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Switching Feedlot Dietary Fiber Level for Cattle Fed in Winter[1]

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Abstract

Four feeding regimens were evaluated in two different outside facilities [tree windbreak provided (SP) vs no wind protection provided (NP)] over two winter seasons. Feeding regimens were 1) 7.5% (DM basis) alfalfa hay (AH) diet (Low-Low); 2) 15% (DM basis) AH diet switched to a 7.5% (DM basis) AH diet under cold stress conditions (High-Low); 3) 7.5% (DM basis) AH diet switched to a 15% (DM basis) AH diet under cold stress conditions (Low-High); and 4) 15% (DM basis) AH diet (High-High). For feeding regimens High-Low and Low-High, cold stress was determined by use of a model, based on weather conditions and previous DMI, to predict lower critical temperature. Cattle fed in facilities with SP tended to perform better under a Low-Low feeding regimen; cattle fed in facilities with NP tended to benefit from the extra energy provided by switching to a lower fiber diet (High-Low feeding regimen) during cold stress. Across both facilities, the 5-d moving averages of wind chill index (WCI) and WCI >800 units had the best correlation with change in DMI. All diets except the High-High diet displayed significant linear relationships with increases in DMI and climatic variables in the NP facility, whereas cattle fed only the High-High diet displayed significant relationships in the SP facility. Heat production associated with the added fiber does not appear to be greater than that from added grain. Switching feedlot cattle, under cold stress, to higher fiber diets was not beneficial.

(Key Words: Fiber Level, Cold Stress, Wind Protection, Feedlot, Finishing.)

Introduction

Heat increment, as defined by the NRC (24), is the increase in heat production following consumption of feed by an animal in a thermoneutral environment. Included in heat increment are heat of fermentation and energy expenditure in the digestive process, as well as heat produced as a result of nutrient metabolism. During cold stress, heat increment is useful in offsetting increased rate of heat loss. Conversely, heat increment aggravates heat stress at high temperatures by adding more heat to an already heat-stressed system. Fluctuations in environmental conditions that result from seasonal changes in weather are known to alter maintenance energy requirements, possibly necessitating changes in beef cattle diets (10, 22, 23). The common practice of decreasing dietary energy density (adding fiber) during periods of changing weather patterns and cold stress in the winter might not be beneficial when metabolic rate and animal maintenance energy requirements are increasing (4). Heat increment differences resulting from increasing levels of fiber in higher energy finishing diets are assumed to enhance animal energy balance and performance during cold stress (23). Heat produced anaerobically by microbes in the digestive tract is called the heat of fermentation (8). Rate of heat production of ruminal ingesta (heat of fermentation), just after eating, in ruminants limit-fed concentrate has been observed to be greater (per unit weight basis) than that of the same animals full-fed forage (11); this was seemingly related to higher substrate fermentation in the ruminal contents from the concentrate diet rather than related to the feeding method. However, Webster (29) found the heat increment of fiber in ruminants was higher than that of concentrates at intake levels above the maintenance requirement.

The objective of this research was to evaluate the effects of changing

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TABLE 1. Ingredient and nutrient composition (DM basis) of diets.

	Alfalfa hay level (%)		
Item	**11.25 (common)**	**7.50**	**15.00**
Ingredients, %			
Dry rolled corn	84.08	87.05	81.16
Ground alfalfa hay	11.25	7.50	15.00
Liquid supplement[a]	2.21	2.21	2.21
Soybean meal	0.70	1.36	–
Monensin/tylosin supplement[b]	1.63	1.63	1.63
Limestone	0.13	0.25	–
Calculated nutrient analysis[c]			
ME, Mcal/kg	3.08	3.12	3.05
NE_g, Mcal/kg	1.43	1.46	1.40
CP, %	12.00	12.00	12.00
Ca, %	0.50	0.50	0.50
P, %	0.35	0.36	0.34
K, %	0.63	0.59	0.66

[a] Molasses, urea supplement containing 50.8% crude protein equivalent, 12.69% Ca, 0.79% P, 4.77% K, 0.16% Mg, 0.35% S, 7.93% NaCl, 138,800 IU vitamin A/kg, 27,760 IU vitamin D/kg, and 35 IU vitamin E/kg.

[b] 98.36% fine ground corn, 1.13% monensin concentrate (132.3 g/kg), and 0.51% tylosin (88.2 g/kg).

[c] Based on NRC (1984) values for dietary ingredients.

energy level in response to cold stress on feedlot cattle performance during the finishing period.

Materials and Methods

Two trials were conducted to evaluate the effects of adjusting the fiber level in the feedlot finishing diet for steers fed under cold stress conditions as determined by calculated lower critical temperature (LCT), an indicator of cold stress. Four feeding regimens, using AH as a fiber source, were evaluated in two outside feedlot facilities (SP *vs* NP) during the winter season. Protected cattle were fed in a facility south of the shelterbelt, whereas unprotected cattle were fed in a facility north and east of the shelterbelt. Facilities were described in detail by Mader et al. (16). Feeding regimens were 1) 7.5% AH diet (Low-Low); 2) 15% AH diet switched to a 7.5% AH diet under cold stress conditions (High-Low); 3) 7.5% AH diet switched to a 15% AH diet under cold stress conditions (Low-High); and 4) 15% AH diet (High-High). Cold stress was defined as the point at which ambient temperature was less than the animal's LCT. The LCT was determined by use of equations from the NRC (23) and further refined by Fox et al. (9, 10). An automated weather station was set up in the center of each facility to monitor continuously (sampled every minute and integrated to hourly observations) temperature, relative humidity (RH), wind speed, and wind direction.

The LCT was estimated from

$$\mathrm{LCT} = T_c - I\ (\mathrm{HP}) \qquad (1)$$

where LCT is measured in °C, T_c = core temperature (39°C), I = total insulation [i.e., tissue plus external (°C/Mcal per m^2 per d), and HP = heat production (Mcal/m^2 per d).

The value HP was estimated from values from the NRC (22) for ME intake and NE_g as follows:

$$\mathrm{HP} = (\mathrm{ME} - \mathrm{NE_g})/A \qquad (2)$$

where HP = heat production (Mcal/m^2 per d), ME = ME intake (Mcal/d), NE_g = NE_g intake (Mcal/d), and A = surface area (m^2).

Values for tissue insulation were based on age and body condition, whereas values for external insulation were based upon hair coat depth, hair coat condition (e.g., degree of mud on cattle), hide thickness, and wind speed (9). Surface area was calculated from BW according to the formula $A(\mathrm{m}^2) = 0.09\ \mathrm{kg}^{0.75}$.

For feeding regimens High-Low and Low-High, each day before feeding, average temperature, wind speed, and hair coat condition from the previous 24 h (0800 to 0800 h), along with previous DMI (feed remaining in bunk weighed daily), were used in the equations to determine cold stress status and subsequent diet to be fed. The DMI were based on pen values; therefore, LCT and cold stress status were determined for the average of the pen of steers rather than individual steers. As a result of day-to-day fluctuations in feed intake, which can be independent of climatic conditions, a weighted [(three times the previous 24-h DMI plus two times the previous 24- to 48-h DMI plus the previous 48- to 72-h DMI) ÷ 6] intake value was used. Once a diet change was made, cattle remained on the diet a minimum of 3 d regardless of cold stress status.

The two trials were conducted in consecutive years using 264 (8 or 9 animals per pen, Trial 1; 8 animals per pen, Trial 2) predominantly Continental × English crossbred steers (average initial BW = 422 kg). Before beginning each trial, steers were adapted to a common 11.25% (DM basis) AH diet (Table 1). Starting date and days on feed for Trials 1 and 2 were December 6 and 70 d and December 7 and 109 d, respectively. At the time of initiation of each trial, steers were implanted with Synovex-S® (Fort Dodge Animal Health, Overland Park, KS). Each year, steers were blocked by BW into a light and heavy group and allotted randomly by breed and BW within a block to

16 pens in a 2 × 4 factorial arrangement of treatments with facility and feeding regimen as factors. Initial BW was the average of BW taken on 2 consecutive d. Hot carcass weight adjusted for a 62% dress was used to calculate final BW. Liver abscess scores were assigned at the time of slaughter; marbling score, yield grade, and twelfth rib fat thickness were obtained following a 24-h chill. Solar radiation and precipitation data were obtained from the High Plains Climate Center automated weather station located 0.7 km west and 1.6 km north of the feedlot facilities. Snowfall data were recorded by a National Weather Service observer 0.7 km west of the feedlot. Temperature humidity index (THI) was calculated according to the formula (5, 21, 28):

$$\mathrm{THI} = 0.8\,T_{db} + \mathrm{RH}\ \mathrm{x}\ (T_{db} - 14.3) + 66.3 \qquad (3)$$

where T_{db} = dry-bulb temperature (°C), and RH is expressed as a decimal.

Wind chill index was calculated according to the formula by Maybank and McKercher (17):

$$\mathrm{WCI} = (10\,V^{.5} - V + 10.45)\,(33 - T_{db})$$

where V = wind velocity (m/s), and T_{db} = dry-bulb temperature (°C).

Analysis of variance of steer performance and carcass data was calculated using the GLM procedure of SAS (26). Analysis was performed as outlined by Steel and Torrie (27) for a randomized complete block design with a 2 × 4 factorial arrangement of treatments. Independent variables were BW (covariate), trial, facility, feeding regimen, and the two- and three-way interactions involving trial, facility, and feeding regimen. Facility × feeding regimen interactions ($P<0.10$) and trial × facility × feeding regimen interactions ($P<0.10$) were found for daily gain, measures of efficiency, and some carcass traits in preliminary analyses; hence, subsequent analyses were conducted within the facility. Independent variables included BW (covariate), trial, feeding regimen, and the interaction between trial and feeding regimen. For steers fed in the facility with SP, trial × feeding regimen interactions were not found; however, for cattle fed in facilities with NP, a trial × feeding regimen interaction ($P<0.10$) was found for liver abscess (LA) percentage. Correlation coefficients between climatic variables and increases in DMI were determined each day that DMI increased 5%. These coefficients were determined within the facility and year. Additionally, regression estimates between climatic variables and percentage increase in daily DMI were determined for each feeding regimen within a facility for those days in which an increase in DMI occurred.

TABLE 2. Mean climatic conditions for winter feeding study.

	Wind protection (SP)			No wind protection (NP)		
	Trial			Trial		
Item	1	2	Mean	1	2	Mean
Temperature, °C	–5.13	–3.64	–4.39	–5.15	–3.85	–4.50
Relative humidity, %	78.97	80.54	79.76	78.93	80.36	79.65
THI[a]	26.56	28.48	27.52	26.53	28.23	27.38
Precipitation, cm	3.99	3.94	3.97	3.99	3.94	3.97
Snow, cm	48.64	43.84	46.24	48.64	43.84	46.24
Wind speed, km/h	9.41	9.13	9.27	13.30	13.70	13.50
Wind direction[b]						
Numeric value, °	236.9	210.8	223.9	321.7	319.0	320.4
Sector	SW	SW	SW	NW	NW	NW
Solar radiation[c]	72.3	87.0	79.7	72.3	87.0	79.7
Wind chill index (WCI)[d]	880.5	837.6	859.1	953.4	924.3	938.9
Proportion of days with WCI >800	41/69	55/108	48/88.5	50/69	64/108	57/88.5
Proportion of days with WCI >1,000	14/69	24/108	19/88.5	23/69	40/108	31.5/88.5
Proportion of days with WCI >1,200	6/69	6/108	6/88.5	8/69	13/108	10.5/88.5
Proportion of days with THI ≤35	45/69	65/108	55/88.5	47/69	66/108	56.5/88.5

[a] THI (temperature humidity index) = $0.8T_{db} + \mathrm{RH} \times (T_{db} - 14.3) + 46.3$, where T_{db} = dry bulb temperature (°C) and RH = relative humidity expressed as a decimal [Thom (28); NOAA (21)].

[b] Resultant wind direction (north = 0°); SW = South west and NW = North West.

[c] Measured in kcal/m^2 per h.

[d] WCI = $(10 \cdot V^{0.5} - V + 10.45)(33 - T_{db})$, where V = wind velocity (m/s).

Results and Discussion

Average temperature and solar radiation during the trials (Table 2) were similar to 30-yr normal temperature (–5.5°C) and solar radiation (79.2 kcal/m^2 per h) found during the 3 mo of December, January, and February. However, in both years, RH tended to be greater than normal (71.5%), whereas wind speed tended to be less than normal (17.9 km/h). Wind speed was 31.3% (9.27 *vs* 13.50 km/h), and WCI was 8.5% (859.1 *vs* 938.9 kcal/m^2 per h) less in the SP facility than in the NP facility. Restricting winter winds from the north and west resulted in the prevailing winter wind coming from the southwest in the SP facility.

Steers were on cold stress diets an average of 28 and 58 d (mean = 43 d

TABLE 3. Effect of winter feeding regimen on performance and carcass characteristics of steers fed in area with wind protection provided (SP)—2-yr summary.

	Alfalfa hay (%)				
Item	7.5 and 7.5[a]	15 and 7.5	7.5 and 15	15 and 15	SE
Initial wt., kg	424	423	423	421	3.2
Daily intake					
DM, kg	9.72	9.79	9.85	9.94	0.17
ME, Mcal[b]	30.33	30.14	30.41	30.26	0.50
Daily gain, kg	1.24	1.10	1.17	1.20	0.05
Efficiency					
Gain/DMI	0.127	0.113	0.119	0.121	0.004
Gain/ME intake[b]	0.040	0.036	0.038	0.040	0.001
Final wt, kg[c]	535	521	528	529	4.4
Actual dressing percentage	60.91	61.28	60.95	61.37	0.23
Carcass traits					
Fat thickness, cm	1.63^{d}	1.44^{e}	1.55^{de}	1.57^{d}	0.04
Marbling score[f]	541	547	540	546	9
Yield grade	3.7^{h}	3.3^{g}	3.4^{g}	3.5^{gh}	0.1
Liver abscess, %	0	0	0	3.1	1.6

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[a] The first number in the pair represents the percentage of alfalfa in the normal diet; the second number represents the percentage of alfalfa in the cold stress diet.

[b] Dietary ME was calculated from NRC (22) values of ME for dietary ingredients.

[c] Based on 62% dressing percentage.

[d,e] Means within a row lacking a common superscript letter differ ($P<0.10$).

[f] 550 = average small; 650 = average modest.

[g,h] Means within a row lacking a common superscript letter differ ($P<0.05$).

or 48% of time on feed) in Trials 1 and 2, respectively. The proportion of days with a THI = 35 tended to overestimate the number of days steers were on cold stress diets (55 to 56.5 d), whereas the proportion of days that the WCI was >1,000 tended to underestimate the number of days (19 to 31.5 d) steers were on cold stress diets. The proportion of days that the WCI was >800 overestimated the number of cold stress diet days in Trial 1 (28 *vs* 45.5 d) but was reasonably close to the mean number of days cattle were on cold stress diets in Trial 2 (58 *vs* 59.5 d). The proportion of days that the WCI was >800 is likely the best indicator of when cattle begin experiencing cold stress. Levels of WCI >1,000 and >1,200 would possibly provide an indication of when cattle are under severe (WCI > 1,000) and extreme (WCI > 1,200) cold stress. Although THI = 35 and WCI are suggested indicators of environmental stress, an index including three factors (wind, temperature, and humidity) instead of two would likely be a better indicator of cold stress. In addition, body condition and pen condition would influence the degree to which climatic conditions are stressful to the animal.

In Trial 1 (Yr 1), steers assigned to High-Low and Low-High dietary regimens were each switched to the cold stress diets seven times within each facility and were on those diets 27 and 28 d, respectively, when fed in the SP facility and 28 d each when fed in the NP facility. In Trial 2 (Yr 2), steers fed in the SP facility assigned to the High-Low and Low-High dietary regimens were switched to cold stress diet six and eight times, respectively, but were fed those diets for 52 d each. For steers fed in the NP facility during Trial 2, eight diet switches were made with the cold stress diet being fed 62 and 67 d for steers assigned to the High-Low and Low-High dietary regimens, respectively. During both trials, cattle were fed the cold stress diets for an average of 6 d each time they were switched to that diet.

As a result of facility and feeding regimen interactions ($P<0.10$), data are presented within the facility. For steers fed in the SP facility (Table 3), no differences were detected in DMI, ME intakes, and ADG, as influenced by winter feeding regimen. Dry matter intake numerically increased with increasing amounts of fiber fed, whereas ME intakes were very similar among treatment groups. Steers assigned to the low fiber level (7.5% AH) throughout the trial were the most efficient numerically. Switching from high to low fiber levels (High-Low) tended toward lower ($P<0.15$) efficiency of feed and energy conversions compared with groups that were maintained on either the Low or High feeding regimens. Switching from low to high fiber levels (Low-High) during periods of cold stress did not alter ($P>0.20$) feed or energy conversions compared with steer groups fed constant fiber levels. Steers assigned to the High-Low dietary regimen tended to have lower ($P<0.10$) fat thicknesses (backfat) than did steers fed constant fiber levels, which is indicative of the numerically lower gains and lighter carcass weights experienced by the steer group fed the High-Low dietary regimen (Table 3). Steers assigned to the Low dietary regimen had greater ($P<0.05$) yield grades than steers assigned to the diet-switching regimens. Yield grades of steers assigned to the High dietary regimen were intermediate. Differences in LA incidence among dietary regimens were not detected.

In the NP facility (Table 4), DM and ME intakes were greater ($P<0.10$) by steers assigned to the High-High dietary regimen when compared with steers assigned to the Low-Low and High-Low dietary regimens. Although no differences were found in ME intakes that could be attributed to dietary regimen, ME intakes were numerically greater for the High treatment group, a trend slightly different from that found for steers fed in the SP facility. Differences in efficiency of gain among dietary regimens also were not detected. Although steers assigned to the High-Low dietary regimen were numerically the most efficient when compared with the other dietary regimens, a trend opposite to that was observed for steers fed in the SP facility. From a performance standpoint, these data suggest that, in protected facilities, switching diets under cold stress is not beneficial, but switching from High to Low fiber diets might be beneficial in facilities in which wind protection is not provided.

In the NP facility, dressing percentage tended ($P<0.10$) to be lower for steers assigned to the Low-High dietary regimen compared with steers assigned to the High-Low and High dietary regimens, which was the same as the trend found in the SP facility. Fat thickness, marbling score, and yield grade differences among dietary regimens were not evident, although a trial × feeding regimen interaction ($P<0.05$) was found for percentage LA (Table 4). Although trial in the analysis was considered a random variable, it should be noted that the highest incidence of LA (18%) occurred in Trial 1 for steers fed the Low dietary regimen in the NP facility. The potential for cattle to go off-feed during cold stress would be greatest under the latter conditions. However, reasons to switch diets (increase fiber level) of cattle under cold stress likely would be to decrease variation in feed intake or to increase heat increment. These data suggest that no benefits to an increase in fiber level exist other than possibly a decrease in the incidence of LA.

TABLE 4. Effect of winter feeding regimen on performance and carcass characteristics of steers fed in area with no wind protection provided (NP)—2-yr summary.

	Alfalfa hay (%)				
Item	7.5 and 7.5^{a}	15 and 7.5	7.5 and 15	15 and 15	SE
Initial wt., kg	424	421	420	425	3.4
Daily intake					
DM, kg	9.79^{b}	9.68^{b}	9.93^{bc}	10.28^{c}	0.14
ME, Mcal^{d}	30.55	29.82	30.64	31.29	0.45
Daily gain, kg	1.13	1.20	1.12	1.13	0.06
Efficiency					
Gain/DMI	0.116	0.123	0.113	0.111	0.005
Gain/ME intake	0.036	0.040	0.036	0.036	0.002
Final wt., kg^{e}	525	528	521	526	6.2
Actual dressing percentage	60.73^{bc}	61.02^{c}	60.32^{b}	60.93^{c}	0.17
Carcass traits					
Backfat, cm	1.51	1.54	1.48	1.56	0.05
Marbling score^{f}	548	540	540	546	18
Yield grade	3.6	3.7	3.5	3.6	0.1
Liver abscess, %^{g}	9.0	3.1	6.3	3.1	2.9

[a] The first number in the pair represents the percentage of alfalfa in the normal diet; the second number represents the percentage of alfalfa in the cold stress diet.

[b,c] Means within a row lacking a common superscript letter differ ($P<0.10$).

[d] Dietary ME was calculated from NRC (22) values of ME for dietary ingredients.

[e] Based on 62% dressing percentage.

[f] 550 = average small; 650 = average modest.

[g] Trial × feeding regimen interaction ($P<0.10$).

Diet-switching programs, independent of climatic factors, have been considered (1, 2). Switching from one fiber level to another during the finishing period has been considered to decrease both diet cost per unit of energy (decrease fiber level) and digestive upsets (increase fiber level). Providing low fiber levels (2% roughage) in finishing diets early in the feeding program followed by high fiber levels (10% roughage) fed later in the feeding program tended to produce more efficient gains than a feeding regimen in which high fiber levels were fed initially followed by low fiber or a feeding program in which a constant (10% roughage) fiber level was fed throughout the feeding period. Effects of alternating fiber levels throughout a finishing period have not been thoroughly evaluated. Potential benefits might be realized by modifying fiber level, particularly when cattle performance "stalls-out" or when the feeding period is extremely long (>150 d). However, in studies reported herein, neither of these conditions was evident.

In predominantly starch-containing diets, slight to moderate increases in fiber might not increase heat increment substantially, provided the fiber is not digested as a result of low levels of fiber-digesting microbes in the rumen. Nevertheless, MacRae and Lobley (14) concluded that a major cause of the differential heat losses between fiber and concentrate (starch) is attributable to differences in volatile fatty acid production between fiber and concentrate digestion. In animals fed concentrate diets, the larger production of propionate, relative to acetate, supplies adequate $NADPH_2$ to convert acetate to fat. In animals fed fibrous diets, the lack of $NADPH_2$ results in a metabolic excess of acetate, which

TABLE 5. Correlation coefficients associated with various climatic factors and daily DMI.

	Alfalfa hay (%)							
	7.5 and 7.5[a]		15 and 7.5		7.5 and 15		15 and 15	
Item[b]	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
SP area								
Temperature	–0.42[d]	–0.09	–0.59[d]	–0.55	–0.33	0.83	–0.44[c]	0.23
THI	–0.44[d]	–0.07	–0.58[d]	–0.53[d]	–0.36	0.10	–0.47[c]	0.20
WCI	0.40[c]	0.08	0.63[d]	0.55[d]	0.50[d]	–0.06	0.32	–0.21
WCI5D	0.10	0.08	0.55[d]	0.54[d]	0.36	–0.21	0.34	–0.29
WCI >800	0.38[c]	0.19	0.62[d]	0.55[d]	0.47[c]	–0.11	0.30	–0.21
WCI5D >800	0.15	0.14	0.57[d]	0.58[d]	0.42	–0.23	0.35	–0.27
NP area								
Temperature	–0.30	0.07	–0.20	0.19	–0.16	0.10	–0.22	0.09
THI	–0.29	0.07	–0.23	0.19	–0.16	0.13	–0.28	0.06
WCI	0.26	–0.08	0.21	–0.14	0.20	0.01	–0.08	–0.13
WCI5D	0.50[d]	–0.06	0.59[d]	–0.11	0.08	0.15	0.26	0.05
WCI >800	0.28	0.11	0.19	–0.05	0.23	0.03	–0.06	–0.07
WCI5D >800	0.52[d]	–0.06	0.58[d]	–0.13	0.08	0.18	0.27	0.01

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[a] The first number in the pair represents the percentage of alfalfa in the normal diet; the second number represents the percentage of alfalfa in the cold stress diet.

[b] SP = feedlot area with wind protection, THI = temperature-humidity index, WCI = windchill index, WCI5D = WCI 5-d moving average, WCI >800 = WCI >800 units, WCI5D >800 = WCI >800 5-d moving average, and NP = feedlot area without wind protection.

[c] $P < 0.10$; rho = 0

[d] $P < 0.05$; rho = 0

has to be metabolized by less efficient processes and/or eliminated as heat (12). The heat increment caused by the feeding of acetate was nearly 50% greater than that caused by dietary propionate in sheep fed above maintenance (3). In the present study, benefits from added heat increment through fiber addition to the diet were not detected. The lower digestibility of fiber *vs* starch seems to offset any efficiency enhancement associated with feeding cold-stress diets containing high heat increment ingredients.

In other studies, Kappel et al. (13) reported that increasing the dietary crude fiber level from 4 to 16% resulted in increased feed intake and lower gain to feed ratios in feedlot steers. Season and fiber level interactions were not significant, indicating that fiber heat increment did not influence diet utilization differently during summer and winter. However, Rea and Ross (25) and Moose et al. (19) reported that fiber heat increment influenced diet utilization in sheep when fed under warm or cool conditions. Muhamad et al. (20) reported diet × season interactions for feedlot steers fed different ratios of corn and corn silage. In the winter, ME intakes tended to be greatest by steers fed a 55:45 corn to corn silage ratio diet *vs* 25:75 and 85:15 corn to corn silage ratio diets, whereas, in the summer, ME intakes were greater by steers fed the 85:15 corn to corn silage ratio diet. Highest ME intakes were attained by feeding the low heat increment diet in the summer and the moderate energy (or heat) increment diet in the winter, suggesting some benefits might exist to feeding diets that differ in heat increment, depending on the season of the year. Gains followed the same trend as ME intakes; however, the ME to gain ratio tended to be less and more favorable in both seasons for steers fed the high energy diet. In the present study, benefits of feeding higher fiber diets at any time were not observed, particularly in the SP facility.

No significant trends in correlation coefficients were found between percentage change in DMI (DDMI) and RH or wind speed in the SP or NP facility (Table 5). As expected, negative correlations were obtained between DDMI and temperature and THI. These tended to be greater (more negative) and significant in the SP *vs* NP facilities. In Canadian studies, Milligan and Christison (18) found high (>0.70 or =0.70) correlations between the climatic factors, temperature, and wind chill, and the performance factors, gain, and the feed to gain ratio.

In the SP facility, significant correlations were observed between DDMI and WCI and between DDMI and WCI that were >800 (daily and 5-d moving average) for Low-Low and High-Low treatment groups, which were cattle groups fed the highest energy (7.5% AH) diet during cold stress. Fewer significant correlations were noted in cattle fed the 15.0% AH diets during cold stress (Low-High and High-High treatment groups). In the NP facility, very few significant correlations were obtained between DDMI and climatic variables. The greatest number of significant correlations were obtained between DDMI and the 5-d moving averages of WCI and WCI that were >800.

Across both facilities, the 5-d moving averages of WCI and WCI that were >800 had the best correlation with DDMI, but only in the Low-Low and High-Low feeding regimens. If higher fiber diets were fed under cold stress (Low-High) or continually (High-High), fewer significant correlations were found, suggesting that higher fiber diets do moderate effects that cold stress may have on DMI.

TABLE 6. Effect (regression equation slope) of climatic conditions (independent variable) on percentage increase in DMI (dependent variable) when averaged across years.

	Alfalfa hay (%)			
Item[b]	7.5 and 7.5	15 and 7.5	7.5 and 15	15 and 15
SP area				
Temperature	0.069 ± 0.084	–0.070 ± 0.086	–0.091 ± 0.073	-0.150 ± 0.065[c]
THI	0.044 ± 0.053	–0.043 ± 0.44	–0.065 ± 0.047	-0.093 ± 0.042[c]
WCI	–0.003 ± 0.004	0.003 ± 0.004	0.003 ± 0.003	0.005 ± 0.003[d]
WCI5D	–0.006 ± 0.004	0.004 ± 0.004	0.001 ± 0.003	0.005 ± 0.003
WCI >800	0.004 ± 0.006	0.006 ± 0.007	0.002 ± 0.005	0.014 ± 0.004[e]
WCI5D >800	0.001 ± 0.006	0.004 ± 0.006	–0.001 ± 0.006	0.014 ± 0.005[f]
NP area				
Temperature	–0.172 ± 0.051[e]	–0.241 ± 0.058[e]	–0.236 ± 0.070[e]	–0.103 ± 0.078
THI	–0.108 ± 0.033[e]	–0.152 ± 0.038[e]	–0.142 ± 0.045[e]	–0.063 ± 0.050
WCI	0.005 ± 0.002[f]	0.007 ± 0.002[e]	0.008 ± 0.002[e]	0.002 ± 0.003
WCI5D	0.007 ± 0.002[f]	0.009 ± 0.002[e]	0.006 ± 0.003[c]	0.001 ± 0.003
WCI >800	0.007 ± 0.002[f]	0.012 ± 0.003[e]	0.012 ± 0.004[f]	0.005 ± 0.004
WCI5D >800	0.006 ± 0.003[c]	0.012 ± 0.003[e]	0.009 ± 0.004[c]	0.004 ± 0.005

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[a] The first number in the pair represents the percentage of alfalfa in the normal diet; the second number represents the percentage of alfalfa in the cold stress diet.

[b] SP = feedlot area with wind protection, THI = temperature-humidity index, WCI = windchill index, WCI5D = WCI 5-d moving average, WCI >800 = WCI >800 units, and WCI5D >800 = WCI >800 5-d moving average, and NP = feedlot area without wind protection.

[c] $P<0.05$.

[d] $P<0.10$.

[e] $P<0.001$.

[f] $P<0.01$.

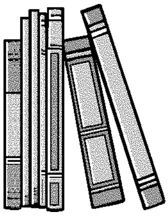
Linear slopes for increases in DMI with climatic variables are presented in Table 6. Effects of climate on DMI were significant in SP facilities for steers fed the High-High diet only. For these cattle, negative slopes ($P<0.05$) were noted, indicating that increases in temperature and THI resulted in decreases in DMI. Regression of the increase in DMI on days when WCI was >800 and 5-d moving average of WCI that were >800 revealed larger increases ($P>0.01$) in DMI with increases in these two weather variables for steers fed the High-High dietary regimen in the SP facility. An opposite effect was observed in the NP facility. Effects of climate on DMI were significant when low fiber diets were fed (i.e., Low-Low, Low-High, and High-Low), suggesting cattle on these diets were more susceptible to climatic change in the NP facilities. In the NP facility, negative linear ($P<0.05$) relationships were obtained between increases in DMI and temperature and THI for all treatments except steers fed the High-High dietary regimen, whereas positive ($P<0.05$) slopes were found for WCI, 5-d average WCI, WCI >800, and 5-d average WCI >800.

With the exception of a temporary reduction in intake occurring with sudden changes in temperature or climatic conditions, cold stress tends to stimulate intake (23) as was seen in steers fed in the NP facility. Mader et al. (16) concluded that, for cattle exposed to moderate cold stress, intakes tended to be greater in the NP facility than in the SP facility in the winter, but, for cattle subjected to more severe cold stress, an opposite trend was observed (15). The more susceptible cattle are to acute cold stress, the greater the initial reduction in intake. Apparently, cattle that are fed in more open facilities and exposed to cold stress display typical increases in intake during cold stress, but fewer relationships are observed in cattle for which the cold stress is diminished. The absence of a relationship between increases in DMI and climatic conditions in the SP facility likely suggests their increases in DMI were a result of normal daily fluctuations in intake rather than a response to environmental conditions. The shelterbelt located to the north of the facility was effective in moderating the effects of increases in WCI resulting from increasing winds. In the SP facility, wind protection (shelterbelt) decreased wind speed by 31.3%, whereas WCI was decreased 8.5%.

Shelterbelts are typically designed to decrease air flow from one or two directions, typically north and west. However, at the research center where these data were collected, winter wind direction is north (13.75%), west (7.60%), and northwest (25.46%) 46.81% of the time (National Weather Service, Sioux City, IA; 40 km East-North East of feedlot facilities). The increases in DMI associated with increasing WCI measures in the NP facility are needed to accommodate increases in metabolic rate often associated with cold environmental conditions. With acclimatization to cold, sheep and cattle can show a 30 to 40% increase in resting metabolic rate (7, 31, 32), which is independent of feeding level (7, 30). Christopherson and Young (6) reported that the metabolic rate of feedlot cattle increased ca. 2 kcal/kg of $BW^{0.75}$ for each degree that the environmental temperature is below LCT, which would support the greater intake response resulting from cold stress. However, cold stress increases passage rate and decreases digestibility (23), which would likely contribute to increased intakes when cattle feel comfortable enough to eat. Effects of switching diets were minimal, although opposite trends in gain and efficiency resulting from switching diet regimen tended to be observed between facilities. Cattle fed in the SP facility tended to have better performance on a Low-Low feeding regimen in which no changes in fiber level occurred, whereas cattle fed in the NP facility tended to benefit from the extra energy provided by switching to a lower fiber diet (High-Low feeding regimen) during cold stress.

Implications

These results suggest that provision of added fiber during cold environmental conditions does not provide more heat during cold stress than added grain. Extra energy from grain is needed to offset the increase in maintenance requirement of feedlot cattle exposed to cold stress. Increased dietary levels of grain offered to cattle fed in areas lacking wind protection are beneficial. Because cold stress and fiber level both tend to increase rate of passage, overall diet digestibilities are likely diminished by adding fiber to diets of cattle exposed to cold stress. Benefits may be obtained by switching to higher fiber diets if DMI variation and incidence of LA are reduced.



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