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January 2008

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Arias, Rodrigo A. and Mader, Terry L., "Modeling Daily Water Intake in Cattle Finished in Feedlots" (2008). *Nebraska Beef Cattle Reports*. 29.
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Modeling Daily Water Intake in Cattle Finished in Feedlots

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Summary

*Simple regression and multiple regression analyses were conducted to estimate factors affecting daily water intake (DWI) of finishing cattle. Seasonal simple linear regression equations were very poor predicting DWI ($r^2 < 0.15$). Best results were obtained with the overall simple regression. The multiple regression analysis showed that daily minimum temperature (or THI), solar radiation, and dry matter intake were the most important factors affecting DWI in cattle finished in feedyards. The following prediction equation was developed: daily water intake, gal*d*$^{-1}$ *= -0.52677+ (0.1229 *DMI, lb*d*$^{-1}$*) + (0.01137*solar radiation, kcal*d*$^{-1}$*) + (0.06529*daily minimum temperature, °F).*

Introduction

Water is a very limited resource in many places, and its demand is expected to increase in next years as result of the development of the ethanol industry and by the greater demand for irrigation purposes. The relationship among ambient temperature and water intake in beef cattle has been a topic of interest but there are still some questions that need to be answered. Previous research conducted in Nebraska suggests that one steer consume around 9.0 gal/day of water during the summer and 4.5 gal/day during the winter (*2007 Nebraska Beef Report,* pp. 47-49). The current DWI recommendations of NRC are based in the work developed by Winchester and Morris in middle '50s. Their work was developed under technical conditions, type of diet, and cattle genetics among other factors that are different than those used at the present. The interaction among climatic factors, type of diet, breed, and the animal weight, as well as the different physiological strategies adopted by each animal make it difficult to predict DWI and the performance of cattle. Besides, there is limited information concerning how other environmental factors along with temperature can simultaneously affect the physiology and performance of cattle under commercial feedlot conditions. Thus, the objectives of this study were to establish which environmental variables affect daily water intake and to find the best model to predict daily water intake in cattle finished in feedyards.

Procedure

The dataset used for this analysis was derived from eight experiments that were conducted at the University of Nebraska Northeast Research and Extension Center and used predominantly Angus or Angus crossbreds. Five of these experiments utilized steers and they were previously reported (*2007 Nebraska Beef Report, pp. 47-49*). Three new experiments were added to this dataset. The first experiment used 270 heifers to compare the effect of different growth promotant strategies in the winter. The experiment was conducted over a 104-day feeding period during the winter season of 1999-2000. The second experiment was conducted as a replication of the previous one for summer season of 2001 with 270 heifers fed 105 days. The last experiment used included 90 heifers and 48 steers which were fed over a period of 92 days to compare the effects of NaCl and fat supplementation on DMI, behavior, DWI and tympanic temperature during the summer of 2002 (*2006 Nebraska Beef Report,* pp. 62-65).

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 DWI. 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 number of observations resulted in 4,463 data points. However, due to water meter malfunction or possible recording error, approximately 2.3% of the total data points were removed from the final dataset. For each season, simple regression analyses for linear, quadratic, cubic and quartic polynomial degrees were determined between daily water intake and each environmental variable using JMP 5.0.1.2 © (SAS Institute Inc). Inflection points were determined from the second derivative from the best polynomial equations. The inflection points represent a threshold or shift in the rate of change in DWI. Subsequent multiple regression analyses used forward stepwise regression procedures of SAS© with DWI (gal/day) as the response variable. Multiple regression analyses were conducted using both genders for each season (summer and winter) and both seasons and genders for the complete overall model. The number of final parameters included in each model was determined based on change in the magnitude of R^2 value. A parameter was included in the model if its addition produced an increase greater than 0.01 units in total R^2.

Results

Table 1 displays the means and standard deviations for the climatic variables and recorded animal performance variables. Cattle finished during the summer consumed 86% more water than those finished during the winter (8.6 ±2.3 vs. 4.6 ±1.1 gal/day). The summer average was very similar to that one reported in a study conducted in feedyards located in the Texas high plains using 50,000

Table 1. Means for daily water intake and other climatic factors across seasons for feedlot cattle (±SD)‡.

Season	Water Intake (gal/day)	DMI (lb/day)	Temperature (°F) Max	Temperature (°F) Min	Temperature (°F) Mean	RH (%)	Wind speed (mph)	Solar radiation (kcal/day)	Precipitation (in/day)	THI (%)
Summer	8.55^a ±2.3	21.1^b ±3.26	81.5 ± 9.2	59.9 ± 8.7	70.5 ± 8.1	77.7^a ±10.7	8.9^a ±4.89	4567^a ±1493	0.068^a ±0.24	69.0^a ± 7.08
Winter	4.56^b ±1.0	24.7^a ±2.58	39.6 ±15.3	16.2 ±12.8	28.4 ±12.8	74.9^b ±12.6	7.7^b ±4.76	2058^b ±1081	0.017^b ±0.08	32.4^b ±11.4
Overall	6.49 ±2.7	23.0 ±3.44	59.9 ±24.4	37.4 ±24.5	48.7 ±23.7	76.2 ±11.8	8.3 ±4.8	63274 ±1804	0.042 ±0.18	50.1 ±20.6

‡Means with unlike superscript within column differ ($P < 0.001$). The comparison was made only between the winter season and the summer season and did not consider temperatures.

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

Variables	r^2 values Summer Model	Winter Model	Overall Model
Minimum Temperature	0.0985	0.0199	0.5586
Maximum Temperature	0.0608	0.0650	0.5350
Solar Radiation	0.1408	0.0322	0.4674
Wind Speed	0.0002	0.0440	0.0018
Dry Matter Intake	0.0031	0.0176	0.1236
Relative Humidity	0.0000	0.0699	0.0004
Precipitation	0.0011	0.0231	0.0057
Mean Temperature	0.1126	0.0439	0.5707
THI[a]	0.1176	0.0549	0.5730

[a]THI = Ta – (0.55*(RH/100)*(Ta-58); where Ta = ambient temperature and RH = % relative humidity.

head of cattle. There was also greater variability in DWI during the summer than during the winter. These results are in agreement with our previous results, when variation was observed in the amount of water consumed by cattle maintained under the same diet and same environmental conditions. Average DMI was 17% greater in the winter than in the summer (24.7±2.58 vs. 21.1±3.26 lb /day, respectively). These differences are typical as it has been demonstrated that feed intake increases as the temperature falls below the thermoneutral conditions. Previous studies conducted at UNL have showed that large variations in DMI can exist in feedlot cattle, and that seasonal patterns are likely dependent on normal vs. abnormal environmental conditions.

Simple regression analysis

Table 2 displays the coefficients of determination of simple linear regression analyses for both genders for the summer, the winter, and overall. The combination of data from each gender did not improve the r^2 value of seasonal models. These were lower than 0.2 for all the models. For the summer model, solar radiation (r^2=0.14), THI (r^2=0.12) and mean temperature (r^2=0.11) had the best r^2 values. Daily maximum temperature (r^2=0.07), relative humidity (r^2=0.07), and THI (r^2=0.05) were the best predictors for the winter season. In the complete overall model, the highest r^2 values were obtained with THI and mean temperature (r^2= 0.57), daily minimum temperature (r^2=0.56), and daily maximum temperature (r^2= 0.53). These results confirm the importance of environmental temperature on DWI. Subsequently, the environmental variables with the highest r^2 values for each season were fitted to quadratic, cubic and quartic polynomial regressions equations. The objective was to identify the best predictor for DWI. As result of these procedures for the summer and the winter model little improvement in r^2 were observed. However, the complete overall model using daily minimum temperature as predictor was improved, reaching r^2=0.59 with a simple cubic regression.

Multiple regression analysis

The parameters included in each model after multiple regression analysis, as well as their respective coefficients are displayed on Table 3. Seasonal models were very poor in predicting DWI. The summer model explained only 23.6% of the variability and included three factors; solar radiation (R^2= 0.14), daily minimum temperature (R^2= 0.05), and dry matter intake (R^2= 0.04). Moreover, the winter model included six of the seven variables evaluated, excluding only daily minimum temperature. Relative humidity, daily

(Continued on next page)

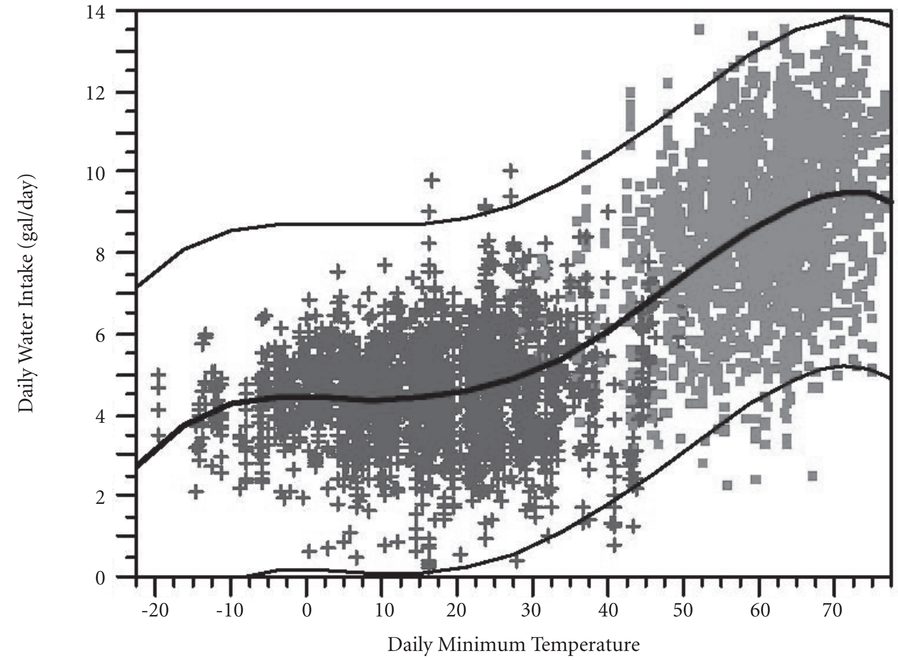
Table 3. Partial regression coefficients ±SE for models assessing environmental and performance factors affecting water intake in feedlot cattle[a].

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	-1.06096	0.478	—	2.71761	0.259	—	-0.52677	0.231	—
Dry Matter Intake	0.14422	0.013	0.0430	0.05097	0.007	0.0139	0.12293	0.009	0.0168
Solar Radiation	0.01030	0.000	0.1420	0.00224	0.000	0.0134	0.01137	0.000	0.0734
Max Temperature	—	—	—	0.01891	0.001	0.0462	—	—	—
Min Temperature	0.07285	0.005	0.0514	—	—	—	0.06529	0.001	0.5586
Wind Speed	—	—	—	- 0.04610	0.004	0.0448	—	—	—
Relatively Humidity	—	—	—	- 0.01315	0.002	0.0700	—	—	—
Precipitation	—	—	—	- 2.36970	0.245	0.0468	—	—	—
Total R^2			0.2364			0.2350			0.6487

[a]P values for all statistics < 0.01

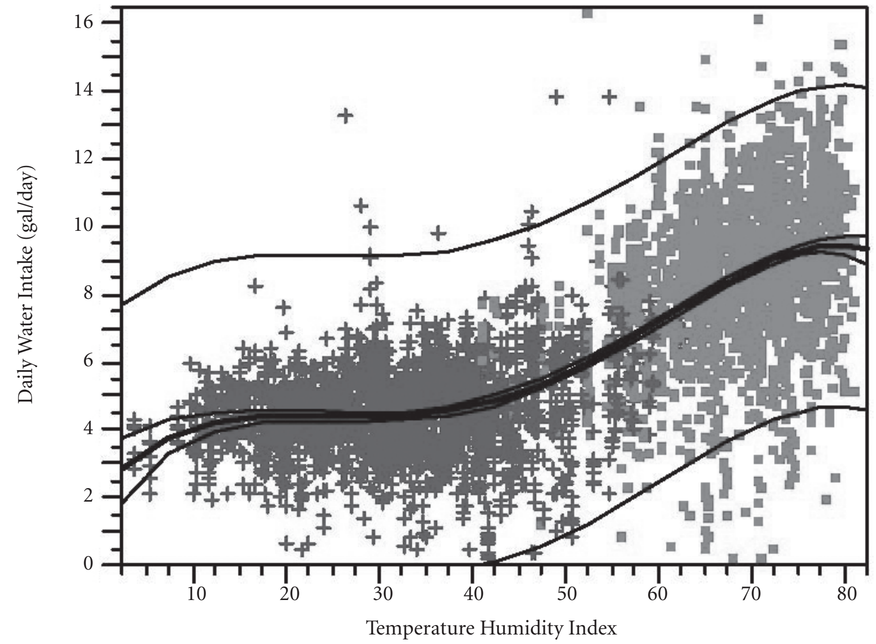
maximum temperature, precipitation, and wind speed were the four most important factors accounting for 20.8% of the variability, (of a total of 23.5%) accounted for the winter model. Wind speed, precipitation and relative humidity displayed a negative effect on DWI. On the other hand, the complete overall model explained 64.9% of the total variability of DWI for cattle finished in feedlots. The same three factors included in the summer model were included in the final overall model. However, daily minimum temperature accounted for 55.9% of variability, whereas solar radiation only accounted for 7.3% of DWI. When the analyses used THI instead of daily maximum and minimum temperature in the model, the R^2 values did not change ($R^2 = 0.65$, data not shown).

Figure 1 illustrates that DWI was relatively constant for daily minimum temperatures between -10°F and 40°F. This means that in that range of temperatures the amount of water that cattle consume does not change so much. Nevertheless, a great variability was found among animals. Therefore, there is an individual response of each animal, which is peculiar and hard to predict. A greater variability in DWI was observed for the summer season with daily minimum temperatures between 40° and 75°F. When daily minimum temperature was used as predictor, using a quartic polynomial equation, it explained 60% of the variability. This value was slightly inferior to the same quartic polynomial equation using THI as predictor (r^2=0.63). The inflection points for daily minimum temperature were 4.8° and 49.8°F. The upper threshold would represent a trigger in the amount of DWI per unit of DMI. This means that cattle begin to increase the amount of DWI per unit of DMI after this daily minimum temperature. Figure 2 shows a similar pattern for DWI, but using THI instead of daily minimum temperature. The best model was reached using THI as predictor accounting for 63% of the



Water intake = 4.4433 - (0.0019 Tmin) - (1.1544 e-3 Tmin^2) + (8.7853 e-5 Tmin^3) - (8.0418 e-7 Tmin^4)
$r^2 = 0.60$, inflection points = 4.80 and 49.82.
Inflection points would represent a thresholds or shift in the rate of change of daily water intake.

Figure 1. Daily water intake in function of daily minimum temperature (°F, Tmin) for overall season in feedlot cattle. The "+" signs represent the winter season and the "■" represent the summer season.



Water intake = 1.6973 + (0.3861 THI) – (0.0187 THI^2) + (3.568 e-4 THI^3) – (2.1034 e-6 THI^4)
$r^2 = 0.625$, inflection points = 24.64 and 60.17.
Inflection points would represent a thresholds or shift in the rate of change of daily water intake.

Figure 2. Daily water intake in function of temperature humidity index (THI) for overall season in feedlot cattle. The "+" signs represent the winter season and the "■" represent the summer season.

variability. It was slightly superior to daily minimum temperature (r^2= 0.60). The upper threshold for THI found in this study (60.2) was slightly under the value reported as normal in the Livestock Weather Safety Index (LWSI = 72-74). The importance of daily minimum temperature has been previously established as a strategy used by cattle to dissipate the overload of heat during the nighttime. Similarly, a high THI during nighttime could have the same effects of high minimum temperatures. Both factors would represent the limitation of cattle to lose heat by convection and conduction processes during summer nights. Therefore, THI as well as daily minimum temperature would represent indirect modulators of DWI, and they can be used to predict DWI.

All variables used to determine DWI with simple regression procedures showed lower r^2 values than the final R^2 values from multiple regression analyses. Multiple regression analyses improved the explanation of the variability across the seasons and were better models to predict water intake than with simple regression models. These results also confirm that DWI increases significantly during the summer season. Daily minimum temperature and THI play an important role on DWI of cattle as was demonstrated by the summer and the complete overall models, whereas maximum temperature seems to be the most important factor during the winter season.

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