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Undegradable intake protein supplementation of compensating spring-born steers and summer-born steers during summer grazing[1]

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ABSTRACT: Three trials were conducted to determine the effects of previous winter gain (Trials 1 and 3) and age of calf (Trials 1 and 2) on response to undegradable intake protein (UIP) supplementation during summer grazing. In Trial 1, 48 spring-born steers (243 kg) were used in a 4 × 2 factorial arrangement. Steers were wintered at four rates of gain: 0.65 (FAST), 0.24 (SLOW), 0.38 (S/F), and 0.38 (F/S) kg/d. The intermediate rates of gain (S/F and F/S) were created by switching steers from slow to fast or fast to slow midway through the wintering period. Following winter treatments, steers were assigned to one of two summer treatments: supplemented (S) or nonsupplemented (NS). In Trial 2, 32 summer-born steers were wintered at an ADG of 0.25 kg/d and allotted to the same summer treatments as Trial 1. The supplement was formulated to supply 200 g/d of UIP. Steers from both trials grazed upland Sandhills range from May to September 1998. In Trial 3, 49 spring-born steers (228 kg) were used in a 2 × 7 factorial arrangement of treatments. Steers were wintered at two rates of gain, 0.71 (FAST) and 0.24 kg/d (SLOW) and then assigned randomly to one of six levels of UIP supplementation or an energy control. Protein supplements were formulated to deliver 75, 112.5, 150, 187.5 225, or 262.5 g/d of UIP. Sources of UIP for all trials were treated soybean meal and feather meal. In Trial 1, there were no ($P > 0.05$) winter by summer treatment interactions, and UIP supplementation increased ($P = 0.0001$) pasture gains over NS steers. In Trial 2, supplementation increased ($P = 0.001$) pasture ADG of summer-born steers by 0.15 kg/d compared with NS steers. In Trial 3, a winter gain by UIP supplementation interaction was observed ($P = 0.09$). Gain of FAST steers responded quadratically ($P = 0.09$) across UIP levels, with the maximum gain occurring at the 150 g/d UIP level. The SLOW steers responded linearly ($P = 0.02$) to increasing UIP levels; however, the response was negative. Levels of UIP above 150 g/d reduced steers gains; therefore, the data were reanalyzed excluding these levels. These new analyses showed that FAST steers responded linearly ($P = 0.08$; 0.2 kg/d) to increasing UIP, whereas the SLOW steers had no response to UIP. In Trials 1 and 3, SLOW steers experienced compensatory gain and had higher gains overall. We concluded that previous winter gain affected the response to UIP supplementation with the FAST winter gain group having a greater response.

Key Words: Cattle, Compensatory Growth, Grazing, Protein Degradation, Protein Intake

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Introduction

Wintering cattle in temperate regions often requires the use of harvested feedstuffs. However, growing these cattle on limited feed or low-quality forage during the winter may allow for producers to take advantage of compensatory growth during summer grazing. These systems take advantage of the most cost-efficient gains while the animal is grazing actively growing forage during the summer (Lewis et al., 1990). Enhanced intake has been often cited as a major factor influencing compensatory growth in previously restricted animals. Increases in amount of DMI (kg/d; Fox et al., 1972; Wanyoike and Holmes, 1981) and DMI relative to body weight (Hironaka and Kozub, 1973; Downs, 1997) have been reported in compensating animals. If improved intake is a factor in compensatory gain, then forage quality may affect the ability of an animal to compensate.

Rapid degradability of proteins in actively growing forages and the high requirements for metabolizable protein in young growing cattle may affect an animal's ability to compensate while grazing these forages. This factor may make undegradable intake protein (**UIP**) the first-limiting nutrient during compensatory gain and a limiting factor in the gains of younger cattle. This

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hypothesis is supported by several studies that have reported improvements in gain in cattle that were supplemented with UIP during grazing (Anderson et al., 1988; Karges et al., 1992; Klopfenstein, 1996). We hypothesize that cattle experiencing a higher degree of compensatory gain should have a higher requirement for metabolizable protein and ultimately UIP and should respond to UIP supplementation more than cattle with lower degrees of compensation.

The objectives of this research were to 1) evaluate the effects of UIP supplementation on compensating spring-born steers and summer-born steers, 2) determine the effects of compensatory gain and UIP supplementation on forage intake during summer grazing, and 3) evaluate the potential impact of UIP supplementation on subsequent feedlot performance.

Materials and Methods

Trials 1 and 2

In Trial 1, 48 spring-born steers (243 kg) were used in a completely randomized design with a 4×2 factorial treatment arrangement. Steers were wintered at four rates of gain: 0.65 (**FAST**), 0.24 (**SLOW**), 0.38 [slow/fast (**S/F**)], and 0.38 kg/d [fast/slow (**F/S**)]. Intermediate rates of gain were accomplished by switching steers from FAST to SLOW (F/S) or SLOW to FAST (S/F) midway through the wintering period. During the winter phase, steers grazed cornstalk residues from December 4, 1997, to February 16, 1998, and were supplemented during this period. The FAST steers received 2.27 kg·steer^{-1}·d^{-1} (DM basis) of wet corn gluten feed plus 0.045 kg·steer^{-1}·d^{-1} of a vitamin and mineral supplement. The SLOW steers received 0.91 kg·steer^{-1}·d^{-1} of a protein supplement consisting predominantly of sunflower meal. Following the stalk grazing phase (February 20, 1998), FAST and SLOW steers were placed into the feedlot and allowed ad libitum access to ammoniated wheat straw. The FAST steers continued to receive 2.27 kg·steer^{-1}·d^{-1} of wet corn gluten feed and a vitamin and mineral supplement, whereas SLOW steers received 0.09 kg·steer^{-1}·d^{-1} of a vitamin and mineral supplement during this period. During this period, steers that were assigned to the F/S or S/F treatment were sorted to their corresponding treatment. For example, a steer assigned to the F/S treatment group would be placed on the FAST treatment on corn stalks and then reassigned to the SLOW treatment upon entering the feedlot. Steers were maintained in the feedlot until the end of the wintering phase on April 28, 1998.

In Trial 2, 32 summer-born steers (June to July 1997; 204 kg) were weaned on January 14, 1998, and wintered at the Gudmundsen Sandhills Laboratory (Whitman, NE). Steers were wintered on dormant native range or meadow hay and fed 1.65 kg·steer^{-1}·d^{-1} of a protein and energy supplement consisting of predominantly wheat middlings until May 1, 1998. Steers were fed to gain 0.25 kg/d during the wintering phase.

In both trials, steers were allowed to graze spring forage before grazing summer range. Spring-born steers from Trial 1 grazed fertilized smooth brome grass pasture from April 28 until May 26, 1998. Summer-born steers (Trial 2) grazed subirrigated meadow (predominantly cool season grass) from May 1, 1998, until May 21, 1998. At the end of spring grazing, weights were obtained, and all steers were assigned within winter treatment (Trial 1 only) to summer treatments. The wintered spring-born steers (>14 mo age; 340 kg) and summer-born steers (11 mo age; 235 kg) were assigned to one of two summer treatments: supplemented (**S**) or nonsupplemented (**NS**). The supplement supplied 0.2 kg/d of UIP per day attained by individually feeding 1.3 kg of supplement 3 d/wk. Supplement consisted of 78.5% SoyPass (nonenzymatically browned soybean meal), 18.5% feather meal, and 3% molasses (DM basis). Steers grazed upland Sandhills range (259.1 ha; 1.18 AUM (animal unit month)/ha; 45 kg BW = 0.1 AUM) consisting of a mixture of warm and cool season species from May 27 to September 8, 1998. At the conclusion of summer grazing, steers were placed in the feedlot and limit-fed in order to equalize gut fill before final weights were taken on two consecutive days. Animals were assigned to feedlot pen according to trial (1 or 2), previous winter treatment (FAST or SLOW), and summer treatment (S or NS). All steers were adapted to the finishing diet over a 20-d period by gradually replacing alfalfa in the initial diet with corn in four step-up diets. The final diet consisted of 7% alfalfa hay, 40% wet corn gluten feed, 48% high-moisture corn, and 5% supplement (DM basis). Steers from Trial 1 were fed 92 d, and summer-born steers (Trial 2) were fed 141 d, at which time animals were marketed to a commercial abattoir (IBP, West Point, NE). Carcass characteristics measured included hot carcass weight, fat depth, marbling score, and USDA Yield Grade.

Data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) for a completely randomized design. Animal was the experimental unit and model effect included winter and summer treatment in Trial 1 and only summer effects in Trial 2. Age and summer effects were tested using a combined data set containing only summer and feedlot gain data from both trials.

Intake Determination. All spring-born steers (Trial 1) and 12 summer-born steers (Trial 2) were used for determination of grazed forage intake. The intake period consisted of two, four consecutive day collection periods separated by a 2-d noncollection period. The intake period was conducted from July 6, 1998, to July 15, 1998. Each steer used for intake measurement was dosed orally with chromium sesquioxide (CrO_3) boluses in an intraruminal continuous release device (Captec Pty. Ltd., Auckland, New Zealand) 7 d before the initiation of the first 4-d collection period. During the collection period, fecal samples were collected from the rectum daily at 0800.

Total fecal collection was utilized to validate the chromium release rate from the continuous release bolus

(Hollingsworth et al., 1995). Six steers were harnessed with fecal bags and received the same bolus as administered to the steers used for the determination of intake. Steers were gathered twice daily, and fecal collection bags were removed and weighed to determine content. Feces from fecal collection bags was subsequently mixed and subsampled for analysis. Rectal grab samples were taken during the morning collection. All fecal samples were oven dried in a 60°C forced air oven, ground through a 1-mm Wiley mill screen, and stored until analysis. Chromium concentrations in the feces were determined using the method described by Williams et al. (1962). Forage intake was then estimated by dividing fecal output by indigestibility of the forage diet.

Forage Analysis. Forage diet samples were obtained once every 2 wk with three ruminally fistulated steers. All surgical procedures were reviewed and approved by the University of Nebraska Institutional Animal Care and Use Committee. Steers were gathered and rumen contents were evacuated completely and the rumen sponged to remove any additional contents. Steers were then allowed to graze for approximately 30 min to obtain a diet sample. Diet samples after grazing were collected and frozen until the end of the study. All diet samples for the summer trial were freeze-dried and ground through a 2-mm screen using a Wiley mill for in situ analysis and a 1-mm screen for CP and IVDMD. Dry matter and organic matter content were determined using the standard method as outlined by AOAC (1996). Crude protein content was analyzed using the combustion method (AOAC, 1996) using a nitrogen analyzer (Perkin-Elmer, Norwalk, CT). In vitro dry matter digestibility was determined using a modification of Tilley and Terry (1963). Samples were incubated in a 50:50 mixture of ruminal fluid and McDougall's (McDougall, 1948) buffer solution (1 g/L urea added) at 39°C for 48 h, followed by a 24-h digestion in pepsin (Sigma P-7000; Sigma, St. Louis, MO). Undegradable intake protein was measured using modified procedures of Mass et al. (1999) in which diet samples were incubated in situ using Dacron bags (Ankom, Inc., Fairport, NY) for 2, 12, and 96 h. Modifications of the original procedure were to include a 10-h lag in passage, during which active digestion is occurring, and estimating rate of passage from IVDMD analysis as outlined by Klopfenstein et al. (2001).

Intake determination and diet samples were analyzed using the GLM procedure of SAS. Intake data were analyzed using steer as experimental unit with period and summer treatments in the model statement. Diet samples were analyzed as a completely randomized design, using collection date and animal in the model. Treatment means were separated using the LSMEANS statement of SAS for both analyses.

Trial 3

Forty-nine spring-born steers (228 kg) were used in a 2 × 7 factorial treatment design. Steers were allotted randomly to one of two rates of winter gain, FAST (0.71 kg/d; n = 25) and SLOW (0.24 kg/d; n = 24). Steers were treated to gain at their respective rates using the same protocol for FAST and SLOW treatments as in Trial 1. At the end of the wintering phase, steers were then assigned randomly, within winter treatment, to one of six levels of UIP supplementation (n = 3) or an energy control (n = 7). Protein supplements were formulated to deliver 50, 75, 100, 125, 150, and 175% of the supplemental UIP requirement (150 g/d) established by Anderson et al. (1988). The protein supplement was composed of 74% SoyPass (treated soybean meal), 19% feather meal, 3% molasses, and 4% salt. The energy supplement consisted of 56% soyhulls, 9% tallow, 6% Carolac (a rumen-protected fat), 24% molasses, and 5% salt. Tallow and rumen-protected fat were used to minimize the amount of digestible energy available to the microbes in the rumen and increase the amount of energy reaching the small intestine that could be utilized by the animal. This should effectively reduce microbial crude protein production in the rumen and allow for differences in performance to be attributed to differences in UIP levels. Combinations of the protein and energy supplements provided the graded levels of UIP (Table 1), and all supplements were formulated to be isocaloric. Supplements were fed individually 4 d/wk at 0600.

Steers grazed four 3.2-ha fertilized smooth brome (*Bromus inermis*) pastures in a rotational grazing system from May 5 to June 11, 1999. Steers were then moved to 4.1-ha pastures containing a mixture of warm-season grasses and were maintained there in a four-pasture rotational system until the end of the trial (August 19, 1999). A fifth pasture was used in late July because of slow regrowth of the warm-season grasses due to low precipitation. Steers were weighed for two consecutive days at the initiation of the trial and for three consecutive days prior to moving from brome to warm-season pastures. At the conclusion of the trial, steers were placed in the feedlot and limit-fed in order to equalize fill before final weights were taken for two consecutive days. Steers were then assigned within winter treatment to feedlot pens for finishing. Steers were stepped-up to the finishing diet which consisted of 47% high moisture corn, 44% wet corn gluten feed, 5% alfalfa, and 4% supplement. All steers were fed for 106 d, at which point animals were marketed to a commercial abattoir (IBP, West Point, NE). Carcass characteristics measured included hot carcass weight, fat depth, marbling score, and USDA Yield Grade.

Data were analyzed for linear, quadratic, and cubic responses to UIP supplementation using orthogonal contrasts in GLM in SAS. Winter by summer linear, quadratic, and cubic interactions were tested using GLM procedures of SAS. Model effects included winter treatment and summer UIP level. Coefficients for orthogonal contrast were generated using the ORPOL procedure for unequally spaced data.

Table 1. Composition of graded levels of undegradable intake protein (UIP) for summer supplement treatments (Trial 3)

Percentage of requirement[a]	UIP supplied (g/d)	Energy supplement[b] (%)	Protein supplement[c] (%)
0	0	100	0
50	75.0	66	34
75	112.5	51	49
100	150.0	37	63
125	187.5	24	76
150	225.0	11	89
175	262.5	0	100

[a]Requirement established by Anderson et al. (1988).
[b]Energy supplement consisted of 56% soyhulls, 9% tallow, 6% Carolac (a rumen-protected fat), 24% molasses, and 5% salt.
[c]Protein supplement consisted of 74% SoyPass (treated soybean meal), 19% feather meal, 3% molasses, and 4% salt.

Intake Determination. All steers receiving the energy control supplement (n = 14) and the highest levels of protein supplementation (n = 14) were used in two intake determination periods. Each period consisted of two, five consecutive day collection periods, separated by a 2-d noncollection period. One intake period was completed, while steers grazed brome pastures (May 31 to June 5), whereas the second occurred during the warm-season grazing phase (July 12 to July 23). Each steer used for intake measurement was orally dosed with CrO_3 boluses in an intraruminal continuous release device (Captec Pty. Ltd., Australia) 7 d prior to the initiation of the first 5-d collection period. During the collection periods, fecal samples were collected from the rectum daily at 0600. Validation of bolus release rate, sample analysis, and intake calculations were completed as in Trial 1.

Forage Analysis. Biweekly diet samples were collected via ruminally fistulated steers. All surgical procedures were reviewed and approved by the University of Nebraska Institutional Animal Care and Use Committee. All collections and analyses were completed as described in Trial 1.

Results and Discussion

Forage Analysis

In Trials 1 and 2, CP, UIP (% DM), and IVDMD averaged 10.5%, 2.80%, and 63.1%, respectively, for the season. These values are similar to results shown by Lardy et al. (1997) for Sandhills native range. In Trial 3, CP, UIP (% DM), and IVDMD averaged 16.8%, 1.22%, and 70.3%, respectively, for the brome pastures and 15.5%, 1.55%, and 60.6%, respectively, for warm-season pastures.

Performance

Trial 1. During the wintering phase, FAST steers gained 0.65 kg/d and SLOW steers gained 0.24 kg/d, whereas F/S and S/F steers gains were intermediate at 0.38 kg/d (Table 2). Weights at the end of the wintering phase were different ($P = 0.001$) due to differences in ADG during that period. There was an effect ($P = 0.09$) of winter treatment on spring ADG with S/F steers having a higher ADG than the other treatments. However, due to the short duration of this period (28 d),

Table 2. The effect of dietary treatment on weight and performance during the wintering phase (148 d) and spring grazing period (28 d) (Trial 1)

	Winter treatment[a]				
	FAST	F/S	S/F	SLOW	SEM
Initial wt, kg	245	246	241	241	4.4
Winter ADG, kg/d	0.65[b]	0.38[c]	0.39[c]	0.24[d]	0.02
Winter end wt, kg	340[b]	302[c]	299[c]	277[d]	4
Spring ADG, kg/d	1.25[e]	1.21[e]	1.50[f]	1.18[e]	0.10
Spring end wt, kg	375[b]	336[c]	339[c]	309[d]	5

[a]FAST steers fed to gain 0.65 kg/d; F/S and S/F fed to gain 0.38 kg/d by switching from FAST to SLOW and vice versa during the winter period; SLOW steers fed to gain 0.24 kg/d.
[b,c,d]Means within a row with different superscripts differ ($P < 0.001$).
[e,f]Means within a row with different superscripts differ ($P < 0.10$).

Table 3. Effect of winter and summer treatments on performance during the summer grazing (105 d) and feedlot finishing (92 d) periods of spring-born steers (Trial 1)

	Winter treatment[a]				Summer treatment[b]		Effects[c]	
	FAST	F/S	S/F	SLOW	NS	S	Win	Sum
Summer								
ADG, kg/d	0.83[d]	0.87[d]	0.87[d]	0.99[e]	0.81	0.96	0.001	0.001
End wt, kg	469[d]	435[e]	439[e]	422[e]	431	450	0.001	0.01
Feedlot								
ADG, kg/d	2.28	2.18	2.12	2.04	2.23	2.07	0.30	0.08
DMI, kg/d	14.7	14.2	14.4	13.9	14.3	14.2	0.20	0.60
Gain:feed	0.16	0.15	0.15	0.15	0.16	0.15	0.21	0.12
Final wt, kg	679[f]	635[g]	633[g]	609[g]	636	641	0.006	0.73

[a]FAST steers fed to gain 0.65 kg/d; F/S and S/F fed to gain 0.38 kg/d by switching from FAST to SLOW and vice versa during the winter period; SLOW steers fed to gain 0.24 kg/d.
[b]Summer treatments: NS = nonsupplemented, S = supplemented.
[c]Win = winter treatment effect; Sum = summer treatment effect. No significant winter × summer treatment interactions.
[d,e]Means within a row with different superscripts differ ($P < 0.01$).
[f,g]Means within a row with different superscripts differ ($P < 0.05$).

differences in weights at the initiation of the summer grazing period were the same as at the end of the wintering phase.

There was no ($P = 0.60$) summer by winter treatment interaction for summer grazing or feedlot ADG; therefore, main effect means are reported (Table 3). Supplementation increased ADG (0.15 kg/d; $P < 0.001$) during summer grazing over NS steers. In addition, there was an effect ($P < 0.001$) of winter treatment on summer ADG as SLOW steers experienced compensatory growth and had higher gains overall. The SLOW steers gained 0.99 kg/d, whereas F/S and S/F gained 0.87 kg/d and FAST gained 0.83 kg/d. However, SLOW steers were only able to compensate for 29% of the difference created by winter treatment (66 vs 47 kg for initial and final summer grazing weight differences, respectively). Baker et al. (1985), Steen (1986), and Downs (1997) reported similar compensations in steers wintered at low rates of gain.

The SLOW steers were programmed to produce a higher degree of compensatory gain than FAST steers during summer grazing, while F/S and S/F were treated to be intermediate. We hypothesized that SLOW steers would have the greatest demand for UIP and would therefore respond more to UIP supplementation. Results from the summer ADG analysis do not support this hypothesis. Although not statistically different, FAST steers responded more to UIP supplementation than SLOW, F/S, or S/F groups. Supplemented FAST steers gained 0.24 kg/d more than their NS counterparts, whereas SLOW S steers gained only 0.14 kg/d over unsupplemented steers. Fast/slow and S/F steers responded similarly to UIP supplementation as SLOW steers with S steers gaining 0.12 kg/d more than NS steers. These results contradict previous studies that report increased response to protein by compensating animals (Carstens et al., 1991; Drouillard et al., 1991; Patterson et al., 1995).

Table 4. Effect of summer treatment on performance during the summer grazing and feedlot finishing phase of summer-born steers (Trial 2)[a]

	Summer treatment[b]			
	S	NS	SEM	*P*-value
Summer				
Initial wt, kg	237	233	5.2	0.62
ADG, kg/d	0.81	0.66	0.03	0.0004
End wt, kg	329	316	5.5	0.09
Feedlot				
ADG, kg/d	1.76	1.77	0.06	0.86
DMI, kg	10.9	10.9	—	—
Gain:feed	0.16	0.16	—	—
Final wt, kg	574	565	11.7	0.58
Carcass				
Marbling[c]	508	513	12.9	0.75
Yield grade	2.1	2.3	0.12	0.42

[a]Summer grazing period consisted of 105 d, and the finishing phase was 141 d in length.
[b]Summer treatments: S = supplemented, NS = nonsupplemented.
[c]Marbling score of 400 = slight, 500 = small, 600 = modest.

Table 5. The effect of dietary treatment on weight and performance during the wintering phase (Trial 3)

	Winter treatment[a]			
	FAST	SLOW	SEM	*P*-value
Initial wt, kg	230	225	3.0	0.20
ADG, kg/d	0.71	0.24	0.01	0.0001
End wt, kg	344	263	2.4	0.0001

[a]Winter treatments applied November 30, 1998, through May 5, 1999. FAST steers fed to gain 0.71 kg/d; SLOW steers fed to gain 0.24 kg/d.

Results from the feedlot finishing phase are presented in Table 3. Summer treatment did not effect ($P = 0.60$) DMI in the feedlot, however, average daily gain in the feedlot was higher ($P = 0.08$) for NS steers. There was also a trend ($P = 0.12$) for improved feed efficiency for NS steers. Therefore, any increase in gain with summer supplementation was lost during the feedlot phase with spring-born steers. There was an effect of winter treatment ($P = 0.006$) on final weight since SLOW steers could not completely compensate weight differences created by winter treatments during summer grazing. Carcass data showed no effects ($P > 0.25$) on fat, marbling, or yield grade across winter or summer treatments.

Trial 2. Summer-born steers responded to supplementation (0.15 kg/d; $P < 0.001$); however, the response was less than expected (Table 4). Body weight at the end of the grazing period was greater ($P < 0.10$) for S steers than the NS group. There were no differences ($P = 0.86$) in DMI or ADG during the finishing phase. Gain advantages created by summer supplementation were maintained during the finishing period. However, final weights were not different ($P > 0.58$) between treatments. There were no differences in carcass characteristics between summer treatments.

There were no age by summer treatment interactions ($P > 0.25$) when comparing spring-born (Trial 1) and summer-born steers (Trial 2). Weights at the end of and ADG during summer grazing were lower ($P < 0.001$) for summer-born than spring-born steers. The response to UIP supplementation was similar for all steers. Evaluation of protein requirements, using the NRC model (1996), indicated that summer-born steers should be more deficient in MP than spring-born steers, when grazing summer native range. It was anticipated that younger steers should respond more to UIP supplementation than older steers. Since the response to UIP, however, was similar for spring- and summer-born steers, there appears to be no difference in requirements between age groups while grazing Sandhills upland range.

During the feedlot finishing phase, DMI and ADG were lower ($P < 0.001$) for summer-born steers; however, feed efficiency was lower ($P < 0.001$) for spring-born steers. Final weights were lower ($P < 0.001$) for summer-born steers, but there were no differences in carcass characteristics due to age.

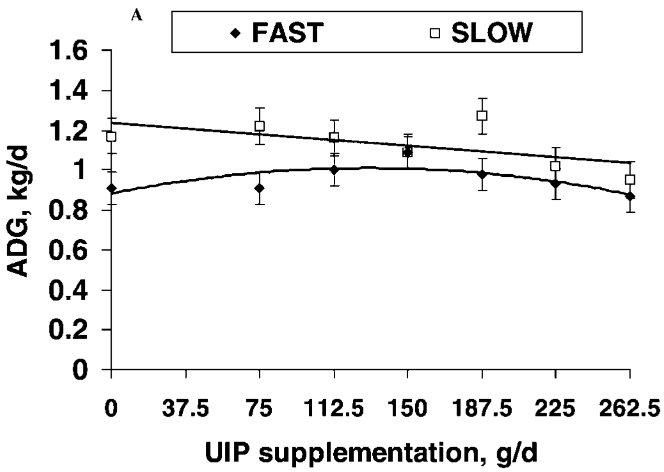
Trial 3. Results from the wintering period are reported in Table 5. There was an effect ($P < 0.0001$) of winter treatment on ADG during the wintering phase. The FAST steers gained 0.71 kg/d, while SLOW steers gained 0.24 kg/d, resulting in a body weight difference ($P < 0.0001$) between treatments at the conclusion of the wintering phase.

A winter gain by UIP supplementation interaction ($P = 0.09$) was observed for ADG during summer grazing; therefore, simple effects of supplementation within winter treatment are reported. Average daily gain of FAST steers changed quadratically ($P = 0.09$) as UIP levels increased with the maximum response occurring at the 150 g/d level. The SLOW steers responded linearly ($P = 0.02$) to increasing UIP levels; however, the response was negative. Supplemental levels above 150 g/d caused a reduction in gains of FAST steers. This response has been documented before (Anderson et al., 1988). To determine the response to UIP supplementa-

Table 6. Grazed forage intake during summer grazing period (Trials 1 and 2)

	Summer treatment[a]			
Item	S	NS	SEM	*P*-value
Trial 1				
DMI, kg[b]	10.1	10.8	0.34	0.16
DMI, % BW	2.61	2.86	0.08	0.04
Trial 2				
DMI, kg	8.1	8.1	0.39	0.98
DMI, % BW	2.90	3.12	0.13	0.12

[a]Summer treatments: S = supplemented, NS = nonsupplemented.
[b]Dry matter intake determined by dividing fecal output by diet indigestibility.



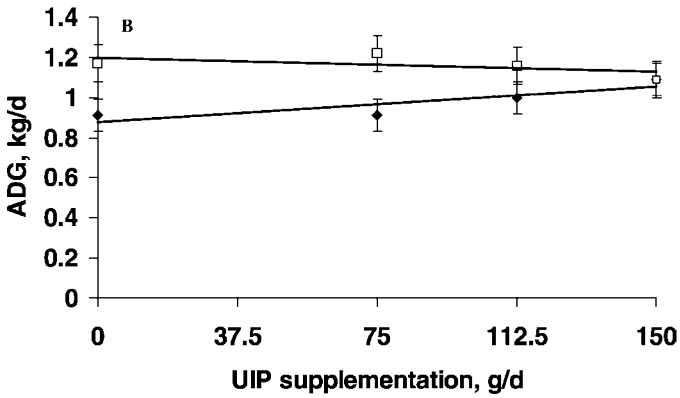


Figure 1. Average daily gain (kg/d) of steers during the summer grazing period across all levels (A) and excluding levels >150 g/d (B; Trial 3). Summer × winter interaction ($P < 0.10$). Quadratic effect ($P = 0.09$) of summer treatment for cattle with higher winter gains (0.71 kg/d; FAST) and linear effect ($P = 0.02$) for cattle with lower winter gains (0.24 kg/d; SLOW) across all levels (A). Linear effect ($P = 0.08$) of summer treatment for FAST cattle excluding levels >150 g/d (B).

tion below 150 g/d, the data were reanalyzed excluding levels greater than 150 g/d in both winter treatment groups. The reanalyses showed that FAST steers responded linearly ($P = 0.08$; 0.20 kg/d) to increasing UIP, whereas the SLOW steers had no response to UIP (Figure 1). This supports the results from Trial 1, in which FAST steers responded more to supplementation than cattle maintained at lower rates of gain during the winter. Therefore, it appears that previous winter supplementation affects the response to UIP supplementation during the summer grazing period.

There are several possible explanations for the increased response to UIP supplementation of FAST steers over SLOW steers. Greater forage intake may have increased the rate of passage and ultimately increased bacterial crude protein synthesis in the SLOW steers. Increased bacterial crude protein synthesis would subsequently change the metabolizable protein

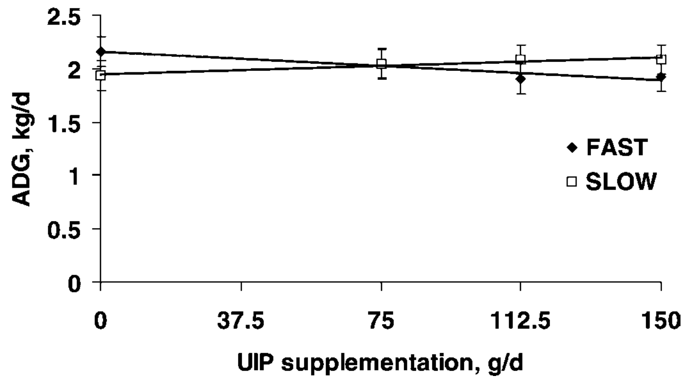


Figure 2. Average daily gain (kg/d) of steers during the finishing phase excluding levels > 150 g/d (Trial 3). Summer × winter interaction ($P < 0.10$). Linear effect of summer treatment for FAST cattle ($P = 0.09$). FAST steers fed to gain 0.71 kg/d and SLOW steers fed to gain 0.24 kg/d.

supply to the small intestine and animal (NRC, 1996). In addition, increases in UIP supply may alter intake and rate of passage and may therefore affect the degradation of forage protein in the rumen. Greater efficiency of protein use may also become a possible explanation for the differences in gain between SLOW and FAST steers. Fox et al. (1972) showed increases in efficiency of protein utilization as high as 85% when compensating steers were compared to controls.

The SLOW steers experienced compensatory growth and had higher gains overall (0.26 kg/d increase for SLOW vs FAST steers that received the energy control). Due to the length and severity of restriction in the SLOW steers during the winter, they were able to compensate only 25% of the difference created by the winter treatments (80 vs 65 kg for initial and final grazing weight differences, respectively). This compensation was similar to that seen in Trial 1. Results from Trials 1 and 3 show a limit to the amount of compensation that can be expected after a prolonged restriction during the wintering period.

A summer by winter treatment interaction for feedlot performance occurred ($P = 0.09$) in Trial 3; therefore, data were analyzed within each winter treatment. Data were analyzed excluding the same treatment groups as described in the grazing phase (UIP levels >150 g/d). Analysis of UIP levels 150 g/d and lower showed that there was no effect of summer supplementation level on feedlot performance in the SLOW steers. A linear effect ($P = 0.09$) of previous summer supplementation on feedlot ADG occurred in FAST steers; however, the slope was negative (Figure 2). Steers that responded to UIP supplementation during the summer had lower ADG than steers that received the energy control and lower levels of UIP during the grazing period. This decrease in gains allowed for steers to compensate for weight differences created by summer treatments. This response agrees with the results from Trial 1, in which

Table 7. Summer-grazed forage intake of steers within forage type (Trial 3)[a]

	Winter treatment[b]			
	FAST	SLOW	SEM	*P*-value
Brome				
DMI, kg[c]	7.0	7.1	0.30	0.76
DMI, % BW	1.92	2.52	0.09	0.0001
Warm season				
DMI, kg	9.5	9.6	0.32	0.81
DMI, % BW	2.29	2.80	0.09	0.0006

[a]Significant forage type effect ($P < 0.05$).
[b]FAST steers fed to gain 0.71 kg/d; SLOW steers fed to gain 0.24 kg/d.
[c]Dry matter intake determined by dividing fecal output by diet indigestibility.

steers that received a UIP supplement during the summer grazing period had lower ADG during the finishing phase compared to NS steers. In Trials 1 and 3, supplementation of compensating steers was not beneficial because all weight advantages created by summer supplementation were negated during the finishing phase.

There were no differences in carcass characteristics due to summer treatments in either FAST or SLOW steers. There was an effect ($P = 0.0002$) of winter treatment on hot carcass weight since SLOW steers were able to only compensate 25% of the weight difference created by winter treatments during the grazing phase. There were no other effects of winter treatment on carcass characteristics.

Intake Determination

Trials 1 and 2. Results from intake determination are summarized in Table 6. In Trial 1, there was no winter by summer treatment interaction ($P = 0.38$) for grazed forage intake, expressed as either kilograms or as a percentage of body weight. There was an effect ($P = 0.04$) of summer supplement treatment on grazed forage intake with S steers consuming less forage DM, when expressed as a percent of BW, than NS steers. There was no effect of winter treatment on kilograms of grazed forage intake ($P = 0.40$) or on intake when expressed as a percentage of body weight ($P = 0.25$). In Trial 2, there was no effect ($P = 0.91$) of summer treatment on kilograms of grazed forage intake. Unsupplemented steers tended ($P = 0.12$) to eat more forage when expressed as a percentage of body weight.

Trial 3. There was an effect ($P < 0.005$) of forage type on forage intake therefore means within forage type are reported (Table 7). There was no significant effect ($P > 0.75$) of winter treatment on DMI (kilograms) during the brome or warm-season grazing period; however, there was a significant winter treatment effect ($P < 0.0001$) when DMI was expressed as a percentage of body weight. For both forage types, FAST and SLOW steers consumed similar ($P > 0.75$) amounts of DM (kilograms per day); however, due to weight differences created by the winter treatments, the SLOW steers consumed more ($P < 0.01$) DM as a percentage of BW. This is similar to results reported by Downs (1997) in steers that were experiencing compensatory gain during the summer grazing period.

The increase in consumption, when expressed as a percentage of BW that occurred in Trial 3, may partially explain the compensatory gain that occurred with the SLOW steers. The NRC (1996) estimates the NE_m requirement to be equal to 0.077 Mcal/kg $BW^{.75}$. Since there was a difference ($P < 0.001$) in weight between the two winter treatments at the initiation of the summer grazing period, the NE_m requirement for FAST steers is higher than the SLOW group. The FAST steers would need to use a larger percentage of their dietary energy intake to meet their NE_m needs. Since the FAST and SLOW steers had equal DM intake and therefore equal energy intakes, the SLOW steers would have more energy available for NE_g. This increase in NE_g in the SLOW steers can explain the compensatory gain that was experienced during the summer.

Implications

Previous winter gain and subsequent compensatory growth affected the response to undegradable intake protein during summer grazing; however, the response was opposite of expected. Steers wintered at slower rates of gain and experiencing compensation during the summer showed less response to undegradable intake protein supplementation than steers wintered at faster gains. Summer-born steers showed similar gain responses to slow winter gain steers, resulting in no additional gain response at younger ages. Forage dry matter intakes (expressed as a percentage of body weight) were higher for steers wintered at slow gains compared to steers wintered at higher gains. Weight advantages gained by supplementing spring-born steers during the summer were compensated for during the finishing phase; therefore, supplementation during summer grazing does not appear to be economical for spring-born steers. This does not seem to be the case with summer-born steers, as additional gain with supplementation was maintained throughout the finishing phase.

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