Effect of environmental conditions on feed intake and activity of corn- and barley-fed steers

Hannah M. DelCurto-Wyffels,*†, Julia M. Dafoe,† Cory T. Parsons,†, Darrin L. Boss,† Timothy DelCurto,* Samuel A. Wyffels,† Megan L. Van Emon,*‡ and Jan G. P. Bowman*

*Department of Animal and Range Sciences, Montana State University, Bozeman, MT 59717, USA †Northern Agricultural Research Center, Montana State University, Havre, MT 59501, USA

© The Author(s) 2021. Published by Oxford University Press on behalf of the American Society of Animal Science.
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted reuse, distribution, and reproduction in any medium, provided the original work is properly cited.

Transl. Anim. Sci. 2021.5:S139–S143
https://doi.org/10.1093/tas/txab178

INTRODUCTION

Environmental conditions and their impact on beef cattle production have long been recognized (Milligan and Christison, 1974; Young, 1981; Delfino and Mathison, 1991), and seasonal variations of climatic conditions have been documented to impact feedlot cattle performance (Elam, 1971; Milligan and Christison, 1974). Cattle wintered at northern latitudes are often exposed to periods of severe cold, which increases energy expenditure to maintain homeothermy (Webster, 1970, 1971). Thus, during periods of cold stress animal behavior is altered (Gonyou et al., 1979) and feed consumption will often increase with a decrease in average daily gain (ADG), resulting in an overall decline in feed efficiency (Young, 1981).

To meet the energy demands of feedlot cattle at northern latitudes, an energy dense and high-quality feed source is essential. Corn has traditionally been the most popular grain source in the United States (Samuelson et al., 2016); however, barley is commonly fed to beef cattle in Canada due to its adaptation to the environmental conditions at northern latitudes (Bowman, 2001). Although the National Research Council reports lower energy values for barley than corn (NRC, 2016), work by Bowman et al. (2019) suggests that barley and corn often have similar net energy values. However, utilization of these different feedstuffs has been shown to yield differences in performance (Nichols, 1988; Dion and Seoane, 1992; DelCurto-Wyffels et al., 2021) and digestive utilization in feedlot steers (Orskov, 1986).

Feeding behavior and activity are frequently monitored to evaluate cattle well-being and health status (Weary et al., 2009). However, limited work has been conducted in regard to cattle behavioral changes, both feeding and activity behavior, when fed differing basal diets and under variable environmental conditions. The influence of environmental conditions and differing finishing diets on cattle feedlot behavior remains to be fully defined. Therefore, the objectives of this study were to evaluate the effects of changing environmental conditions at northern latitudes on feeding behavior and activity of steers fed corn-or barley-based finishing diets. We hypothesized that steer behavior is affected by both diet and environmental conditions.

MATERIALS AND METHODS

Experimental procedures described herein were approved by the Agriculture Animal Care and Use Committee of Montana State University (#2016-AA26). For two consecutive years, Angus-based yearling steer calves were fed in a feedlot trial at the Northern Agricultural Research Center in Havre, MT, from February 27, 2017 to June 12, 2017 (105 d; 427.3 ± 3.7 kg; n = 48) in year 1, and February 26, 2018 to June 11, 2018 (105 d; 406.8 ±
3.4 kg; \( n = 47 \) in year 2. Upon entry to the feedlot, steers were stratified by body weight (BW) and assigned to one of two primary basal grain dietary treatments including: 1) Number 2 feed corn or 2) Hocket barley. Both barley and corn were dry-rolled, and diets contained 80% grain, 12% barley straw, 3% canola oil, and 5% supplement on an as-fed basis. Supplements consisted of vitamin/mineral packages for feedlot steers and protein sources, including wheat middlings and canola meal.

Steer weights were obtained at the beginning and every 28 d throughout the study until the end of the feeding trial. Feed intake measurements: daily dry matter intake (DMI, kg/d) and intake (g/kg BW/d), were all calculated from GrowSafe data for each individual steer on a daily basis. Daily intake variation, measured as coefficient of variation (CV, %), was based on daily intake estimates for individual animals.

To determine time spent lying (min/d), HOBO accelerometers (HOBO Pendant G acceleration data logger; Onset Corp., Pocasset, MA) were fitted to 12 steers per treatment group. Accelerometers were attached for 15-d increments at the beginning, middle, and end of the trial. These devices were programmed to record at 1-min intervals and were attached to the front leg above the pastern (Ito et al., 2009). From the data, the degree of vertical tilt (y-axis) was used to determine whether the animal was lying or standing.

An Onset (Bourne, MA) HOBO U30-NRC Weather Station was placed near the feedlot and programmed to collect air temperature, relative humidity, and wind speed and direction data every 10 min for the entirety of the feedlot trial. Temperatures adjusted for windchill were calculated using the National Weather Service formula modified for cattle (Osczevski and Bluestein, 2005; Tucker et al., 2007; Graunke et al., 2011). Short-term relative temperature changes were then derived by subtracting daily average temperatures from a rolling previous 10-d average. Daily relative temperature change was then paired with daily intake and activity readings for each individual animal for the duration of the feedlot trial each year. Each day was then classified as colder than the 10-d average (<1 SD from the mean), average (±0.5 SD from mean), or warmer than the 10-d average (>1 SD from the mean) temperature, adjusted for windchill, within each year of the feedlot trial to evaluate relative temperature change on steer intake behavior and activity.

Daily individual intake (kg/d and g/kg BW/d), the CV of intake, and steer lying activity were analyzed using ANOVA with a generalized linear mixed model including diet, relative temperature change class, and the interaction of diet and relative temperature change class as fixed effects, with year and individual steer as random intercepts. Individual steer was used as a random intercept to account for autocorrelation of multiple measurements for each individual. Individual steer was considered the experimental unit. Data were plotted and transformed if needed to satisfy assumptions of normality and homogeneity of variance. An alpha ≤ 0.05 was considered significant, and an alpha ≤ 0.10 was considered a tendency. Orthogonal polynomial contrasts were used to determine linear and quadratic effects of relative temperature change for each analysis and means were separated using the Tukey method when \( P < 0.05 \). All statistical analyses were performed in R (R Core Team, 2020).

RESULTS

Steer daily intakes displayed a diet by temperature class interaction \( (P = 0.05; \text{Figure 1}) \). Barley-fed steers did not alter daily intakes in response to relative temperature change \( (P \geq 0.44) \). However, there was a tendency \( (P = 0.08) \) for corn-fed steers to alter intake in response to daily temperatures, where intakes decreased linearly \( (P = 0.04) \) with decreases in relative temperature. Additionally, corn-fed steers had greater \( (P \leq 0.03) \) intakes than barley-fed steers on days with average and above average temperature but did not differ \( (P = 0.71) \) on
days below the 10-d average temperature. Steer daily intake expressed as g/kg BW/d also displayed a diet by temperature class interaction \((P = 0.04; \text{Figure 2})\). There was a quadratic effect \((P < 0.01)\) of relative temperature change on intake g/kg BW/d for barley-fed steers, where intake g/kg BW/d increased \((P = 0.01)\) on days colder than the 10-d average and tended to increase \((P = 0.08)\) on days warmer than the 10-d average. There was a linear effect \((P = 0.03)\) of relative temperature change on intake g/kg BW/d for corn-fed steers, where intake g/kg BW/d increased with increases in relative temperature. Diet did not have an effect \((P = 0.84)\) on intake g/kg BW/d on days colder than the 10-d average; however, corn-fed steers tended \((P = 0.06)\) to have greater intakes g/kg BW/d than barley-fed steers on average and warmer than average days. Relative temperature change had no effect \((P = 0.60)\) on variation in intake, expressed as the CV. However, diet influenced \((P < 0.01)\) variation of intake, where corn-fed steers had a greater CV than barley-fed steers \((21.89 \pm 1.46 \text{ vs. } 18.72 \pm 1.46\%\)). Diet had no effect \((P > 0.12; \text{Figure 3})\) on steer lying activity; however, temperature class influenced \((P < 0.01)\) lying time. There was a quadratic effect \((P < 0.01)\) of relative temperature change on lying time per day, where regardless of diet, lying time decreased \((P < 0.01)\) on days colder than the 10-d average but did not change \((P = 0.47)\) between days with average and warmer than the 10-d average temperature.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Influence of relative temperature change on average daily intake (expressed as g/kg BW/d) by beef steers consuming either barley- or corn-based feedlot diets at the Northern Agricultural Research Center, Havre, MT.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Influence of relative temperature change on lying time (expressed as min/d) by beef steers consuming either barley- or corn-based feedlot diets at the Northern Agricultural Research Center, Havre, MT.}
\end{figure}

**DISCUSSION**

Our results suggest intake expressed on a g/kg BW/d basis increased on days colder than the 10-d average for barley-fed steers but only increased on days above the 10-d average for corn-fed steers. In grazing beef cattle, mean daily forage intake expressed as a percentage of BW increased when temperature deviated (either increase or decrease) from temperature averages \((\text{Beverlin et al., 1989})\). \textit{Senft and Rittenhouse (1985)} concluded that short-term behavioral responses in extreme weather conditions may be critical to the energy balance of domestic animals in both grazing and feedlot scenarios. In feedlot cattle trials, intake increased linearly from \(10 \, ^\circ\text{C}\) to \(-10 \, ^\circ\text{C}\); however, at temperatures below \(-10 \, ^\circ\text{C}\) variation of intake among animals was high, likely due to difference in individual response to cold temperatures \((\text{NRC, 1981})\). In contrast, our results suggest relative temperature change did not influence variation in intake.

In addition to feed intake, cattle behavioral activity is used as an indication of animal comfort and well-being. Specifically, lying behavior is often a sign of cattle well-being \((\text{Rutten et al., 2013; Chapa et al., 2020})\). Limited work has been conducted evaluating lying response to environmental changes in beef cattle \((\text{Richeson et al., 2018})\). Dairy cattle have been found to decrease daily lying time with decreased air temperature \((\text{Hendriks et al., 2020})\). In grazing cattle, shorter lying times have also been reported when cattle experience colder or inclement
weather conditions (Tucker, 2007). Our study found that feedlot beef cattle also decreased lying time on days colder than the 10-d average. Conversely, other authors have found cattle exposed to cold temperatures and winter weather conditions increased time spent lying down as temperature decreased; however, cattle in these studies had access to bedding (Gonyou et al., 1979; Redbo et al., 2001). Thus, it has been suggested frozen ground conditions underfoot may impact standing and lying time (Hendriks et al., 2020), specifically with a wet or frozen surface contributing a reduction in the time cattle lie down (Tucker, 2007; Hendriks et al., 2020). Additionally, the conflicting results of the above studies may be due to differences in microclimates associated with wind and temperature. Increasing wind speed is correlated to convection heat loss, which reduces the temperature an animal experiences (Osczevski and Bluestein, 2005; Graunke et al., 2011, Wyffels et al., 2020). Therefore, wind can have a profound effect on effective environmental temperature, which could relate to differing animal behavioral responses.

**IMPLICATIONS**

We found that short-term temperature changes impacted both beef feedlot cattle intake behavior and activity. Differing basal diets interacted with short-term environmental changes to influence animal feeding behavior, but diet had limited impact on cattle lying behavior. Overall, environmental shifts and cold temperature conditions could result in greater energetic needs and ultimately impact steer behavior. By providing information related to beef cattle feedlot behavior, we can more effectively manage cattle feeding systems at northern latitudes to improve feed efficiency.

**LITERATURE CITED**

Beverlin, S., K. Havstad, E. Ayers, and M. Petersen. 1989. Forage intake responses to winter cold exposure of free-ranging beef cows. Appl. Anim. Behav. Sci. 23:75–85. doi:10.1016/0168-1591(89)90008-7

Bowman, J. G. P. 2001. Barley for beef cattle. In: Cow-calf management guide. Nutrition section, vol. 332, 2nd ed. Moscow (ID): Western Beef Resource Committee; JRA dams Publishing; p. 1–5.

Bowman, J. G. P., D. L. Boss, L. M. M. Surber, and T. K. Blake. 2019. Estimation of the net energy value of barley for finishing beef steers. Transl. Anim. Sci. 3:1550–1560. doi:10.1093/tas/txz128

Chapa, J. M., K. Maschat, M. Iwersen, J. Baumgartner, and M. Drillich. 2020. Accelerometer systems as tools for health and welfare assessment in cattle and pigs—a review. Behav. Proc. 181. doi:10.1016/j.beproc.2020.104262

DelCurto-Wyffels, H. M., J. M. Dafoe, C. T. Parsons, D. L. Boss, T. DelCurto, S. A. Wyffels, M. L. Van Emon, and J. G. P. Bowman. 2021. Corn versus barley in finishing diets: effect on steer performance and feeding behavior. Animals 11(4):935. doi:10.3390/ani11040935

Delfino, J. G., and G. W. Mathison. 1991. Effects of cold environment and intake level on the energetic efficiency of feedlot steers. J. Anim. Sci. 69:4577–4587. doi:10.2527/1991.69114577x

Dion, S., and J. Seoane. 1992. Nutritive value of corn, barley, wheat and oats fed with medium quality hay to fattening steers. Can. J. Anim. Sci. 72:367–373. doi:10.4141/cjas92-044

Elam, C. 1971. Problems related to intensive indoor and outdoor beef production systems. J. Anim. Sci. 32:554–559. doi:10.2527/jas1971.323554x

Gonyou, H., R. Christopherson, and B. Young. 1979. Effects of cold temperature and winter conditions on some aspects of behaviour of feedlot cattle. Appl. Anim. Ethol. 5:113–124. doi:10.1016/0303-3762(79)90083-X

Graunke, K. L., T. Schuster, and L. M. Lidfors. 2011. Influence of weather on the behaviour of outdoor-wintered beef cattle in Scandinavia. Livest. Sci. 136(2–3):247–255. doi:10.1016/j.livsci.2010.09.018

Hendriks, S., C. Phyn, S.-A. Turner, K. Mueller, B. Kuhn-Sherlock, D. Donaghy, H. Huzsey, and J. Roche. 2020. Effect of weather on activity and lying behaviour in clinically healthy grazing dairy cows during the transition period. Anim. Prod. Sci. 60:148–153. doi:10.1071/AN18569

Ito, K., D. Weary, and M. Von Keynesrug. 2009. Lying behavior: assessing within- and between-herd variation in free-stall-housed dairy cows. J. Dairy Sci. 92:4412–4420. doi:10.3168/jds.2009-2235

Milligan, J., and G. Christison. 1974. Effects of severe winter conditions on performance of feedlot steers. Can. J. Anim. Sci. 54:605–610. doi:10.1016/j.asjp.2007.04.013

Nichols, W. T. 1988. Wheat versus corn and barley in beef finishing rations [thesis]. Corvallis (OR): Oregon State University.

NRC. 1981. Effect of environment on nutrient requirements of domestic animals. Washington (DC): The National Academies Press.

NRC. 2016. Nutrient requirements of beef cattle. 8th rev. ed. Washington (DC): The National Academies Press.

Orskov, E. R. 1986. Starch digestion and utilization in ruminants. J. Anim. Sci. 63:1624–1633. doi:10.2527/jas1986.6351624x

Osczevski, R., and M. Bluestein. 2005. The new wind chill equivalent temperature chart. Bull. Am. Meteorol. Soc. 86(10):1453–1458. doi:10.1175/BAMS-86-10-1453

R Core Team. 2020. R: a language and environment for statistical computing. Vienna (Austria): R Foundation for Statistical Computing. Available from http://www.R-project.org/.

Redbo, I., A. Ehrelink, and P. Redbo-Torstensson. 2001. Behavioural responses to climatic demands of dairy heifers housed outdoors. Can. J. Anim. Sci. 81:9–15. doi:10.4141/A00-071

Richesnson, J. T., T. E. Lawrence, and B. J. White. 2018. Using advanced technologies to quantify beef cattle behavior. Transl. Anim. Sci. 2:223–229. doi:10.1093/tas/txy004

Rutten, C. J., A. G. J. Yelthuis, W. Steeneweld, and H. Hogewezen. 2013. Invited review: sensors to support health management on dairy farms. J. Dairy Sci. 96:1928–1952. doi:10.3168/jds.2012-6107

Samuelson, K. L., M. E. Hubbert, M. L. Galvez, and C. A. Lüst. 2016. Nutritional recommendations of
Influence of environment on cattle behavior

feedlot consulting nutritionists: the 2015 New Mexico State and Texas Tech University survey. J. Anim. Sci. 94:2648–2663. doi:10.2527/jas.2016-0282

Senft, R. L., and L. R. Rittenhouse. 1985. A model of thermal acclimation in cattle. J. Anim. Sci. 61:297–306. doi:10.2527/jas1985.612297x

Tucker, C. B., A. R. Rogers, G. A. Verkerk, P. E. Kendall, J. R. Webster, and L. R. Matthews. 2007. Effects of shelter and body condition on the behaviour and physiology of dairy cattle in winter. Appl. Anim. Behav. Sci. 105(1–3):1–13. doi:10.1016/j.applanim.2006.06.009

Weary, D. M., J. M. Huzzey, and M. A. von Keyserlingk. 2009. Board-invited review: using behavior to predict and identify ill health in animals. J. Anim. Sci. 87:770–777. doi:10.2527/jas.2008-1297

Webster, A. 1970. Direct effects of cold weather on the energetic efficiency of beef production in different regions of Canada. Can. J. Anim. Sci. 50:563–573. doi:10.4141/cjas70-077

Webster, A. J. 1971. Prediction of heat losses from cattle exposed to cold outdoor environments. J. Appl. Physiol. 30:684–690. doi:10.1152/jappl.1971.30.5.684

Wyffels, S. A., J. M. Dafoe, C. T. Parsons, D. L. Boss, T. DelCurto, and J. G. Bowman. 2020. The influence of age and environmental conditions on supplement intake by beef cattle winter grazing northern mixed-grass rangelands. J. Anim. Sci. 98(7):skaa217. doi:10.1093/jas/skaa217

Young, B. A. 1981. Cold stress as it affects animal production. J. Anim. Sci. 52:154–163. doi:10.2527/jas1981.521154x

Translate basic science to industry innovation