

JOURNAL OF ANIMAL SCIENCE

The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

Impacts of increasing amounts of supplemental soybean meal on intake and digestion by beef steers and performance by beef cows consuming low-quality tallgrass-prairie forage

C. P. Mathis, R. C. Cochran, G. L. Stokka, J. S. Heldt, B. C. Woods and K. C. Olson

J Anim Sci 1999. 77:3156-3162.

The online version of this article, along with updated information and services, is located on the World Wide Web at:

<http://jas.fass.org>



American Society of Animal Science

www.asas.org

Impacts of Increasing Amounts of Supplemental Soybean Meal on Intake and Digestion by Beef Steers and Performance by Beef Cows Consuming Low-Quality Tallgrass-Prairie Forage¹

C. P. Mathis², R. C. Cochran, G. L. Stokka, J. S. Heldt³, B. C. Woods, and K. C. Olson⁴

Department of Animal Sciences and Industry, Kansas State University, Manhattan 66506

ABSTRACT: Two experiments were conducted to evaluate the impacts of increasing levels of supplemental soybean meal (SBM) on intake, digestion, and performance of beef cattle consuming low-quality prairie forage. In Exp. 1, ruminally fistulated beef steers (n = 20; 369 kg) were assigned to one of five treatments: control (forage only) and .08, .16, .33, and .50% BW/d of supplemental SBM (DM basis). Prairie hay (5.3% CP; 49% DIP) was offered for ad libitum consumption. Forage OM intake (FOMI) and total OM intake (TOMI) were increased (cubic, $P = .01$) by level of supplemental SBM, but FOMI reached a plateau when the daily level of SBM supplementation reached .16% BW. The concomitant rises in TOMI and OM digestibility (quadratic, $P = .02$) resulted in an increase (cubic, $P = .03$) in

total digestible OM intake (TDOMI). In Exp. 2, spring-calving Hereford × Angus cows (n = 120; BW = 518 kg; body condition [BC] = 5.3) grazing low-quality, tallgrass-prairie forage were assigned to one of three pastures and one of eight treatments. The supplemental SBM (DM basis) was fed at .08, .12, .16, .20, .24, .32, .40, and .48% BW/d from December 2, 1996, until February 10, 1997 (beginning of the calving season). Performance seemed to reach a plateau when cows received SBM at approximately .30% BW/d. Below this level, cows lost approximately .5 unit of BC for every .1% BW decrease in the amount of supplemental SBM fed. Providing supplemental SBM is an effective means of improving forage intake, digestion, and performance of beef cattle consuming low-quality forages.

Key Words: Beef Cattle, Forage, Intake, Digestibility, Protein

©1999 American Society of Animal Science. All rights reserved.

J. Anim. Sci. 1999. 77:3156–3162

Introduction

Providing supplements with a high concentration of CP to beef cows grazing low-quality winter range can reduce BW and body condition (BC) losses that normally occur (DelCurto et al., 1990; Beaty et al., 1994; Hollingsworth-Jenkins et al., 1996). Infusion studies (Köster et al., 1996; Mathis, 1998; Olson, 1998) suggest that the responses observed in such instances are primarily due to increased degradable intake protein (DIP). The amount of DIP needed to maximize forage intake and digestion of low-quality, tallgrass-prairie forage was estimated by Köster et al. (1996) by modeling

the forage intake and digestion response in a DIP titration study. To effectively apply such information to practical field settings, it is desirable to conduct similar research under field conditions. Soybean meal (SBM) is relatively high in DIP concentration and, as such, should be a useful feedstuff for evaluating performance response to supplemental DIP. The objectives of these studies were to evaluate the impact of increasing levels of SBM on intake and digestion of low-quality prairie hay, to identify the point at which increasing levels of SBM elicit maximum performance response, and to characterize the rate of performance decline below the maximum response.

Materials and Methods

Experiment 1: Digestion Trial

Ruminally fistulated beef steers (n = 20; average initial BW = 369 kg) were blocked by weight and randomly assigned within block to one of the following treatments: forage only (control) or forage plus supplemental SBM (DM basis) at .08, .16, .33, or .50% BW/d. Supplemental SBM was offered to steers at 0630, and forage was offered after the steers consumed all of the SBM

¹Article No. 99-99-J from the Kansas Agric. Exp. Sta.

²To whom correspondence should be addressed. Present address: Extension Animal Resources, New Mexico State Univ., Las Cruces 88003.

³Present address: Land O'Lakes/Harvest States Feed, P. O. Box 5047, Sioux Falls, SD 57117-5047.

⁴Present address: Dept. of Animal Science, Univ. of Missouri, Columbia 65211.

Received November 19, 1998.

Accepted May 22, 1999.

Table 1. Chemical compositions of forages and supplemental soybean meal

Item	Component, % DM				
	OM	CP	DIP	NDF	ADIA
Tallgrass-prairie hay (Exp. 1)	92.5	5.3	2.6 ^b	69.4	3.22
Soybean meal (Exp. 1)	92.7	53.4	34.7 ^c	9.8	0
Dormant tallgrass-prairie range (Exp. 2) ^a	93.3	2.7	1.3 ^b	76.0	4.91
Soybean meal (Exp. 2)	92.7	53.9	35.0 ^c	10.1	0

^aEstimated from clipped samples.

^bEstimated using a single-point enzymatic assay.

^cTabular value from NRC (1996).

(0700). Before the trial began, the forage was ground to pass through a 75- × 75-mm screen and offered to each steer at a level equal to 130% of intake over the previous 5-d period. Steers were housed in an enclosed barn, where they were maintained in individual tie-stalls (1.2 × 1.7 m) with ad libitum access to fresh water and trace mineralized salt (96.0 to 98.5% NaCl, .4% Zn, .16% Fe, .12% Mn, .033% Cu, .01% I, and .004% Co). The Kansas State University Animal Care and Use Committee approved the animal care practices and surgical procedures. Chemical composition of forage and SBM are shown in Table 1.

Steers were adapted to their respective stalls and treatments for 14 d, and data were collected during the subsequent 9-d period. Samples of hay were collected daily from d 15 through 21, and orts were collected from d 16 through 22. Additionally, fecal grab samples were collected daily at 0630 from d 17 through 23. Daily samples of orts and feces were dried for 96 h at 55°C in a forced-air oven. Hay, ort, and fecal samples were ground (No. 4 Wiley mill, Thomas Scientific, Swedesboro, NJ) to pass through a 1-mm screen. Samples of orts were composited within steer and across days for each experiment. Feces were composited in the same manner.

Ground samples of forage, orts, feces, and ruminal digesta were dried for approximately 12 h at 105°C in a convection oven to determine DM content. Voluntary intake from d 15 through 21 was calculated by subtracting the total dry weight of the orts from the total dry weight of the forage offered. Ground samples of forage, orts, and feces were then heated for 8 h at 450°C in a muffle furnace for OM determination. Crude protein of the forage and supplement was determined as 6.25 × Kjeldahl N (AOAC, 1990). These samples also were analyzed for NDF, ADF, and acid detergent insoluble ash (ADIA) using the procedure described by Van Soest and Robertson (1985). Fecal output and nutrient digestibility were calculated using ADIA as an internal marker as described by Cochran and Galyean (1994). Forage DIP content was estimated using a 48-h single-point enzyme (*S. griseus* protease; Sigma Chemical Co., St. Louis, MO) assay as described by Mathis et al. (1998). The amount of DIP offered via the SBM was estimated using the tabular value for the concentration of DIP in SBM (66% of CP) published by the NRC (1996).

We also used a single-point enzyme assay to estimate the DIP in SBM for comparison.

Samples of ruminal fluid were collected from each steer using a suction strainer (Raun and Burroughs, 1962; 19 mm diameter; 15 mm mesh) prior to feeding (0 h) and at 3, 6, 9, and 12 h after feeding on d 23. The pH of ruminal fluid was measured immediately after collection using a portable pH meter with a combination electrode (Orion Research, Boston, MA).

Frozen (-20°C) ruminal fluid samples for ammonia (2 mL of ruminal fluid plus 8 mL of 1 N HCl) and VFA (8 mL of ruminal fluid plus 2 mL 25% wt/vol metaphosphoric acid) measurement were thawed and centrifuged at 30,000 × g for 20 min. Ammonia was analyzed using the procedure described by Broderick and Kang (1980). Concentrations of VFA in ruminal fluid were determined with a gas chromatograph (model 5890, Hewlett-Packard, Avondale, PA) as described by Vanzant and Cochran (1994).

Experiment 2: Cow Performance Trial

On December 2, 1996, pregnant Angus × Hereford beef cows (n = 120; average initial BW = 518 kg; average initial body condition [BC] = 5.3 on a scale of 1 to 9) were stratified by BW and BC and blocked into 15 groups of eight cows each. Within each group, cows were assigned randomly to one of eight levels of supplemental SBM so that each pasture contained five cows per treatment. Supplemental SBM (DM basis) was fed at .08, .12, .16, .20, .24, .32, .40, and .48% BW/d. Each block was assigned randomly to one of three native tallgrass-prairie pastures. The dominant forages in the tallgrass-prairie pastures were big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and indiangrass (*Sorghastrum nutans*; Olson, 1998). Each pasture was approximately 120 ha (3 ha/cow). This allotment is similar to historical stocking rates per cow-calf pair in the Flinthills Region to achieve a moderate grazing pressure. Cows within each pasture were sorted into their respective treatment groups at 0700 each day and group-fed their respective levels of supplemental SBM. Treatments were applied for 69 d from the beginning of the winter grazing season (December 2, 1996) until the 1st d of the calving season (February 10, 1997). After the calving season began and until each cow

calved, cows were fed supplemental SBM at .30% BW/d. This level of supplemental SBM was determined to be the point of maximal BC response during the treatment period. Following parturition, cows were fed 4.54 kg·cow⁻¹·d⁻¹ of long-stem alfalfa hay as a supplement until sufficient new grass growth was available in the spring (late April). Thereafter all cows and calves grazed bluestem range at moderate stocking rates without supplementation throughout the summer. Body weight and BC were measured for all cows after an overnight shrink on d 0 (start of winter grazing), 35, 69 (start of calving), 93 (average calving date), 155 (breeding), and 274 (weaning). Body condition scores of all cows (whole units on a scale of 1 to 9; 1 = extremely emaciated; 9 = extremely obese) were averages of scores by four trained individuals. Pregnancy status following breeding was determined by rectal palpation. Weights of calves were measured at birth and on d 155 and d 274. Calf ADG was calculated as weaning weight minus birth weight divided by calf age.

Statistical Analyses

In Exp. 1, all data regarding intake and nutrient digestion were analyzed using the GLM procedure of SAS (1988). Terms in the model were block and treatment. The LSMEANS option was used to generate individual treatment means; appropriate error terms were specified when the LSMEANS option was used. The GLM procedure of SAS (1988) was used to analyze ruminal characteristics that were measured at different times using individual steer as the experimental unit. These variables (pH, ammonia N, and VFA) were analyzed as a split-plot design; whole plot effects included treatment and block, and subplot effects were time and time × treatment. Whole plot effects were tested using treatment × block as the error term. The residual error was used to test subplot effects. When dependent variables exhibited a time × treatment interaction ($P > .05$), data were plotted graphically to evaluate the interaction and the potential effect it might have on the interpretation of main effects. Treatment sums of squares were partitioned into linear, quadratic, and cubic effects.

In Exp. 2, all data excluding pregnancy rate were analyzed as a randomized complete block design using the GLM procedure of SAS (1988). Terms in the model were treatment and pasture. Each treatment group in a pasture was considered to be an experimental unit. Treatment means were generated using the LSMEANS option in SAS (1988). Means were separated using linear, quadratic, and cubic contrasts. The break-point in response to SBM was estimated with a single-slope, broken-line model (Robbins, 1986) using the NLIN procedure of SAS (1988). Pregnancy rate was analyzed using the LOGISTIC procedure in SAS (1992).

Results

Experiment 1: Digestion Trial

Chemical composition of forages and supplemental SBM used in Exp. 1 and 2 are shown in Table 1. The

chemical composition of the tallgrass-prairie hay fed in Exp 1. was similar to that reported for tallgrass-prairie hay used in previous studies (Woods et al., 1997; Heldt, 1998). Forage OM intake (**FOMI**) and total OM intakes (**TOMI**) increased (cubic; $P > .01$) with increasing SBM supplementation (Table 2). The largest incremental response to supplemental SBM occurred with addition of the first level of SBM. However, FOMI seemed to reach a plateau when the daily level of SBM supplementation reached .16% BW, whereas TOMI exhibited an additional increase at the highest level of supplemental SBM (.5% BW). Organic matter digestibility (**OMD**) was enhanced as the amount of supplemental SBM increased and also seemed to exhibit diminished response at the higher levels (quadratic, $P = .02$). Intake and digestion of NDF responded in a manner similar to that observed for FOMI and OMD, respectively. The rises in both TOMI and OMD with increasing level of supplemental SBM resulted in an increase in total digestible organic matter intake (**TDOMI**). The largest proportional response was observed with the initial level of supplement fed (cubic, $P = .03$).

A treatment × time interaction ($P > .05$) was present for ruminal ammonia N and total VFA concentration, as well as for the molar percentages of butyrate, valerate, and isovalerate. Because the interactions were primarily functions of variation in magnitude of difference within each time period, data were averaged across time and are presented as means (Table 3). Ruminal pH tended (linear, $P = .11$) to decline slightly with increasing level of supplemental SBM, whereas ruminal ammonia N concentration increased ($P > .01$) dramatically in response to supplementation. Total VFA concentration also was elevated (linear, $P = .02$) by increasing the amount of supplemental SBM consumed. The molar percentages of both acetate and propionate responded in a cubic ($P \leq .06$) fashion, resulting in an increase (cubic, $P = .01$) in the acetate:propionate ratio followed by a drop at the higher levels of supplementation. The molar proportions of butyrate, isobutyrate, valerate, and isovalerate increased linearly ($P < .04$) with rising levels of SBM supplementation.

Experiment 2: Cow Performance Trial

Cumulative cow BW and BC losses from d 0 through 69 (beginning of calving; Table 4) were reduced by increasing levels of supplemental SBM; however, both BW and BC showed a clear plateau (quadratic, $P < .01$) in response. A single-slope, broken-line model revealed that the plateau for BC in response to supplemental SBM occurred at approximately .3% BW (Figure 1). A similar response was observed for BW change during this period (d 0 through 69). Feeding SBM above this level yielded little additional reduction in BC or BW loss during that period of time. Below the plateau of approximately .3% BW, each .1% of BW decrease in SBM fed resulted in a .5-unit decrease in BC. From d 70 through 155, cows that previously consumed higher

Table 2. Effects of increasing amount of soybean meal (SBM) on organic matter (OM), neutral detergent fiber (NDF), and degradable intake protein (DIP) intakes, and OM and NDF digestion in beef steers fed low-quality tallgrass-prairie hay (Exp. 1)

Item	Supplemental SBM (% BW)					SEM ^a	Contrast ^b		
	0	.08	.16	.33	.50		L	Q	C
Initial body weight, kg	365	379	368	372	358				
	g/kg BW ⁷⁵								
OM intake									
Forage	75.7	97.5	110.3	100.5	110.0	4.9	<.01	.02	.01
Total	75.7	100.8	116.9	113.9	130.0	4.9	<.01	.02	.01
Digestible OM intake	37.9	57.4	67.3	69.5	81.6	3.7	<.01	.03	.03
NDF intake	57.4	74.2	84.2	77.6	85.0	3.7	<.01	.02	.01
Digestible NDF intake	28.0	41.6	47.7	44.8	49.6	2.9	<.01	.02	.02
	% of Intake								
Total tract digestibility									
OM	50.0	56.8	57.6	60.9	62.6	1.2	<.01	.02	.18
NDF	48.7	56.0	56.6	57.7	58.2	1.6	<.01	.03	.12
	g/kg BW ⁷⁵								
DIP intake									
Forage	2.12	2.73	3.09	2.82	3.07	.14	<.01	.02	.01
Total	2.12	4.00	5.63	7.90	10.69	.14	<.01	.02	.01

^aStandard error of the mean (n = 4).

^bL = linear, Q = quadratic, C = cubic.

levels of supplemental SBM generally lost more BW and BC. Furthermore, the same cows generally gained less BW and BC between d 156 and 274 (summer grazing season) than cows that received less supplemental SBM during the winter grazing season. However, the level of SBM supplementation during the winter grazing season did not alter cumulative BW and BC changes from d 0 through 274.

The level of SBM fed from d 0 until 69 had no effect on calf birth date ($P \geq .52$) or calf ADG ($P \geq .43$; Table 5). However, both birth weight ($P = .16$) and calf weaning weight ($P = .12$) tended to respond in a quadratic fashion to the increasing amounts of supplemental SBM. There

were no differences among treatments in pregnancy rate ($P = .51$).

Discussion

These experiments demonstrate that providing supplemental SBM to beef cattle consuming low-quality forage can dramatically improve intake, digestion, and performance. In Exp. 1, FOMI and TOMI were 46 and 54% above values for the negative control (forage only) when steers were fed SBM at .16% BW (level at which maximal FOMI was achieved). Stokes et al. (1988) observed a 57% increase in TOMI over the negative con-

Table 3. Effects of increasing amount of supplemental soybean meal (SBM) on fermentation characteristics in beef steers fed tallgrass-prairie hay (Exp. 1)

Item	Supplemental SBM, % BW					SEM ^a	Contrast ^b		
	0	.08	.16	.33	.50		L	Q	C
pH	7.02	6.97	6.98	6.93	6.91	.05	.11	.82	.98
Ammonia N ^c , mM	.62	1.14	2.36	4.12	6.20	.34	<.01	.57	.82
Total VFA ^{c,d} , mM	59.9	67.8	68.2	70.4	74.8	3.7	.02	.54	.38
	mol/100 mol								
Acetate	76.4	77.7	77.0	75.7	74.6	.4	<.01	.03	.06
Propionate	14.2	13.1	13.3	13.9	14.2	.3	.17	.02	.02
Butyrate ^c	8.2	8.0	8.3	8.5	8.9	.3	.04	.55	.74
Isobutyrate	.43	.38	.45	.51	.63	.04	<.01	.17	.50
Valerate ^c	.39	.40	.50	.67	.78	.03	<.01	.92	.15
Isovalerate ^c	.35	.32	.47	.67	.91	.05	<.01	.24	.44
Acetate:propionate	5.44	5.90	5.80	5.44	5.26	.10	<.01	.01	.01

^aStandard error of the mean (n = 4).

^bL = linear, Q = quadratic, C = cubic.

^cTreatment × time ($P < .05$).

^dVolatile fatty acid.

Table 4. Effects of increasing amounts of supplemental soybean meal (SBM) on cumulative and period changes in body weight (BW) and condition score (BC) of beef cows grazing dormant, tallgrass-prairie forage (Exp. 2)

Item	Supplemental SBM, % of BW								Contrast ^b			
	.08	.12	.16	.20	.24	.32	.40	.48	SEM ^a	L	Q	C
No. of cows	15	15	15	15	15	15	15	15				
Initial BW, kg	516	522	515	523	510	516	513	526	12	.66	.45	.31
Period BW change, kg												
Day 0–35 ^c	-27	-20	-14	-10	-4	-1	2	4	4	<.01	.01	.71
Day 36–69 ^c	-22	-7	-7	-6	6	7	8	14	7	<.01	.02	.20
Day 70–155 ^c	-66	-75	-84	-90	-95	-103	-111	-105	7	<.01	.05	.82
Day 156–274 ^c	118	108	118	87	89	98	97	79	9	<.01	.56	.22
Cumulative BW change, kg												
Day 0–69 ^c	-49	-27	-20	-16	1	8	10	17	5	<.01	<.01	.29
Day 0–155 ^c	-116	-121	-103	-102	-93	-95	-101	-88	18	.02	.36	.10
Day 0–274 ^c	1	14	15	-15	-4	-3	-5	-10	9	.21	.94	.85
Initial BC ^d	5.28	5.22	5.28	5.17	5.33	5.22	5.30	5.37	.15	.14	.20	.86
Period BC change												
Day 0–35 ^c	-.82	-.58	-.75	-.45	-.18	-.23	-.15	-.23	.10	<.01	<.01	.40
Day 36–69 ^c	-.42	-.15	-.17	-.08	-.17	.17	.07	.25	.10	<.01	.47	.55
Day 70–155 ^c	-.33	-.50	-.43	-.43	-.38	-.77	-.73	-.91	.11	<.01	.52	.73
Day 156–274 ^c	1.21	1.15	1.24	.93	.63	.70	.78	.73	.13	.01	.13	.79
Cumulative BC change												
Day 0–69 ^c	-1.23	-.74	-.86	-.53	-.35	-.07	-.08	.02	.10	<.01	<.01	.86
Day 0–155 ^c	-1.58	-1.23	-1.29	-.98	-.73	-.83	-.82	-.93	.14	<.01	<.01	.62
Day 0–274 ^c	-.28	.00	-.05	.00	-.10	-.13	-.03	-.22	.12	.81	.14	.48

^aStandard error of the mean (n = 3).

^bL = Linear, Q = quadratic, C = cubic.

^cDay 0 = December 2 (start of winter grazing period); Day 35 = January 6; Day 69 = February 10 (start of calving); Day 155 = May 8 (start of breeding); Day 274 = October 1 (weaning).

^dBody condition scale: 1 = extremely emaciated; 9 = extremely obese.

control when supplemental SBM was fed at .24% BW. Guthrie and Wagner (1988) found that forage DMI was increased by 45% and total DMI was increased by 52% when SBM was supplemented at .28% BW. In Exp. 1 of our study, OMD was approximately 25% higher when SBM was supplemented at .50% BW compared with the negative control. The magnitude of this response is also similar to previous findings. Stokes et al. (1988) reported a 20% increase in OMD when SBM was fed

at .24% BW, and Guthrie and Wagner (1988) reported a 28% enhancement when SBM was supplemented at .28% BW. When the effects of TOMI and OMD were combined in our study, TDOMI was increased 115% above the negative control by the highest level of supplemental SBM. The increase in TDOMI beyond the peak in FOMI seemed to be due primarily to the provision of additional SBM per se, not to a change in the magnitude of positive associative effects on OMD.

Soybean meal provides not only DIP, but also contains undegradable intake protein (UIP), carbohydrates, lipids, minerals, and vitamins (NRC, 1996). It is unlikely that the intake or digestion responses observed in this experiment were due to provision of minerals or vitamins. In contrast, there is both circumstantial (Guthrie and Wagner, 1988; DelCurto et al., 1990; Beaty et al., 1994) and direct (Köster et al., 1996; Mathis, 1998) evidence that indicates that DIP is capable of prompting the types of responses observed in this experiment. Moreover, recent infusion studies conducted by Heldt (1998) and Olson (1998) suggest that when cattle are consuming low-quality, N-deficient forages, supplemental DIP is more likely to be effective in stimulating improvements in forage intake and digestion than supplementation with starch, sugars, or digestible fiber. We believe that the effects on intake and digestion in our study were primarily due to the provision of supplemental DIP. This suggestion does not imply that supplemental UIP is unimportant,

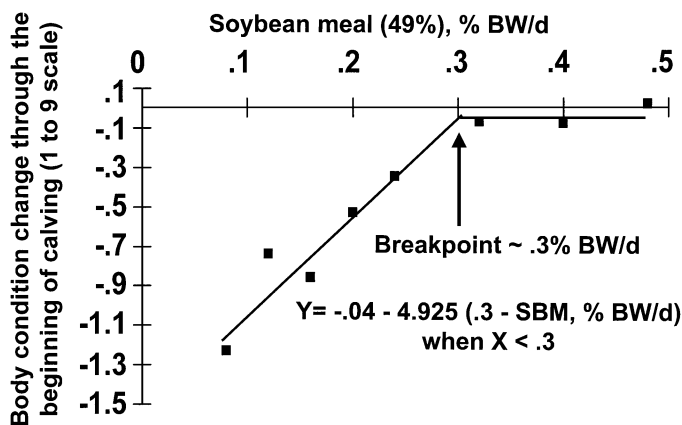


Figure 1. Single-slope, broken-line analysis of the change in body condition in response to soybean meal supplementation during the period from the beginning of Exp. 2 until the beginning of the calving season.

Table 5. Effects of increasing amount of supplemental soybean meal (SBM) on pregnancy rate and performance of calves from beef cows grazing dormant, tallgrass-prairie forage (Exp. 2)

Item	Supplemental SBM, % of BW								SEM ^a	Contrast ^b		
	.08	.12	.16	.20	.24	.32	.40	.48		L	Q	C
Pregnancy rate, % ^c	93	93	93	100	87	93	93	87				
Calf birth date (Gregorian day)	66	69	66	63	63	62	75	67	4.3	.59	.52	.59
Birth wt, kg	38.1	37.7	37.7	40.5	40.1	38.7	42.5	38.5	1.4	.14	.16	.24
Calf ADG, birth to weaning, kg ^d	.95	.91	.95	.95	.95	.95	.95	.91	.05	.84	.43	.53
Weaning wt, kg	233	221	232	244	235	239	234	228	8.1	.88	.12	.76

^aStandard error of the mean (n = 3).

^bL = linear, Q = quadratic, C = cubic.

^cChi-square ($P = .51$).

^dAverage daily gain.

rather, that under conditions of significant N deficiency, the effects of administering a unit of supplemental DIP will have a more positive effect on total digestible OM intake than will a unit of supplemental UIP. This view is supported by the fact that the majority of fiber digestion occurs in the rumen and that, in order for supplemental UIP to contribute to the ruminal N pool, it must be digested intestinally and recycled to the rumen.

Previous estimates of the quantity of DIP required to elicit maximal forage utilization and/or performance by forage-fed cattle generally have fallen in the range of 7 to 13% of the digestible OM (Karges et al., 1991; Hollingsworth-Jenkins et al., 1996; Köster et al., 1996; NRC, 1996). We executed the same calculation at the point of maximal FOMI (.16% BW), because TDOMI did not clearly reach a plateau, using the NRC (1996) table values for SBM DIP (65% of CP) and an enzymatic estimate (84% of CP). When the NRC (1996) estimate was used, the total DIP intake expressed as a percentage of the TDOMI was 8.4%. When the enzymatic estimate was used, the calculated value was 9.4%. Both of these values fall within the range of previous estimates; however, they fall below the breakpoint experimentally determined with similar forage and type of livestock (11.1%; Köster et al., 1996). We suspect that some of the discrepancy in these estimates may be due to the fact that recycling of the digestible UIP is typically not considered in such calculations (as in level 1 of the 1996 Beef NRC). If digestible UIP contributes significant amounts of N to the ruminal pool, then the need for dietary DIP to meet the "requirement" would be less than in those situations in which little of the rumen's functional DIP supply is provided by digestible UIP.

The increase in ruminal ammonia N concentration observed in Exp. 1 is in accord with other research (Guthrie and Wagner, 1988; Stokes et al., 1988; Köster et al., 1996) and reflects the increasing levels of ruminally available N provided by SBM. Based on the findings of Satter and Slyter (1974), ruminal ammonia N was insufficient in the basal forage diet, and the average concentrations did not approach the general level they considered to be desirable (≈ 3.6 mM) until the level of supplementation exceeded .16% BW. However, the most noticeable change in NDF digestibility (NDFD)

was with the initial level of supplementation. Changes in NDFD were relatively small thereafter. Although the NDFD is confounded with increasing intake, and likely rate of passage, the pattern of response suggests that the largest proportion of the ruminal N deficiency was met with the initial level of supplement fed. This concurs with Satter and Slyter's (1974) suggestion that the actual concentration at which microbial growth was limited in their study was closer to 1.4 mM. The higher level (3.6 mM) was suggested to allow for a margin of error.

The rise in total VFA concentrations indicates an increase in energy available to the host animal and can be explained by increased TOMI and OMD. The increase in total VFA concentration is likely responsible for the small decline in ruminal pH. However, ruminal pH was not low enough to negatively affect fiber digestion (Hoover, 1986). Although statistical differences were observed for the molar proportions of all of the VFA measured, in most cases the magnitude of changes with increasing SBM were not large.

The improvements that SBM supplementation elicited in intake and digestion and the associated impacts on protein and energy supply were reflected in the BW and BC responses of the beef cows in Exp. 2. This agrees with previous research in which feeds rich in protein were given to beef cows consuming low-quality forage during the winter grazing season (DelCurto et al., 1990; Beaty et al., 1994; Hollingsworth-Jenkins et al., 1996). The fact that BW and BC reached a plateau during the winter feeding period indicates that in the process of attempting to meet the DIP need with supplemental SBM we were able to meet the metabolizable protein (MP) need as well from the combination of microbial CP and UIP. That is, sufficient MP was supplied by the forage and supplement to allow the maximal expression of gain that the energy constraints of the diet would allow. The fact that the cows receiving the higher levels of supplemental SBM generally lost more BW and BC from d 69 through 155 than cows previously fed lower levels of SBM may have been the result of increased efficiency in those cows that had previously experienced greater weight loss. This is supported 1) by the work of Ferrell and Jenkins (1985), who suggested that main-

tenance energy expenditure increases as the size of the visceral organs increase, and 2) by Koong et al. (1985), who demonstrated that at a lower plane of previous nutrition visceral organ size is less. Additionally, such differences also might reflect effects on milk production.

Implications

Providing supplemental soybean meal to beef cattle consuming low-quality forage has the potential to dramatically improve intake, digestion, and performance. Improvement of forage utilization seems to be due primarily to the provision of a source of degradable intake protein, which, in turn, results in increased protein and energy supply to the host. Knowledge of the amount of a protein supplement needed for maximal performance and the value of each unit below that level provides a useful tool for evaluating the potential economic impact of a single unit of supplement on production.

Literature Cited

- AOAC. 1990. Official Methods of Analysis (15th Ed.). Association of Official Analytical Chemists, Arlington, VA.
- Beaty, J. L., R. C. Cochran, B. A. Lintzenich, E. S. Vanzant, J. L. Morrill, R. T. Brandt, Jr., and D. E. Johnson. 1994. Effect of frequency of supplementation and protein concentration in supplements on performance and digestion characteristics of beef cattle consuming low-quality forages. *J. Anim. Sci.* 72:2475–2486.
- Broderick, G. A., and J. A. Kang. 1980. Automated simultaneous determination of ammonia and total amino acids in ruminal fluid and in vitro media. *J. Dairy Sci.* 63:64–75.
- Cochran, R. C., and M. L. Galyean. 1994. Measurement of in vivo forage digestion by ruminants. In: G. C. Fahey, Jr., M. Collins, D. R. Mertens, and L. E. Moser (Ed.) *Forage Quality, Evaluation, and Utilization*. pp 613–643. Am. Soc. Agron., Crop Sci. Soc. Am., Soil Sci. Soc. Am., Madison, WI.
- DelCurto, T., R. C. Cochran, L. R. Corah, A. A. Beharka, E. S. Vanzant, and D. E. Johnson. 1990. Supplementation of dormant tallgrass-prairie forage: II. Performance and forage utilization characteristics in grazing beef cattle receiving supplements of different protein concentrations. *J. Anim. Sci.* 68:532–542.
- Ferrell, C. L., and T. G. Jenkins. 1985. Cow type and the environment: Nutritional aspects. *J. Anim. Sci.* 61:725–741.
- Guthrie, M. J., and D. G. Wagner. 1988. Influence of protein or grain supplementation and increasing levels of soybean meal on intake, utilization and passage rate of prairie hay in beef steers and heifers. *J. Anim. Sci.* 66:1529–1537.
- Heldt, J. S. 1998. Effect of various supplemental carbohydrate sources on the utilization of low-quality tallgrass-prairie forage. Ph.D. dissertation. Kansas State University, Manhattan.
- Hollingsworth-Jenkins, K. J., T. J. Klopfenstein, D. C. Adams, and J. B. Lamb. 1996. Ruminally degradable protein requirement of gestating beef cows grazing native winter sandhills range. *J. Anim. Sci.* 74:1343–1348.
- Hoover, W. H. 1986. Chemical factors involved in ruminal fiber digestion. *J. Dairy Sci.* 69:2755–2766.
- Karges, K. K., T. Klopfenstein, and V. Wilkerson. 1991. Protein requirements of beef cows fed native range hay. *Nebr. Beef Cattle Rep.* MP-56:32–34.
- Koong, L. J., C. L. Ferrell, and J. A. Nienaber. 1985. Assessment of interrelationships among levels of intake and production, organ size and fasting heat production in growing animals. *J. Nutr.* 115:1383–1390.
- Köster, H. H., R. C. Cochran, E. C. Titgemeyer, E. S. Vanzant, I. Abdelgadir, and G. St-Jean. 1996. Effect of increasing degradable intake protein on intake and digestion of low-quality, tallgrass-prairie forage by beef cows. *J. Anim. Sci.* 74:2473–2481.
- Mathis, C. P. 1998. Degradable intake protein supplementation to beef cattle consuming low-quality forages. Ph.D. dissertation. Kansas State University, Manhattan.
- Mathis, C. P., R. C. Cochran, E. S. Vanzant, I.E.O. Abdelgadir, J. S. Heldt, K. C. Olson, J. Caton, D. Faulkner, T. Klopfenstein, K. Moore, S. Paisley, and C. Sheaffer. 1998. Evaluation of *in situ* and *in vitro* techniques for estimating degradable intake protein content in forages. *J. Anim. Sci.* 76(Suppl. 2):77.
- NRC. 1996. Nutrient Requirements of Beef Cattle (7th Ed.). National Academy Press, Washington, DC.
- Olson, K. C. 1998. Prediction of pasture availability and nutritive value of tallgrass prairie forage in beef cattle production systems. Ph.D. dissertation. Kansas State University, Manhattan.
- Raun, N. S., and W. Burroughs. 1962. Suction strainer technique in obtaining rumen fluid samples from intact lambs. *J. Anim. Sci.* 21:454–457.
- Robbins, K. R. 1986. A method, SAS program, and example for fitting the broken-line to growth data. Res. Rep. 8089, Univ. of Tennessee Agric. Exp. Sta. pp 1–8.
- SAS. 1988. SAS User's Guide: Statistics. SAS Inst. Inc., Cary, NC.
- SAS. 1992. SAS User's Guide: Statistics. SAS Inst. Inc., Cary, NC.
- Satter, L. D., and L. L. Slyter. 1974. Effect of ammonia concentration on rumen microbial protein production in vitro. *Br. J. Nutr.* 32:199–208.
- Stokes, S. R., A. L. Goetsch, A. L. Jones, and K. M. Landis. 1988. Feed intake and digestion by beef cows fed prairie hay with different levels of soybean meal and receiving postruminal administration of antibiotics. *J. Anim. Sci.* 66:1778–1789.
- Van Soest, P. J., and J. B. Robertson. 1985. *Analysis of Forage and Fibrous Feeds: A Laboratory Manual*. Cornell University, Ithaca, NY.
- Vanzant, E. S., and R. C. Cochran. 1994. Performance and forage utilization by beef cattle receiving increasing amounts of alfalfa hay as a supplement to low-quality, tallgrass-prairie forage. *J. Anim. Sci.* 72:1059–1067.
- Woods, B. C., R. C. Cochran, J. S. Heldt, C. P. Mathis, and K. C. Olson. 1997. Effect of supplementation frequency and amount of nonprotein nitrogen in supplements on intake and digestion of low-quality forage. *J. Anim. Sci.* 75(Suppl. 1):95 (Abstr.).

Citations

This article has been cited by 6 HighWire-hosted articles:
<http://jas.fass.org#otherarticles>