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Forage Intake Responses to Winter Cold Exposure of Free-ranging Beef Cows

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ABSTRACT

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Winter foraging behaviors of pregnant crossbred beef cows grazing Montana native rangeland were examined over a continuous 46-day period in January and February. The objective was to examine daily estimates of two principle grazing behaviors, forage intake and time spent grazing, in response to fluctuations in acclimated thermal environments. Sixteen 5-year-old cows (525-575 kg) were fitted with vibracorders to monitor daily grazing time (DGT). Fecal organic matter output was estimated using total fecal collections and a Cr_2O_3 dilution technique. In vitro organic matter disappearance (IVOMD) was determined from extrusa obtained from four rumen-fistulated cows. Mean daily forage intake expressed as a percentage of body weight day (% BW per day) increased ($P<0.05$) when present day ambient air or wind-chill temperatures deviated (either an increase or a decrease) from temperature averages of 1, 2 or 3 previous days, but the magnitude of response was small (<0.0005% BW per day per °C deviation). Daily intake was unresponsive ($P>0.05$) to deviations from acclimated temperatures calculated for the previous 4-20 days. Dietary extrusa IVOMD averaged 34.5% and remained consistent ($P>0.05$) during the winter grazing period. Daily grazing time decreased ($P<0.05$) with ambient or wind-chill temperature deviations from acclimated thermal regimes of the past 1-3 days, and the magnitude of response was also small (<0.01 h per day per °C deviation). The slight responses of these two principal foraging behaviors indicated thermal fluctuations (8 to -16°C) within a familiar winter environment were minimally stressful with no resulting adverse effects upon the animal.

INTRODUCTION

Daily nutrient ingestion and resulting nutritional status of free-ranging beef cows, can be viewed as a product of foraging behaviors (Arnold and Dudzinski, 1978). These behaviors are generally described by rates and durations of forage

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harvest whose energetic costs may comprise one-quarter to one-half of free-ranging energy requirement (Osuji, 1974). Behavioral responses to features of foraging environments, especially aspects of forage dynamics, have been reported (Leaver, 1985).

Abnormal alterations in ethogram signatures (which should include daily patterns of certain foraging behaviors) may be viewed as indicators of animal stress (Ewbank, 1985). Ramification for the animal of these alterations would define the nature of the stress as physiological (harmless), overstress (some damage) or distress (pathological) (Ewbank, 1985). A primary stressor variable under free-ranging conditions is the thermal environment, and behaviors may vary with the temperature of the environment relative to a lower critical temperature and duration of exposure (Kennedy, 1985). Adams et al. (1986) postulated that two principal foraging behaviors, daily time spent grazing and forage intake, are positively correlated for range beef cows as ambient air temperatures decline. Senft and Rittenhouse (1985) have hypothesized that daily forage intake of range beef cattle declines in response to short-term thermal stress. Recently, Dunn et al. (1988) reported that daily foraging durations were insensitive to fluctuations in ambient winter air temperatures. Responses of daily forage intake to fluctuating and harsh thermal environments, however, have not been quantified for range beef cattle over extended periods. Our objective was to test the hypothesis of Senft and Rittenhouse (1985) by examining foraging behavior responses (including daily forage intake) of pre-partum range beef cows to fluctuations in winter thermal conditions.

MATERIALS AND METHODS

The study area was a 324-ha pasture located on the Red Bluff Research Ranch (latitude 45°35′N; longitude 111°34′W), Norris, Montana, that contained sandy and silty range sites typical of the foothills of south-west Montana. Dominant vegetation include bluebunch wheatgrass (*Agropyron spicatum*), needleandthread (*Stipa comata*), Idaho fescue (*Festuca idahoensis*) and basin wildrye (*Elymus cinereus*). Elevation ranged from 1400 to 1900 m. The average winter ambient air temperature during the study was 0°C, comparable to a 50-year (1937–1986) average winter temperature of −1°C. An important feature of the pasture was the dominant south-westerly wind that minimized snow cover and maintained accessible forage throughout the winter.

Sixteen pregnant Hereford×Angus and Tarentaise×Angus crossbred cows were selected from the Red Bluff Ranch herd. Selection was based on body weight (525–575 kg) and age (5 years old). All cows had been artificially inseminated to a common Angus sire with expected calving dates approximately 15 March 1987. Ambient air temperature and wind speed were measured continuously using a meteorograph and anemometer, respectively.

All cows grazed native range from 15 December 1986 to 25 February 1987 without supplementation other than an initial intramuscular injection with 20 000 000 IU Vitamin A and access to a loose iodized salt mixture containing 30% dicalcium phosphate and 30% potassium chloride. For 6 months preceding the trial, cows grazed native range without access to supplemental feeds. Data were collected for a 46-day period (10 January–25 February). Initial and final mean body weights (kg) and condition scores (visual and palpable scale of 1=thin–10=fat; LaMontagne, 1981) were 550 ± 37.8 (SE), 543 ± 43.7, 4.1 ± 0.3 and 3.5 ± 0.2, respectively. Cows wore vibracorders (Stobbs, 1970) to estimate daily grazing time (DGT). Each day was divided into three grazing intervals: 0701–1300, 1301–1900 and 1901–0700 h. These intervals were chosen to represent morning, afternoon and night-time grazing periods (Dunn et al., 1988). To illustrate, sunrise and sunset events on 11 January and 25 February were 0803 and 1656, and 0710 and 1805, respectively. Animals wore the same vibracorder throughout the trial and charts were changed weekly at 1130 h. Charts were read as hours grazed per interval (DGTI), rounded to 15 min. Total DGT was the sum of DGTI for each interval for each day. No other activity levels were assigned.

Fecal organic matter output (FO) was estimated using total fecal collections and a Cr_2O_3 dilution technique (Raleigh et al., 1980) based on daily rectal grab samples. Total fecal collections were obtained from four groups of four cows ($n=16$) where collections (96 h) were obtained from each group within a week in January and a week in February. Previous observations of winter foraging patterns indicated a regular non-grazing period from 1100 to 1330 h. Collection bags were changed at 1130 h each day of these eight periods to minimize disruption of normal grazing patterns. In addition, all cows were bolused daily at 1130 h with 10 g Cr_2O_3 in a gelatin capsule (size No. 10), and individual rectal grab samples for Cr_2O_3 analysis were collected.

Total collected fecal material was weighed, mixed, sampled and frozen. Rectal grab samples were immediately frozen. After thawing, dry matter and organic matter were determined for each fecal sample following AOAC (1980) procedures. The remainder of the sample was dried at 100°C for 3 days then ground through a 2-mm screen using a Wiley mill. Cr_2O_3 concentration for each sample was determined through spectrophotometry using a method derived from Fenton and Fenton (1979) and Costigan and Ellis (1986). FO per day was estimated from rectal grab samples based on the following equation:

$$\text{FO (g per day)} = [Cr_2O_3 \text{ (g fed per day)}]/[Cr_2O_3 \text{ in dry fecal sample)}]$$

Rectal grab samples were adjusted individually for each cow based on FO from total fecal collections.

Extrusa samples of grazed forage were collected weekly (using a total evacuation technique) with four additional cows fitted with rumen cannulas (Lesperance et al., 1960). Animals were penned overnight without feed or water. The next morning, rumen canulas were removed, rumen extrusa was extracted and cannulas replaced. Contents were covered and maintained at 37–39°C. The inside of the rumen was washed down with water and excess removed. Animals were allowed to graze freely with other research animals for 1–1.5 h. Animals were then gathered and the rumen extrusa was removed, mixed, subsampled and frozen. Initial rumen contents were returned to the rumen and the cows were released. Cows used for digestibility estimates grazed concurrently with other research animals. In vitro organic matter digestibility (IVOMD) of each freeze-dried and ground (1 mm) sample was determined using the Barnes modification of the Tilley and Terry technique (Harris, 1970). Forage organic matter intake (OMI) was estimated using the following equations:

$$=\mathrm{OMI} = [\text{daily FO (kg)}]/(1\text{-IVOMD})$$

Statistical Analysis System's General Linear Model (SAS, 1985) was utilized to determine the effect of the ambient air temperature of previous days (lag (L) = 1–20 days) on daily OMI, DGT, and DGTI. This analysis utilized components of a model developed by Senft and Rittenhouse (1985) to examine possible thermal acclimation lengths for cattle. Dunn et al. (1988) described these components for an earlier study that examined only DGT and DGTI responses to ambient air temperature fluctuations. These components included running mean temperatures ($T_{\mathrm{accli}\ (L)}$), daily mean temperature (T_i), and short-term thermal stress (STTS). Running mean temperatures were calculated using mean daily temperatures for the L days previous to the present day (i), where

$$\mathrm{T}_{accli}\,(L) = [\,(\text{sum of } L \text{ days for } j=1\text{–}L)\,(T_{(i-j)})\,]/L$$

The variable L did not indicate the complete time for physiological acclimation, but time in the immediate past that has the greatest impact on the current acclimation state. L values of 1–20 days were chosen to include values of 9–14 days reported by Senft and Rittenhouse (1985) as the time course of thermal acclimation for cattle throughout a year. T_i was calculated as the weighted mean of daily maximum temperature ($T_{\mathrm{max}(i)}$), daily minimum temperature ($T_{\mathrm{min}(i)}$) and minimum temperature for the following day ($T_{\mathrm{min}(i+1)}$):

$$\mathrm{T}_i = [2(\mathrm{T}_{max}(i) + (\mathrm{T}_{min}(i) + (\mathrm{T}_{min}(i+1)\,]/4$$

STTS on Day i was defined as the difference between T_i and the hypothetical acclimated temperature [$T_{\mathrm{accl}\ (i)}$]:

$$\mathrm{STTS} = (\mathrm{T}_i) - \mathrm{T}_{accl}(i))$$

Responses of OMI, DGT and DGTI to STTS for L values of 1–20 days were analyzed. Independent variables were individual cow, STTS, and individual cow by STTS. Individual cow by STTS was the error term. In addition to STTS, the effect of wind-chill temperature (WCT) on OMI, DGT, and for acclimation lengths (L=1–20 days) was analyzed using SAS GLM (general linear models) (SAS, 1985). WCT was calculated using an equation from Johnson et al., (1987) derived from data of Ames (1974) and Ames and Insley (1975). The equation incorporates linear terms for wind speed and temperature and a quadratic term for wind-speed squared:

$$WCT = (-1.4109) - (0.00334 \times wind)(+0.995 \times temp.) - (0.000013 \times wind)^2$$

Wind speed (km per day) was averaged daily and averaged per grazing interval while T_i was utilized as the temperature value. Dependent variables in the model included OMI, DGT, and DGTI. Independent variables were WCT, individual cow, and WCT by individual cow. The error term was WCT by individual cow. The influence of fecal collection periods on DGT and DGTI was also examined using SAS GLM (SAS, 1985). Dependent variables were DGT and DGTI. Independent variables were presence or absence of fecal bags, fecal collection period (two), each group (four) of four cows, and the group by period interaction (error term).

RESULTS AND DISCUSSION

General trends

Weekly means for dietary extrusa IVOMD were relatively constant STTS distribution during this 46-day winter period (Table 1). Though there is no biological basis for viewing these data on a weekly basis, the lack ($P>0.05$) of differences indicates relative stability in the digestible energy of forage selected by these cows during the winter period. Values (average of 34.6%) are within the range reported by others (Turner, 1985; Dunn et al., 1988) for cool-season

TABLE 1

Means with standard deviations for wind-chill temperatures (WCT), ambient air temperatures (T_i), grazing time (DGT), fecal organic matter output (FO) and rumen extrusa in vitro organic matter disappearance (IVOMD) for weekly periods during the winter

Week	WCT (°C)	T_i (°C)	DGT (h per day)	FO (% BW)[1]	IVOMD (%)
11-17 Jan.	−4.7±0.7	−6.1±0.7	8.6±0.1	0.63±.06	34.8±3.6
18-24 Jan.	−4.3±0.2	−5.7±0.2	8.1±0.1	0.60±.07	36.6±1.6
25-31 Jan.	3.3±0.2	1.8±0.2	8.2±0.1	0.61±.08	34.3±2.3
1- 7 Feb.	4.7±0.1	3.2±0.1	9.0±0.1	0.59±.08	38.6±1.8
8-14 Feb.	6.1±0.1	4.7±0.1	8.9±0.1	0.58±.07	34.1±1.2
15-21 Feb.	−0.4±0.2	−1.8±0.2	8.9±0.1	0.60±.07	31.0±1.7
22-28 Feb.	−4.6±0.3	−6.0±0.3	7.5±0.2	0.66±.09	32.7±0.5

[1]Percentage of body weight per day.

graminoid forages during winter dormancy. Fecal outputs (average of 0.61% BW) are similar to data reported by others for beef cattle grazing winter rangeland in the foothills of the Northern Rocky Mountains (Turner, 1985; Dunn, 1986). Conrad et al. (1964) and Ellis (1978) reported a consistent excretion of undigested dry matter for cattle consuming roughage diets.

Average DGT (8.5 h per day) was similar to autumn and winter grazing times reported by Malechek and Smith (1976) and Dunn et al. (1988), but higher than that reported by Adams et al. (1986). Probable but unreported differences among these studies in range forage characteristics, especially available quantities, may be a more important influence upon DGT than winter temperatures. The consistency in DGT would also imply a relatively stable forage base throughout this study, given that DGT can have an inverse relationship with forage availability (Allden and Whittaker, 1970).

Biting rates are typically within a range of 50–60 bites min^{-1} (Leaver, 1985). Given a winter season average of 510 min of grazing time per day and an OMI of 5.5 kg (for cows of an average body weight of 550 kg), forage harvest rates of 25 500–30 600 bites per day would range from 0.18 to 0.22 g per bite. For temperate forages, Leaver (1985) reported a critical forage harvest level of 0.3 g per bite. It may be inappropriate to presume that reductions in OMI in response to winter thermal stress are possible without resulting in severe animal disfunction. Efforts to improve the nutritional status of grazing beef cows during winter should include maintenance of suitable quantities of available forage that maximize harvest rates in addition to traditional supplementation for improving nutrient utilization within the gastrointestinal tract.

Methodology

The presence of fecal bags did not reduce ($P > 0.01$) DGT compared to non-harnessed cows (Table 2). Total fecal collections, however, reduced ($P < 0.01$) grazing time during the morning interval by 30 min, a 20% reduction. Fecal bags were changed at 1130 h each day of the 96-h collection period and weight

TABLE 2

Influence of total fecal collections on grazing times relative to non-harnessed cows[1]

Grazing Interval	Grazing time (h)		P
	Harnessed cows	Non harnessed cows	
Daily	8.1 ± 0.12	8.9 ± 0.07	NS
0701-1300 h	2.0 ± 0.08	2.5 ± 0.04	0.01
1301-1900 h	4.0 ± 0.08	4.2 ± 0.04	NS
1901-0700 h	2.1 ± 0.12	2.1 ± 0.06	NS

[1]Least-squares means and standard errors.

of fecal material within a bag (20–30 kg of fresh feces) may have impeded morning grazing activities. Grazing times during the other two intervals of a day were not influenced ($P > 0.01$) by total fecal collections.

Utilizing these data, Olson-Rutz (personal communication, 1988) reported that a sample size of nine cows would minimize confidence intervals ($\alpha = 0.05$) to 10% of means for FO and DGT. Other published reports on sample size requirements are not available for these experimental conditions.

Stress responses

Daily forage organic matter intake demonstrated ($p < 0.05$) small positive responses to STTS (Table 3) and WCT (Table 4) for acclimation lags of 1, 2 and 3 days. Given the relative consistency in dietary extrusa IVOMD, this response can be interpreted as an increase in FO. The maximum absolute magnitude observed for STTS was 16°C. No other acclimation lengths were sig-

TABLE 3

Responses of daily forage organic matter intake (OMI) to short-term thermal stress (STTS) and magnitude of response for acclimation lengths of 1–20 days

Acclimation length (days)	OMI (% BW)[1]	Magnitude of Response (% BW °C^{-1} STTS)[2]
1	**	+0.0003
2	**	+0.0003
3	*	+0.0006
4-20	NS	-

[1]Percentage of body weight.
[2]Percentage of body weight per degree STTS.
*$P < 0.05$; ** $P < 0.01$.

TABLE 4

Responses of daily forage organic matter intake (OMI) to wind-chill temperature (WCT) and magnitude of response for acclimation lengths of 1–20 days

Acclimation length (days)	OMI (% BW)	Magnitude of response (% BW °C^{-1} WCT)[2]
1	*	+0.0005
2	**	+0.0002
3	*	+0.0003
4-20	NS	-

[1]Percentage of body weight.
[2]Percentage of body weight per degree WCT departure from acclimated WCT.
*$P < 0.05$; **$P < 0.01$.

nificant. This observation does not agree with the hypothesis of Senft and Rittenhouse (1985) that forage intake would decline in response to STTS. These authors constructed their model based on grazing behavior data obtained over a 12-month period. As suggested by Senft and Rittenhouse (1985) and supported by Dunn et al. (1988), thermal acclimation lengths may vary within and between seasons and cows may be insensitive in grazing behaviors to thermal fluctuations during winter months in northern latitudes. Conversely, DGT demonstrated ($P<0.05$) small negative responses to STTS and WCT for acclimation lengths of 1, 2 and 3 days. As with OMI, no other acclimation lengths examined were significant. Thus, OMI and DGT did not respond to STTS in a similar fashion. It is possible that other foraging behaviors, especially rates of forage intake and choice of foraging locations, may alter in response to thermal stressors.

The sensitivity of afternoon and evening grazing intervals to STTS (Table 5) and WCT (Table 6) illustrate an adjustment of within-day grazing times with a corresponding maintenance of consistent DGT. Afternoon intervals showed a consistent small negative response to STTS for acclimation lags of 8 days or longer ($P<0.05$ to $P<0.001$). Scattered responses to STTS for the

TABLE 5

Significant responses of daily grazing times to short-term thermal stress (STTS) and magnitude of response for acclimation lengths of 1-20 days

Acclimation length (days)	Grazing intervals			
	Daily 0701-0700 h	1301-1900 h	1901-0700	0701-1300 h
1	(−0.010)[1]*			
2	(−0.003) **			
3	(−0.005)*			
4				
5				
6			(−0.0001)*	
7				
8		(−0.0005)*	(+0.0002)*	
9		(−0.0006)**		
10		(−0.0006)**		
11		(−0.0006)**		
12		(−0.0006)***		
13		(−0.0006)***		
14		(−0.0007)***	(−0.0008)*	
15		(−0.0007)***		
16		(−0.0007)***		
17		(−0.0006)***	(+0.0001)*	
18		(−0.006)***	(+0.0003)*	
19		(−0.007)***	(+0.001)*	
20		(−0.005)***	(+0.001)*	

[1]Hour per degree STTS.
*$P<0.05$; **$P<0.01$; ***$P<0.001$.

TABLE 6

Significant responses of daily grazing times to wind-chill temperature (WCT) and magnitude of response for acclimation lengths of 1-20 days

Acclimation length (days)	Grazing intervals			
	Daily 0701-0700 h	1301-1900 h	1901-0700 h	0701-1300 h
1	(−0.007)[1]*	(−0.002)*		
2	(−0.003)**			
3	(−0.005)*		(−0.005)*	
4				
5				
6				
7				
8			(−0.007)*	
9			(−0.006)*	
10			(−0.006)**	
11			(−0.006)**	
12			(−0.007)**	
13			(−0.007)***	
14	(−0.010)*		(−0.007)***	
15			(−0.007)**	
16			(−0.008)**	
17			(−0.007)**	
18			(−0.007)**	
19		(+0.001)*	(+0.009)**	
20			(−0.011)***	

[1]Hour per degree WCT departure from acclimated WCT.
$^{*}P<0.05$; $^{**}P<0.01$; ***P0.001.

evening period, for acclimation lags of 6, 8, 14 and 17–20 days, were also observed. Small negative responses to WCT for acclimation lags of 8–20 days were observed for the evening period. Both measures of changing environmental temperatures were informative. In general, grazing during daylight periods was responsive to STTS and evening periods were responsive to WCT. However, STTS appeared more important as only a small percentage (17%) of DGT occurred during the evening periods. The biological importance of a singular acclimation lag period which demonstrated significance, such as an acclimation lag period of 14 days for DGT response to WCT, was discounted.

The demonstrated ability of these free-ranging ruminants to exhibit minimal behavioral responses to alterations in winter thermal environments indicated that winter cold exposure under these conditions could be categorized as a physiological stress (Ewbank, 1985). Whether these minimal behavioral adjustments reflect physiological responses to cold exposure is unknown. Levine (1985) stated that an important underlying factor of possible stressors is uncertainty where an environment presents novel, strange or unfamiliar characteristics. Generally, if a stimulus is frequently repeated subsequent reactions diminish and the subject may appear habituated. Cold exposure in January in the Northern Rocky Mountains might not be considered novel by range beef cattle.

Underwood (1983) and Tyler (1987) emphasized that fluctuations in animal responses to harsh environments are not advantageous. Tyler (1987) and Skogland (1984) reported that Svalbard reindeer both reduce forage intake and employ a generalist foraging strategy during winter. Underwood (1983) reported similar foraging behaviors of African ungulates during the dry season, a dormant forage setting of similarity to cool-season forage species during winter months at northern latitudes. Principal strategies that may be employed by an ungulate within cold and harsh environments include: (1) maximum insulation; (2) minimum foraging activities; (3) adjustments to intake and resulting fasting metabolism (Tyler, 1987). Maintenance of a consistent winter foraging pattern, especially consistency of forage intake may represent a minimizing of collective behaviors for a set body weight and resulting daily energy expenditure within familiar environments. The model of Senft and Rittenhouse (1985) and the hypothesis of Adams et al. (1986) may be appropriate during transitional periods for thermal environments. It is also possible, as suggested by Dunn et al. (1988), that grazing experiences mitigate thermal stress responses during familiar and transitional periods.

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