde, R. D. Glock, J. D. Tatum, G. L. Cowman, and G. C. Smith. 1995a. Injection-site lesions in carcasses of cattle receiving injections at branding and at weaning. J. Anim. Sci. 73:3235-3240.

George, M. H., J. B. Morgan, R. D. Glock, J. D. Tatum, G. R. Schmidt, J. N. Sofos, G. L. Cowman, and G. C. Smith. 1995b. Injection-site lesions: incidence, tissue histology, collagen concentration, and muscle tenderness in beef rounds. J. Anim. Sci. 73:3510-3518.

Gill, J. L. and H. D. Hafs. 1971. Analysis of repeated measurements of animals. J. Anim. Sci. 33:331-336.

Gould, J. W. 1984. Projectile. U.S. Patent 4,449,982.

Hicks, C. R. 1964. Fundamental Concepts in the Design of Experiments. Holt, Rinehart, and Winston, New York.

Hixon, D. L., D. J. Kesler, T. R. Troxel, D. L. Vincent, and B. S. Wiseman. 1981. Reproductive hormone secretions and first service conception rate subsequent to ovulation control with Syncro-Mate B. Theriogenology 16:219-229.

Jacobsen, N. K., D. A. Jessup, and D. J. Kesler. 1995. Contraception of captive black-tailed deer by remotely delivered norgestomet ballistic implants. Wildl. Soc. Bull. 23:718-722.

Kesler, D. J. 1993. Solid dosage formation and delivery of lyophilized products. In: L. Antosiak (ed.), Tablet Manufacturing, Medical Manufacturing TechSource, Inc., Ann Arbor, MI, pp. 200-223.

Kesler, D. J. 1997. Remotely delivered contraception with needle-less norgestomet implants. In: T.J. Kreeger (ed.), Contraception in Wildlife Management, U.S. Government Printing Office, Washington, D.C., pp. 171-184.

Kesler, D. J. and D. T. Bechtol. 1998. Efficacy of sustained release needle-less ceftiofur sodium implants in treating calves with bovine respiratory disease. J. Vet. Med. (In Press).

Kesler, D. J. and R. J. Favero. 1989. Estrous synchronization and fertility enhancement in cattle with ballistically administered pharmaceutical agents, Proc. Int. Symp. Cont. Release of Bioactive Mat. 16:251-252.

Kesler, D. J. and R. J. Favero. 1996. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: factors limiting and enhancing efficacy. Agri-Pract. 17:12-17.

Kesler, D. J. and R. J. Favero. 1997. Needle-less implant delivery of gonadotropin releasing hormone enhances the calving rate of beef cows synchronized with norgestomet and estradiol valerate. Drug Del. Ind. Pharm. 23:607-610.

Nanda, A. S., W. R. Ward, and H. Dobson. 1989. Effects of naloxone on the oestradiol-induced LH surge and cortisol release in transported cows. J. Reprod. Fert. 87:803-807.

Rasmussen, F. and O. Svendsen. 1976. Tissue damage and concentration at the injection site after intramuscular injection of chemotherapeutics and vehicles in pigs. Res. Vet. Sci 20:55-60.

Rogers, G. M. and C. M. King. 1996. The comparison of injection site reactions caused by two commercial multivalent clostridial vaccines. Agri-Practice 17:28-33.

Swartz, J. A., R. J. Warren, D. A. Osborn, D. W. Henderson, and D. J. Kesler. 1997. Captive and field tests of a method for immobilization and euthanasia of urban deer. Wildl. Soc. Bull. 25:532-541.

Stokka, G. L., A. J. Edwards, M. F. Spire, R. T. Brandt, and J. E. Smith. 1994. Inflammatory response to clostridial vaccines in feedlot cattle. J. Am. Vet. Med. Assoc. 204:415-419.

Tulloh, N. M. 1961. Behavior of cattle in yards. II. A study of temperament. Anim. Behav. 9:25-30.

U. S. Government. 1993. Code of Federal Regulations. Food and Drugs 21 Parts 170-199. Subchapter B Food for Human Consumption. Office of the Federal Register, U.S. Government Printing Office, Washington, D.C.

Wesson, J. A., P. F. Scanlon, R. L. Kirkpartick, and H. S. Mosby. 1979. Influence of chemical immobilization and physical restraint on steroid hormone levels in blood of white-tailed deer. Can. J. Zool. 57:768-776.

Willis, P., G. L. Heusner, R. J. Warren, D. Kesler, and R. A. Fayrer-Hosken. 1994. Equine immunocontraception using porcine zona pellucida: a new method for remote delivery and characterization of the immune response. J. Equine Vet. Sci., 14:364-370.

Table 1. Cortisol concentrations of deer and cattle treated and handled in various ways

Animal	Treatment/Handling	Cortisol Concentrations (ng/mL) Pre-Treatment Control	Post-Treatment Treated	Source
Cattle	Injection[a]	3.9	10.2	Herein
Cattle	Injection[b]	2.1	10.8	Alam and Dobson[h]
Cattle	Palpation[c]	2.1	11.4	Alam and Dobson[h]
Cattle	Venipuncture[d]	2.1	10.8	Alam and Dobson[h]
Cattle	Needle-less Implant	3.9	9.1	Herein
Cattle	Weaning & Transport[e]	---	52.0	Faulkner et al.[i]
Deer	Syringe Dart[f]	---	25.5	Swartz[j]
Deer	Needle-less Implant	4.0	5.0	Herein
Deer	Needle-less Implant	3.1	4.0	Swartz[j]
Deer	Restraint[g]	---	75.9	Wesson et al.[k]

[a]Heifers were intramuscularly administered 5 cc of sterile saline via 18 g needles 3.81 cm long.

[b]Cows were intramuscularly administered 2 cc of sterile saline via 19 g needles 3.81 cm long.

[c]The uterus of luteal phase cows were palpated for 5 minutes.

[d]Cows were tied securely with a rope halter and bled once via jugular venipuncture.

[e]Calves were weaned and then transported to the feedyard at which time they were bled.

[f]Deer were remotely administered a syringe dart containing ketamine HCl and xylazine HCl.

[g]Deer were physically restrained without drug treatment.

[h]Alam and Dobson (1986).

[i]Faulkner et al. (1992).

[j]Swartz et al. (1997).

[k]Wesson et al. (1979).

Table 2. Selected attributes and value of a model delivery system

	Attribute	Value
1.	Simple and convenient to use	Minimize error and labor
2.	Safe for veterinarians/producers	Minimize human injury
3.	Requires minimal processing	Minimize labor
4.	Evokes minimal stress	Reduce the negative effects of stress on performance and recovery to therapy
5.	No treatment induced injury	Improve animal welfare and maximize profits
6.	No chance of mis-dosing	Maximize drug efficacy
7.	No tissue lesions	Improve meat quality and maximize profits
8.	No needles	Avoids broken needles in animal and disposal requirments
9.	Eliminate the transfer of blood products	Reduce the spread of disease
10.	Minimize repeat therapy	Eliminate additional handling and labor

Table 3. Delivery profiles and examples of compounds delivered in needle-less implants

Delivery Profile	Time	Example
Immediate Release	within 1-2 minutes	Succinylcholine Chloride[b]
Rapid Release	within 1-4 hours	Prostaglandin $F_{2\alpha}$[cd] Gonadotropin Releasing Hormone[ce]
Prolonged Delivery	over days or weeks	Luteinizing Hormone[f] Cephalosporin[g]
Pulsed Delivery[a]	over a month	pZP Vaccine[h]
Sustained Delivery	a year or more	Norgestomet[ijk]

[a]Rapid release at the time of treatment and another rapid release about 1 month later.
[b]Swartz et al. (1997)-under authorization and supervision of the University of Georgia's veterinarian and animal care committee.
[c]Kesler and Favero (1989).
[d]DeNicola et al. (1997b).
[e]Kesler and Favero (1997).
[f]DeNicola et al. (1996b).
[g]Kesler et al. (1997).
[h]Willis et al. (1994).
[i]Jacobsen et al. (1995).
[j]DeNicola et al. (1997a).
[k]Kesler (1996).

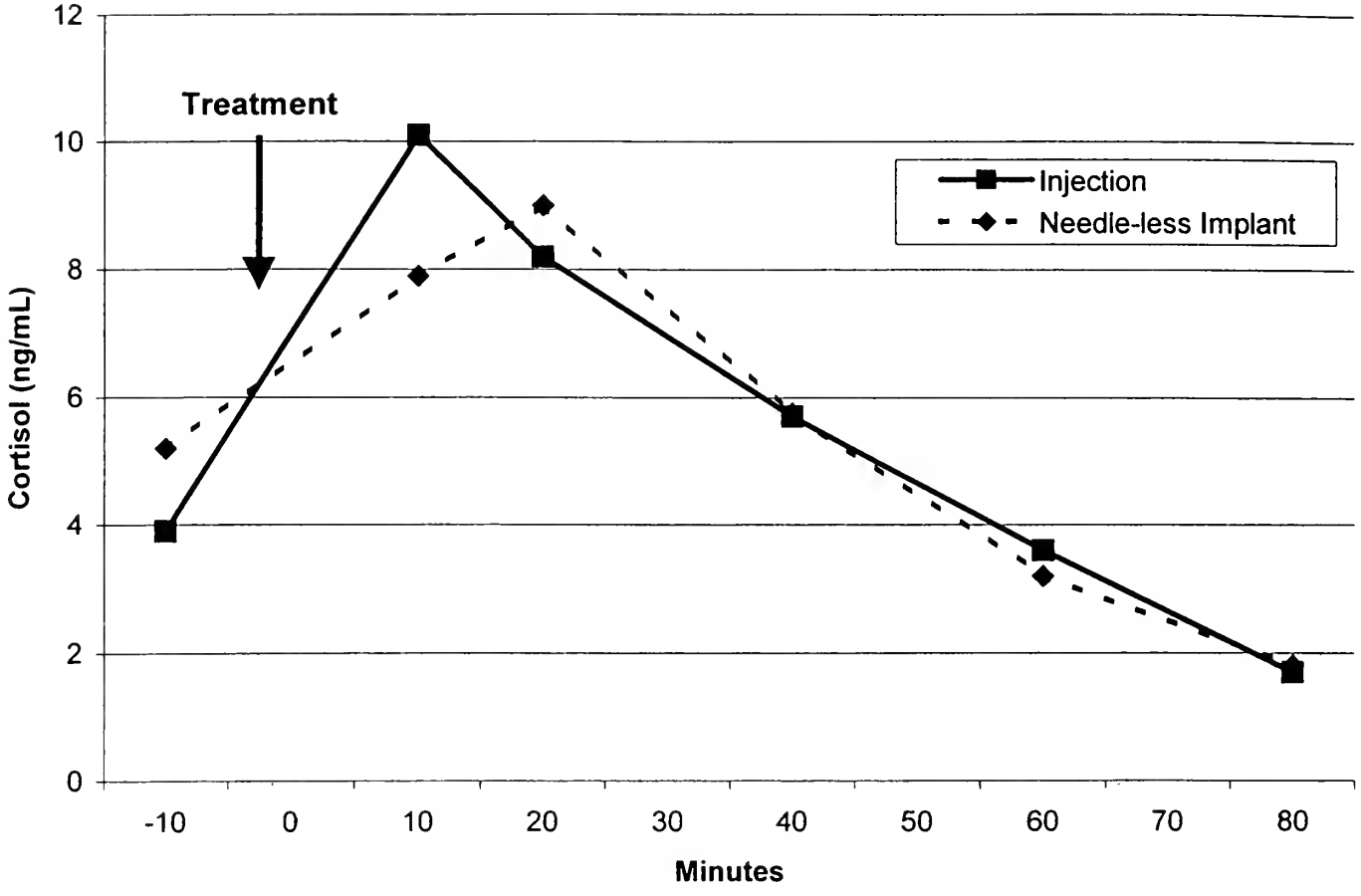

Figure 1. Serum cortisol concentrations (ng/mL) of cannulated heifers before and after administration of needle-less implants or injections.

PREGNANCY DETECTION VIA THE EARLY CONCEPTION FACTOR ASSAY: A PRELIMINARY REPORT

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SUMMARY

A group of sixteen mature lactating cows were bled 30 hours and 21 days after insemination (day +1). Before insemination, cows were administered GnRH (day -9), $PGF_{2\alpha}$ (day -2), and GnRH (day 0) for synchronization. Serum samples were assayed for early conception factor (+30 hour blood samples; ECF) and progesterone (day +21 blood samples; P_4). Pregnancy was confirmed by transrectal ultrasonography 29 days post-insemination; two of the cows were pregnant and 14 were open. In evaluation #1, all samples were assayed for ECF (+30 hour samples) and progesterone (+21 day samples). In evaluation #2, four samples were randomly selected and assayed twice for ECF and progesterone. In evaluation #3, four samples from cows not inseminated were selected from another study and assayed for pregnancy via the ECF assay. In evaluation #1, both assays (ECF and progesterone) were 100% accurate in diagnosing open cows (cows open ÷ cows diagnosed open) although eight of the cows diagnosed pregnant via ECF, and two cows diagnosed pregnant via progesterone were open. Both pregnant cows were diagnosed pregnant with both assays. In evaluation #2, both assays were 100% repeatable. In evaluation #3, three of the four non-inseminated cows were diagnosed pregnant. Therefore, these authors can not recommend the early conception factor assay; however, further research is warranted.

INTRODUCTION

A new method of pregnancy detection has been advertised. This method involves the assay of serum samples collected 12 to 48 hours after insemination. The manufacturer (Concepto Diagnostics of Knoxville, TN) reports that it "is a unique immunoassay to identify the open cow within 12-48 hours of breeding. The test is conducted only on serum samples using the monoclonal-polyclonal antibody 'dip stick' methodology with gold as the indicator. This is not an absolute diagnosis of open cows. There are approximately 4% false positive results in serum samples collected 12-24 hours" after insemination (Concepto Diagnostics, 1998). Because the manufacturer does not identify the compound being assayed and because no early conception factor (at the time described by the manufacturer) has been reported in the scientific literature, the authors purchased kits and evaluated the assay on a group of cows synchronized with the "Ovsync" procedure.

METHODS AND MATERIALS

Early conception factor kits were purchased from Concepto Diagnostics (Knoxville, TN) and used for three evaluations. The early conception factor assay utilizes test cassettes, droppers, and wash solution. Test cassettes are removed from a foil pouch and labeled. One drop of serum is added to the well in the cassette followed by four drops of wash solution. Results are read 0.5 to 2 hours later by observing for the presence of one (nonpregnant) or two (pregnant) bands. Materials for 25 assays and were purchased for $128 ($5.12 per assay).

Evaluation 1. A group of sixteen mature lactating cows were bled 30 hours and 21 days after insemination (day +1). Before insemination, cows were administered GnRH (day -9), $PGF_{2\alpha}$ (day -2), and GnRH (day 0) for synchronization (the "Ovsync" procedure). Serum samples were assayed for early conception factor (+30 hour blood samples; ECF) and progesterone (day +21 blood samples; P_4). Pregnancy was confirmed by transrectal ultrasonography 29 days post-insemination.

Evaluation 2. Four samples from evaluation 1 were randomly selected and assayed via the ECF assay a second time on another day.

Evaluation 3. Four samples from cows not inseminated were selected from another study and assayed via the ECF assay.

RESULTS AND DISCUSSION

Because it was difficult to ascertain the presence of the second band (the band indicating pregnancy) on the test cassettes, six individuals were asked to read the cassettes for pregnancy. Individuals read the cassettes without knowledge of the decision of the others. Four of the six individuals agreed in all cases.

In evaluation 1, two of the cows were diagnosed pregnant and 14 open by ultrasound. Both assays (ECF and progesterone) were 100% accurate in diagnosing open cows (cows open ÷ cows diagnosed open), although eight of the cows diagnosed pregnant via ECF and two cows diagnosed pregnant via progesterone were open (Table 1). This may suggest high embryonic loss. Both pregnant cows were diagnosed pregnant with both assays. In evaluation #2, both assays were repeatable ($P < .05$; Table 1). In evaluation #3, three of the four non-inseminated cows were diagnosed pregnant (Table 1).

The ECF assay correctly identified open cows and pregnant cows although eight of the cows diagnosed pregnant were open. The eight open cows diagnosed pregnant may have had early embryonic loss. The assay was 100% consistent (evaluation 2). However, three of the non-inseminated cows were diagnosed pregnant (evaluation 3). Therefore, the assay is not measuring a substance produced by the embryo. However, because the assay correctly identified open cows and pregnant cows in evaluation 1 although eight of the cows diagnosed pregnant were open, the ECF assay may be assaying some factor associated with favorable establishment of pregnancy.

Progesterone was determined on day 21 as a control assay. Although progesterone has never been demonstrated to be 100% accurate because of embryonic loss, it was more ($P < .01$) reliable than the early conception factor assay. Therefore, these authors can not recommend the early conception factor assay, but the progesterone assay may be a useful management tool.

LITERATURE CITED

Concepto Diagnostics. 1998. Early conception factor assay kit for cattle. Knoxville, TN: Concepto Diagnostics.

Table 1. Results of the early conception factor (ECF) and progesterone (P_4) assays

Assay	Evaluation	Accuracy	Repeatability[a]
Diagnosed Pregnant via ECF	1 & 2	2/10 (20%)	3/3
Diagnosed Open via ECF	1 & 2	6/ 6 (100%)[b]	1/1
ECF Combined	1 & 2	8/16 (50%)	4/4 (100%)[b]
Diagnosed Pregnant via P_4	1 & 2	2/ 4 (50%)	1/1
Diagnosed Open via P_4	1 & 2	12/12 (100%)[c]	3/3
P_4 Combined	1 & 2	14/16 (88%)[c]	4/4 (100%)[b]
Not Inseminated	3	1/ 4 (25%)	---

[a]Evaulation 2.
[b,c]Values with superscripts are different from chance ($P < .05$ and $P < .01$, respectively).

NORGESTOMET IMPLANTS ENHANCE EMBRYO SURVIVAL IN POSTPARTUM COWS: A PRELIMINARY REPORT

M. L. Rosmarin, T. F. Lock, J. M. Dahlquist, T. G. Nash, D. B. Faulkner, and D. J. Kesler

SUMMARY

Objectives of this study were to determine if norgestomet administered on days 5 to 24 post-AI would 1) facilitate embryo survival in cows with short luteal phases (< 10 days) and cows with premature corpus luteum regression (16-20 d post-AI) and 2) enhance the establishment of pregnancy. Beef cows suckling calves from the University of Illinois (n=138) were administered Syncro-Mate B (SMB) and bred via AI 48 hours after implant removal (48-h AI). Cows were 12 to 106 days postpartum at the 48-h AI and randomly assigned to one of two groups. Treated cows (n=69) were implanted with two norgestomet/silicone implants on the convex surface of the ear. The other 69 cows were not treated on days 5 to 24 post-AI (controls). Two implants released ≥315 μg norgestomet per day (> two times the dose that suppresses estrus and a dose that maintains pregnancy in ovariectomized heifers). Blood samples were collected before SMB implantation (to determine anestrus/estrus-cycling status) and twice weekly after SMB implant removal for 38 days and assayed for progesterone (P_4). All cows were observed twice daily for 31 days after SMB implant removal for estrus and bred via AI. Cows were examined for pregnancy via transrectal ultrasonography 24 and 38 days after AI. Qualitative data were analyzed by chi-square analysis. Pregnancy rate and P_4 were analyzed by split-plot analysis of variance.

Norgestomet implants increased ($P < .01$) the 24 d pregnancy rate (pregnancy rates = 30% and 57% for control and norgestomet treated cows, respectively). The 24 d pregnancy rate (54%) for the previously anestrus cows administered norgestomet was not different ($P > .20$) from the untreated estrus-cycling cows. The 24 d pregnancy rate for the norgestomet treated cows with progesterone concentrations indicative of cows with subnormal luteal phases (60%) was not different ($P > .20$) from the pregnancy rate of untreated estrus-cycling cows (41%). The pregnancy rate decreased ($P < .05$) from d 24 to 38 in the norgestomet treated cows; however, the pregnancy rate on d 38 for the previously anestrus cows administered norgestomet was greater ($P < .05$) than for the untreated previously anestrous cows. Although norgestomet implants maintained pregnancy in the absence of corpora lutea, embryonic loss occurred after norgestomet implant removal on d 24 in the absence of corpora lutea.

In summary, norgestomet enhanced embryo survival in cows with premature corpus luteum regression and cows with short luteal phases and may be incorporated into procedures to enhance the establishment of pregnancy. Also, cows with less than one standard deviation of mean P_4 concentrations of pregnant cows on days 6 or 7 would be poor recipient candidates for embryo transfer.

INTRODUCTION

Calving rates of cattle bred after estrus synchronization are often lower than desired (Odde, 1990; Kesler and Favero, 1996). Factors that negatively affect the establishment of pregnancy include lack

of synchronization (Burns et al., 1993; Kesler and Favero, 1996; Kesler et al., 1997a), subnormal luteal phases (Kesler and Favero, 1996), and embryonic/fetal mortality (Ayalon, 1978; Diskin and Sreenan, 1980; Roche, 1981).

Studies have demonstrated that supplemental progestins (progesterone and norgestomet) during the luteal phase may enhance the establishment of pregnancy to the previous insemination (Johnson et al., 1958; Robinson et al., 1989; Favero et al., 1993). Further, Kesler (1997) demonstrated that norgestomet implants maintain pregnancy to term in heifers ovariectomized 10 d after insemination. We hypothesized that norgestomet implants administered five to 24 d after AI would allow cows to maintain embryos in the absence of corpora lutea and permit the determination, via transrectal ultrasonography, of embryo loss due to corpus luteum regression. Additional objectives were to determine if norgestomet implants would 1) facilitate the establishment of pregnancy in cows with short luteal phases, and 2) enhance the establishment of pregnancy.

MATERIALS AND METHODS

Angus and crossbred beef cows from the University of Illinois Beef Unit (Urbana; n = 52) and the Orr Beef Center (Baylis, IL; n = 86) were included in this experiment. Cows were 12 to 106 d postpartum at the time of the first AI and were fed alfalfa and fescue hay or grazed legume and grass pasture and fed a complete vitamin and mineral mixture to meet NRC requirements (NRC, 1996). Cows at both locations received booster vaccines against infectious bovine rhinotracheitis, bovine virus diarrhea, parainfluenza$_3$, campylobacteriosis, and leptospira canicola-grippotyphosa-hardjo-icterohaemorrhagiae-pomona (Preg-Guard 9® at Urbana and Cattlemaster 4 + VL5® at Baylis) 21 d before the first AI. The vaccine used at Baylis also contained bovine respiratory syncytial virus vaccine. Cows were bled 10 d before and immediately before the administration of Syncro-Mate B® (SMB; Merial, Athens, GA) which was administered to all cows to synchronize estrus. The SMB procedure consists of an intramuscular injection of norgestomet (3.0 mg) and estradiol valerate (5.0 mg) in sesame oil and a subcutaneous 6.0-mg norgestomet implant on the convex surface of the ear (Kesler and Favero, 1995). After nine d, SMB implants were removed and cows were artificially inseminated about 48 h later with commercially frozen semen.

Five d after the 48-h AI, the cows were randomly assigned to two groups. Treated cows (Urbana, n = 26; Baylis, n = 43) were implanted with two norgestomet/silicone implants that were subcutaneously inserted into the convex surface of the ear. Control cows (Urbana, n = 26; Baylis, n = 43) were untreated but were moved through the chute as the treated cows. The norgestomet/silicone implants were 3.45 mm in diameter and 20 mm in length. Previous research demonstrated that two of these implants release more than 2.5 times a dosage of norgestomet that suppresses estrus (Kesler et al., 1995; Machado and Kesler, 1996) and an amount of norgestomet that maintains pregnancy in ovariectomized heifers (Kesler, 1997). The norgestomet/silicone implants were removed 10 d after implantation and two new norgestomet/silicone implants were administered and left in situ until 24 d after the 48-h AI.

Additional blood samples were collected from the cows immediately after SMB implant removal, at the 48-h AI, and 3, 6 or 7, 9 or 10, 13, 16 or 17, 20, 24, 27, 30 or 31, 34, and 38 d after the 48-h AI. All blood samples were collected via jugular venipuncture into syringes using 18 g needles that were

3.81 cm long. Blood samples were immediately placed in an ice water bath until centrifugation at 2,000 x g for 10 min at 4°C (Wiseman et al., 1983). Serum was separated and stored in one mL vials at - 20°C until assayed. Progesterone concentrations were determined by a validated ELISA (Kesler et al., 1990).

All cows were observed for estrus twice daily, morning and evening, for 31 d beginning the day after SMB implant removal. Standing to be mounted by other cows was the criterion used to determine estrus. Cows in estrus from 72 h to 31 d after SMB implant removal were bred via AI approximately 12 h after the detection of estrus. Commercially frozen semen was used for all artificial inseminations and service sire was chosen before cows were randomly assigned to groups. Fertile bulls were then included with the cows on d 31.

Cows with progesterone ≥ 1.5 ng/mL in either one or both of the two blood samples collected before SMB treatment were considered to be estrus-cycling. Cows with < 1.5 ng/mL in both blood samples collected before SMB treatment were considered anestrus. Cows determined not to be synchronized with SMB (cows with progesterone concentrations ≥ 1.0 ng/mL at the 48-h AI and 3 d later) were eliminated from the study.

Cows were examined for pregnancy via transrectal ultrasonography using an ultrasound with a 7.5 MHZ linear array transducer 24 and 38 d after the 48-h AI (Pierson et al., 1988). Thirty-five of 36 cows (97%) pregnant on d 38 were identified as pregnant on d 24 similar to results of Pierson et al. (1988).

First service pregnancy rate was based on transrectal ultrasonography determination of pregnancy on d 38. Cows were classified as calving from an insemination if they calved 283 ± 10 d later. Thirty-four of the 36 (94%) cows diagnosed pregnant by transrectal ultrasonography calved 283 ± 10 d later. One of the two diagnosed pregnant by transrectal ultrasonography that did not calve aborted about six mo after insemination as a result of anaplasmosis. The loss of pregnancy in the other cow was not observed. Second service pregnancy rate was based on calving.

Because location had no effect ($P > .10$), it was not included in the results. Qualitative data were analyzed by chi-square analysis (Cochran and Cox, 1957). Pregnancy rate was also analyzed as a 2 x 2 x 2 factorial split-plot analysis of variance design with treatment (control and norgestomet treated), estrous cycles (anestrus and estrus-cycling), and time (d 24 and d 38) as the main effects (Gill and Hafs, 1971). Progesterone concentrations were analyzed as a 2 x 3 x 6 factorial split-plot analysis of variance design with treatment (control and norgestomet treated), pregnancy status (pregnant from the first AI [38 d], pregnant on d 24 but not on d 38, and not pregnant from the first AI), and time (d 0 to 16 or 17) as the main effects (Gill and Hafs, 1971).

RESULTS

Norgestomet implants increased ($P < .01$) the 24 d pregnancy rate (pregnancy rates = 30% and 57% for control and norgestomet treated cows, respectively). The 24 d pregnancy rate (54%) for the previously anestrus cows administered norgestomet was not different ($P > .20$) from the untreated estrus-cycling cows. The 24 d pregnancy rate for the norgestomet treated cows with progesterone

concentrations indicative of cows with subnormal luteal phases (60%) was not different ($P > .20$) from the pregnancy rate of untreated estrus-cycling cows (41%). The pregnancy rate decreased ($P < .05$) from d 24 to 38 in the norgestomet treated cows; however, the pregnancy rate on d 38 for the previously anestrus cows administered norgestomet was greater ($P < .05$) than for the untreated previously anestrous cows. Although norgestomet implants maintained pregnancy in the absence of corpora lutea, embryonic loss occurred after norgestomet implant removal on d 24 in the absence of corpora lutea.

CONCLUSION

These data demonstrate that the pregnancy rate in norgestomet treated cows after their first postpartum ovulation was equivalent to the pregnancy rate of untreated cows beyond their first postpartum ovulation. Furthermore, the pregnancy rate in norgestomet treated cows with progesterone concentrations of cows with subnormal luteal phases was equivalent to cows with normal estrous cycles.

LITERATURE CITED

Ayalon, N. 1978. A review of embryonic mortality in cattle. J. Reprod. Fertil. 54, 483.

Burns, P. D., Spitzer, J. C., Bridges, Jr., W. C., Henricks, D. M., and Plyler, B. B., 1993. Effects of metestrous administration of a norgestomet implant and injection of norgestomet and estradiol valerate on luteinizing hormone and development and function of corpora lutea in suckled beef cows. J. Anim. Sci. 71, 983.

Cochran, W. G. and Cox, G. M., 1957. Experimental Design (2nd ed.). John Wiley & Sons, New York.

Diskin, M. G. and Sreenan, J. M., 1980. Fertilization and embryonic mortality rates in beef heifers after artificial insemination. J. Reprod. Fertil. 59, 463..

Favero, R. J., Faulkner, D. B., and Kesler, D. J., 1993. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. J. Anim. Sci. 71, 2594.

Gill, J. L. and Hafs, H. D., 1971. Analysis of repeated measurements of animals. J. Anim. Sci. 33, 331.

Johnson, K. R., Ross, R. H., and Fourt, D. L., 1958. Effect of progesterone administration on reproductive efficiency. J. Anim. Sci. 17, 386.

Kesler, D. J. 1997. Norgestomet implants maintain pregnancy in ovariectomized heifers. Theriogenology 48, 89.

Kesler, D. J., Dyson, T. S., Summers, R. N., Steckler, T. L., and Nash, T. G., 1997a. Effect of prostaglandin $F_{2\alpha}$ treatment before norgestomet and estradiol valerate treatment on regression, formation, and function of corpora lutea in beef heifers. Anim. Reprod. Sci. 47, 281.

Kesler, D. J. and Favero, R. J., 1995. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 1: mechanism of action. Agri-Pract. 16, 6.

Kesler, D. J. and Favero, R. J., 1996. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: factors limiting and enhancing efficacy. Agri-Pract. 17, 12.

Kesler, D. J., Favero, R. J., and Troxel, T. R., 1995. A comparison of hydron and silicone implants in the bovine norgestomet and estradiol valerate estrus synchronization procedure. Drug. Dev. Ind. Pharm. 21, 475.

Kesler, D. J., Khazali, H., and Favero, R. J., 1990. Quantification of steroids via a polymer linked second antibody immunoassay: methods of linking anti-rabbit IgG to poly(styrene). In: Progress in Biomedical Polymers. Ed., C.G. Gebelein and R. Dunn. Plenum Publishing Co., New York, p. 157.

Machado, R. and Kesler, D. J., 1996. The efficacy of norethindrone acetate and norgestomet implants in suppressing estrus in beef cows. Drug Dev. Ind. Pharm. 22, 1211.

NRC. 1996. Nutrient Requirements of Beef Cattle. National Academy Press, Washington, DC.

Odde, K.B. 1990. A review of synchronization of estrus in postpartum cattle. J. Anim. Sci. 68, 817.

Pierson, R. A., Kastelic, J. P., and Ginther, O. J., 1988. Basic principles and techniques for tranrectal ultrasonography in cattle and horses. Theriogenology 29, 3.

Robinson, N. A., Leslie, K. E., and Walton, J. S., 1989. Effect of treatment with progesterone on pregnancy rate and plasma concentrations of progesterone in Holstein cows. J. Dairy Sci. 72, 202.

Roche, J. F. 1981. Reproductive wastage following artificial insemination of heifers. Vet. Record 109, 401.

Wiseman, B. S., Vincent, D. L., Thomford, P. J., Scheffrahn, N. S., Sargent, G. F., and Kesler, D. J., 1983. Changes in porcine, ovine, bovine and equine blood progesterone concentrations between collection and centrifugation. Anim. Reprod. Sci. 5, 157.

Table 1. Effect of norgestomet on pregnancy rate, P_4 concentrations, and embryonic loss

	Control	Norgestomet Treated	P <
Pregnancy Rate-d 24 (anestrus)	1/20 (5%)[a]	14/26 (54%)[cef]	.01
Pregnancy Rate-d 38 (anestrus)	0/20 (0%)[b]	7/26 (27%)[d]	.01
Pregnancy Rate-d 24 (cyclic)	18/44 (41%)[ae]	21/36 (58%)[c]	.13
Pregnancy Rate-d 38 (cyclic)	15/44 (34%)[b]	14/36 (39%)[d]	NS
P_4 ng/mL (d 6 or 7): pregnant	3.77 ± .74[g]	3.49 ± .56[g]	----
embryonic loss	1.66 ± .79[g]	2.62 ± .42[g]	----
Pregnant (d 38)/pregnant (d 24):			
< 1.0 ng/mL P_4 d 0-10	0/0 (0%)	0/3 (0%)	----
< 1.5 ng/mL P_4 d 20	0/0 (0%)	0/8 (0%)	----
> 1.0 d 6 & > 1.5 ng/mL P_4 d 20	15/19 (79%)	21/24 (88%)	NS

[a,b]Values with similar superscripts differ (P < .01).

[c,d,e]Values with similar superscripts are not different (P > .25).

[f]The pregnancy rate for norgestomet treated cows that ovulated and had short luteal phases was 50% (3/6) which was similar to the pregnancy rate on d 24 for the cyclic cows (41%).

[g]Cows with embryonic loss had lower (P < .05) P_4 concentrations than pregnant cows.

ESTRUS RESPONSE AND PREGNANCY RATES OF BEEF FEMALES ADMINISTERED INTRAVAGINAL PROGESTERONE INSERTS AND $PGF_{2\alpha}$ FOR ESTRUS SYNCHRONIZATION: A PRELIMINARY REPORT

D. J. Kesler, J. M. Dahlquist, T. G. Nash, and H. D. Hafs

SUMMARY

One hundred and fifty-five beef heifers and 146 beef cows suckling calves were randomly assigned to one of three treatment groups: untreated controls, one injection of $PGF_{2\alpha}$, and administration of a intravaginal progesterone insert for seven days along with the administration of $PGF_{2\alpha}$ on the sixth day. This study was part of a larger study that was conduced to evaluate the efficacy of the intravaginal progesterone insert. Females were observed twice daily for estrus for 31 days beginning two days after the time of $PGF_{2\alpha}$ treatment (the day after progesterone insert removal). Females were bred via the AM/PM rule when observed in estrus. At insert removal, eleven of the heifers and one cow did not have inserts in situ (it was assumed that they lost their inserts; 12% loss rate overall). Overall, more ($P < .01$) progesterone insert treated females were in estrus 2 to 4 days after insert removal than untreated and $PGF_{2\alpha}$ treated females. Furthermore, more ($P < .01$) progesterone insert treated females established pregnancy 2 to 4 days after insert removal than untreated and $PGF_{2\alpha}$ treated females. In summary, the combined use of the intravaginal progesterone insert and $PGF_{2\alpha}$ is an efficacious procedure for synchronizing estrus in beef heifers and cows.

INTRODUCTION

Although several estrus synchronization procedures have been developed, none developed yet have been highly accepted by beef producers. Therefore, there continues to be an need for a highly efficacious estrus synchronization procedure. The combined use of a intravaginal progesterone insert and $PGF_{2\alpha}$ has been proved highly efficacious and acceptable in New Zealand. This procedure is now being considered for approval in the U.S. This study was part of a larger study to determine efficacy of the procedure for approval in the U.S.

METHODS AND MATERIALS

One hundred and fifty-five beef heifers and 146 beef cows suckling calves were randomly assigned to one of three treatment groups: untreated controls, one injection of $PGF_{2\alpha}$, and administration of a intravaginal progesterone insert for seven days along with the administration of $PGF_{2\alpha}$ on the sixth day. Females were observed twice daily for estrus for 31 days beginning two days after the time of $PGF_{2\alpha}$ treatment (the day after progesterone insert removal). Females were bred via the AM/PM rule when observed in estrus. All females used in this study were part of the University of Illinois Beef Herd and were located at either Urbana and Balyis, Illinois.

RESULTS

At insert removal, eleven of the heifers and one cow did not have inserts in situ (it was assumed that they lost their inserts; 12% loss rate overall). Estrus and pregnancy results are summarized in Tables

1 and 2. Overall, more ($P < .01$) progesterone insert treated females were in estrus 2 to 4 days after insert removal than untreated and $PGF_{2\alpha}$ treated females. Furthermore, more ($P < .01$) progesterone insert treated females established pregnancy 2 to 4 days after insert removal than untreated and $PGF_{2\alpha}$ treated females.

CONCLUSION

The combined use of the intravaginal progesterone insert and $PGF_{2\alpha}$ is an efficacious procedure for synchronizing estrus in beef heifers and cows.

Table 1. Estrus response after estrus synchronization with progesterone inserts and $PGF_{2\alpha}$

Group	n	Day 1	Day 2	Day 3	Day 4
Heifers:					
Untreated Controls	52	0	2	3	3
$PGF_{2\alpha}$[a]	51	2	13	3	4
Progesterone Insert[b]:					
all	52	0	18	14	6
minus lost inserts[c]	41	0	15	13	5
Cows:					
Untreated Controls	47	1	2	5	4
$PGF_{2\alpha}$[a]	48	2	6	7	4
Progesterone Insert[b]:					
all	51	0	14	20	3
minus lost inserts[d]	50	0	14	20	3
Combined:					
Untreated Controls	99	1%	4%	8%	7%
$PGF_{2\alpha}$[a]	99	4%	19%	10%	8%
Progesterone Insert[b]:					
all	102	0%	31%	34%	9%
minus lost inserts[e]	90	0%	31%	37%	8%

[a]Administered one injection of Lutalyse.

[b]Administered an intravaginal insert for seven days and an injection of Lutalyse one day before insert removal.

[c]Eleven inserts were lost, they were not within the vagina seven days after insertion.

[d]One insert was lost, it was not within the vagina seven days after insertion.

[e]Twelve inserts were lost, they were not within the vagina seven days after insertion.

Table 2. Estrus response and pregnancy rates after estrus synchronization with progesterone inserts and $PGF_{2\alpha}$

Group	n	Three Day Period (d 2-4[a]) Estrus	Pregnancy[b]	Pregnancy[c]
Heifers:				
Untreated Controls	52	8 (15%)	4/ 8 (50%)	4/ 52 (8%)
$PGF_{2\alpha}$[d]	51	20 (39%)	6/20 (30%)	6/ 51 (12%)
Progesterone Insert[e]:				
all	52	38 (73%)	18/38 (47%)	18/ 52 (35%)
minus lost inserts[f]	41	33 (81%)	18/33 (55%)	18/ 41 (44%)
Cows:				
Untreated Controls	47	11 (23%)	4/11 (36%)	4/ 47 (9%)
$PGF_{2\alpha}$[d]	48	17 (35%)	12/17 (71%)	12/ 48 (25%)
Progesterone Insert[e]:				
all	50	36 (72%)	25/36 (69%)	25/ 50 (50%)
minus lost inserts[g]	49	36 (74%)	25/36 (69%)	25/ 49 (51%)
Combined:				
Untreated Controls	99	19[x] (19%)	8/19 (42%)	8/ 99[x] (8%)
$PGF_{2\alpha}$[d]	99	37[y] (37%)	18/37 (49%)	18/ 99[x] (18%)
Progesterone Insert[e]:				
all	102	74 (73%)	43/74 (58%)	43/102 (42%)
minus lost inserts[f]	90	69[z] (77%)	43/69 (62%)	43/ 90[y] (48%)

[a]Days two, three, and four after insert removal.

[b]Number pregnant, days 2-4, divided by number bred.

[c]Number pregnant, days 2-4, divided by total number of females within the group.

[d]Administered one injection of Lutalyse.

[e]Administered an intravaginal insert for seven days and an injection of Lutalyse one day before insert removal.

[f]Eleven inserts were lost, they were not within the vagina seven days after insertion.

[g]One insert was lost, it was not within the vagina seven days after insertion.

[h]Twelve inserts were lost, they were not within the vagina seven days after insertion.

[x,y,z]Values with different superscripts differ ($P < .01$).

MOUNTING ACTIVITY DETECTED BY MEANS OF MOUNTING ACTIVITY MONITORS OF BEEF FEMALES ADMINISTERED SYNCRO-MATE B FOR ESTRUS SYNCHRONIZATION

D. J. Kesler, R. J. Favero, and D. B. Faulkner

SUMMARY

One hundred and ninety-one beef females were administered Syncro-Mate B for estrus synchronization. At the time of implant removal, females were administered either a KaMar Heatmount device or Heat-Mark marking paint. Immediately before AI, 48 hours after implant removal, the status of the devices and paint were evaluated. The status of the KaMar Heatmount device was recorded as white, partial (both red and white), red, and missing. The status of the Heat-Mark marking paint was recorded as < 10% paint removed, 10-89% paint removed, and ≥ 90% paint removed. Overall, 43-44% of the females calved from the synchronized AI. Frequencies of females calving within categories differed ($P < .01$) for both methods of monitoring mounting activity. Fifty-four percent (52/97) and 30% (24/79) of the females classified in estrus (red KaMar Heatmount device or ≥ 90% Heat-Mark marking paint removed) or not in estrus (partially red or white devices or < 90% paint removed), respectively, calved. Females classified in estrus had a higher ($P < .01$) calving rate than females classified not in estrus; however, a valuable number of females not in estrus calved. Results from this study support the recommendation that females synchronized with Syncro-Mate B be bred at a predetermined time, about 48 hours, after norgestomet implant removal. Both methods of identifying females in estrus were similar ($P > .10$), but because 12.5% of the females (n=15) lost their KaMar Heatmount devices, the Heat-Mark marking paint may be more useful if estrus detection is needed to select females with optimal fertility.

INTRODUCTION

Estrus synchronization provides producers a means to utilize AI, improve reproductive management, produce uniform groups of calves, hasten ovarian cycles (Hixon et al., 1981), etc. Syncro-Mate B is an estrus synchronization procedure that provides a high degree of synchrony, thus allowing for a single timed insemination (Kesler and Favero, 1996). Anderson et al. (1982) reported similar pregnancy rates for heifers that exhibited estrus and heifers that did not exhibit estrus after Syncro-Mate B treatment, and mass insemination of females 48 to 52 hours after implant removal is recommended by the manufacturer (Darling, 1993).

Estrus detection is time intensive and subject to error particularly when large numbers of females are in estrus at a given time as occurs after estrus synchronization. Various estrus detection aids have been developed (Williamson et al., 1972; Williams et al., 1981). The objective of this study was to evaluate two estrus detection aids (KaMar Heatmount device and Heat-Mark marking paint) after synchronization with Syncro-Mate B and to evaluate calving rates of females that exhibited estrus and females that did not exhibit estrus after Syncro-Mate B treatment.

METHODS AND MATERIALS

One hundred and ninety-one beef females (71 heifers and 120 cows) from five herds were administered Syncro-Mate B for estrus synchronization. Syncro-Mate B consists of an intramuscular injection of norgestomet (3.0 mg) and estradiol valerate (5.0 mg) in a sesame oil and benzyl alcohol carrier and a hydron implant that contains 6.0 mg norgestomet. The implant was subcutaneously inserted into the dorsal surface of the ear. The injection and implant were administered at the same time. The norgestomet implants were removed nine days after insertion and all females were artificially inseminated about 48 hours after implant removal.

At implant removal, females at four of the herds were randomly assigned to receive either a KaMar Heatmount device or Heat-Mark marking paint. All females at one herd received KaMar Heatmount devices. The KaMar Heatmount device is a white patch that turns to a red color when adequate pressure is applied for sufficient time. Heat-mark marking paint is a stick of soft green paint that when applied to the tail head is removed when animals are mounted. The KaMar Heatmount devices were glued and Heat-mark marking paint was applied between (± 5 cm) the points of the hip bones on the midline. Heat-mark marking paint was applied in three 20 cm strokes along the midline. Immediately before AI the status of the devices and paint was evaluated and recorded. The status of the KaMar Heatmount devices was recorded as white, partial (both red and white), red, and missing. The status of the marking paint was recorded as < 10% paint removed, 10-89% paint removed, and ≥ 90% paint removed. Pregnancy rates were based on calving the following calving season (Domatob et al., 1997).

Data were analyzed by chi-square analysis (cell probabilities-Mendenhall, 1971; categorical data-Cochran and Cox, 1957). Results were similar for heifers and cows and among the locations and were pooled for analysis.

RESULTS AND DISCUSSION

Overall, 43-44% of the females calved to the synchronized AI and was similar to past research (Kesler and Favero, 1996). Frequencies of females calving within categories differed ($P < .01$) for both methods of monitoring mounting activity (Table 1). Fifty-four percent (52/97) and 30% (24/79) of the females classified as in estrus (red KaMar Heatmount device or ≥ 90% Heat-Mark Marking paint removed) or not in estrus (partially red or white devices or < 90% paint removed), respectively, calved. Females classified in estrus had a higher ($P < .01$) calving rate than females classified not in estrus; however, a valuable number of females not in estrus calved. A lower pregnancy rate for females not in estrus was expected because past research has demonstrated that Syncro-Mate B does not sychronize all treated females. A smaller percentage of metestrus females than diestrus females have responded to Syncro-Mate B treatment (Kesler et al., 1997).

More ($P < .05$) females with Heat-Mark marking paint were classified in estrus than females with KaMar Heatmount devices, but calving rates were similar ($P > .10$) for the two methods of detecting estrus. Therefore, there was a larger, although nonsignificant ($P > .10$), number of females with Heat-Mart marking paint classified in estrus that calved than females with KarMar Heatmount devices (Table 1). One negative attribute of the KaMar Heatmount devices was that 15 (12.5%) were missing 48 hours after administration. KaMar Heatmount devices may have been rubbed off while

females were being mounted because calving rates were similar to females with red KaMar Heatmount devices. If females that lost their KaMar Heatmount device were classified in estrus, the number females that were in estrus and the number of females that calved and were classified in estrus would be similar ($P > .10$) between the two groups.

There are situations in which producers may want to determine estrus. When expensive semen is used or when recipient females for embryo transfer are being selected, one may want to select females with optimal fertility. In most situations, the data in the present experiment would support the recommendation that females synchronized with Syncro-Mate B be bred at a predetermined time, about 48 hours, after norgestomet implant removal. Both methods of identifying estrus females were similar, but because 12.5% of the females lost their KaMar Heatmount devices in a 48 hour period, the Heat-Mark marking paint may be more useful if estrus detection is desired.

LITERATURE CITED

Anderson, G. W., Babonis, G. D., Riesen, J. W., and Woody, C. O. 1982. Control of estrus and pregnancy in dairy heifers treated with Syncro-Mate B. Theriogenology 17:623-633.

Cochran, W. G. and Cox, G. M. 1957. Experimental Design. John Wiley & Sons, New York.

Darling, L. 1993. Veterinary Pharmaceuticals and Biologicals. Veterinary Medicine Publishing Co., Lenexa, KS.

Domatob, F. N., Favero, R. J., Ireland, F. A., Faulkner, D. B., and Kesler, D. J. 1997. Methods of identifying and inseminating nonpregnant beef females after synchronization of second estrus with norgestomet implants. Theriogenology 47:1077-1086.

Hixon, D. L., Kesler, D. J., Troxel, T. R., Vincent, D. L., and Wiseman, B. S. 1981. Reproductive hormone secretions and first service conception rates subsequent to ovulation control with Syncro-Mate B. Theriogenology 16:219-229.

Kesler, D. J., Dyson, T. S., Summers, R. N., Steckler, T. L., and Nash, T. G. 1997. Effect of prostaglandin $F_{2\alpha}$ treatment before norgestomet and estradiol valerate treatment on regression, formation, and function of corpora lutea in beef heifers. Anim. Reprod. Sci. (In Press).

Kesler, D. J. and Favero, R. J.. 1996. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: Factors limiting and enhancing efficacy. Agri-Pract. 17:12-17.

Mendenhall, W. 1971. Introduction to Probability and Statistics. Duxbury Press, Belmont, CA.

Williams, W. F., Yver, D. R., and Gross, T. S. 1981. Comparison of estrous detection techniques in dairy heifers. J. Dairy Sci. 64:1738-1741.

Williamson, N. B., Morris, R. S., Blood, D. C., and Cannon, C. M. 1972. A study of oestrous behavior and oestrous detection methods in a large commercial dairy heard. I. The relative efficiency of methods of oestrous detection. Vet. Rec. 91:50-58.

Table 1. Pregnancy rates and mounting activity of females with KaMar Heatmount Devices and Heat-Mark Marking Paint after synchronization with norgestomet and estradiol valerate

Item	KaMar Heatmount Devices	Heat-Mark Marking Paint
Pregnancy Rate:		
Red or ≥90% Removed[f]	30/ 54[a] (56%)	22/ 43[a] (51%)
Partial or 10-89% Removed[g]	7/ 16[b] (44%)	5/ 15[b] (33%)
White or <10% Removed[g]	8/ 35[c] (23%)	4/ 13[c] (31%)
Missing	7/ 15 (47%)	------
Combined	52/120 (43%)	31/ 71 (44%)
Mounting Activity:		
Red or ≥90% Removed ÷ Total (%)	54/120[d] (45%)	43/ 71[e] (61%)
Red or ≥90% Removed & Pregnant ÷ Total Number Pregnant (%)	30/ 52 (58%)	22/ 31 (71%)

[a,b,c]Values with different superscripts within the same column indicate that the frequencies within categories differed ($P < .01$) from chance.

[d,e]Values within the same row with different superscripts differ ($P < .05$).

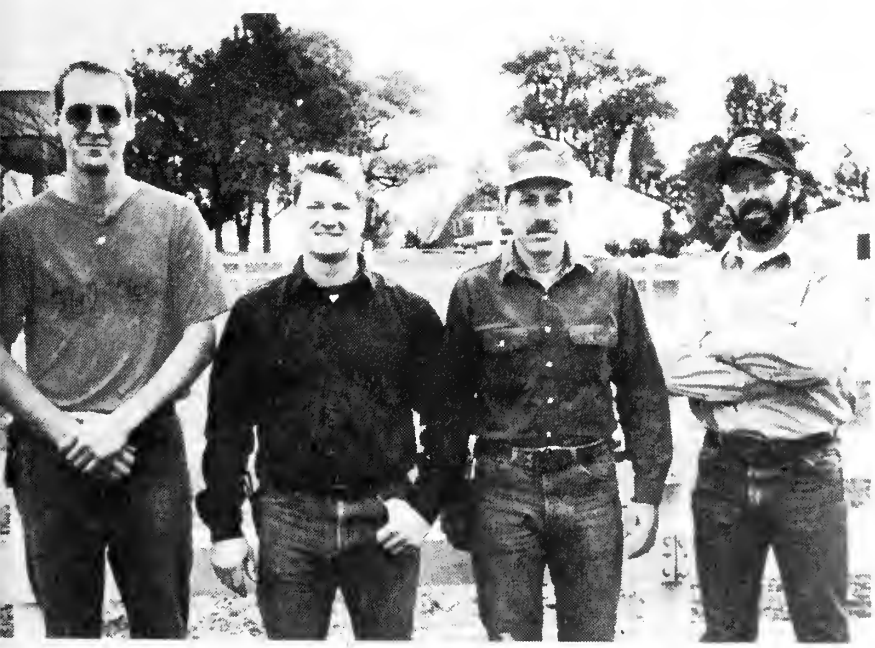
[f,g]Overall pregnancy rate (both mounting activity monitors combined) for females with red monitors or≥90% paint removed and females with partially red or white monitors or <89% paint removed was 54% (52/97) and 30% (24/79), respectively ($P < .01$).

ORR CENTER

(L-R) Larry Spencer, Danny Graham

DIXON SPRINGS
AGRICULTURAL CENTER
Beef Research Unit Personnel

Back Row: (L-R)
Phillip Morris, Marvin Williamson, Jerry Wells, Steve Morris, Brian Bremer
Seated: (L-R)
Larry Richards, Kenneth Kerley, Lyndell Bates



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