Liquid supplement and forage intake by range beef cows[1]

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ABSTRACT: One hundred eighty crossbred cows were assigned to one of six native range pastures during two winters to evaluate forage and supplement intake as affected by liquid supplement (yr 1: 50% crude protein, 84% from urea; yr 2: 57% crude protein, 91% from urea) delivery method and cow age (2, 3, 4, 5, or 6 yr). Treatments were: 1) no supplement (Control); 2) a lick-wheel feeder containing liquid supplement (ADLIB); and 3) a computer-controlled lick-wheel feeder that dispensed 0.9 $kg \cdot cow^{-1} \cdot d^{-1}$ of liquid supplement (average 0.5 kg of dry $matter \cdot cow^{-1} \cdot d^{-1}$; Restricted). Each treatment was applied to two pastures. Forage digestibility was increased (P = 0.03) by supplementation. Supplemented cows lost less (P = 0.05) body condition than unsupplemented cows (average –0.3 vs –0.6). Blood urea nitrogen (BUN) was highest (P = 0.001) for ADLIB (8.7 mg/dL), intermediate for Restricted (6.2 mg/dL), and lowest for Control (2.3 mg/dL). Forage DMI was 31% higher (P = 0.01) in 1995 than in 1996, and was increased (P = 0.02) by supplementation both years. Cows supplemented with ADLIB consumed 23% more forage dry matter than Control cows, whereas Restricted cows consumed 21% more dry matter than ADLIB cows. Supplement intake by cows on ADLIB was greater (P = 0.001) than by cows on Restricted in both years. Supplement intake was lowest (P = 0.002) by 2-yr-old cows, intermediate by 3-yr-olds, and greatest by 4-, 5-, and 6-yr-old cows. Variation in supplement intake by individual cows was higher (P = 0.09) for cows in the Restricted treatment (coefficient of variation [CV] = 117%) than those on ADLIB (CV = 68%) during the first year, but did not differ between supplement treatments (average CV = 62%) in the second year. The proportions of cows consuming less than 0.3 kg/d of supplement dry matter intake (DMI) and consuming less than the target amount of supplement (0.5 kg DMI) were less (P = 0.001) for ADLIB than for Restricted during both years. ADLIB cows spent more (P = 0.001) time at the supplement feeder and had more (P < 0.002) supplement feeding bouts than Restricted cows during both years. During the first year, 2- and 3-yr-old cows spent less (P < 0.01) time at the feeder and had fewer feeding bouts per day than 6-yr-old cows. Age had no effect (P > 0.24) on feeding behavior during the second year. Supplementation of beef cows grazing winter range with 50 to 57% crude protein liquid supplement increased forage digestibility and intake. Restricting supplement access increased forage consumption and variability of supplement intake.

Key Words: Age, Animal Feeding, Cows, Feeding Behavior, Radio

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Introduction

Supplementation programs for grazing cows have not always been shown to be effective, primarily because measures, such as subsequent pregnancy rate, calving interval, or calf growth, have not been consistently improved (DelCurto et al., 1990). Some of this inconsistency may be due to variation in supplement intake by individual cows. Variation in supplement intake can be influenced by supplement delivery method (Bowman and Sowell, 1997) and social interactions of individual cows within the herd (Wagnon, 1965). Social dominance within a herd is associated with age (Wagnon, 1965; Friend and Polan, 1974) and may be modified by supplement delivery method (Bowman et al., 1999). The objectives of this study were to evaluate the effects of liquid supplement delivery method and cow age on forage intake, supplement intake, and supplement feeding behavior by mixed-age groups of cows grazing native range.

Materials and Methods

One hundred eighty mixed-age, crossbred pregnant cows were assigned to one of six native rangeland pas-

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tures in the fall after weaning in each of 2 yr (1995 and 1996). Thirty cows (along with three ruminally cannulated cows) grazed each pasture from November 7, 1995 to January 4, 1996 and from November 12, 1996 to January 10, 1997. The study pastures were located at Ft. Keogh Livestock and Range Research Laboratory in Miles City, MT. Pastures averaged 253 ha in size, and ranged from 162 to 351 ha. Pastures were classified as a Northern mixed-grass prairie dominated by western wheatgrass (*Agropyron smithii*), needleandthread (*Stipa comata*), and blue grama (*Bouteloua gracilis*). Forage standing crop during the study averaged 1,000 kg/ha, and ranged from 738 to 1,523 kg/ha per pasture. Long-term annual precipitation was 356 mm, with temperatures ranging from 38°C in the summer to –40°C in the winter. Suggested stocking rates for these areas were 1.3 ha/animal unit month (AUM) (Lacey and Taylor, 1985). Our stocking rates for the six pastures were 1.3, 2.5, 3.8, 3.8, 4.3, and 4.5 ha/AUM, which were very conservative in order to ensure that intake was not limited by forage availability. The total snowfall during November and December 1995 was 26 cm, whereas the total snowfall for November and December 1996 was 58 cm (WRCC, 2000). In addition, two dates during the study in 1996 recorded record high snowfall, November 23 (8 cm; average for that date was 0.3 cm) and December 22 (12 cm; average for that date was 0.8 cm).

The distribution of cows by age in 1995 was 48 2-yr-olds, 41 3-yr-olds, 41 4-yr-olds, 24 5-yr-olds, and 24 6-yr-olds. The distribution of cows by age in 1996 was 59 2-yr-olds, 46 3-yr-olds, 37 4-yr-olds, 22 5-yr-olds, and 15 6-yr-olds. Cows from each age group were assigned to each pasture to determine forage and supplement intake as affected by cow age and liquid supplement delivery method. Supplement treatments were: 1) no supplement (Control), 2) ad libitum access to a lick-wheel feeder containing liquid supplement (**ADLIB**), and 3) access to a computer-controlled lick-wheel feeder that dispensed 0.9 kg·cow^{-1}·d^{-1} of liquid supplement on an as-fed basis (average 0.5 kg DM·cow^{-1}·d^{-1}; Restricted; Regulate Liquid Feed Delivery System, Performix Nutrition Systems, Nampa, ID 83701). Each treatment was applied to two pastures. The ADLIB feeder had a capacity of 340 L in 1995 and 511 L in 1996, with two lick-wheels. The Restricted tank held approximately 360 L, with a smaller 26-L feeder tank containing two small lick-wheels. The Restricted delivery system was programmed in 1995 to dispense 29.7 kg/d of liquid supplement (0.52 kg DM·cow^{-1}·d^{-1}), divided into 12 equal aliquots every hour between 0700 and 1900. In 1996, the Restricted tank dispensed 29.7 kg/d of liquid supplement (0.53 kg DM·cow^{-1}·d^{-1}), in 24 equal aliquots every 30 min from 0700 to 1900. Both feeders contained the same liquid supplement formulation. In 1995, the liquid supplement contained a mixture of 50% cane and 50% beet molasses, with 84% of the CP provided by urea. In 1996, the liquid supplement was 100% cane molasses-based, with 91% of the CP provided by urea. No intake limiter was included in the liquid supplement. Liquid supplement in both tanks contained $YbCl_3$ hexahydrate as an external marker to estimate supplement consumption. Liquid supplement averaged 50.0% CP, 57.9% DM, and 1,046.5 parts per million (**ppm**) of Yb in 1995, and 57.0% CP, 58.7% DM, and 465.1 ppm of Yb in 1996. In addition, the liquid supplement contained 1.0% Ca, 1.6% P, 2.7% K, 0.67% Mg, 1.3% S, 866 ppm of Zn, 428 ppm of Cu, 387 ppm of Fe, 420 ppm of Mn, and 3 ppm of Se.

One wk prior to the beginning of the study, cows were confined in small lots with the supplement tanks to allow them to become familiar with the tanks. The supplement feeders remained in one location during both years to reduce confounding factors that might arise due to differences in proximity to water. Under commercial conditions, supplement feeders might have been moved as preferences for grazing areas changed.

Cows were weighed, body condition scored, and then turned on to their assigned pastures on d 1 of the study. Body condition scoring was done individually by three observers using a scale of 1 to 9, and the three values averaged. Cows on ADLIB and Restricted treatments had access to liquid supplement beginning on d 1. Ytterbium chloride was included in the liquid supplement from d 15 to 41 in 1995, and from d 21 to 46 in 1996. Liquid supplement was sampled from an individual tank each time supplement was added, a total of 31 times in 1995 and 16 times in 1996. The larger number of sampling times in 1995 was due to a smaller ADLIB tank. Liquid supplement was analyzed for DM, N (AOAC, 1997), and Yb by inductively coupled plasma emission spectroscopy (Fassel, 1978). On d 35 in 1996, venous blood samples were taken from cows via jugular puncture in nonheparinized tubes. Blood urea N (**BUN**) was measured using a Dade Behring Dimension clinical chemistry system (Dade Behring Inc., Newark, DE), which employed a urea/glutamate dehydrogenase-coupled enzymatic technique (Talke and Schubert, 1965). All cows (including the cannulated cows) were dosed with sustained release Cr_2O_3 boluses (Captec Chrome, Nufarm, Auckland, New Zealand) on d 22 and 23 in 1995, and d 26 and 27 in 1996 to estimate fecal output (**FO**). Fecal grab samples were taken on d 31, 34, and 36 in 1995, and d 35, 37, and 39 in 1996. Fecal samples were dried in a forced-air oven (60°C), ground through a 1-mm screen Wiley mill (Thomas Scientific, Swedensboro, NJ), and composited for each cow on an equal weight basis. Feces were analyzed for DM (AOAC, 1997), Cr by atomic absorption spectrophotometry (Ellis et al., 1982), and Yb by inductively coupled plasma emission spectroscopy (Fassel, 1978).

Fecal Cr concentration and daily Cr release rate were used to estimate FO using the following equation:

$$\text{fecal DM output, g/d} = \frac{\text{Cr release rate, g/d}}{\text{fecal Cr concentration, g/g}}$$

Three ruminally cannulated cows per pasture grazed along with the other 30 experimental cows throughout the study periods both years. The cannulated cows were

Table 1. Supplement intake by ruminally cannulated beef cows supplemented with one of two liquid supplement delivery systems during 2 yr[a]

Item	1995		1996		SE
	AdLib	Restricted	AdLib	Restricted	
Supplement DMI, kg	1.3	1.5	1.0	1.2	0.34
Supplement DMI, g/kg BW	2.4	2.8	1.9	2.3	0.66

[a]Control = no supplement; AdLib = lick-wheel tank; Restricted = Regulate Liquid Feed Delivery System, Performix Nutrition Systems, Nampa, Idaho.

used to collect diet extrusa samples on d 10 and 11 in 1995, and d 12 and 13 in 1996. Extrusa was air-dried and ground through a 2-mm screen in a Wiley mill (Thomas Scientific). Extrusa samples were analyzed for DM, OM, N (AOAC, 1997), NDF, and ADF (Van Soest et al., 1991).

The cannulated cows (aged 2 to 6 yr) used in this study were from a different herd and location than the rest of the cows, and had been used in other liquid supplement studies. Their supplement DMI ranged from 0.7 to 2.4 kg/d in 1995 and from 0.2 to 3.6 kg/d in 1996. The average supplement DMI by the cannulated cows (Table 1) on the ADLIB treatment matched well with the average supplement DMI of noncannulated cows on that treatment in 1995 and 1996 (average of 1.3 and 1.0 kg/d for cannulated cows in 1995 and 1996 compared with an average of 1.3 and 0.9 kg/d for noncannulated cows in 1995 and 1996; see Table 5). However, the cannulated cows on the Restricted diet consumed more supplement DMI than noncannulated cows on that diet during both 1995 and 1996 (average of 1.5 and 1.2 kg/d for cannulated cows in 1995 and 1996, compared with an average of 0.3 and 0.5 kg/d for noncannulated cows in 1995 and 1996). The amount of supplement intake by the cannulated cows on the Restricted diet in comparison to the rest of the Restricted cows indicates that digestibility estimates obtained using cannulated animals may not be representative of the entire herd. Therefore, we measured in situ DM disappearance (**DMD**) of the extrusa samples under more controlled conditions as described below and used those values to estimate forage intake.

Six cannulated cows housed at the Montana State University Nutrition Center were fed grass hay ad libitum (93.7% OM, 5.2% CP, 69.2% NDF, 46.9% ADF). Two cannulated cows received no supplement (Control), two were fed 1.0 kg of supplemental DM/d (representing the average supplement intake by ADLIB cows) and two were fed 0.4 kg of supplemental DM/d (representing the average supplement intake by Restricted cows). Samples of extrusa were composited by pasture and weighed into nylon bags (10×20 cm, 50 μm pore size; Ankom Technology, Fairport, NY). Three bags of extrusa representing each pasture and two blank bags were placed in the rumen of two cows receiving the appropriate supplement treatment and removed after 48 h. After removal, bags were rinsed in cold water and squeezed by hand. Bags were dried in a forced-air oven at 60°C. Residue in the bags was analyzed for DM (AOAC, 1997), corrected with blank-bag DM values, and in situ DMD was calculated.

In situ 48-h DM indigestibility and FO were used to estimate forage intake using the following equation:

$$\text{forage intake, kg/d} = \frac{\text{FO, kg/d}}{\text{Forage 48-h DM indigestibility}}$$

One Cr_2O_3 bolus was weighed, placed in the rumen of each cannulated cow for 15 d in 1995 and 14 d in 1996, removed, and weighed again to estimate daily Cr release rate from the boluses. Chromium release rate averaged 1.03 g/d during both years.

Supplement consumption for individual cows was estimated by the following equation (Bowman et al., 1999):

$$\text{Supplement intake, g/d} = \frac{(\text{fecal Yb concentration, g/g}) \times (\text{FO, g/d})}{\text{supplemental Yb concentration, g/g}}$$

Supplement use (kg DM·cow^{-1}·d^{-1}) was estimated by disappearance of supplement every time supplement was added to the tanks. Disappearance was calculated by measuring the change in depth of supplement in the tank (cm) and multiplying this by a calibrated volume per unit depth (L/cm) for each tank, and then by the density of supplement (1.13 kg/L). The calculated disappearance was corrected to DM basis and then divided by the number of days since the last measurement and by the number of cows per tank.

An antennae (GrowSafe, Inc., Calgary, Canada) was placed above the supplement feeder in one ADLIB and one Restricted pasture during both years. All cows in these pastures were fitted with a radio frequency (**RF**) eartag at the beginning of each study in order to electronically record each visit to the supplement feeder (Sowell et al., 1998; Earley et al., 1999). Each time the RF eartag was directly underneath and within 45 cm of the antennae, the reader panel identified the cow and the exact time it was present. Data were summarized by the hour in 1995, but in 1996, the equipment was reprogrammed to collect data every 1.25 s. The GrowSafe system was used to determine time spent at the feeder (min/d), visits/d (bouts/d), and supplement feeding bout duration (min/bout). In 1995, each hour a cow was identified as being present at the feeder was designated a feeding bout. For example, if a cow were present from 0830 to 0857, then that constituted one feeding bout; however, a cow's presence from 0850 to 0910 constituted two feeding bouts.

In 1996, a feeding bout was defined as a visit to the supplement feeder separated by 5 min of inactivity at the feeder.

Days that cows were handled, or that the computer failed, were excluded from the behavior data analysis. The behavior data from the cannulated cows were also excluded. Twenty-five (out of 52) days of behavior data for each cow were used in the data analysis in 1995. Prior to the beginning of the study in 1996, modifications to the computer system were made in order to improve reliability. Thirty-four (out of 43) days of behavior data for each cow were used in the data analysis in 1996.

Cows were weighed and body condition scored at the end of the study each year. Body condition scoring was done by three observers (1 to 9 scale), and the three values averaged. At calving, calf birth date and birth weight were recorded. At weaning, calf weaning weight (**WW**) was recorded and WW adjusted for age of calf was calculated using the following equation:

$$\text{Age-adjusted WW, kg} = 205[(\text{WW} - \text{birth weight})/(\text{weaning date} - \text{birth date})]$$

Cows were palpated for pregnancy diagnosis at weaning. In addition, the calf birth date the following year was recorded (calf birth date in 1997 for the November 7, 1995 to January 4, 1996 study, and calf birth date in 1998 for the November 12, 1996 to January 10, 1997 study).

Performance and intake data were analyzed as a split-plot design with the main effects of treatment, year, and their interactions tested by pasture(treatment × year). The subplot was cow age, and its interactions with year and treatment were included (SAS Inst., Inc., Cary, NC). Means were separated with LSD tests when a significant *F*-value was detected (*P* < 0.10). Performance and intake data from the cannulated cows were excluded from the statistical analysis. Pregnancy data were analyzed by χ^2 using PROC CATMOD and PROC FREQ of SAS. Pregnancy data from the cannulated cows were excluded from the statistical analysis. Supplement intake distribution was analyzed as a 2 × 2 × 5 factorial, with year, treatment, and age as the main factors, and all with interactions tested. Each age group, within pasture, was used as the experimental unit for the following: the calculation of supplement intake CV and the proportion of cows with fecal samples without Yb (nonconsumers), with less than 0.3 kg of supplement intake, with 0.3 to 0.8 kg of supplement intake, with greater than 0.8 kg of supplement intake, and with below-target supplement consumption.

Each variable of electronically recorded behavior data was confirmed to be normally distributed prior to any analysis (Shapiro and Wilk, 1965). Data were analyzed using the GLM procedure of SAS to test the effects of treatment, date, treatment × date, age, and treatment × age. Individual cow was used as the experimental unit. Cow within treatment × age was used as the testing term for treatment, age and treatment × age, because repeated measures were made on each cow (Gill and Hafs, 1971). Means were separated with LSD tests when a significant *F*-value was detected (*P* < 0.10). No comparisons in supplement feeding behavior between years were made due to differences in electronic data collection methods between years. Behavior data from the cannulated cows were excluded from the statistical analysis.

Results and Discussion

The native range winter forage consumed by grazing cows was low quality as indicated by <6% CP and >77% NDF both years (Table 2). In situ DMD of the unsupplemented winter range forage at 48 h did not differ (*P* = 0.32) between years, and averaged 42.1%. Supplementation increased (*P* = 0.03) 48-h in situ DMD both years. When extrusa collected the first winter was supplemented with ADLIB and Restricted in situ DMD was increased by 34 and 47%, respectively, compared to the Control. Supplementation increased in situ DMD of extrusa collected the second year an average of 26%. Other researchers have reported 6 to 36% increases in DM and OM digestibility of forages due to liquid supplementation (Cohen, 1974; Garg and Gupta, 1992; Kalmbacher et al., 1995; Bowman et al., 1999).

No year × treatment interactions (*P* > 0.28) were seen for cow performance variables; however, year × treatment interaction means are presented for comparison purposes (Table 3). With the exception of calf birth weight and calving interval, all performance variables were affected (*P* < 0.05) by year. Cows lost more weight (*P* = 0.02) and more body condition (*P* = 0.001) during the second winter than the first (–59 vs 2 kg, and –0.7 vs –0.1 BCS, respectively), and ended the second winter supplementation period with lighter average BW (438 vs 529 kg) and lower body condition (4.3 vs 5.5 BCS). The greater weight and body condition loss seen in the second year may have resulted from lower forage availability due to substantially higher snowfall. Calf birth weight did not differ (*P* = 0.13) between years, whereas age-adjusted WW was 10 kg higher (*P* = 0.02) the second year. Fall pregnancy rate was 8 percentage units higher (*P* = 0.08) for cows the second year compared with the first year of the study. Calving interval did not differ (*P* = 0.39) between years.

No effect (*P* = 0.81) of treatment was seen for cow body weight change (Table 3), with all cows losing an average of 29 kg during the winter. However, supplemented cows lost less (*P*= 0.05) body condition than unsupplemented cows (average –0.3 vs –0.6 BCS). Treatment did not affect (*P* > 0.80) calf birth weight (average 39 kg) or age-adjusted WW (average 191 kg). Fall pregnancy rate was not affected (*P* = 0.73) by treatment, averaging 78%, and calving interval was not affected (*P* = 0.31) by treatment, averaging 370 d.

Cow initial and final BW and BCS were lowest (*P* = 0.001) for 2-yr-old cows, followed by 3-yr-old cows, and highest for 4-, 5-, and 6-yr-old cows (Table 4). Two-year-old cows lost less (*P* = 0.01) weight than all other age groups; however, there was no difference (*P* = 0.88) in

Table 2. Composition and in situ dry matter disappearance (DMD) of native winter range extrusa consumed by beef cows either unsupplemented or supplemented with one of two liquid supplement delivery systems during 2 yr

Item	1995			1996			SE	*P*-value
	Control[a]	AdLib	Restricted	Control	AdLib	Restricted		
Composition, % DM								
CP	5.0	4.8	5.4	5.0	5.6	5.3	—	—
OM	92.5	91.2	91.7	92.7	91.7	92.4	—	—
NDF	80.1	80.5	79.1	78.9	77.3	77.8	—	—
ADF	46.9	50.2	48.0	46.4	45.9	44.0	—	—
DMD, 48 h	43.2[w]	58.0[y]	63.8[z]	40.9[w]	50.2[x]	53.0[x]	1.50	0.03

[a]Control = no supplement; AdLib = lick-wheel tank; Restricted = Regulate Liquid Feed Delivery System, Performix Nutrition Systems, Nampa, Idaho.
[w, x, y, z]Within a row, means without a common superscript letter differ ($P < 0.05$).

BCS change between age groups (average –0.4 BCS). Calf birth weight was lowest ($P = 0.02$) for 2-yr-old cows and highest for 6-yr-old cows. Age-adjusted WW was lower ($P = 0.05$) for 2-yr-old cows than for 3-, 4-, 5-, and 6-yr-old cows. A year × age interaction ($P = 0.02$) was seen for age-adjusted WW, with calves of 4- and 5-yr-old cows having higher age-adjusted WW than 2-, 3-, and 6-yr-old in the first year, and calves of 3-, 5-, and 6-yr-old cows having higher age-adjusted WW than 2- and 4-yr-olds in the second year. Fall pregnancy rate was not affected ($P = 0.15$) by cow age, although the 6-yr-old cows averaged 68% pregnant compared to an average of 80% for the other age groups. Cow age did not affect ($P = 0.22$) calving interval, which averaged 370 d.

Forage DMI, expressed in kilograms and in g/kg BW, was 23 and 14% lower ($P < 0.05$), respectively, the second year compared with the first (Table 5). Forage DMI was greatest ($P = 0.02$) by cows supplemented with Restricted (16.3 kg), intermediate by cows supplemented with ADLIB (13.5 kg), and least ($P = 0.02$) by Control cows (11.0 kg). Forage DMI expressed as g/kg BW followed a similar pattern. The 23% reduction in forage DMI seen the second year (15.4 vs 11.8 kg, for 1995 and 1996, respectively) probably resulted from greater snowfall during that winter, as discussed previously, and the resultant lower forage availability. Cohen (1974), Garg and Gupta (1992), Bowman et al. (1999), and Earley et al. (1999) reported increases in forage DMI of 30 to 64% due to liquid supplementation. These authors attributed the observed increased forage intake to increased forage digestibility. In our study, in situ DMD of the forage was increased ($P = 0.03$) by supplementation (Table 2). Delivery of the liquid supplement in the Restricted treatment increased ($P < 0.03$) forage DMI over that of ADLIB cows. This may have resulted from 136 and 200% more time spent at the supplement tank in 1995 and 1996, respectively, by cows on ADLIB compared with cows on Restricted, and therefore less time spent grazing by ADLIB cows (Table 9). However, Bowman et al. (1999), in a one-year study, did not detect differences in forage intake

Table 3. Performance by beef cows grazing native winter range and either unsupplemented or supplemented with one of two liquid supplement delivery systems during 2 yr

Item	1995			1996			SE	*P*-value		
	Control[a]	AdLib	Restricted	Control	AdLib	Restricted		Year	Trt	Year × Tr
No. of cows	60	60	58	59	60	60	—	—	—	—
Initial wt, kg	525	534	522	497	500	494	5.8	0.001	0.37	0.81
Final wt, kg	532	529	525	448	432	434	24.8	0.004	0.90	0.97
Wt change, kg	7	–5	3	–49	–68	–60	22.9	0.02	0.81	0.99
Initial BCS[b]	5.7	5.6	5.5	5.0	5.1	4.8	0.19	0.006	0.52	0.87
Final BCS[b]	5.3	5.7	5.5	4.2	4.4	4.2	0.23	0.001	0.44	0.92
BCS change[bd]	–0.4	0.1	0	–0.8	–0.7	–0.6	0.11	0.001	0.05	0.38
Calf birth wt, kg	39	37	38	39	39	39	0.8	0.13	0.80	0.28
Age-adjusted weaning wt, kg	182	186	188	198	193	195	3.1	0.02	0.89	0.47
Pregnancy rate, %[c]	78	71	72	78	78	88	0.6	0.08	0.73	0.31
Calving interval, d	371	371	366	372	374	367	1.9	0.39	0.31	0.79

[a]Control = no supplement; AdLib = lick-wheel tank; Restricted = Regulate Liquid Feed Delivery System, Performix Nutrition Systems, Nampa, Idaho.
[b]Body condition score on 1 to 9 scale.
[c]Analyzed by χ^2.
[d]Treatment means: Control = –0.6[z], AdLib = –0.3[y], Restricted = –0.3[y] (means without a common superscript letter differ; $P < 0.05$).

Table 4. Performance by beef cows of different ages grazing native winter range during 2 yr

Item	Cow age 2	3	4	5	6	SE	*P*-value Age	Year × age	Trt × age
No. of cows	107	87	78	46	39	—	—	—	—
Initial wt, kg	442[w]	492[x]	530[y]	544[yz]	552[z]	6.7	0.001	0.92	0.48
Final wt, kg	421[w]	464[x]	497[y]	511[yz]	524[z]	6.6	0.001	0.55	0.31
Weight change, kg	–21[y]	–28[z]	–33[z]	–33[z]	–28[z]	3.2	0.01	0.10	0.96
Initial BCS[a]	4.6[x]	5.1[y]	5.6[z]	5.7[z]	5.6[z]	0.10	0.001	0.97	0.37
Final BCS[a]	4.2[x]	4.7[y]	5.2[z]	5.3[z]	5.2[z]	0.11	0.001	0.62	0.20
BCS change[a]	–0.4	–0.4	–0.4	–0.4	–0.4	0.08	0.88	0.34	0.61
Calf birth wt, kg	36[x]	38[y]	39[yz]	39[yz]	40[z]	2.1	0.02	0.68	0.64
Age-adjusted weaning wt, kg	182[y]	191[z]	192[z]	195[z]	193[z]	3.9	0.05	0.02	0.26
Pregnancy rate, %[b]	74	86	76	82	68	0.6	0.15	0.22	0.49
Calving interval, d	366	368	371	373	370	2.4	0.22	0.31	0.22

[a]Body condition score on a 1 to 9 scale.
[b]Analyzed by χ^2.
[w,x,y,z]Within a row, means without a common superscript letter differ ($P < 0.05$).

by cows consuming liquid supplement from the same Restricted and ADLIB supplement delivery systems.

A year × treatment interaction ($P < 0.01$) was seen for supplement DMI estimated from Yb excretion, both in kilograms and g/kg BW (Table 5). Supplement DMI was greatest ($P = 0.003$) in ADLIB cows during the first year (1.3 kg), followed by ADLIB (0.9 kg) and Restricted cows the second year (0.5 kg), and was lowest in Restricted cows the first year (0.3 kg). Supplement DMI expressed in g/kg BW followed a similar pattern; however, the average amount of supplement per unit of BW consumed by cows did not differ ($P = 0.74$) between years (average 1.5 g/kg BW). The change made in supplement delivery in the Restricted treatment during 1996, allowed more frequent, but less, supplement allowance availability at one time. This may have resulted in the increased supplement intake by Restricted cows in the second year compared with the first.

Supplement use as estimated by disappearance of supplement from the tanks was 0.3 and 1.0 kg $DM{\cdot}cow^{-1}{\cdot}d^{-1}$ for Restricted and ADLIB cows, respectively, during the first year, and 0.4 and 0.9 kg $DM{\cdot}cow^{-1}{\cdot}d^{-1}$ for Restricted and ADLIB cows, respectively, during the second year. These estimates of supplement use are remarkably close to the average supplement intakes by individual cows as estimated using the Yb marker (0.3 and 1.3 kg $DM{\cdot}cow^{-1}{\cdot}d^{-1}$ for Restricted and ADLI cows, respectively, for 1995; 0.5 and 0.9 kg $DM{\cdot}cow^{-1}{\cdot}d^{-1}$ for Restricted and ADLIB cows, respectively, for 1996).

Blood urea nitrogen, measured in 1996, was highest ($P = 0.001$) for cows on the ADLIB supplement, intermediate for those on Restricted, and as might be expected,

Table 5. Forage dry matter intake, supplement dry matter intake (estimated from Yb excretion) and blood urea nitrogen (BUN) levels by beef cows grazing native winter range and either unsupplemented or supplemented with one of two liquid supplement delivery systems during 2 yr

Item	1995 Control[a]	AdLib	Restricted	1996 Control	AdLib	Restricted	SE	*P*-value Year	Trt	Year × Tr
No. of cows	60	60	58	59	60	60	—	—	—	—
Forage DMI, kg[b]	1.11	16.0	19.2	10.9	11.1	13.4	0.85	0.01	0.02	0.16
Forage DMI, g/kg BW[c]	21	30	36	23	24	28	19.8	0.06	0.03	0.28
Supplement DMI, kg	—	1.3[z]	0.3.[w]	—	0.9[y]	0.5[x]	0.04	0.06	0.001	0.003
Supplement DMI, g/kg BW	—	2.5[z]	0.6[w]	—	1.9[y]	1.1[x]	0.12	0.74	0.001	0.01
BUN, mg/dL[d]	—	—	—	2.3[x]	8.7[z]	6.2[y]	0.47	—	0.001	—

[a]Control = no supplement; AdLib = lick-wheel tank; Restricted = Regulate Liquid Feed Delivery System, Performix Nutrition Systems, Nampa, Idaho.
[b]Treatment means: Control = 11.0[x], AdLib = 13.5[y] , Restricted = 16.3[z] kg forage DMI (means without a common superscript letter differ; $P < 0.05$).
[c]Treatment means: Control = 22[x], AdLib = 27[y] , Restricted = 32[z] g/kg BW forage DMI (means without a common superscript letter differ; $P < 0.05$).
[d]Measured only in 1996.
[w,x,y,z] Within a row, means without a common superscript letter differ ($P < 0.05$).

was lowest for Control cows that did not receive any supplemental N. Hammond (1997) reported that BUN levels less than 7 mg/dL indicated a deficiency of N relative to DE, and levels elevated above 19 to 20 mg/dL were sometimes associated with reduced reproductive performance. In our study, individual cow BUN levels ranged from 1 to 21 mg/dL, with only one cow having a BUN level above 19 mg/dL. Therefore, despite a wide range in supplement DMI (0 to 4.7 kg), and with urea providing 91% of the supplemental nitrogen, BUN levels were not high enough to cause concern relative to reproductive performance.

No treatment × age interactions ($P > 0.23$) were found for forage or supplement DMI or for BUN levels (Table 6). However, year × age interactions ($P = 0.001$) were seen for forage DMI expressed in kilograms and g/kg BW. During the first year, forage DMI was least ($P = 0.001$) by 2-yr-old cows (11.9 kg), higher by 3-yr-old cows (14.5 kg), higher still by 4- and 6-yr-old cows (average 16.2 kg), and greatest by 5-yr-old cows (18.4 kg). During the second year, forage DMI was least ($P = 0.001$) by 2-yr-old cows (10.5 kg), and not different by 3-, 4-, 5-, and 6-yr-old cows (average 12.1 kg). All age groups consumed less ($P = 0.001$) forage DM the second year compared with the first year. When expressed as g/kg BW, differences in forage DMI were not as large. During the first year, 2-yr-old cows had lower ($P = 0.001$) forage intake than 3-, 4-, and 6-yr-old cows, with 5-yr-old cows having the greatest forage intake. However, during the second year, forage DMI in g/kg BW did not differ ($P = 0.22$) between age groups.

Supplement DMI was affected ($P = 0.002$) by cow age, with 2-yr-old cows consuming the least amount of supplement (0.5 kg; Table 6). Three-yr-old cows consumed more ($P = 0.06$) supplement than 2-yr-olds (0.7 kg), followed by 5-yr-old cows (0.8 kg), who were intermediate in supplement consumption, and the most supplement was consumed by 4- and 6-yr-old cows (average 0.9 kg). Wagnon (1965) reported that 2-yr-old cows were driven away from the supplement tank by older cows. Bowman et al. (1999) found that 3-yr-old cows had greater supplement intake than 2-yr-olds when using ADLIB, however, 2- and 3-yr-old cows consumed similar amounts of liquid supplement when on the Restricted diet. There was no treatment × age interaction ($P = 0.33$) for supplement intake in our study. Blood urea nitrogen levels measured in 1996 were lowest ($P = 0.05$) for 2-yr-old cows and highest for 4-yr-old cows, with the other age groups being intermediate.

Liquid supplement intake distribution by individual cows is presented in Table 7. The largest range in supplement DMI by individual cows was seen on the ADLIB treatment, 0 to 4.7 kg/d in 1995 and 0 to 4.1 kg/d in 1996. The range in supplement DMI was smaller for cows on the Restricted diet (0 to 1.2 kg/d in 1995 and 0 to 1.5 kg/d in 1996) and may have been due to the controlled dispensing pattern of the supplement. There was a year × treatment interaction ($P = 0.09$) for CV of individual cow supplement DMI. The CV for individual cow supple-

Table 6. Forage dry matter intake, supplement dry matter intake (estimated from Yb excretion) and blood urea nitrogen (BUN) levels by beef cows of different ages grazing native winter range during 2 yr

Item	1995					1996					SE	*P*-value		
	2	3	4	5	6	2	3	4	5	6		Age	Year × age	Trt × age
No. of cows	48	41	41	24	24	59	46	37	22	15	—	—	—	—
Forage DMI, kg	11.9^{w}	14.5^{x}	16.1^{y}	18.4^{z}	16.3^{y}	10.5^{v}	11.6^{w}	12.4^{w}	12.0^{x}	12.3^{w}	0.54	0.001	0.001	0.23
Forage DMI, g/kg BW	26^{x}	29^{y}	29^{y}	34^{z}	29^{y}	26^{x}	26^{x}	26^{x}	24^{x}	25^{x}	0.1	0.14	0.001	0.43
Supplement DMI, kg	0.5	0.8	0.9	0.7	1.1	0.5	0.6	0.9	0.8	0.7	0.13	0.002	0.60	0.33
Supplement DMI, g/kg BW	1.1	1.5	1.6	1.6	1.9	1.3	1.4	1.8	1.7	1.5	0.26	0.005	0.85	0.58
BUN, mg/dL[a]	—	—	—	—	—	4.8^{x}	5.9^{yz}	7.0^{z}	5.2^{xy}	5.6^{xyz}	0.50	0.05	—	0.33

[a]Measured only in 1996.
[v,w,x,y,z] Within a row, means without a common superscript letter differ ($P < 0.05$).

Table 7. Supplement intake distribution (estimated from Yb excretion) by beef cows grazing native winter range and supplemented with one of two liquid supplement delivery systems during 2 yr

	1995		1996			*P*-value		
Item	AdLib[a]	Restricted	AdLib	Restricted	SE	Year	Trt	Year × Trt
No. of cows	53	54	59	60	—	—	—	—
Supplement DMI range,kg	0 to 4.7	0 to 1.2	0 to 4.1	0 to 1.5	—	—	—	—
Supplement DMI CV, %[b]	68[y]	117[z]	56[y]	67[y]	11.5	0.01	0.02	0.09
Fecal samples withoutYb	0	3	2	12	—	—	—	—
Fecal samples withoutYb, %	0	5.6	3.3	12.9	3.24	0.12	0.03	0.54
Proportion of cows with supplement DMI								
<0.3 kg, %	10.4[x]	63.9[z]	4.3[x]	33.9[y]	6.67	0.01	0.001	0.08
0.3 to 0.8 kg, %	30.8	20.7	53.2	48.0	8.22	0.006	0.36	0.77
>0.8 kg, %	58.8	15.4	42.5	18.1	7.05	0.35	0.001	0.19
Below target, %[b]	15.4[x]	73.4[z]	21.0[x]	50.1[y]	8.60	0.30	0.001	0.09

[a]AdLib = lick-wheel tank; Restricted = Regulate Liquid Feed Delivery System, Performix Nutrition Systems, Nampa, Idaho.
[b]Coefficient of variation for supplement DMI was calculated as SD/mean with each age group within pasture used as the experimental unit.
[c]Target supplement intake was 0.5 kg DM.
[x,y,z] Within a row, means without a common superscript letter differ ($P < 0.05$).

ment DMI was higher ($P = 0.09$) for Restricted cows than for ADLIB cows in 1995 (117 vs 68% CV), but not different ($P = 0.69$) for the two treatments in 1996 (56 vs 67% CV, for ADLIB and Restricted cows, respectively). The CV of supplement DMI for ADLIB was the same ($P = 0.25$) between years (average 62%). However, the supplement DMI CV for Restricted was lower ($P < 0.01$) the second year compared with the first (67 vs 117% CV, for 1995 and 1996, respectively). The change in the dispensing pattern of Restricted diets the second year, along with any other differences between years, could have contributed to the reduction in CV. Ytterbium was not detected in the feces of a greater ($P = 0.03$) proportion of cows (considered nonconsumers) on the Restricted treatment compared with cows on the ADLIB treatment (9.3 vs 1.7% for Restricted and ADLIB, respectively). This suggests that although the change in dispensing pattern of the Restricted feeder was effective in increasing the mean supplement intake and reducing the CV for supplement intake by that group of cows, it did not result in a reduction in non-consumers.

The proportion of Restricted cows consuming less than 0.3 kg of supplement tended to decrease ($P = 0.08$) from 63.9% in the first year, to 33.9% in the second year (Table 7). This may have resulted from increased familiarity with the supplement delivery methods by individual cows, or from the change made in dispensing pattern for the Restricted treatment. The proportion of ADLIB cows that consumed less than 0.3 kg of supplement did not differ ($P = 0.33$) between years (average 7.4%). A much greater ($P = 0.001$) proportion of Restricted cows consumed less than 0.3 kg of supplement compared with ADLIB cows (48.9 vs 7.4% for Restricted and ADLIB, respectively), and a greater ($P = 0.001$) proportion of ADLIB cows (50.7%) consumed more than 0.8 kg of supplement compared with Restricted cows (16.8%). A large increase ($P = 0.006$) was seen in the proportion of cows consuming 0.3 to 0.8 kg supplement DM from 1995 to 1996 (25.8% for 1995, and 50.6% for 1996). There was a year × treatment interaction ($P = 0.09$) for the proportion of cows consuming less than the manufacturer's target amount of supplement. No difference ($P > 0.10$) was seen in the proportion of cows consuming less than the target supplement amount between 1995 and 1996 in the ADLIB treatment (15.4 vs 21.0% below target amount for 1995 and 1996, respectively). However, the proportion of Restricted cows consuming below target was greatly reduced ($P = 0.001$) from 73.4% in 1995 to 50.1% in 1996.

No effects of age ($P > 0.11$) and no year × age or treatment × age interactions ($P > 0.12$) were seen for supplement intake distribution (Table 8). The largest ranges in supplement intake were seen in 3- and 4-yr-old cows. Supplement intake CV ranged from 52% for 6-yr-old cows to 98% for 5-yr-old cows. Nonconsumers (cows without Yb in their fecal samples) averaged 5.4%. The proportion of cows that consumed less than 0.3 kg/d of supplement averaged 28.1%, those that consumed 0.3 to 0.8 kg/d of supplement averaged 38.2%, and 33.7% of cows consumed more than 0.8 kg/d. The proportion of cows that consumed below-target amounts of supplement averaged 40%.

Bowman and Sowell (1997) reported that variation in individual supplement intake exists regardless of the supplement form or method of delivery. High levels of competition for supplement, as in hand-feeding, generally increases the proportion of animals not consuming supplement, whereas low levels of competition, as with self-fed supplements, generally increases variation in supplement intake (Bowman and Sowell, 1997). For self-fed liquid supplements several factors influence consumption, including tank proximity to water and preferred grazing areas, and supplement formulation and palatability. In addition, supplement dosing frequency and time available are important determinants of intake

Table 8. Supplement intake distribution (estimated from Yb excretion) by beef cows of different ages grazing native winter range and supplemented with one of two liquid supplement delivery systems during 2 yr

	Cow age						P-value		
Item	2	3	4	5	6	SE	Age	Year × age	Trt × age
No. of cows	70	57	47	26	24	—	—	—	—
Supplement DMI range, kg	0 to 2.3	0 to 4.7	0 to 4.1	0 to 2.9	0 to 2.7	—	—	—	—
Supplement DMI CV, %[a]	82	89	63	98	52	12.3	0.12	0.32	0.26
Fecal samples without Yb	7	7	1	1	1	—	—	—	—
Fecal samples without Yb, %	7.6	12.1	1.8	2.5	3.1	3.62	0.24	0.12	0.20
Proportion of cows with supplement DMI									
<0.3 kg, %	36.9	36.1	18.3	34.8	14.6	7.46	0.11	0.24	0.66
0.3 to 0.8 kg, %	41.4	35.4	41.8	32.7	39.6	9.19	0.94	0.92	0.16
>0.8 kg, %	21.7	28.6	39.9	32.5	45.8	7.88	0.25	0.15	0.18
Below target, %[b]	54.4	43.2	37.2	46.3	18.8	9.36	0.12	0.56	0.55

[a]Coefficient of variation for supplement DMI was calculated as SD/mean with each age group within pasture used as the experimental unit.
[b]Target supplement intake was 0.5 kg DM.

for the computer-controlled liquid supplement delivery system.

Supplement feeding behavior as measured by the GrowSafe, Inc. System is presented in Table 9. One ADLIB and two Restricted cows were not electronically recorded as having visited the supplement feeder in 1995. In 1996, all ADLIB cows were electronically recorded as having visited the supplement feeder and two Restricted cows had no recorded time at the supplement feeder. Cows on ADLIB were present at the supplement feeder more ($P < 0.001$) days than Restricted cows, averaging 21 vs 12 d (out of 25) in 1995, and 30 vs 19 d (out of 34) in 1996. Wagnon (1965) reported that increasing supplement allowance increased the number of cows that responded to the call for supplement. Wagnon (1965) collected feeding behavior of hand-fed supplemented cattle for several years and reported that the percentage of cows responding to call differed between years (78 to 88%).

No comparisons of supplement feeding behavior can be made between years; however, cows in the ADLIB treatment spent more ($P = 0.001$) time at the tank, and had more ($P < 0.002$) feeding bouts than cows on the Restricted treatment in both 1995 and 1996 (Table 9). In addition, cows on ADLIB had longer ($P = 0.001$) feeding bout duration than Restricted cows during 1996.

Cow age affected ($P < 0.01$) feeding behavior during 1995, but not during 1996 ($P > 0.24$). In 1995, time spent at the feeder was highest ($P = 0.01$) for 6-yr-old cows (37 min/d), 35% less for 4- and 5-yr-old cows (average 24 min/d), and least for 3-yr-old cows (13 min/d). Time spent at the feeder by 2-yr-old cows (17 min/d) was intermediate between 3-, 4-, and 5-yr-olds. The number of feeding bouts per day was greatest ($P = 0.01$) by 4-, 5-, and 6-yr-old cows (average 3.3 bouts/d), and least by 3-yr-old cows (1.9 bouts/d). The number of bouts by 2-yr-olds (2.5 bouts/d) was not different ($P > 0.10$) from that by 3- or 5-yr-olds.

Arnold and Maller (1974) reported that in a mixed-age group of sheep, the oldest and youngest age groups were the least competitive. Friend and Polan (1974) also reported a quadratic relationship between average time spent eating and social rank of dairy cattle; however, the midranked cows spent the least amount of time eating.

Table 9. Supplement feeding behavior by beef cows of different ages grazing native winter range and supplemented with one of two liquid supplement delivery systems during 2 yr

	Treatment[a]		Cow age						P-value		
Item	AdLib	Restricted	2	3	4	5	6	SE	Trt	Age	Trt × age
1995											
No. of cows	29	30	16	13	14	9	7	—	—	—	—
Total time, min/d	33	14	17^{xy}	13^{x}	24^{y}	24^{y}	37^{z}	3.3	0.001	0.005	0.38
Feeding bouts, bouts/d	4.2	1.5	2.5^{xy}	1.9^{x}	3.3^{z}	2.9^{yz}	3.7^{z}	0.31	0.001	0.01	0.20
Feeding bout duration, min/bout	6	7	5^{x}	5^{x}	6^{x}	7^{x}	9^{y}	0.8	0.31	0.01	0.57
1996											
No. of cows	30	30	20	15	13	8	4	—	—	—	—
Total time, min/d	15	5	8	11	11	11	9	1.8	0.001	0.60	0.78
Feeding bouts, bouts/d	5.5	3.9	4.3	4.7	4.9	4.7	4.7	0.44	0.002	0.95	0.66
Feeding bouts duration, min/bout	3	1	1	2	2	2	2	0.2	0.001	0.24	0.38

[a]AdLib = lick-wheel tank; Restricted = Regulate Liquid Feed Delivery System, Performix Nutrition Systems, Nampa, Idaho.
[x,y,z] Within a row, means without a common superscript letter differ ($P < 0.05$).

There were only four 6-yr-olds on study in 1996 and results for this age group could have been influenced by sample size.

Bowman et al. (1999) collected observations of cow behavior at the same ADLIB and Restricted lick-wheel feeders and used a 30-min separation interval to define different bouts. Based on 8 d of observations, they reported that cows visited the feeders 70% of the days. Cattle on the Restricted feeder averaged 14.1 min/d and 1.5 bouts/d, and cattle on the ADLIB feeder averaged 19.3 min/d and 1.1 bouts/d (Bowman et al., 1999). In addition, 2-yr-old cows visited ADLIB and Restricted supplement feeders less frequently and spent less time there than 3-yr-old cows (Bowman et al., 1999). Ernst (1973) reported that yearling heifers visited a roller lick feeder containing a urea-molasses mixture at least once a day and that bout duration averaged 4 min/bout. Ernst (1973) used a 5-min separation interval between bouts and reported that cows spent 26 min/d at the supplement feeder and averaged 6.5 bouts/d. Wagnon et al. (1966) reported that social rankings of individual cows fed forage in troughs remained constant between 2 yr. Time spent at the supplement feeder, frequency of supplement feeding bouts, and social interactions between age groups in the current study is in agreement with what has been previously reported in the literature.

Implications

Supplying high-nitrogen liquid supplement (50 to 57% CP) to cows grazing low-quality winter native range can increase forage digestibility and intake, and reduce body condition loss. Delivery method of self-fed liquid supplement can influence the variation in supplement intake and the proportion of cows meeting target consumption. The proportion of nonfeeders in a herd will usually increase with restricted access, but that restriction may encourage grazing and forage intake. Restricting supplement access can increase the variability of supplement intake by individual cows. Social interactions by a mixed-age group of cows at liquid supplement feeders can result in lower supplement consumption by 2-yr-old cows compared with older cows.

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