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Environmental Factors Affecting Water Intake in Steers Finishing in Feedlots

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Environmental Factors Affecting Water Intake in Steers Finishing in Feedlots

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Summary

Simple and multiple regression analyses were executed using records of six experiments conducted from 1999 to 2006 at the University of Nebraska Northeast Research and Extension Center. The objective of the study was to obtain the best equation to predict water intake of feedlot steers under summer and winter weather conditions. The analysis permitted regression equations to be obtained for summer, winter and both seasons (overall model). From simple regression analysis, the best predictor of water intake was minimum temperature with $r^2 = 0.61$ *in the overall model. Whereas, from multiple regression analysis the overall model with the best fit had* $R^2 = 0.70$. *This model included 4 factors; daily mean minimum temperature, solar radiation, dry matter intake and wind speed.*

Introduction

Adequate water is essential for maintaining optimum physiological and metabolic function. In some locations and at certain times of the year water availability or access by cattle may be limited. It is important for commercial feedlot operators to know and be able to predict daily water intake of cattle and allow for additional water allotments to implement cooling strategies during summer heat waves. However, there is limited information available on water intake by beef cattle managed in modern commercial feedlots. Water intake recommendations of NRC beef cattle (2000) are based on research summarized by Winchester and Morris during the 1950s. The Winchester and Morris system was developed from a database derived primarily from dairy cattle that were managed under constant temperature chambers, beef cows managed under various regimens in the Imperial Valley, Calif., and a small data set from Beltsville, Md., (six heifers). Climatic conditions, system of production, and management of animals used in the Winchester and Morris database are very different from those found in commercial feedlots, especially in the Midwest. This study was undertaken to derive models to predict daily water intake in feedlot steers.

Procedure

The dataset used for this analysis was derived from six experiments that were conducted at the University of Nebraska Northeast Research and Extension Center and used predominantly Angus or Angus crossbreds. Experiment 1 was conducted in 1999 and used 144 steers to determine effects of different feeding regimens on performance, behavior and tympanic temperatures of steers exposed to environmental heat stress (*2001 Nebraska Beef Report*, pp. 69-73). Experiment 2 was conducted in 1999 (*2001 Nebraska Beef Report,* pp. 77-81) and used 96 steers to determine the effect of water application to feedlot mounds on performance, behavior and tympanic temperatures of steers. Only data from the first 23 days of this study were used, since this was a period in which no water was applied. Experiment 3 used 168 crossbred steers and was conducted during the winter of 2002-03 to assess the effects of salt and fat supplementation on DMI, daily water intake (WI), behavior, and tympanic temperature in finished cattle (*2006 Nebraska Beef Report,* pp. 62-65). Steers in this experiment were fed for a period of 128 days. Experiment 4 used 48 steers over a period of 92 days and was conducted during the summer of 2002 with the same objectives as Experiment 3 (*2006 Nebraska Beef Report,* pp. 62-65). Experiment 5 was conducted in the winter of 2004-05, used 250 crossbred steers and was conducted to evaluate bedding and pen density on feedlot surface conditions and cold stress in feedlot cattle. Experiment 6 was conducted during the winter of 2005-06 with 96 Angus steers over a period of 168 days to evaluate levels of inclusion of dried distillers grains with solubles (DDGS) on performance and water intake of cattle.

The database included daily measures of temperatures (mean, maximum and minimum), precipitation, relative humidity, wind speed, solar radiation and temperature-humidity index (THI); as well as DMI and WI. The THI was calculated as: THI= Ta (0.55- (0.55*(RH/100))*(Ta-58); where Ta = ambient temperature and RH =% relative humidity. The climatic variables were compiled using a weather station located at the feedlot facility. Solar radiation was obtained from the High Plains Climate Center automated weather station located 0.37 miles west and 0.93 miles north of the feedlot facilities. The total combination of these observations resulted in a total of 2,612 data points. Due to water meter malfunction or possible recording error, approximately 2% of the total data points were removed from the final dataset. The criterion of elimination was data with less than ± 2.65 studentized residuals.

For each season, simple regression analysis for linear, quadratic, cubic and quartic polynomial degrees were determined between WI and each environmental variable using JMP 5.0.1.2 © (SAS Institute Inc). Subsequent analysis used stepwise regression procedures of SAS © (SAS Ins. Inc., Cary, N.C.) with water intake (gal/day) used as response variable, and the following independent variables: DMI (lb/day), maximum temperature (°F), minimum tempera-

(Continued on next page)

Table 1 Means for season on daily water intake and other climatic factors for overall data-base (±SD)^{a}.

Season	Water Intake (gal/d)	DMI (lb/d)	Temperature (°F) Max	Temperature (°F) Min	Temperature (°F) Mean	RH (%)	Wind speed (mph)	Solar radiation (kcal/d)	Precipitation (in/d)	THI
Summer	8.97 ±2.37	22.4 ±3.88	80.8 ± 9.5	59.6 ± 8.9	70.2 ± 8.2	77.4^{a} ±10.1	6.7^{b} ±2.66	4575 ± 1452	0.070 ±0.28	68.6 ± 7.07
Winter	4.46 ±1.50	23.6 ±2.72	39.8 ±16.5	17.1 ± 14.1	28.8 ±14.0	74.8^{b} ±12.5	8.2^{a} ±5.13	2249 ± 1204	0.013 ±0.07	32.5 ±12.2
Overall	5.94 ±2.80	23.2 ±3.20	53.3 ±24.2	31.1 ± 23.6	42.4 ±23.1	76.3 ±11.8	7.7^{a} ±4.51	3013 ± 1692	0.032 ±0.17	44.4 ±20.1

[a] Means with unlike superscript within column differ ($P < 0.001$)

ture (°F, mean temperature (°F), wind speed (mph), precipitation (in/d), RH (%), solar radiation (kcal/m^2/d), THI (temperature-humidity index), and experimental error. Multiple regression analysis were conducted using the entire database (both seasons = overall model) and for each season (the summer and the winter). The number of final parameters included in each model was determined when the change in the magnitude of R^2 was greater than 0.01 units with the addition of an additional parameter. An inflection point was determined from the 2nd derivatives of the simple linear polynomial equations. The present study did not consider in the final models THI or daily mean temperature due to the existence of collinearity of these variables with other variables in the multiple regression analysis.

Table 2 Coefficients of determination (r^2) of simple linear regression for environmental variables to predict WI.

Environmental variables	r^2 Summer model	r^2 Winter model	r^2 Overall model
Minimum temperature	0.1495	0.0357	0.5191
Maximum temperature	0.0708	0.0574	0.4778
Solar radiation	0.1158	0.1615	0.4530
Wind speed	0.0010	0.0170	0.0295
Dry matter intake	0.0170	0.0050	0.0051
Relative humidity	0.0016	0.0492	0.0007
Precipitation	0.0016	0.0479	0.0045

Results

Water intake for steers during the summer was 2x greater than during the winter (9.0 ± 2.4 vs. 4.5 ± 1.5 gal/day). There was also greater variability during the summer seasons than during the winter seasons (Table 1). Similar responses were reported by Hoffman et al. (1972; JAS 35(4):871-876) with greater water intake for the summer than the winter (63.2%); and by Kreikemeier et al. (2004; JAS 82:2481-2488), whom also reported greater water intake for the summer than the winter (73.9%). Dry matter intake was 5.5 % lower in the summer than in the winter (22.4 ± 3.9 vs. 23.6 ± 2.7 lb/day). There were no ($P>0.05$) differences in RH between the summer and the winter season, while wind speed was greater ($P<0.001$) in the winter than in the summer season (Table 1).

Table 2 displays the values of coefficient of determination for simple linear regression by season and environmental variable. Daily minimum temperature ($r^2=0.15$) and solar radiation ($r^2 = 0.12$) obtained the highest r^2 values among the variables evaluated for the summer model. For the winter model solar radiation ($r^2 = 0.16$) and daily maximum temperature ($r^2 = 0.06$) were the best variables explaining water intake. In the overall season simple linear regression the best predictors were daily minimum temperature, daily maximum temperature and solar radiation with r^2 of 0.52, 0.48 and 0.45, respectively. Simple linear, quadratic, cubic and quartic regression analyses were performed to determine best fit. The selection of the polynomial equation that fits best was based in the improvement in r^2 value over simple linear regression. These analyses demonstrate the minimum temperature fit better in a simple linear regression ($r^2= 0.15$) for summer, and a simple quartic regression for the overall model ($r^2= 0.61$, values not showed in the tables); whereas for the winter, solar radiation ($r^2 = 0.22$) and daily maximum temperature ($r^2 = 0.09$) were the best variables explaining water intake in simple cubic regression.

The results of multiple regression analysis performed to predict WI

Table 3 Partial regression coefficients ±SE for models assessing environmental and performance factors affecting water intake in feedlot steers^{a}.

Parameter	Summer Estimate	Summer SE	Summer Partial R^2	Winter Estimate	Winter SE	Winter Partial R^2	Overall Estimate	Overall SE	Overall Partial R^2
Intercept	-3.13781	0.666	—	2.96506	0.374	—	-1.04313	0.250	—
Dry matter intake	0.20047	0.017	0.0763	0.07382	0.010	0.0200	0.14994	0.010	0.0285
Solar radiation	0.00046	0.000	0.0840	0.00039	0.000	0.1847	0.00064	0.000	0.1255
Max temperature	—	—	—	0.00636	0.004	0.0506	—	—	—
Min temperature	0.10865	0.008	0.1552	0.02187	0.004	0.0109	0.06470	0.002	0.5391
Wind speed	-0.13291	0.025	0.0224	-0.03819	0.005	0.0176	-0.05801	0.007	0.0092
Relatively humidity	—	—	—	-0.01825	0.003	0.0108	—	—	—
Precipitation	—	—	—	-4.20499	0.386	0.0385	—	—	—
Total R^2			0.3380			0.3333			0.7023

[a] P values for all statistics < 0.0001.

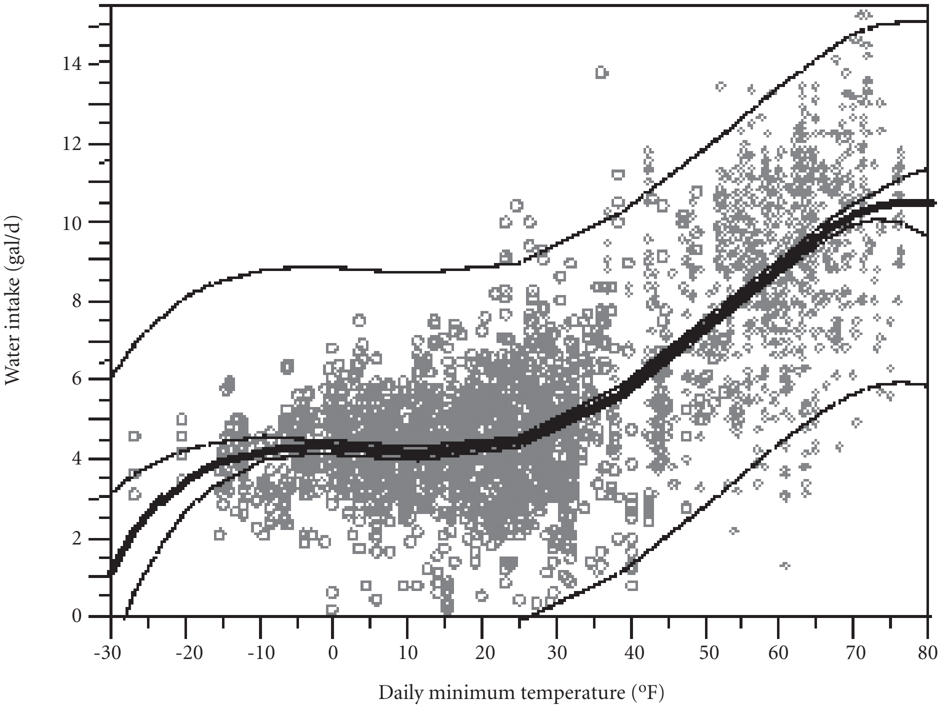

Figure 1 **Water intake in function of daily minimum temperature (mt) for overall season in feedlot steers. Water intake = 4.3250 - 0.0120mt - 8.412e-4 mt^2 +8.17e-5mt^3 - 7.144e-mt^4 (r^2 =0.61, inflection point = 53.5). Inflection point would represent a threshold or shift in the rate of change of daily water intake.**

using environmental variables, as well as DMI are shown in Table 3. The summer season and the overall model included the same four factors; minimum temperature, DMI, solar radiation and wind speed. In the summer and the winter models environmental variables do not account for much of the total variation in water intake achieving $R^2 < 0.5$. The summer model had R^2 of 0.34 with three factors; whereas the winter model had R^2 of 0.33 including all the factors. Solar radiation was the most important factor in the winter model followed by maximum temperature and wind speed. Minimum temperature was the more important factor in the summer and overall model.

Overall models explained nearly 70% of the variation in WI in steers, and included four factors, with minimum temperature accounting for 54% of the total variability, followed by solar radiation accounting for 13% of the variation in water intake. These data demonstrate that minimum temperature has a very important role in the regulation of water intake, and is associated with the loss of heat by animals. In the summer cool nights allow animals to efficiently reduce heat load through conductive and convective processes, while warm nights require animals to drink more water in an effort to reduce heat load. These results agree with NRC equation for dairy cattle, where minimum temperature was also found to play an important role in WI (Dairy cattle NRC, 2001). The lower R^2 values obtained in the present study for the summer and the winter compared with previous reports could be possibly explained by the fact that the weather variables were entered as daily values in the present study and as weekly means in some of the previous research thereby reducing the natural variation in the data and improving the prediction. Figure 1 displays the relationship of water intake with daily minimum temperature (over both seasons) and associated confidence interval (alpha level of 0.01). The quartic degree polynomial equation was selected based on its highest r^2 value. The inflection point for minimum temperature in the overall model was close to 54 °F. This value represents a transition or threshold between warm and cold conditions in each season, and may represent a shift in the animals' heat stress coping ability due to a change in the rate of WI.

All the variables used to determine water intake with simple regression procedure had lower r^2 than the final R^2 from multiple regression procedure. Multiple regression analysis improved predictions across the seasons and resulted in better models to predict water intake than with simple regression models. These results also confirm water intake increases significantly during the summer season. Mean minimum temperature plays an importance role for the summer, whereas solar radiation seems to be the most important factor during the winter season. Putting both summer plus winter seasons together in one model improved the prediction of WI. This model included four factors mean minimum temperature, solar radiation, DMI and wind speed.

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